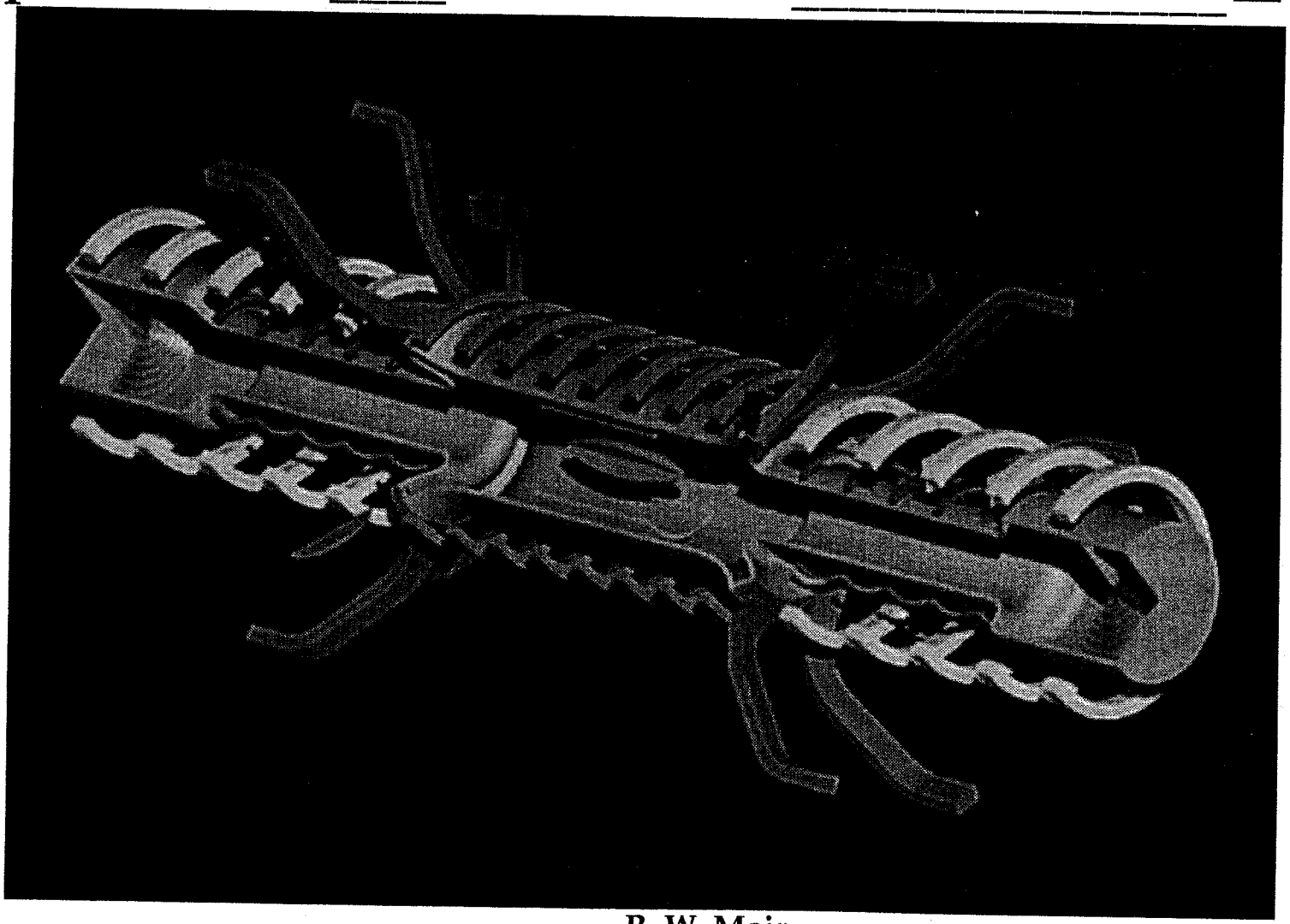
Liquid wall progress report: Status: FRC, ST, and Spheromaks



R. W. Moir
Lawrence Livermore National Laboratory
APEX meeting Feb 16-19, 1999, UCLA

Issues unique to liquid wall use

Tokamak

- how to get liquid in and out/nozzle design/port needs and design/current drive/rad damage to exposed surfaces/ pumping power
- estimate galvanic corrosion rates
- edge plasma/core contamination assessment
- conducting wall design (0.5 m Flibe gap)

FRC

- current drive antenna design/estimate galvanic corrosion rates
- edge plasma/core contamination assessment
- conducting wall design if needed (0.5 m Flibe gap)
- "pacman" fueling pulsed coils

Spheromak

- configuration design/electrodes/insulators/coil locations
- current drive system
- conducting wall design/feedback stabilization (0.5 m Flibe gap)
- edge plasma/core contamination assessment

Goals for liquid walls

Γ~3 to 5 MW/m^2 ----------> >20 MW/m^2

Lifetime of structures

	few years	30 years
thickness of:		
Flibe	0 m ---------->	~0.5 m
Li	0 m---------->	~1.5 m
LiPb	0 m---------->	~1.5 m
LiSn	0 m---------->	~1.5 m

Need to develop and qualify new material > 4 B$

Avoid need to develop and qualify new material save >4B$

COE

~6-8 ¢/kWh

~4-5 ¢/kWh

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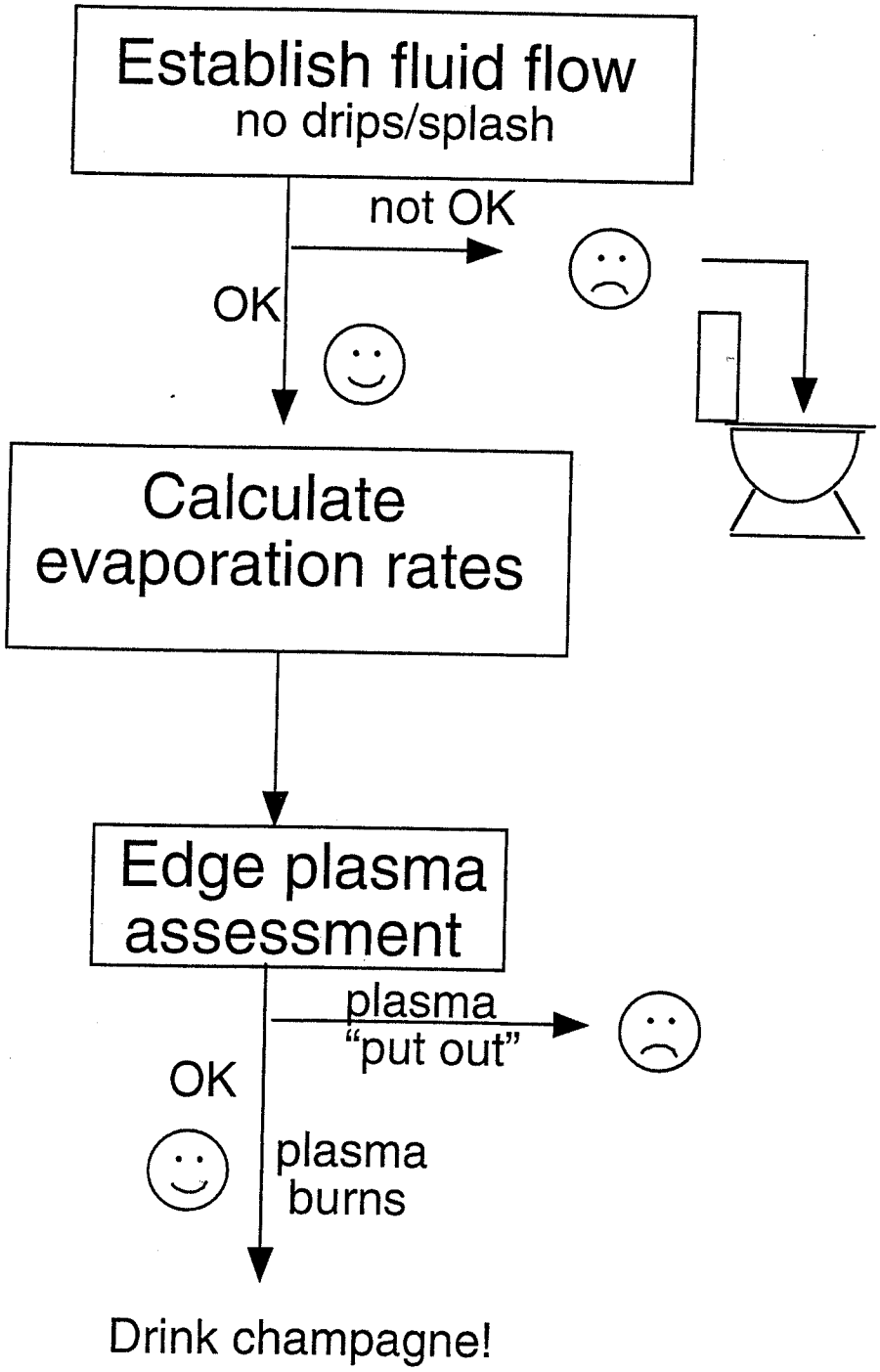
Logic


Establish fluid flow
no drips/splash
not OK
OK
Calculate evaporation rates
Edge plasma assessment
plasma "put out"
OK
plasma burns
Drink champagne!

