The role of water in MNT Spacecraft

A visionary outlook

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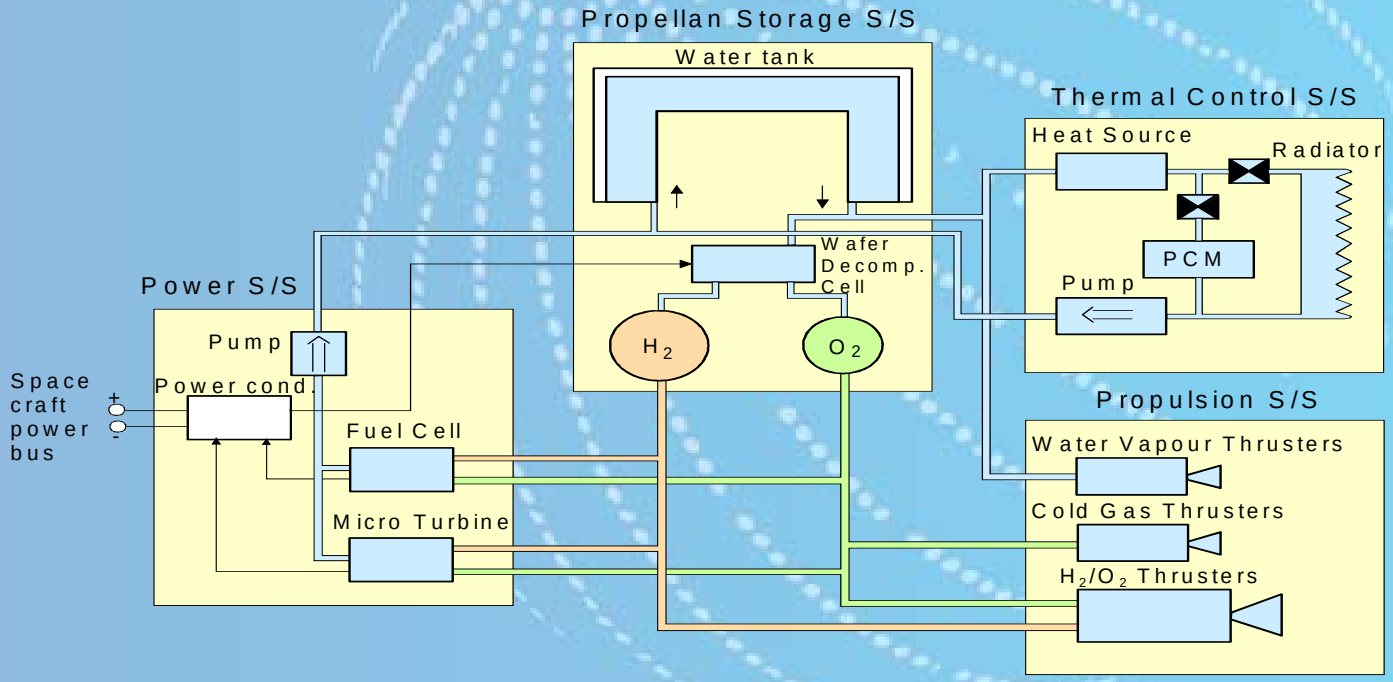
Outline

Water in future Spacecraft-overview
- Water Vapour Micro Thrusters
- Micromechanical Gas Storage
- Membraneless Hydrogen Fuel Cell
- Conclusions

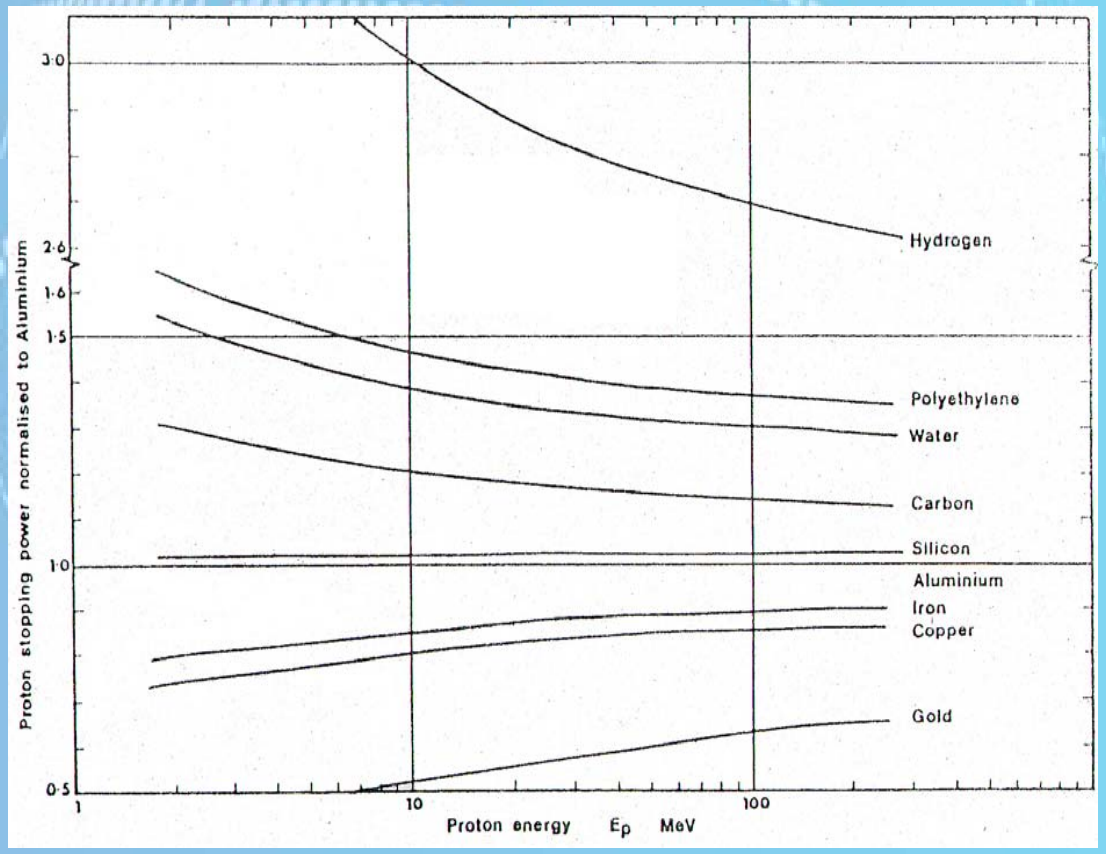


Structure S/S - Radiation shielding

The large cross-section of water against space radiation makes it very useful as radiation shield around sensitive electronic components. The proton stopping power is about 20 % better than aluminum per mass unit.

