Toroidal Flow Liquid Metal Wall Concept or:

The "Soaker Hose" Approach to Liquid Metal Walls

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In a nutshell:

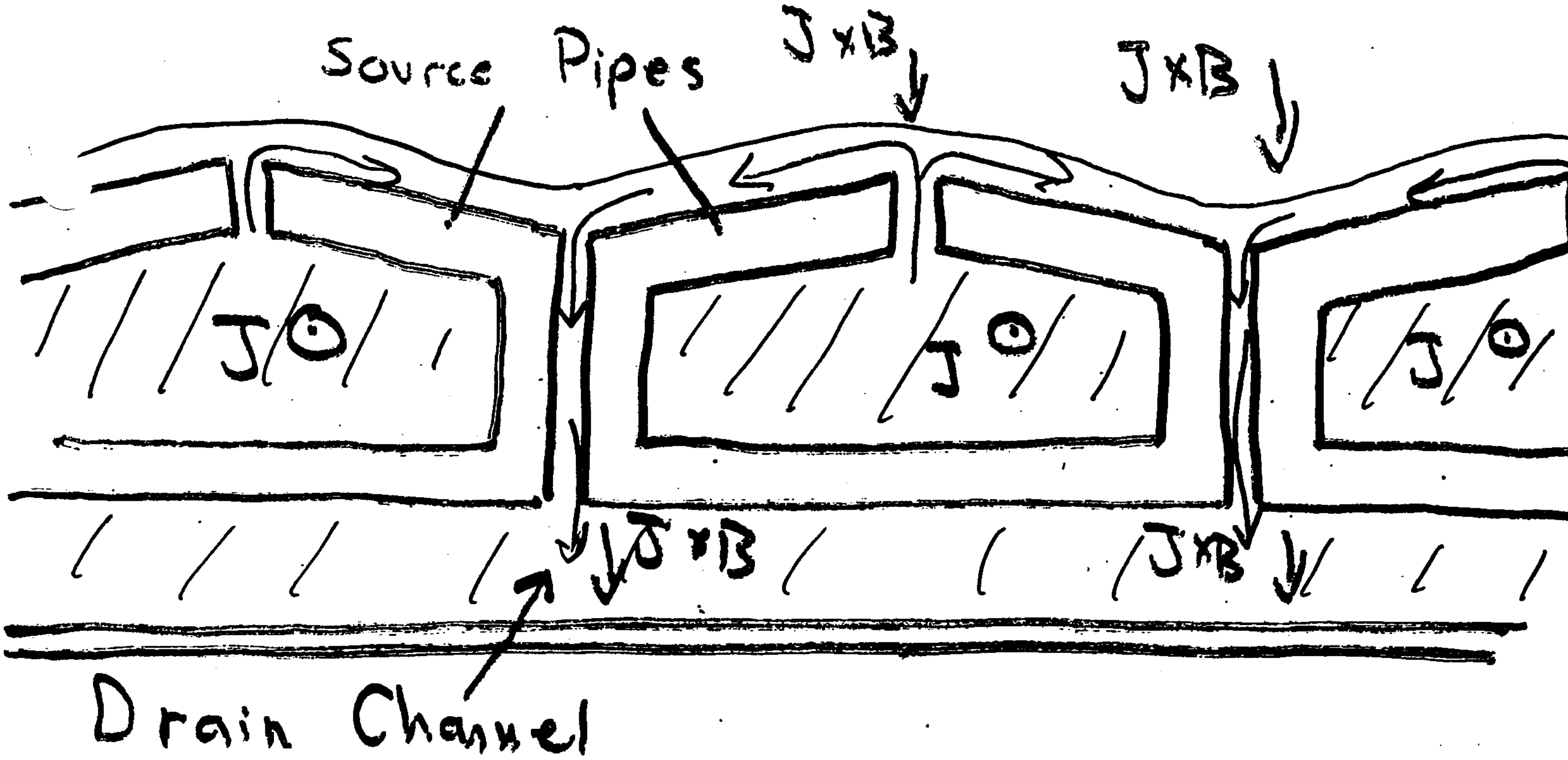
Use J x B forces like gravity to force fluid into the wall (like Bob Woolley)

Employ a system of source pipes in the first wall to bring liquid from the top to the surface

These pipes hove holes (slits) which bring the liquid metal to the surface of the first wall

The metal flows a short distance along the surface to drain holes

The J x B force propels the liquid through the drain holes into a set of drain pipes



The source pipes are pressurized to force the liquid against MHD flow damping

The J x B force in the slits maintains the pressure in the source pipes (preventing squirts)

The liquid pools on the surface, and j X B forces propel it “downhill” to the drain holes

The angle of the incline determines the flow rate across the surface (and thus the residence time on the surface)

The j x B force in the drain holes keeps the drain channel presurized

This pressure forces the liquid through the drain channel to the bottom

Obvoius Questions:

Is the flow resistance in the pipes small enough that the J x B force can keep them pressurized at the required flow rate? (Yes)