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FRC design needs

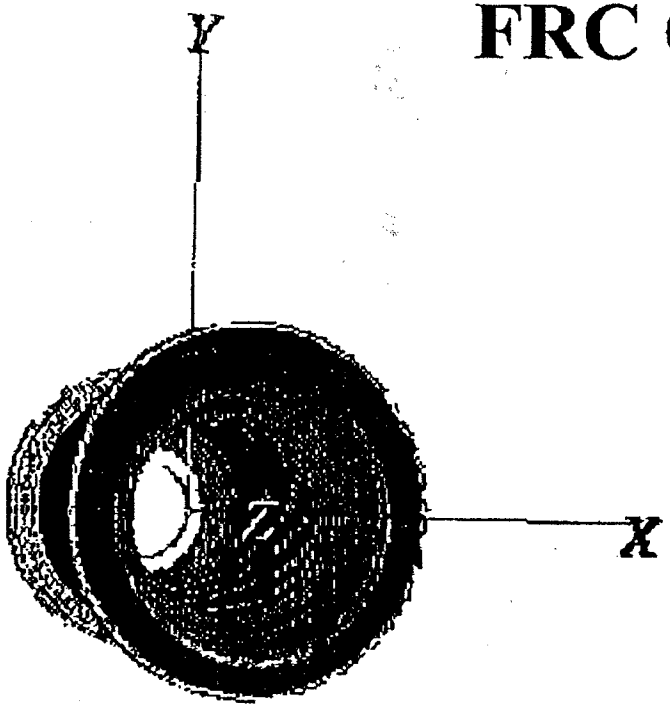
1-current drive system
- antenna & feed system
  - -voltage holding
  - -rad damage
  - -cooling
- plasmoid (CT or Spheromak) fueling
- neutral beam
  - -penetration design
  - -rad damage and cooling

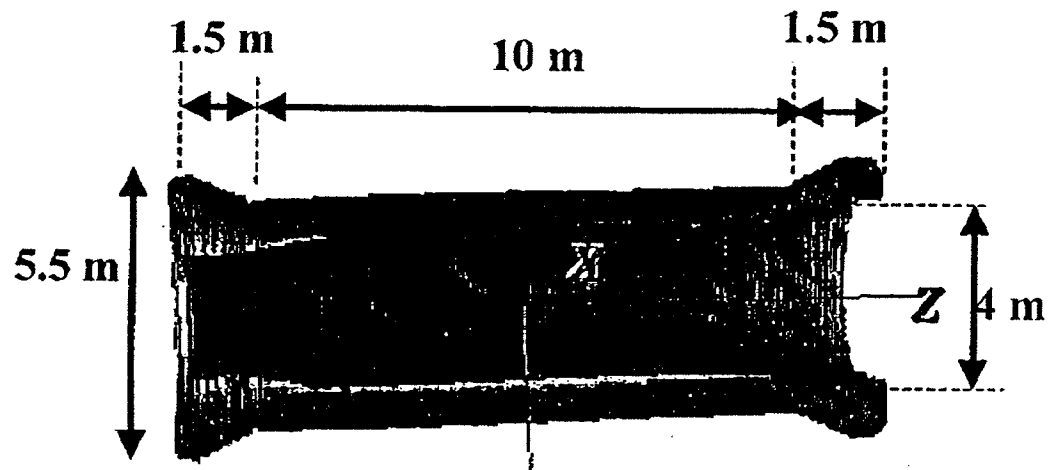
2-ducting design

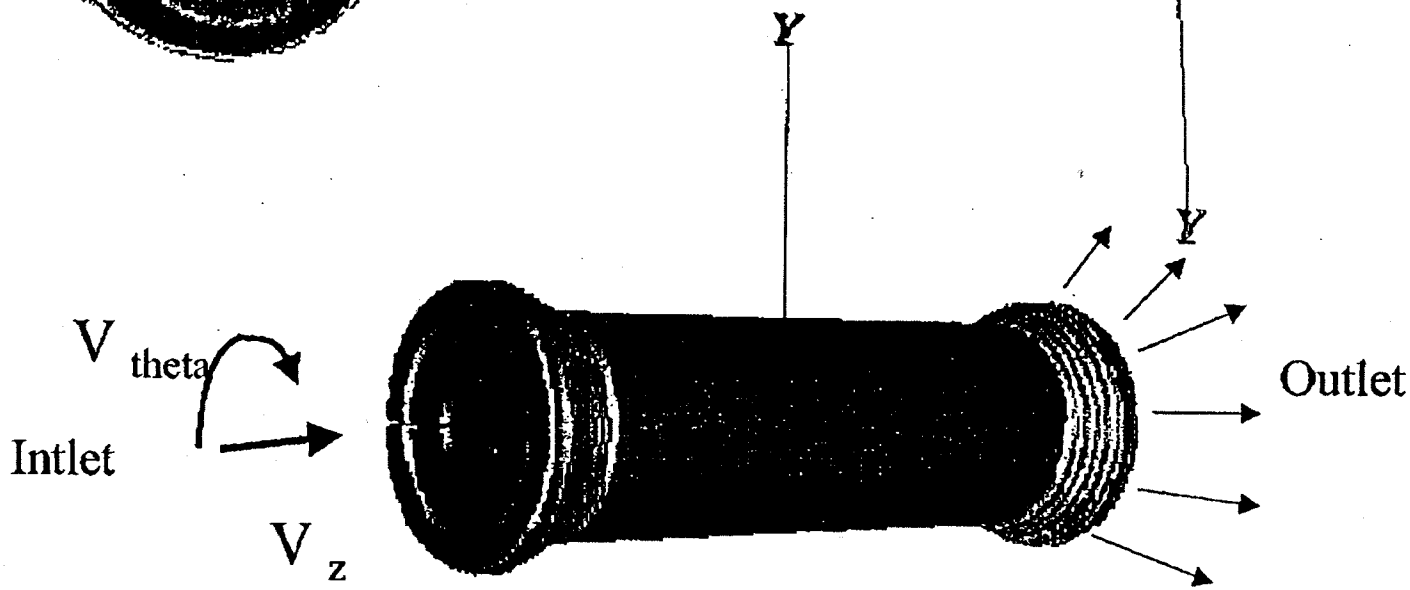
3-inlet/outlet nozzle design
- avoid drips, splash

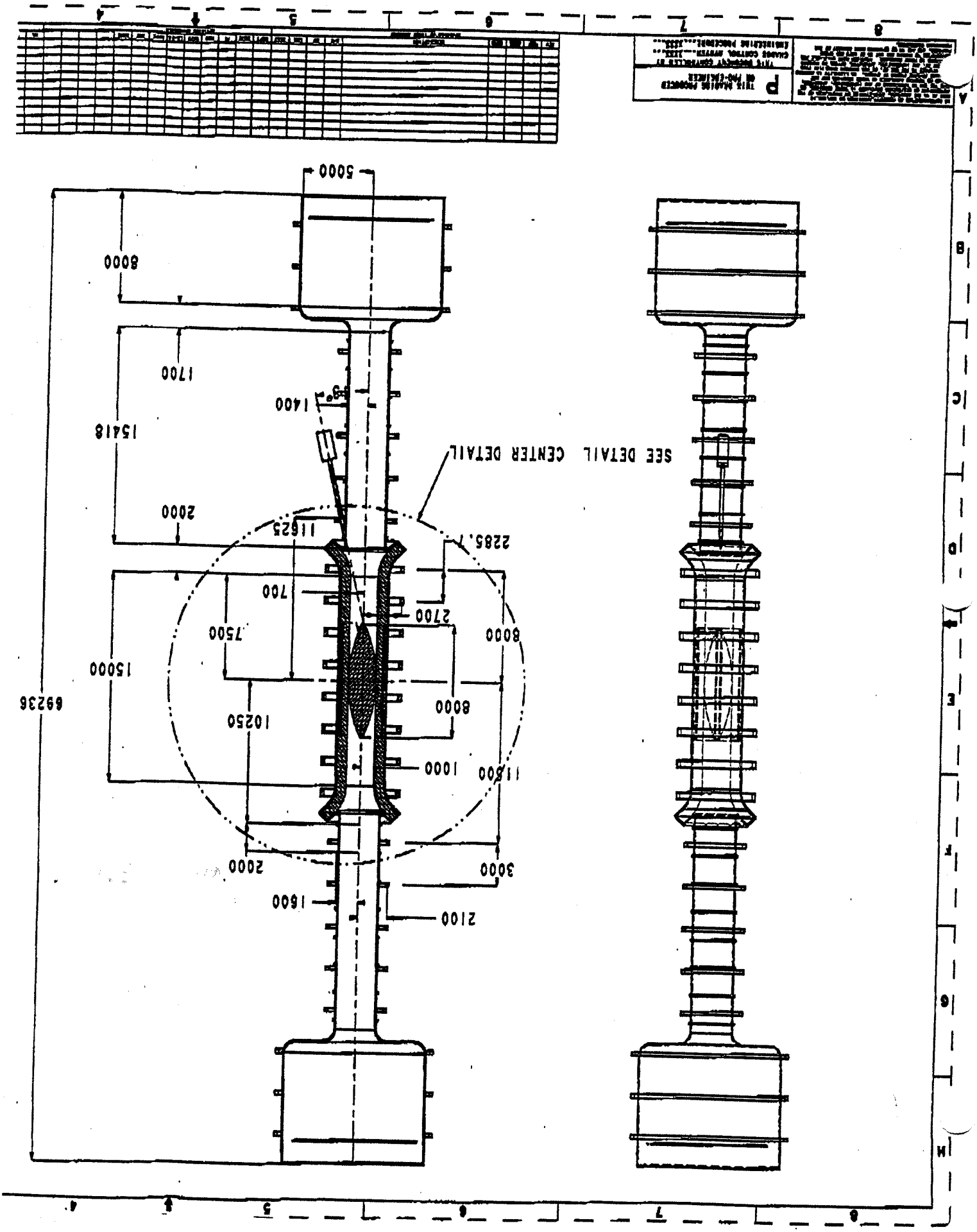
4-penetrations if needed
- avoid drips, splash
- rad damage
- cooling