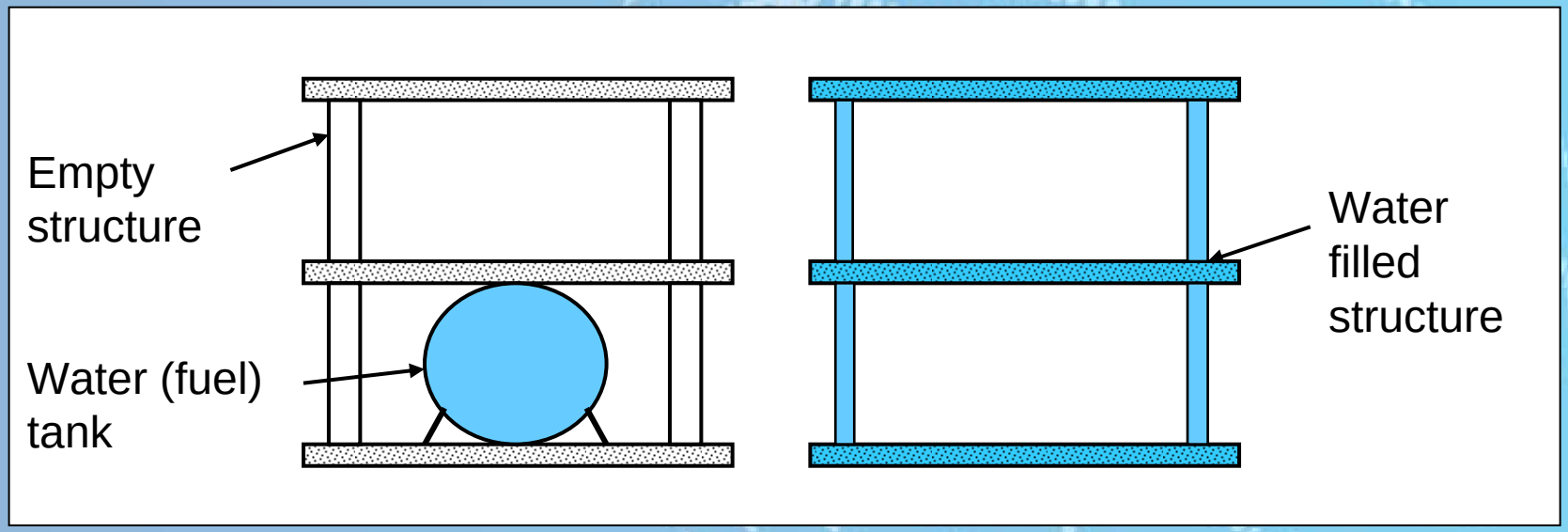
Stopping power for fast neutrons and Bremstrahlung is also excellent.

The water-based radiation shield can be viewed as part of a smart structure being gradually consumed during the mission.



Structure S/S - Structural support

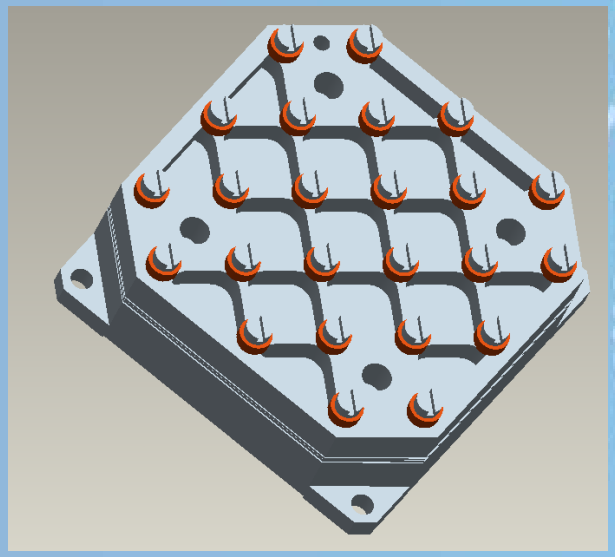
A spacecraft structure is normally exposed to the high mechanical loads during the launch, the mechanical loads in orbit are almost zero. Therefore a temporarily reinforcement of the structure will result in a significant mass-saving of the same.



As water is incompressible, it can be used to prevent buckling of thin-walled tubes used as structural elements. Water filled structures will also be damped due to the viscosity and movement of the liquid. Eigenfrequencies will also be lower as the structural mass increases. If the water is stored in frozen condition, it can further increase the stiffness.

Power S/S
(water related part)

Electrical power can be generated in several ways using Oxygen and Hydrogen, with:



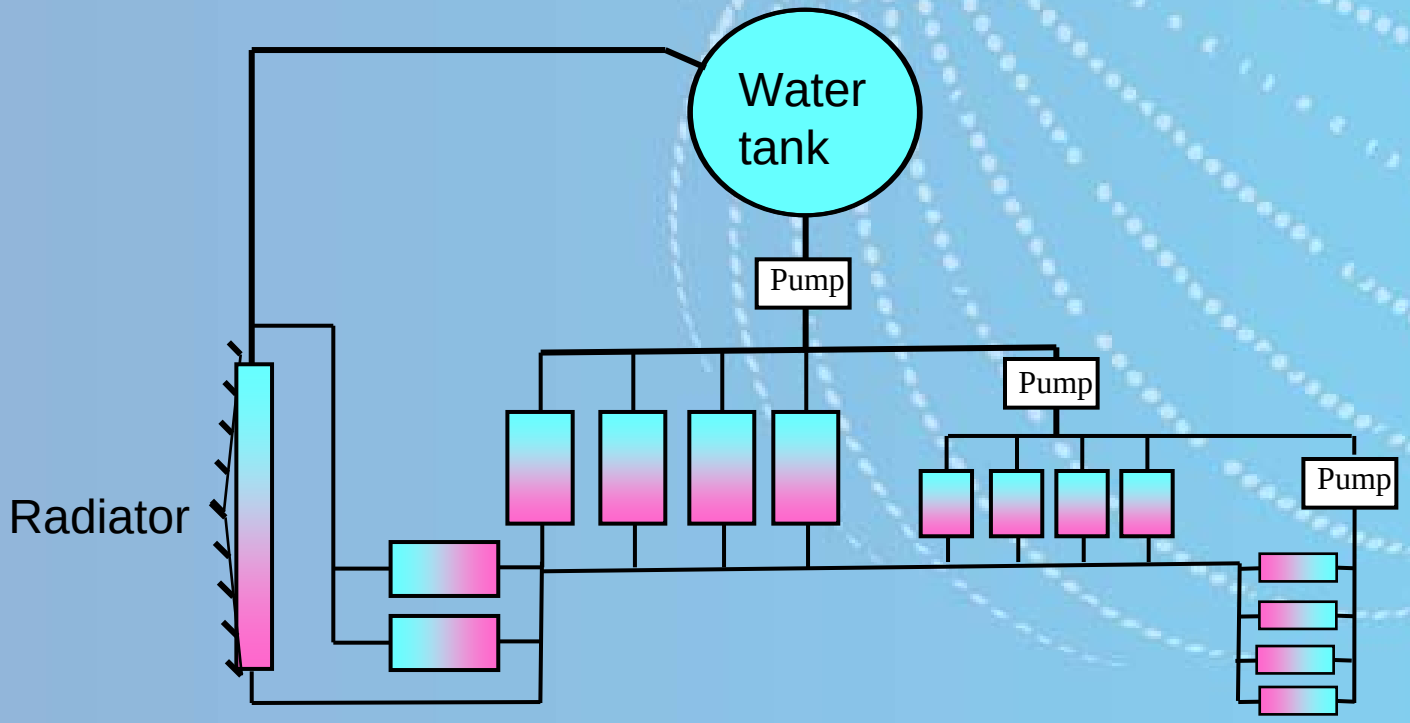
A membraneless Hydrogen Fuel Cell prototype