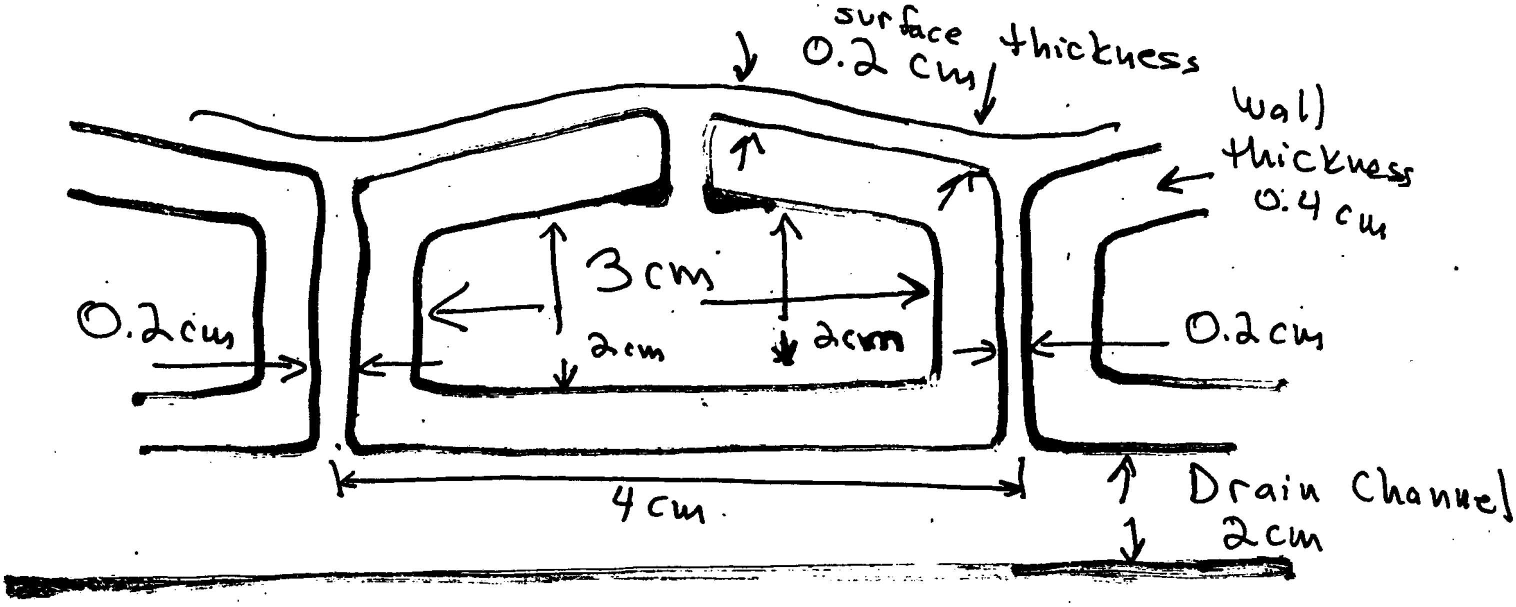
Is the residence time on the surface short enough (e.g. ½ sec) ? (Yes)

Is the Ohmic power to produce the J x B force acceptable? (Yes)

Is it stable against gravity? (? Probably)

Can residence times on the surface be made very short (~ 10 millisec) for use in a divertor? (Yes)

Example Parameters for Liquid Wall



Residence time = .5 second => surface flow velocity $\cong$ 4 cm / sec

6 m long pipe (ARIES) + .2 cm flow thickness
=> flow rate $\cong$ 960 cm^3 / sec

6 cm^2 area => 1.6 meter / sec flow rate

Insulating pipe => Hartman layer drag only (B=7 T, ARIES) => .15 atmosphere / meter initial pressure drop

5.6 m length + gradually decreasing velocity => .45 atmoshere initial pressure

J x B balancing this pressure over.5 cm =>
J = 1.3 x 10^6 Amps/meter => E = .4 V / meter

DRAIN CHANNEL

J×B in drain holes force liquid into drain channel

J×B against flow damping rate $B^2/\rho\eta$

⇒ drain ~~rate~~ 5.6 cm/sec

> 4 cm/sec

⇒ pressure at drain channel = 0.6 atm

is much more than enough to force liquid in the drain channel to the bottom

Ohmic dissipation from J:

4 cm Li total depth (source + drain) => 21 kW electric power / m^2

Ppmping power averaged over first wall < 1 kW / m^2

8 MW fusion power / m^2 @ 45% efficiency
=> 3.6 MW electricity / m^2
=> 0.6 % recirculating power

Gravitational Stability

Oversimplified case: a *uniform* .2 cm thickness Li layer including surface tension *without flow* is Rayliegh Taylor unstable to wavelengths greater than about 6 cm with maximum growth rate ~ 6 sec^{-1}

However, flow shear is a stabilizing effect – dv/dx ~ 20 sec^{-1}

Need to do analysis including this.

Surface replacement rate ~ 2 sec^{-1}. At the possible expense of additional power or complexity, this could be increasd to be faster than the growth rate.

Even without this, if *breaks* are included:

Wavelength could be limited to < 6 cm, where surface tension produces stability

Structural Materials

Crudely estimate stresses

$\lesssim 1\%$ tensile strength

SiC

Also, consequences of small crack on flows is not significant

⇒ high reliability

⇒ don't need Composites ????

Adding 1% B or Be to SiC

makes $\frac{\sigma_{SiC}}{\sigma_{Li}} < 10^{-7}$

⇒ only Hartman Drag

Is This Potentially Near Term?

Pipe flow in channels well understood

Surface flow over inclined planes well understood

Structural aspects seem unchallenging

If gravitational instability is resolved –

Could we do an engineering design near term?

Ready for CDXU? NSTX?
FIRE divertor?
Small scale test in PISCES?