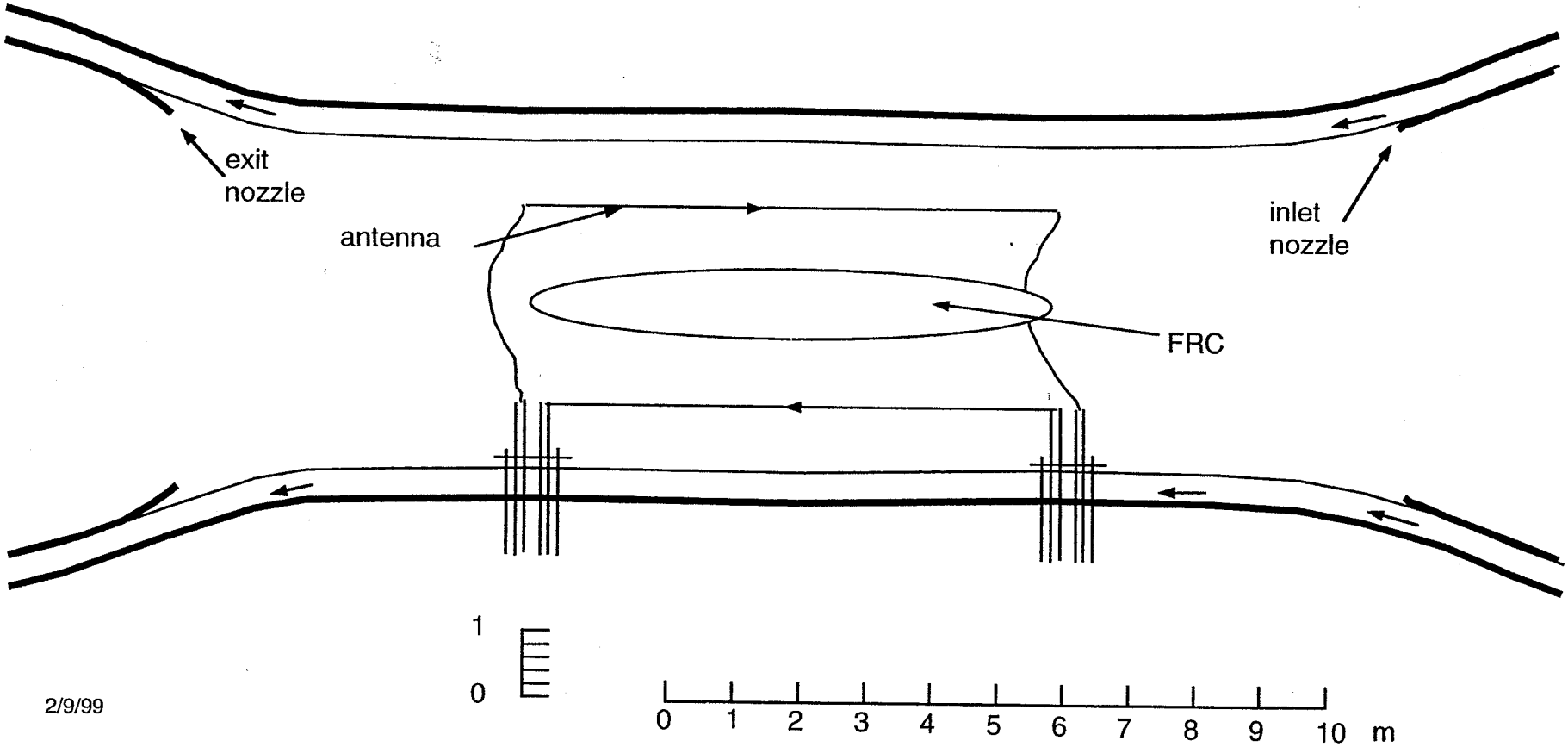
FRC GEOMETRY



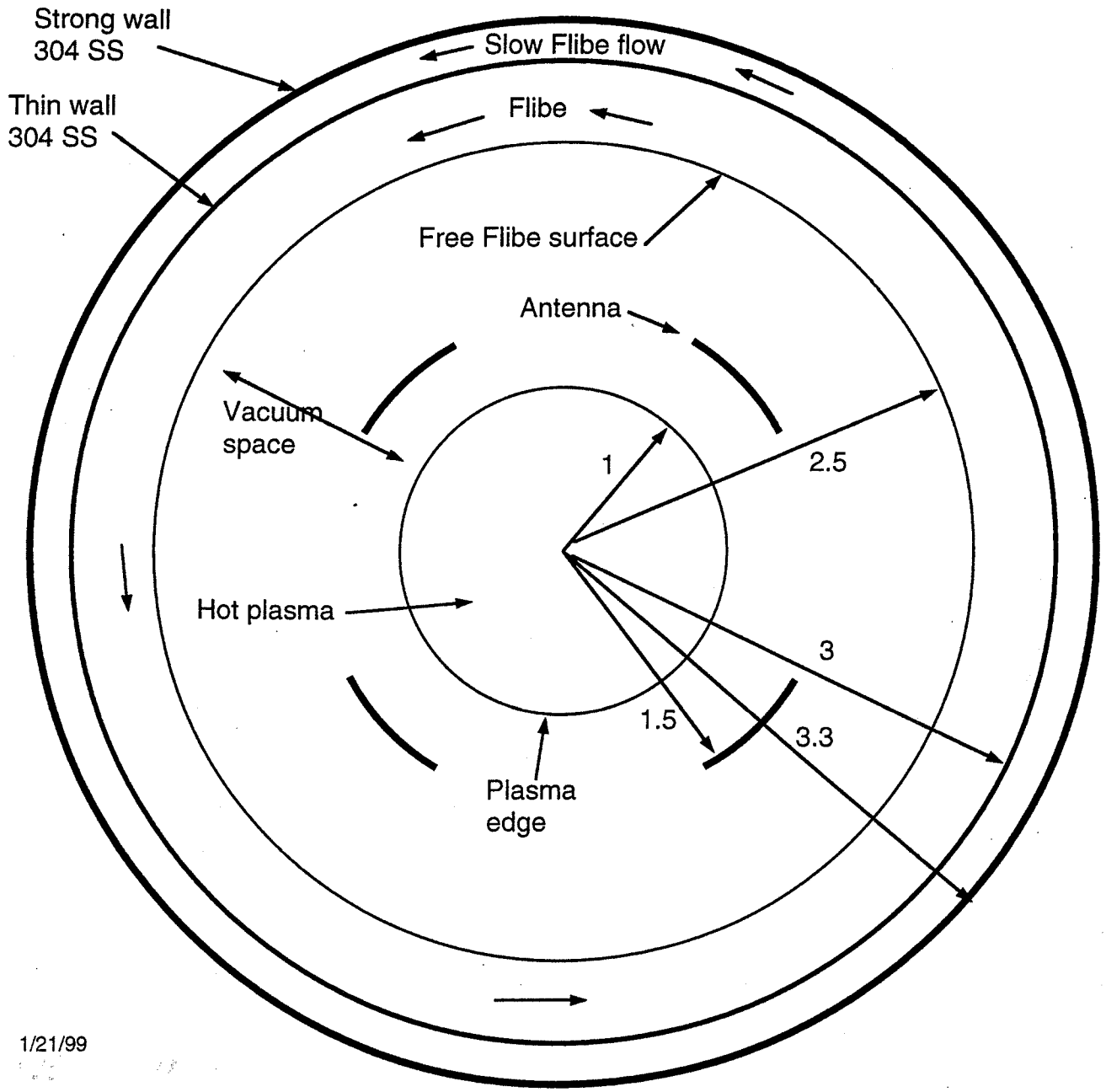




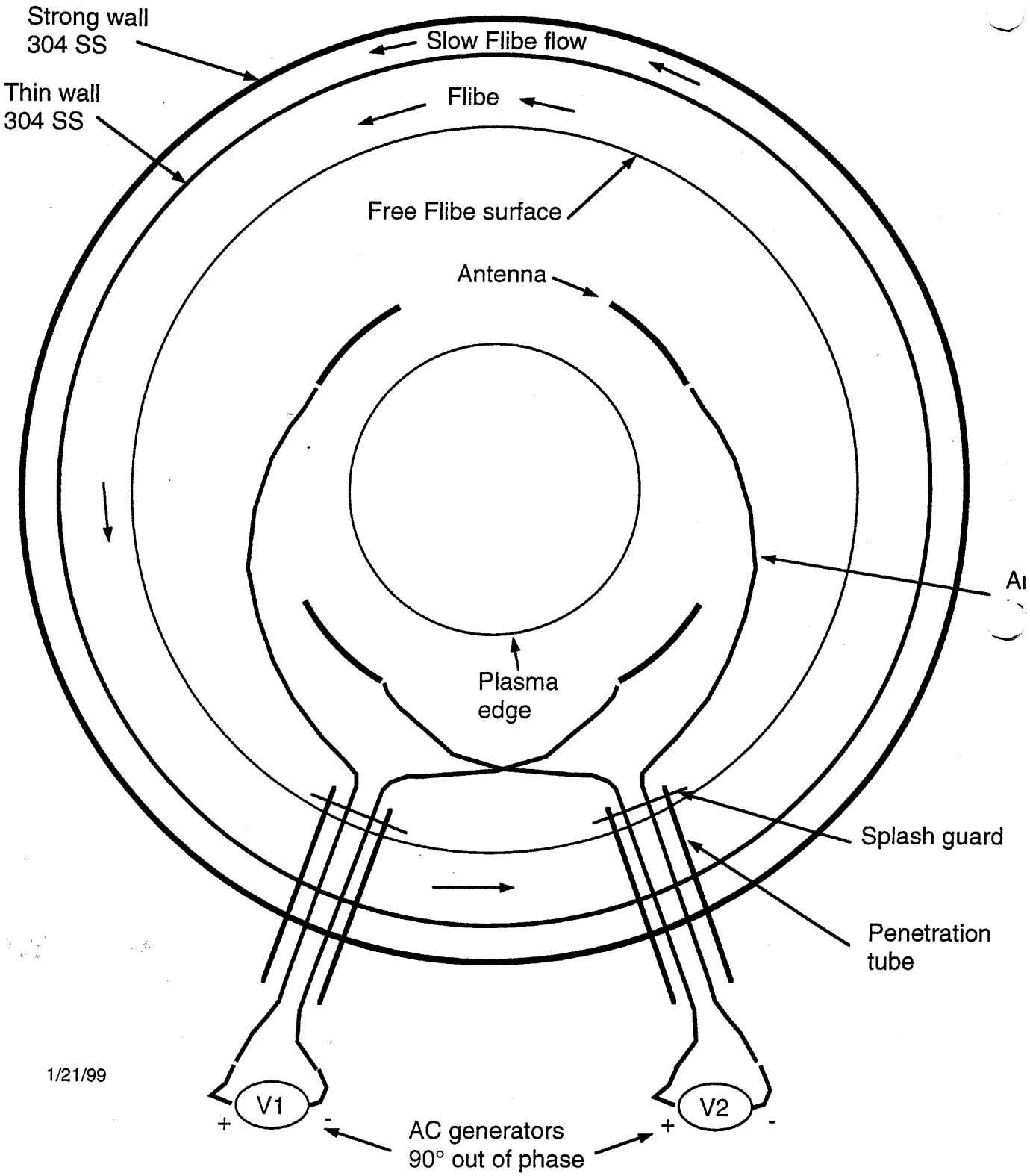

5000
8000
1700
1400
15418
SEE DETAIL CENTER DETAIL
2000
11625
2285
700
2700
7500
8000
15000
69236
8000
10250
1000
11500
2000
3000
1600
2100