- Micro turbines, high efficiency
- Fuel cells, good efficiency
- Thermoelectric generator, poor efficiency

For heat generation can also micro combustion be an efficient alternative

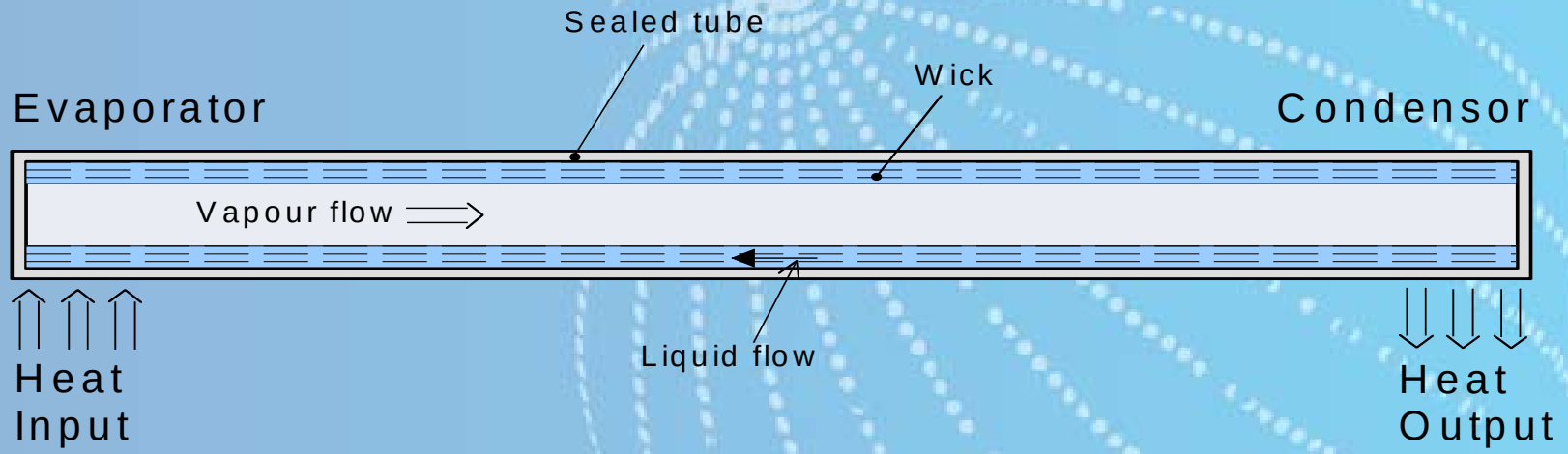
Thermal control S/S

Water is a very efficient medium for energy transportation. In the waterbased spacecraft will water be pumped around in many channels, from larger pipes down to narrow capillary channels, very much reminding of the blood circulation system in a human.



Heat pipes

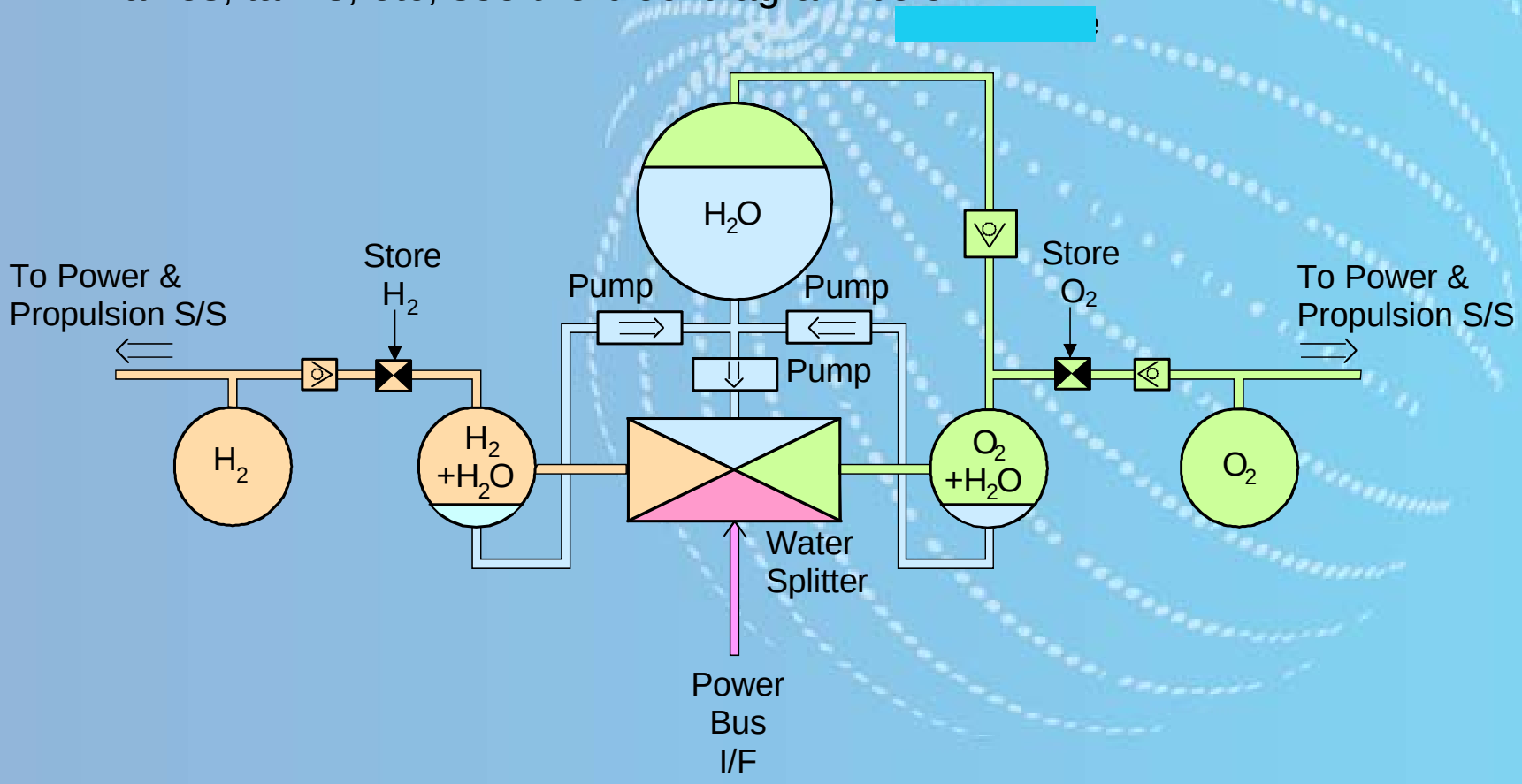
If there is a high demand of heat transportation, as when burning a rocket engine, can waterbased heat pipes be an alternative.



Heat is absorbed at one end by evaporation of the fluid and released at the other end by condensation of the vapour. The heat transport capacity is high, typically 100 times higher than solid copper.

Water S/S - gas production

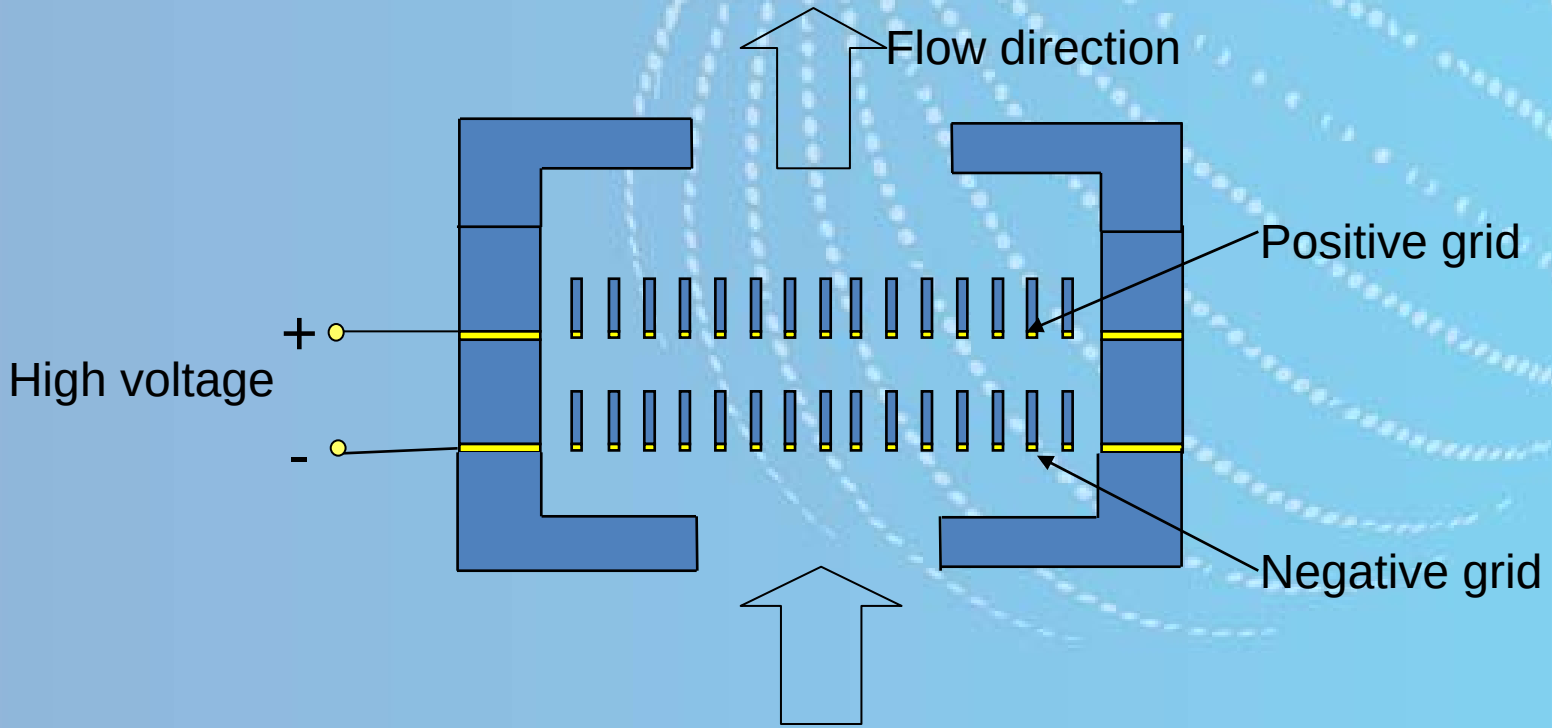
There are at least three pathways to produce Hydrogen by water splitting in space, thermolysis,photolysis and electrolysis. When all parameters are evaluated seems electrolysis to be the best method, but all methods requires quite a lot of support components, pumps, valves, tanks, etc, see the blockdiagram below.



Water S/S-Electrohydrodynamic pumps

Electrohydrodynamic motion arises when the molecules of a polar fluid, such as water, are subjected to a strong electric field. The resulting motion can be used to generate a fluid pressure or flow.

Electrohydrodynamic devices have an inherently simple design, they require high operating voltage, but at a low current. They can produce a high flow rates at low pressure, suitable for circulation of water in a thermal control system.



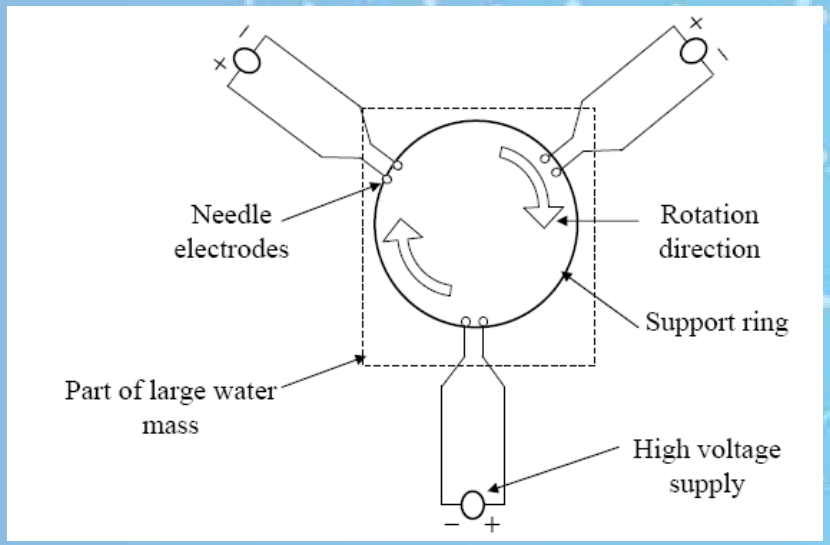
AOCS S/S

Water can be used in several types of attitude or orbit control systems

- Cold gas thrusters
- Bi-prop. rocket engines
- EHD reaction wheels
- Water vapour thrusters
- H_2 Ion thrusters