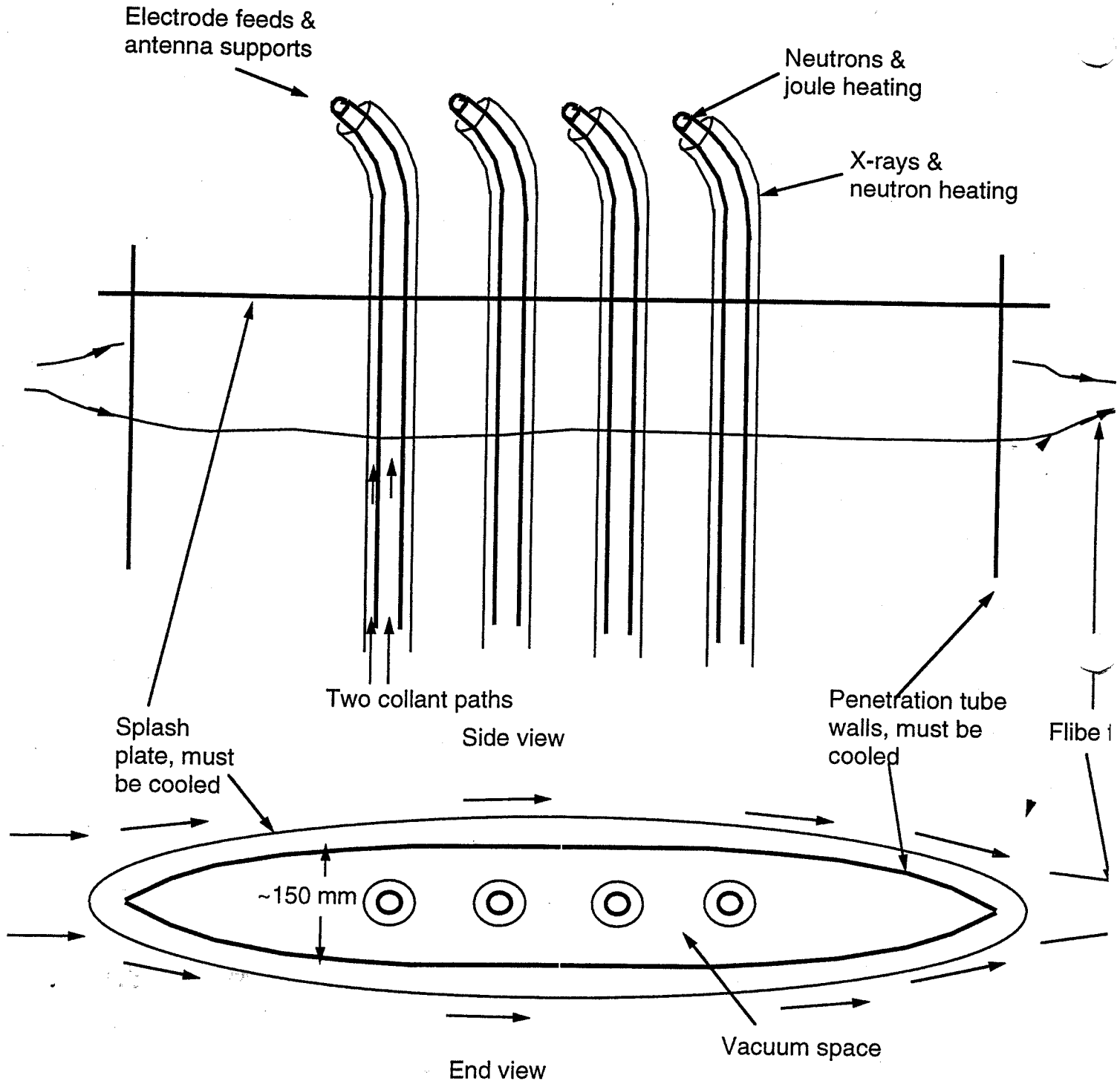


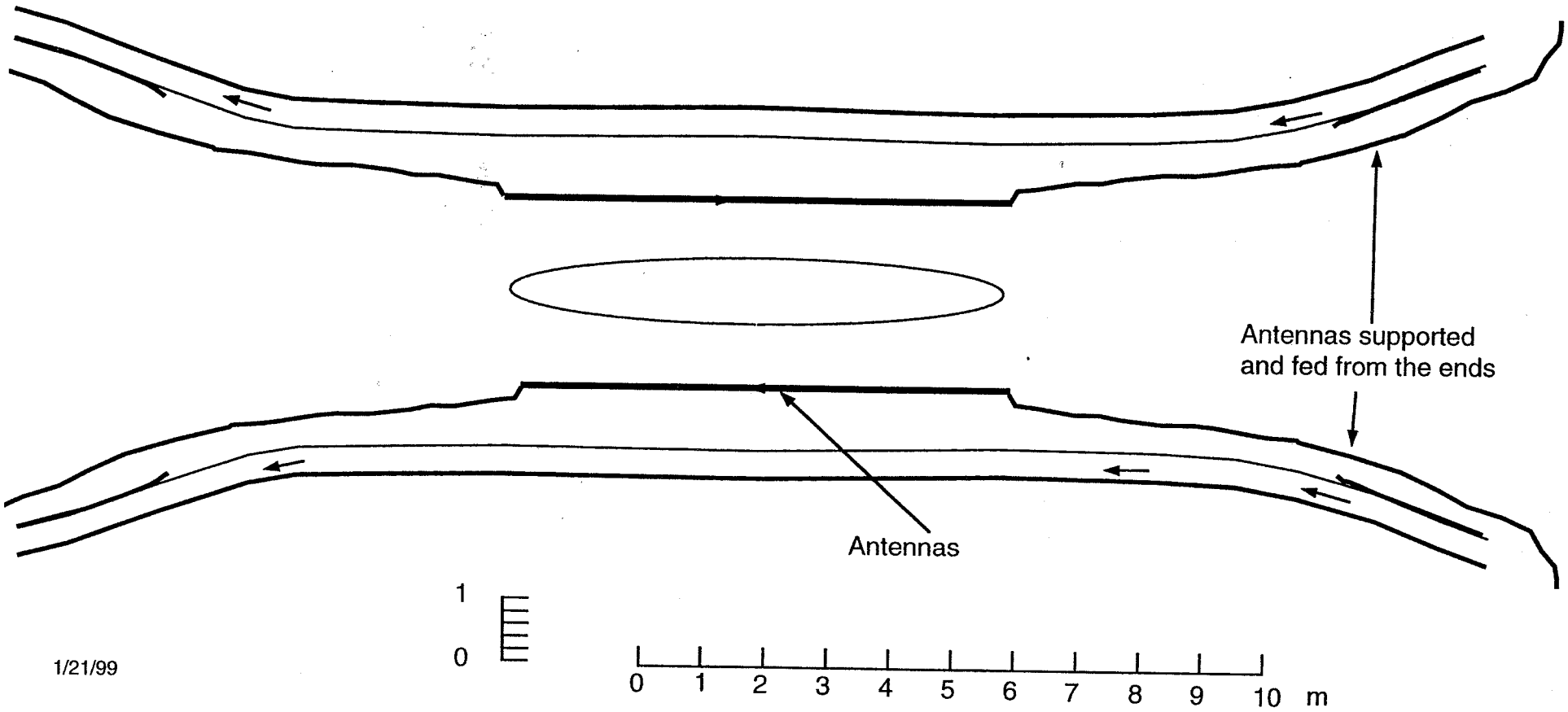
2/9/99


Strong wall
304 SS
Slow Flibe flow
Thin wall
304 SS
Flibe
Free Flibe surface
Antenna
Vacuum
space
1
2.5
Hot plasma
3
1.5
3.3
Plasma
edge

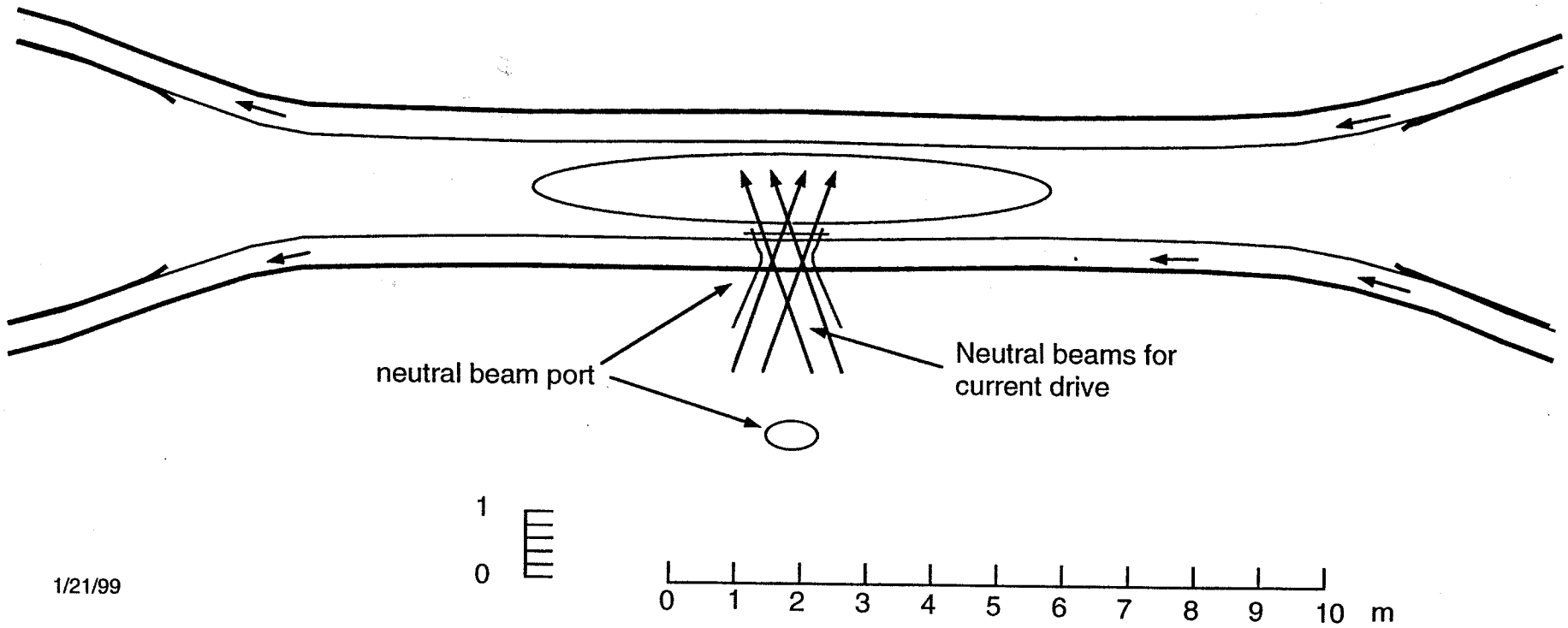
1/21/99


Strong wall
304 SS
Slow Flibe flow
Thin wall
304 SS
Flibe
Free Flibe surface
Antenna
Plasma
edge
Splash guard
Penetration
tube
1/21/99
V1
V2
+
-
+
-
AC generators
90° out of phase