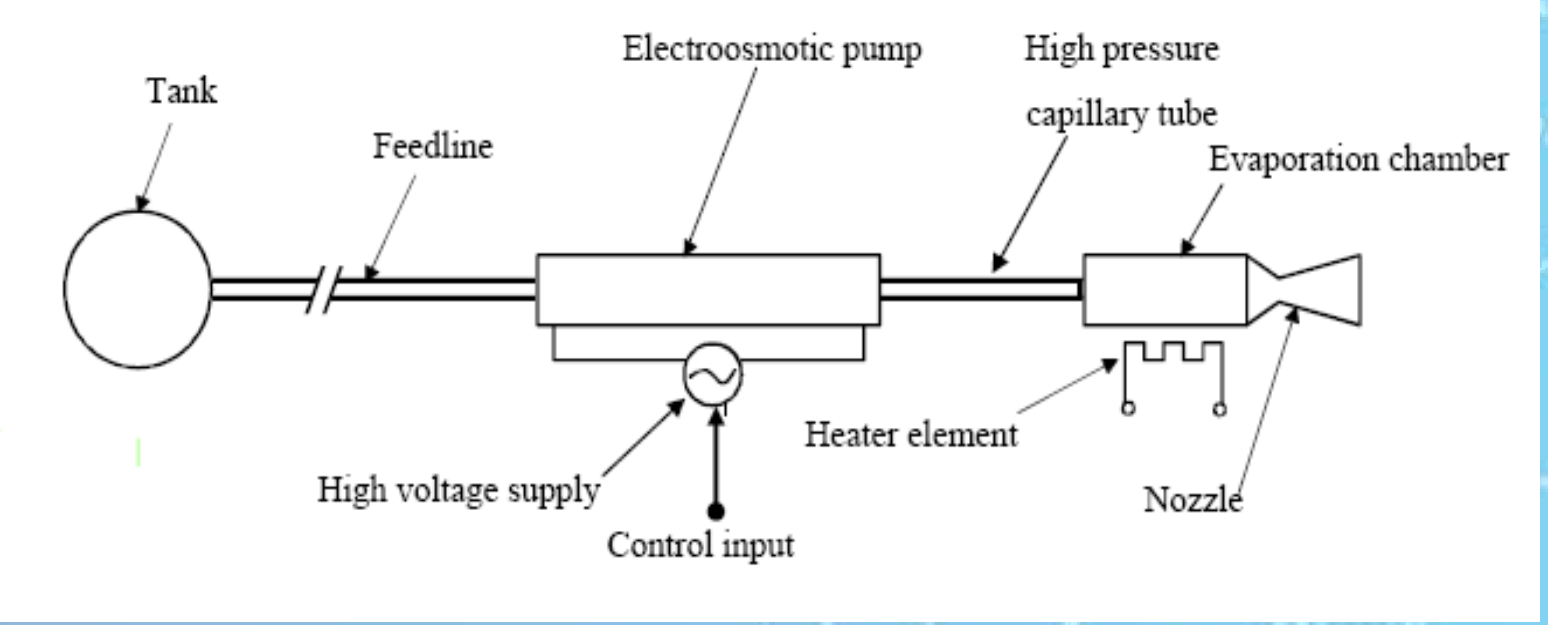
Electrohydrodynamic driven Reaction Wheel

If a support ring shaped as a cylinder or as a toroid with a number of electrodes is immersed in water can the water mass inside the ring be forced to rotate in one direction or the other. A soft reaction wheel is created. A wheel without moving mechanical parts that can stick or wear. As there are no bearings involved can the operation probably be very smooth, suitable for high accuracy pointing, without the use of propellant consuming thrusters.



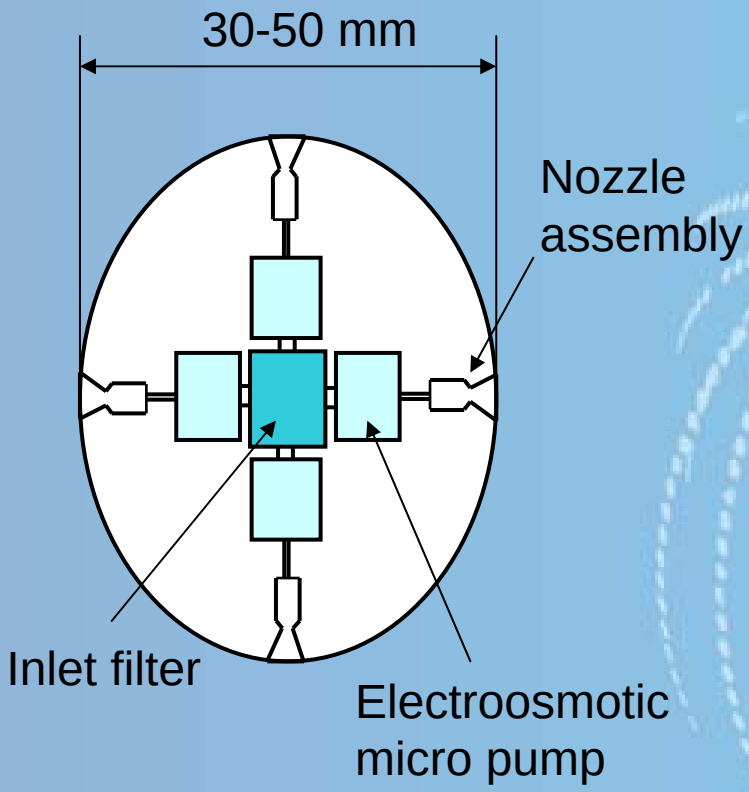
Water Vapour Micro Thrusters

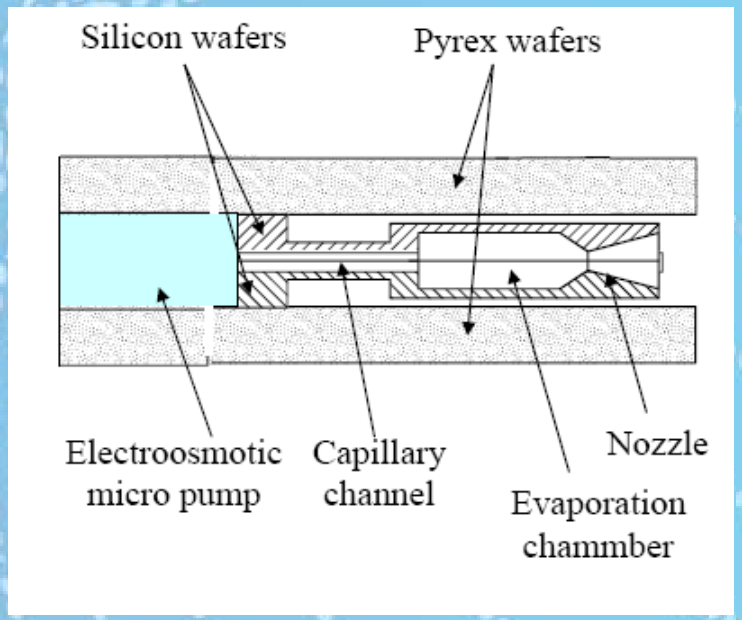
Water vapour is an very efficient propellant for micro thrusters, the specific impulse is 150 sec, compared to 77sec for Nitrogen. It shall also be noted that system efficiency is much higher as heavy high pressure tanks are avoided.



System block diagram

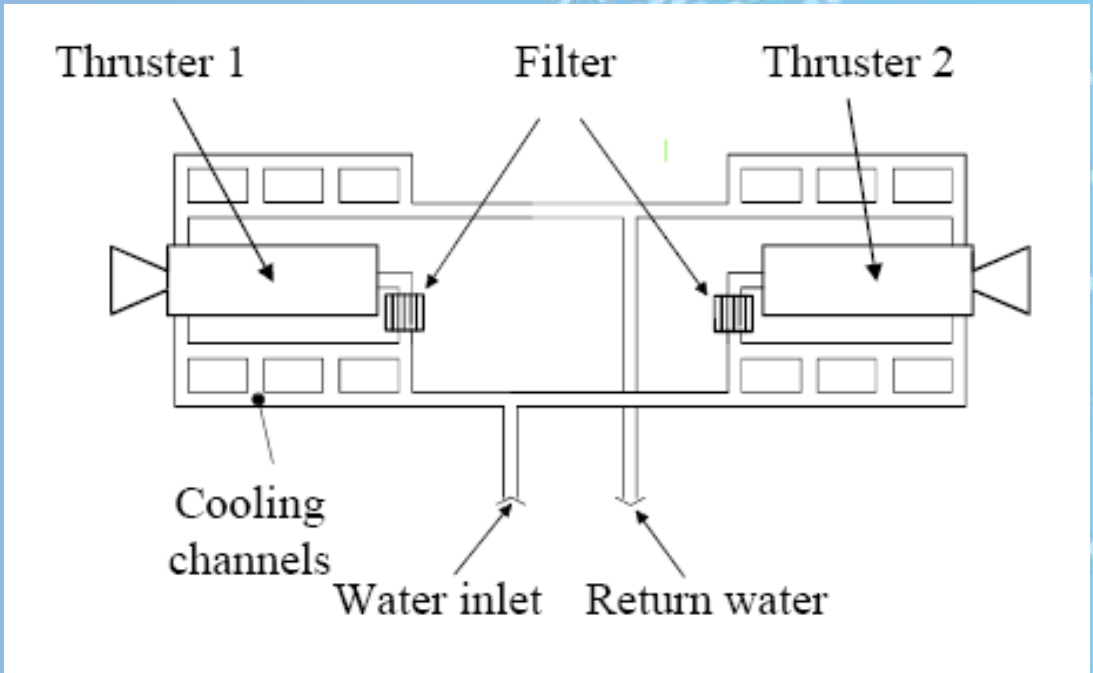
Micro thruster cluster assembly





Cross-section through an integrated micro thruster

Water distribution/thermal control Thruster Pod

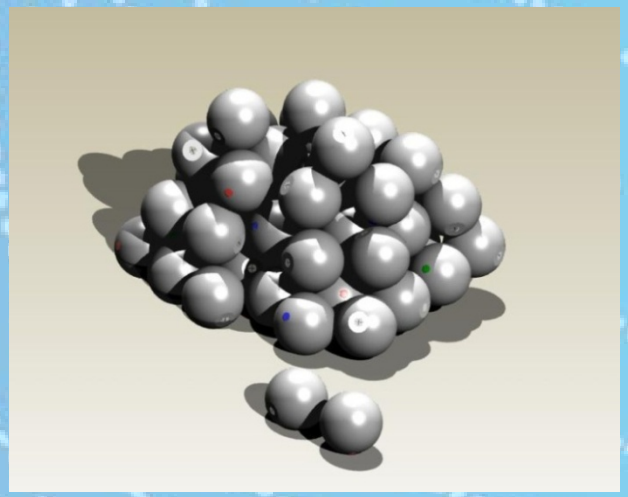


This is an example on integrated thermal control. More water than the trusters consume is constantly circulated in the thruster pod, keeping it at a convenient temperature. When the thrusters are in operation is the excessive heat transported away.

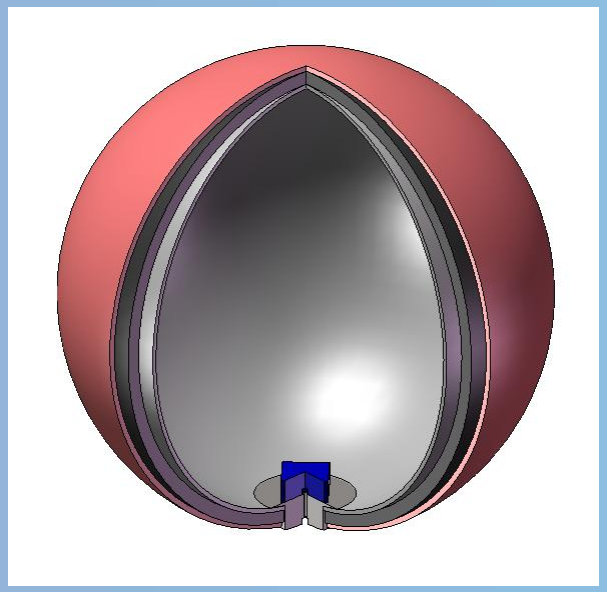
Micromechanical gas storage concept

MacroSpheres, a new concept for high pressure storage of Hydrogen gas, based on the use of a multitude of small autonomous tanks resulting in:

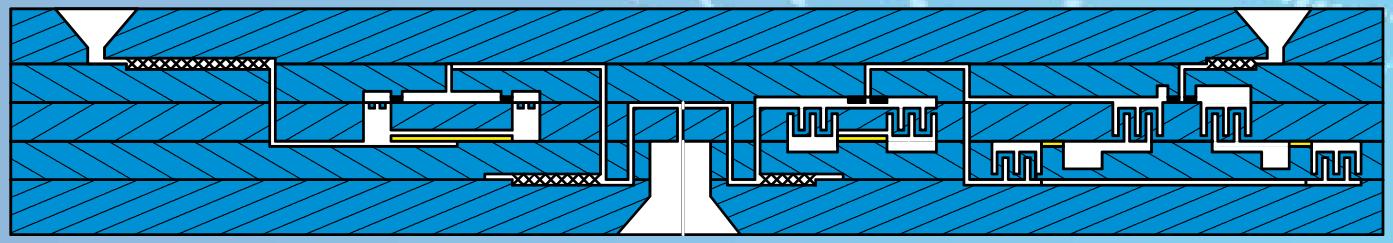
- High storage capacity
- High safety level
- Easy handling
- Refill system
- Low material consumption over life time



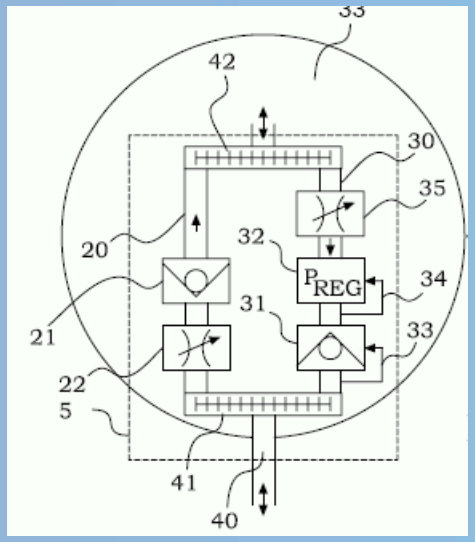
MacroSphere design

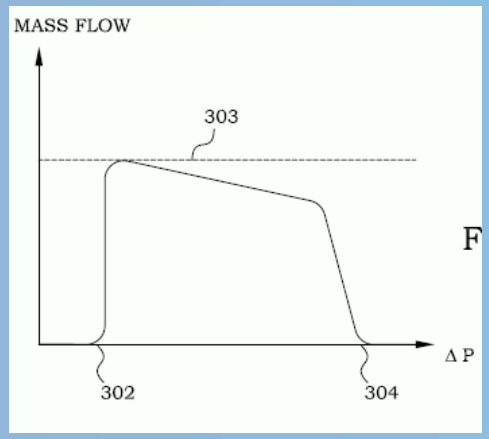


Each MacroSphere is a small composite tank with a gas handling microchip mounted on the inside. The chip contains all micro mechanical structures needed to handle the high pressure fill and release of gas,valves,filters,etc.