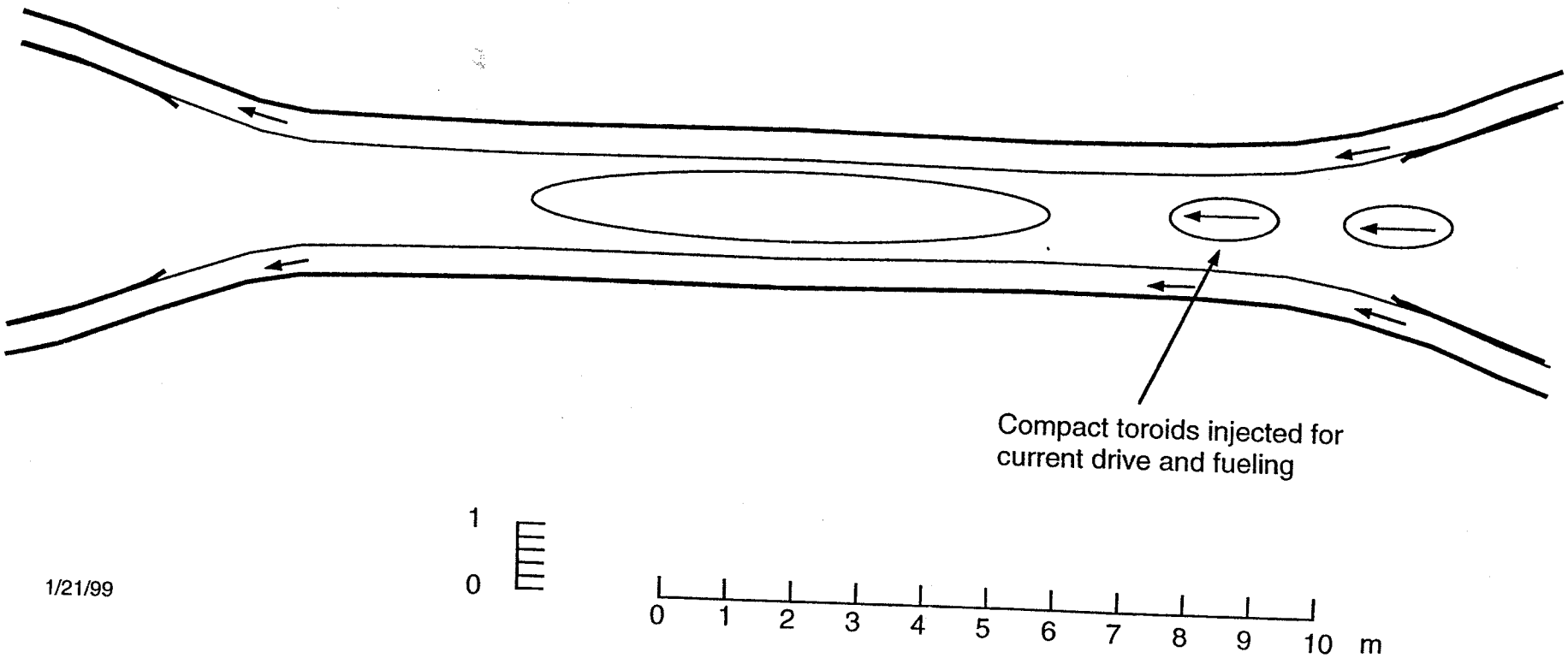

Electrode feeds &
antenna supports
Neutrons &
joule heating
X-rays &
neutron heating
Two collant paths
Side view
Splash
plate, must
be cooled
Penetration tube
walls, must be
cooled
Flibe
~150 mm
Vacuum space
End view


Antennas supported
and fed from the ends
Antennas
1
0
0 1 2 3 4 5 6 7 8 9 10 m

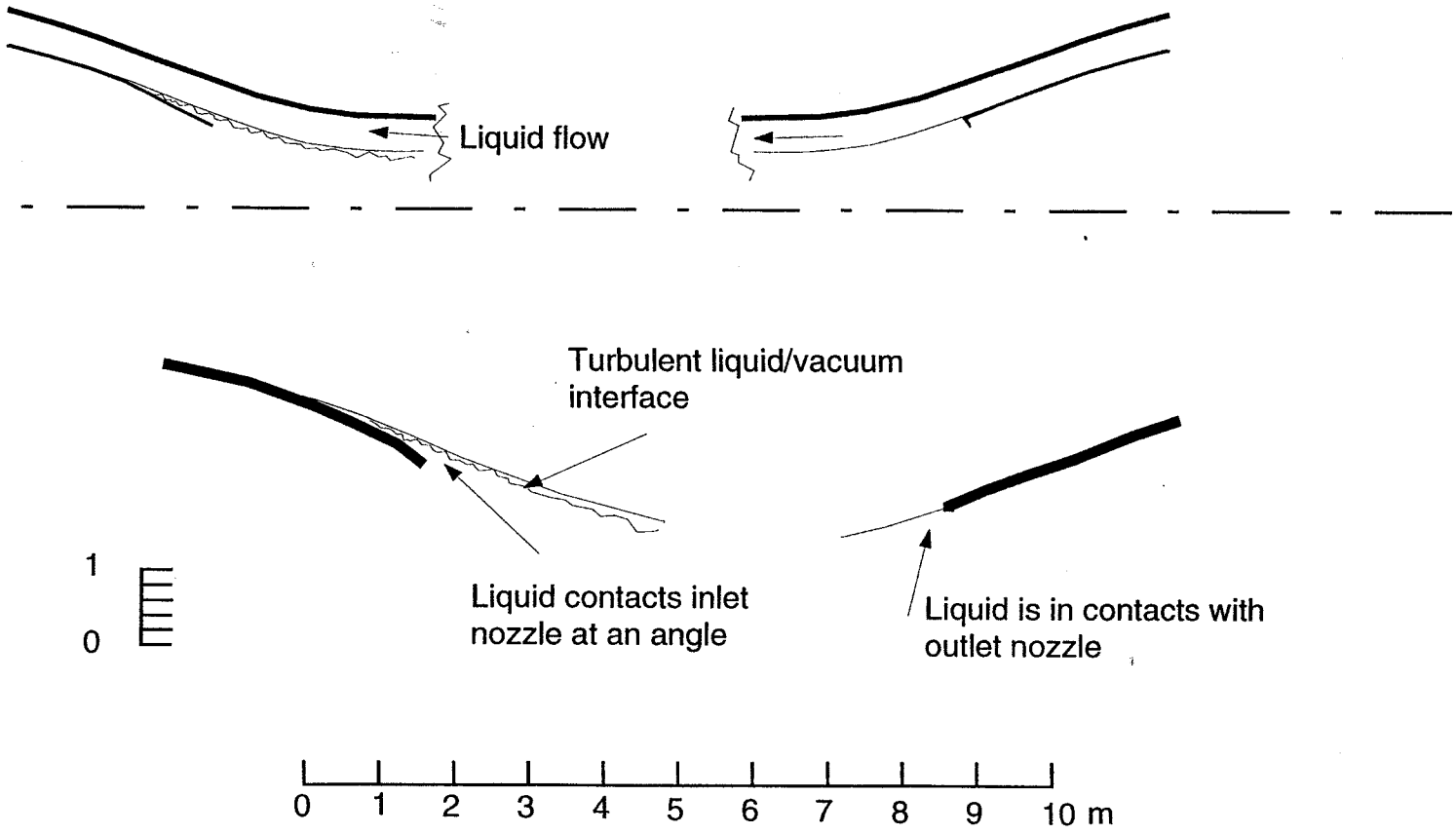
1/21/99


neutral beam port
Neutral beams for
current drive
1
0
0 1 2 3 4 5 6 7 8 9 10 m

1/21/99


Compact toroids injected for
current drive and fueling
1
0
0 1 2 3 4 5 6 7 8 9 10 m

1/21/99


Liquid flow
Turbulent liquid/vacuum interface
1
0
Liquid contacts inlet nozzle at an angle
Liquid is in contacts with outlet nozzle
0 1 2 3 4 5 6 7 8 9 10 m