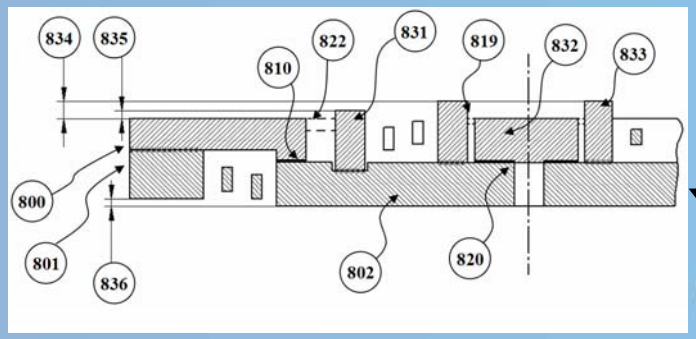
Microchip design

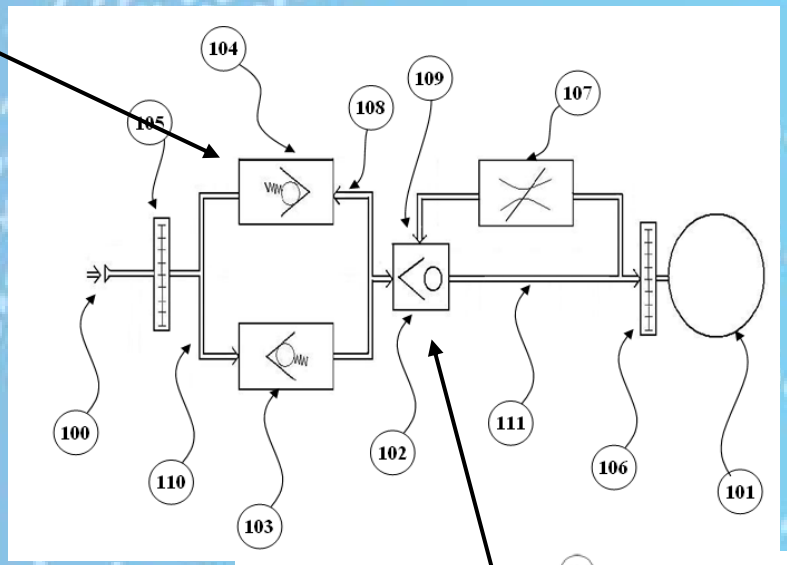


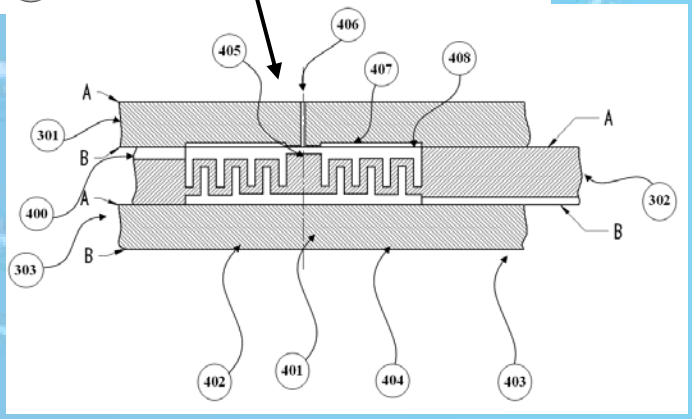


- It is only the relation between the ambient pressure and the internal pressure that controls the gas flow to and from the tank.
- No heating or other stimuli signals are needed to release the gas.
- No mechanical connections or external sealings are needed, the user will never be exposed to high pressure components.

Design high pressure Check Valve

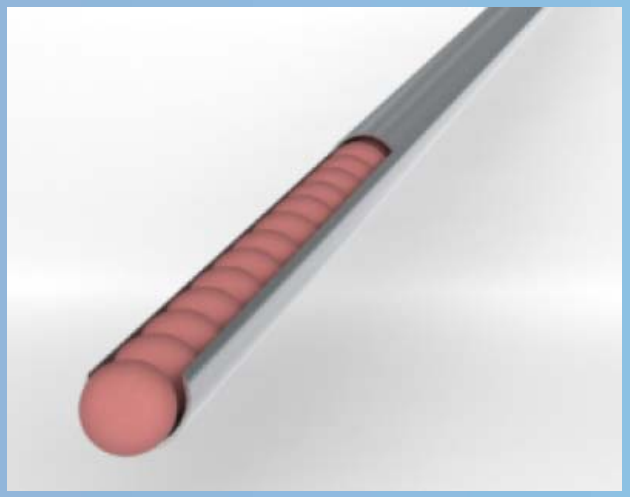






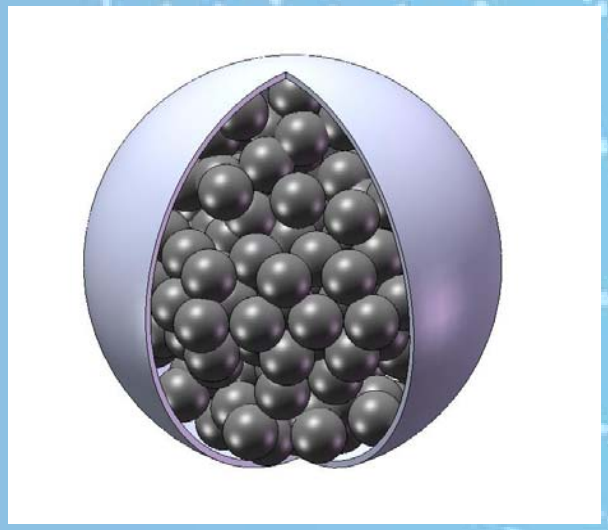
The practical design of the filling valve is not so simple if all requirements shall be taken into account. A system of three valves working together seems to be the best solution. A low pressure Check Valve (104) gives the low crack open pressure, while the normally open high pressure valve (107) takes care of the high back pressure resistance.The medium pressure reversed Check Valve (103) protects the system from destructive over pressure after filling.