2/1/99

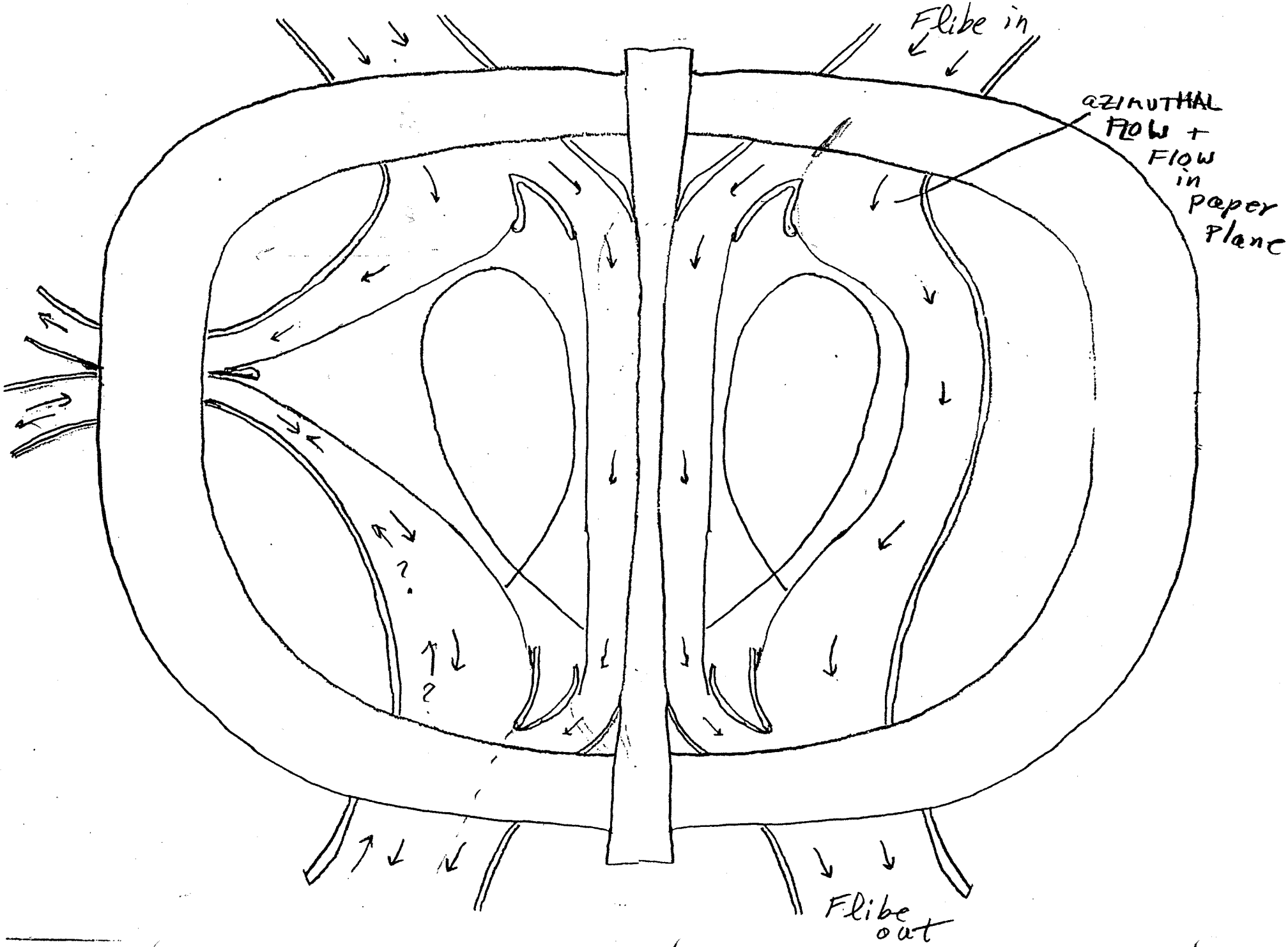
ST design needs

1-ducting design
- TF coil space/access problem

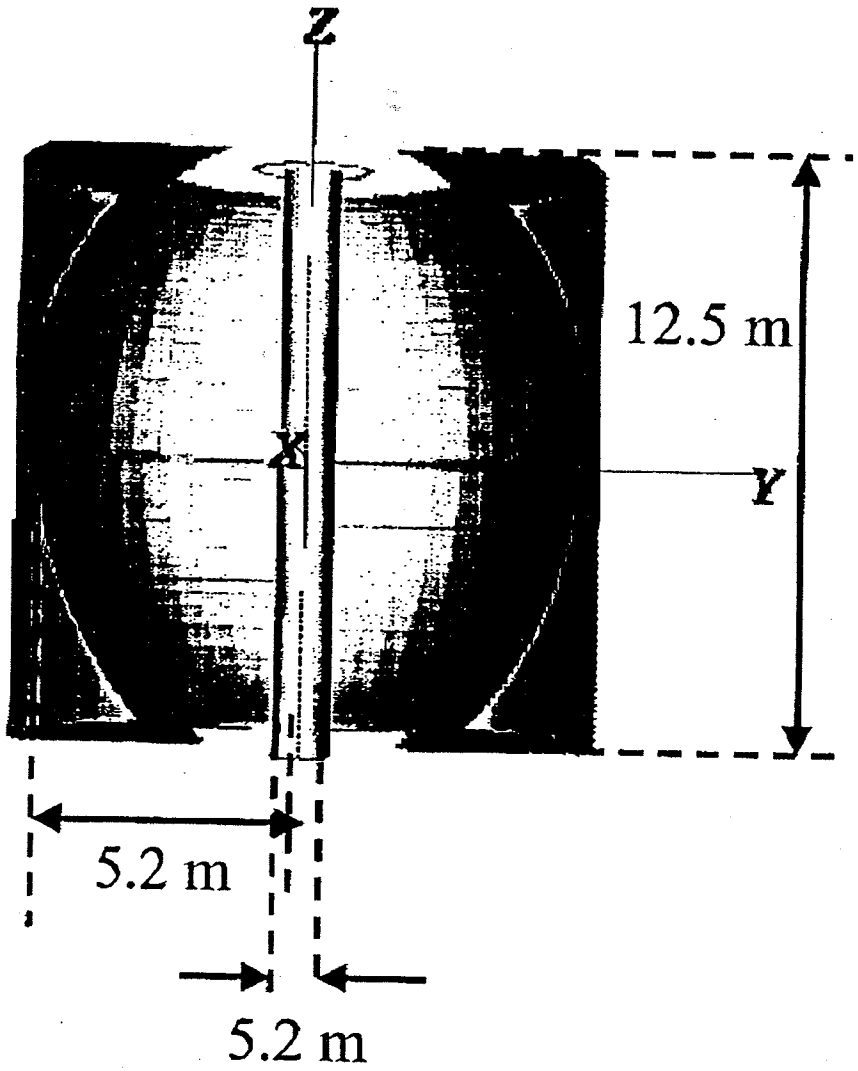
2-inlet/outlet nozzle design
- avoid drips, splash
- rad damage
- cooling

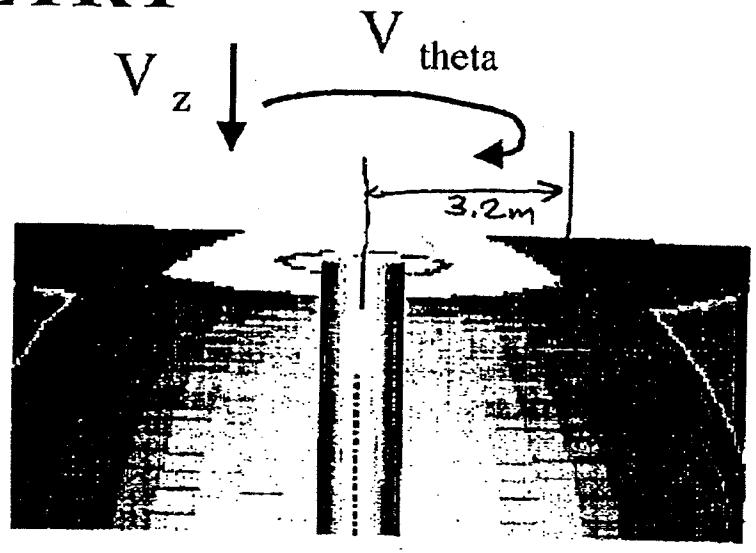
3-penetrations
- avoid drips, splash
- rad damage
- cooling

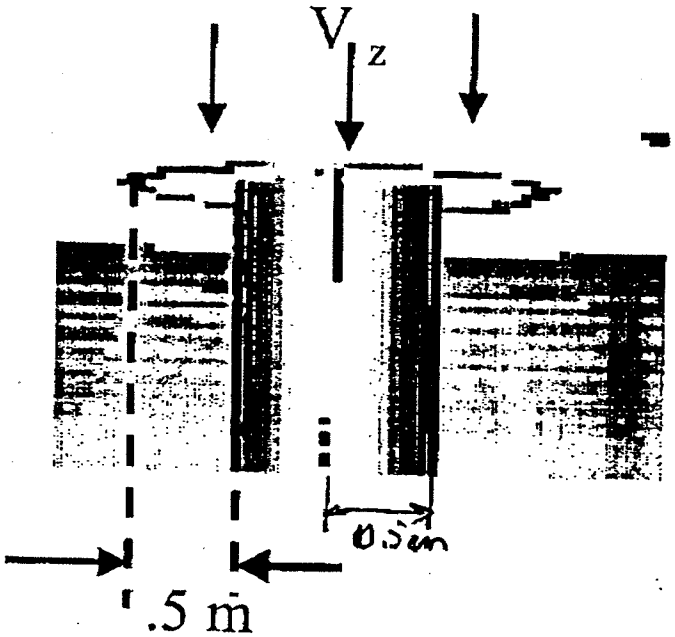
4-current drive and fueling
-
-

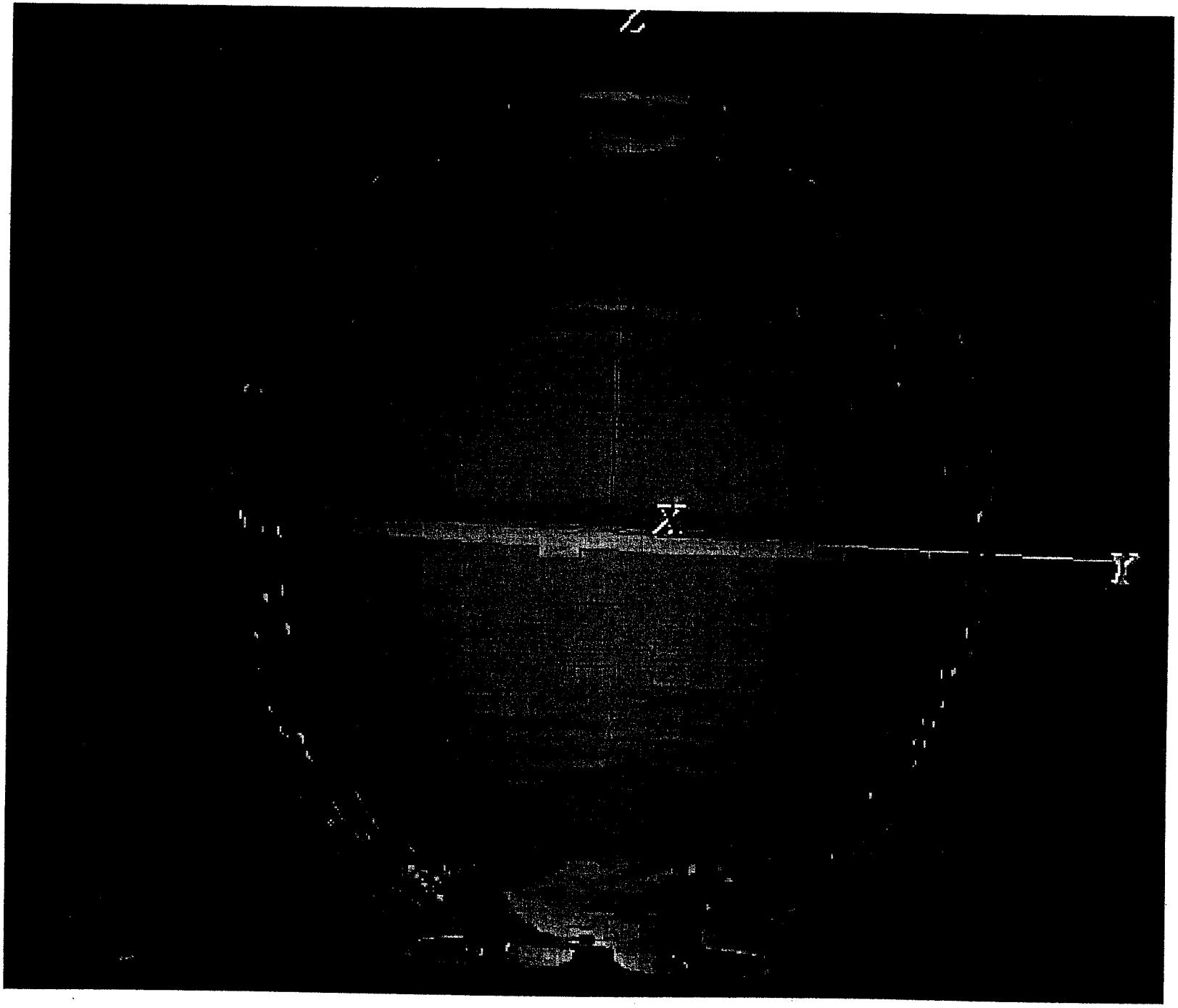

Flibe in
AZIMUTHAL FLOW + FLOW in paper plane
?
?
Flibe out

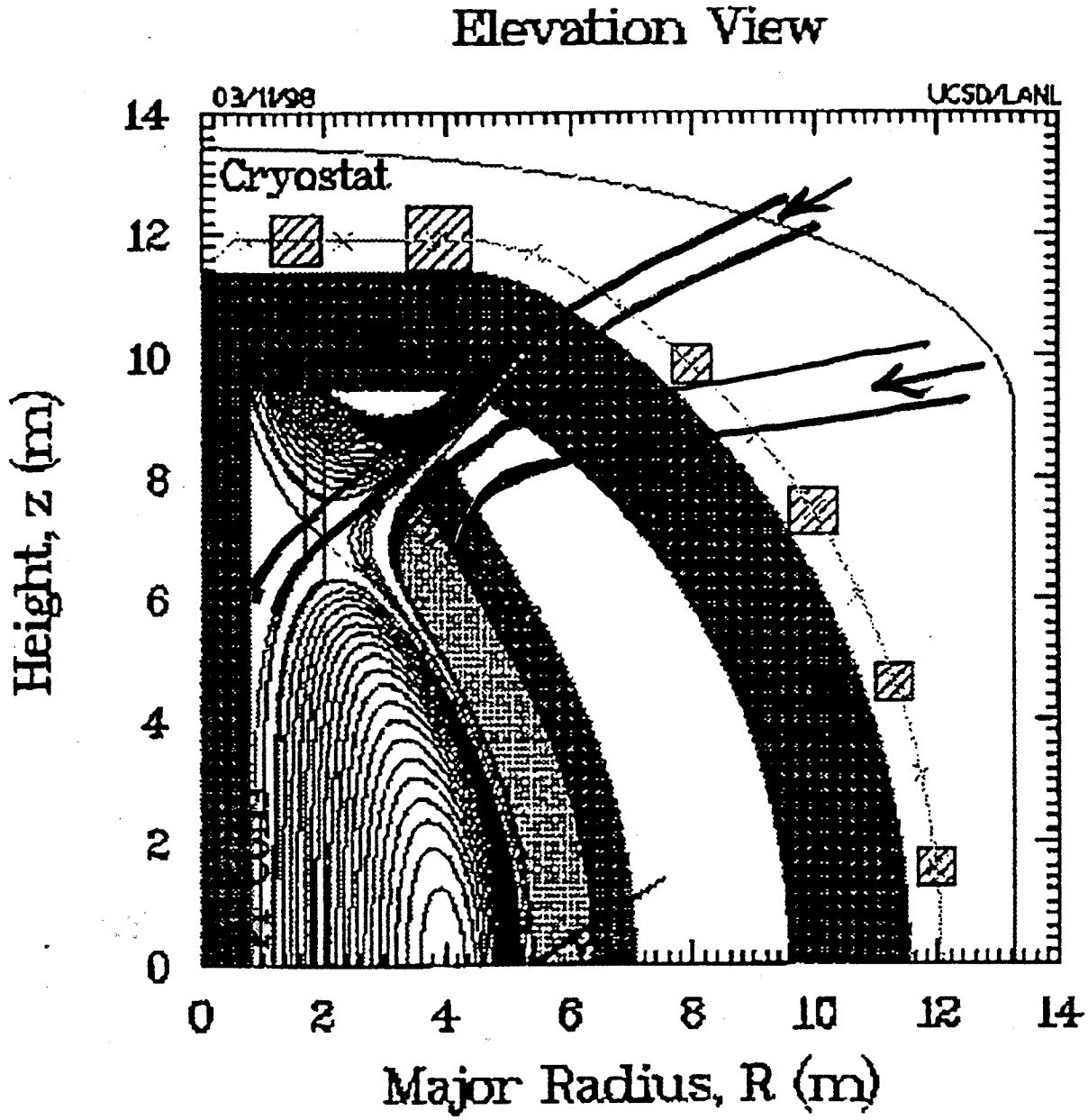
ST GEOMETRY



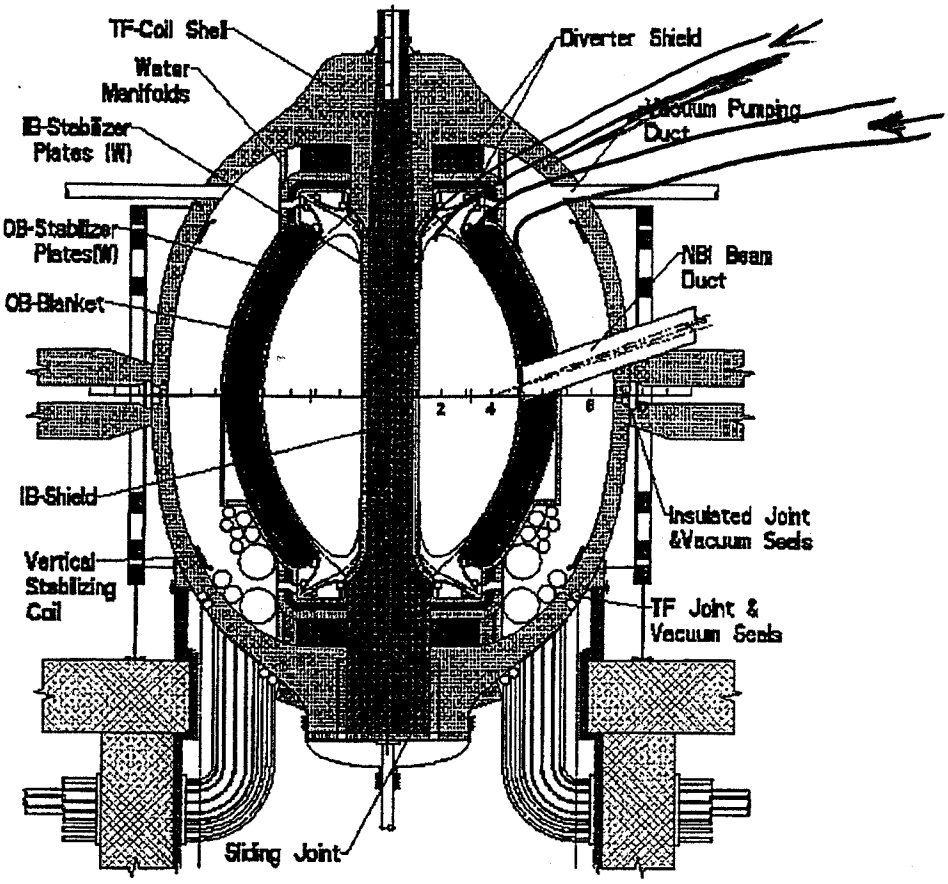





Z
Y
X


Elevation View
03/11/98
UCSD/LANL
Cryostat
Height, z (m)
Major Radius, R (m)
0
2
4
6
8
10
12
14

Elevation View of ARIES-ST Power Core



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Spheromak design needs

1-current drive system
- •electrodes for helicity injection
  - -voltage holding
  - -rad damage
  - -cooling

2-stabilizing conductors embedded in Flibe

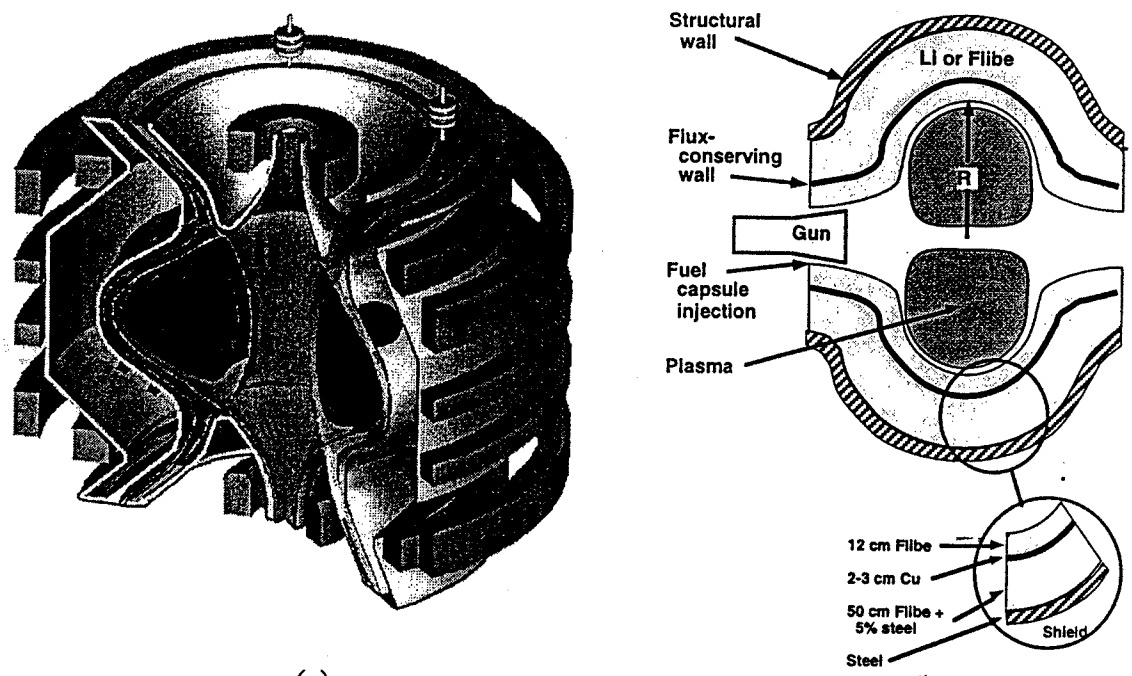
3-fueling

4-ducting design
- •TF coil space/access problem

5-inlet/outlet nozzle design
- •avoid drips, splash

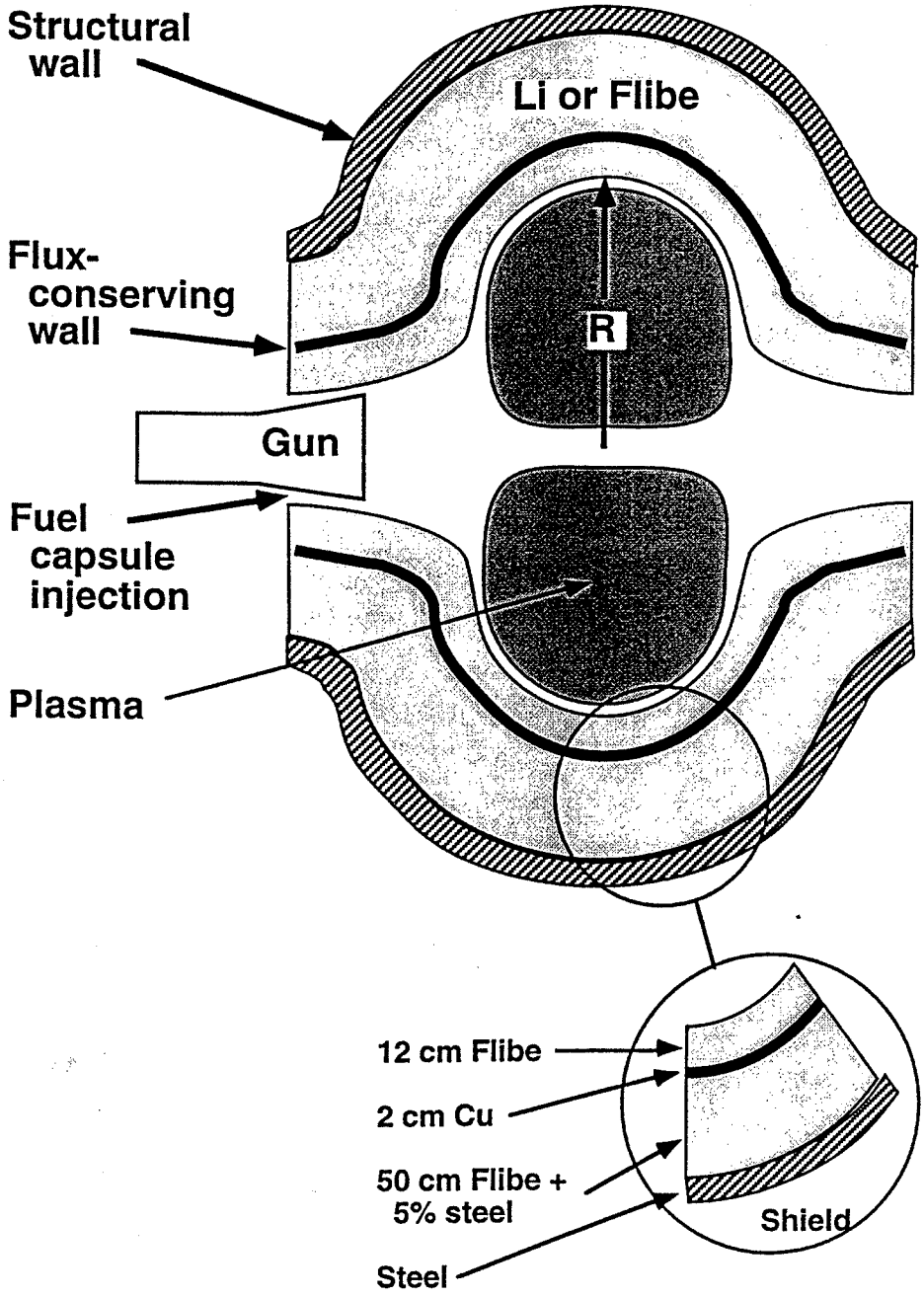
6-penetrations if needed
- •avoid drips, splash
- •rad damage
- •cooling

2/11/99



(a) (b)

Fig. 1. (a) "Conventional" spheromak reactor designed for steady-state operation. (b) Pulsed, high beta spheromak reactor with the fusion energy absorbed by the liquid lithium or Flibe which is replaced by flow between pulses.



Fowler, et al. Fig. 1

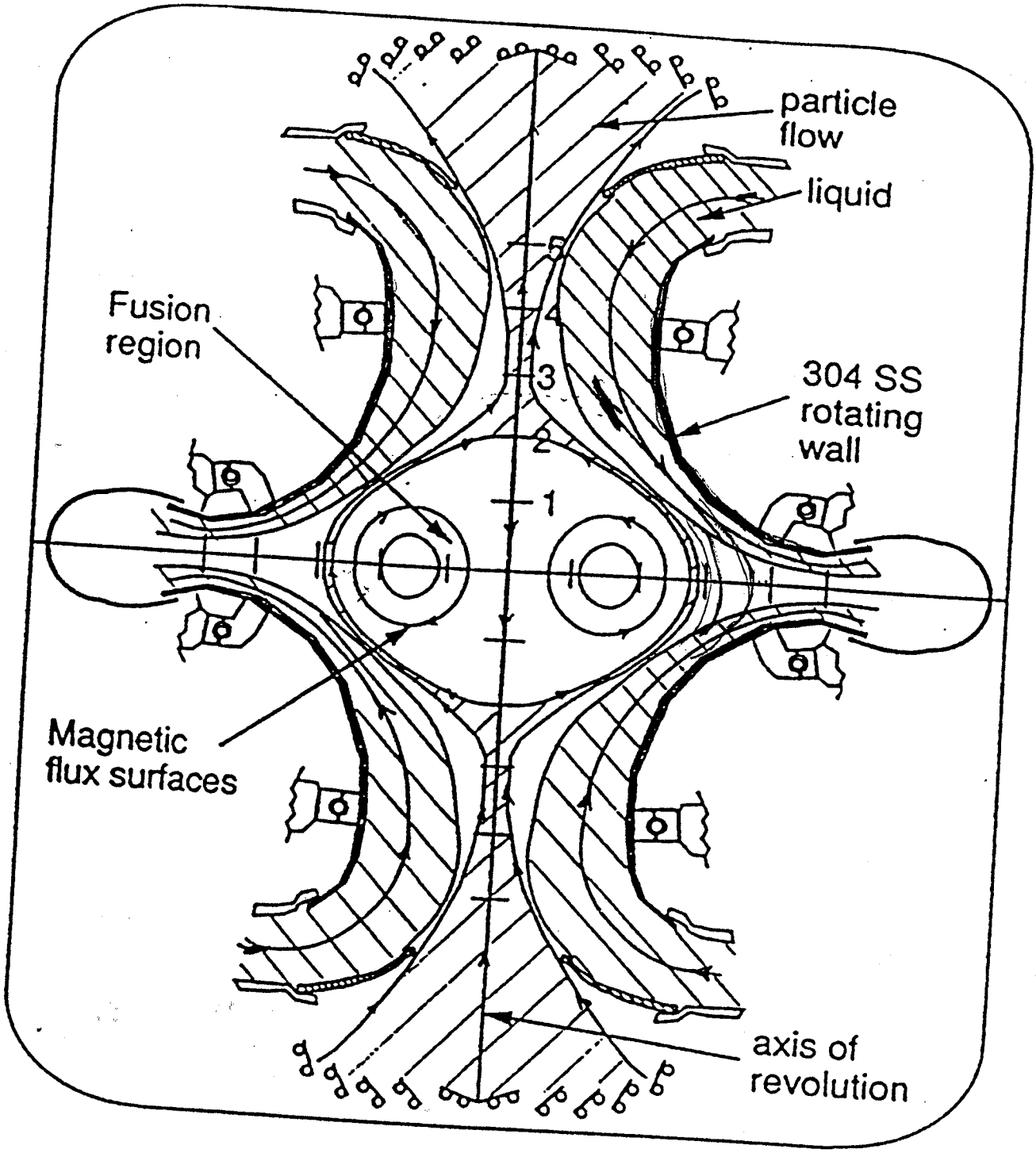


FIG. 4. A low conductivity liquid can be made to almost completely surround a region by creating artificial gravity from spinning the liquid, as shown in the above schematic drawing of a spheromak. Magnet coils are not shown. The moving parts and seals needed here are shown in detail in Fig. 9.