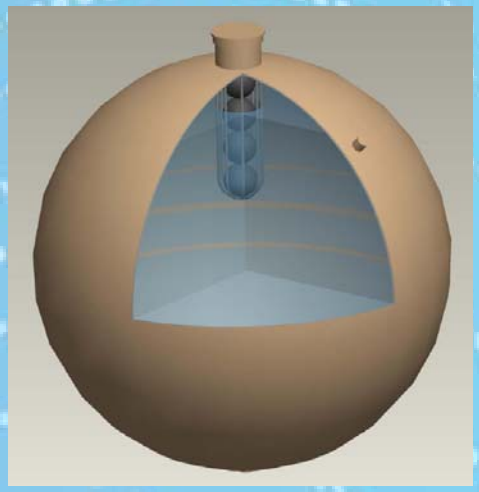
Buffer tank designs



The MacroSpheres can be stored in strait or bended tubes for easy replacement

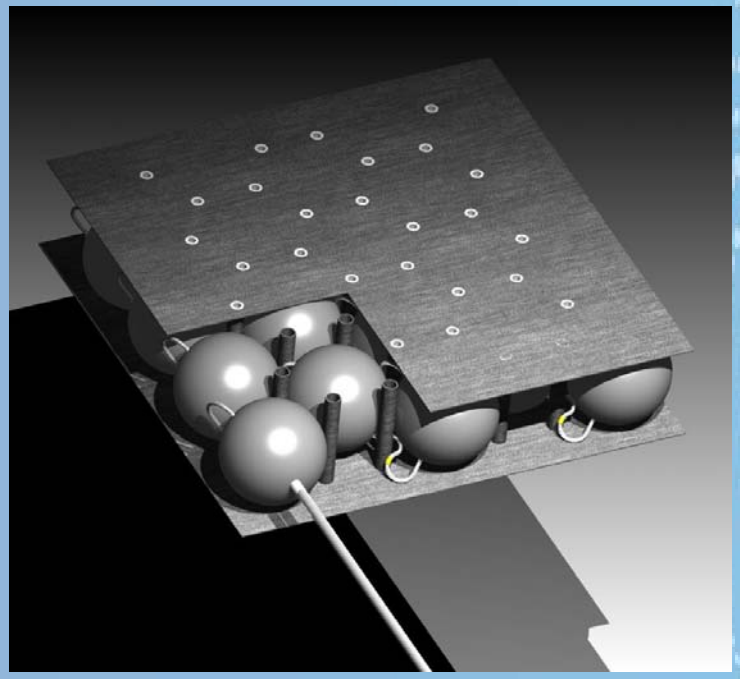
They can also be stored randomly in a larger low pressure tank of arbitrary shape.

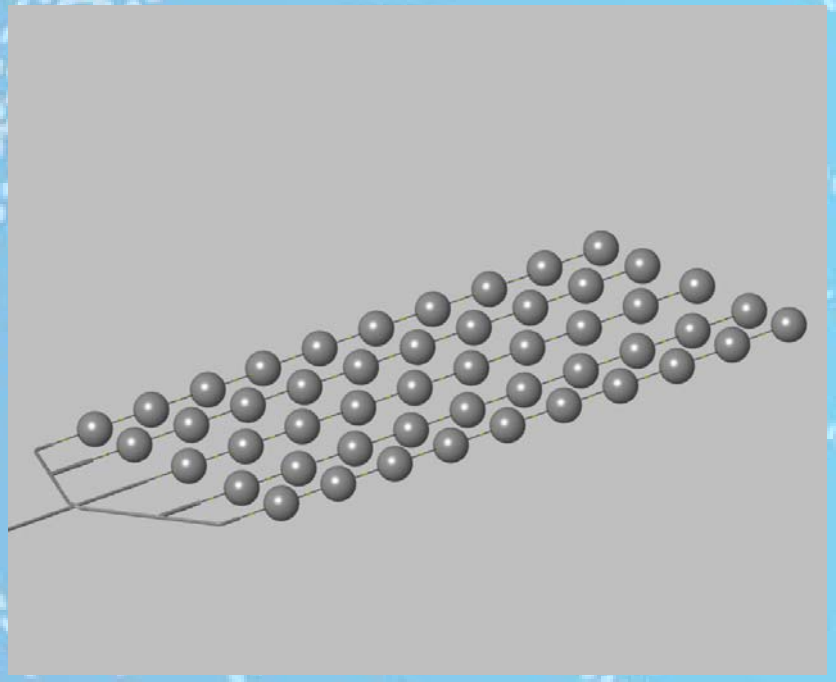




A few MacroSpheres immersed in a fuel tank can pressurize the tank with a low pressure until it is empty.

Distributed Gas Storage Tanks



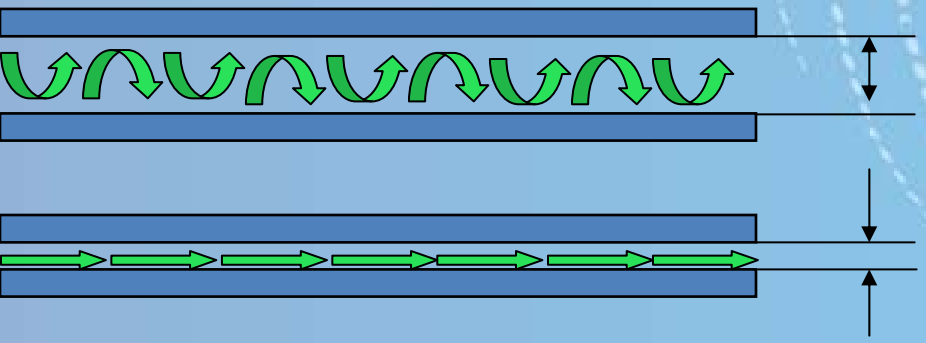


By use of interconnected Macrospheres can efficient Tank panels or other structural components be manufactured

Membraneless Hydrogen Fuel Cell

The advantage of scaling laws and feature size in Micro/Nano Technology can result in a new breed of diffusion based fuel cells without the PEM. If a channel is small enough turbulence can not develop. This allows two gas streams to flow side by side in the same channel without mixing through turbulence, only through diffusion can the molecules mix.

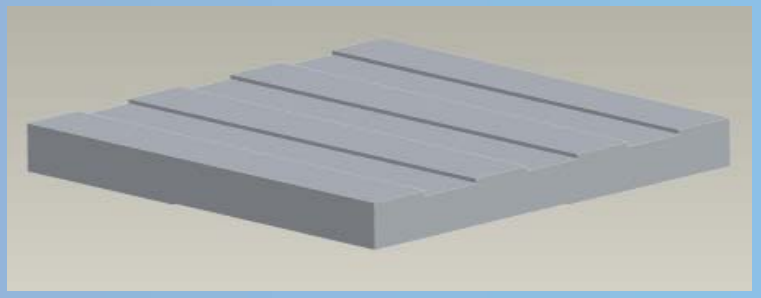
The MNT callanges in this new concept is very contolled high aspect ratio etching over a large surface area and the Wafer to wafer bonding of micro-machined silicon wafers.



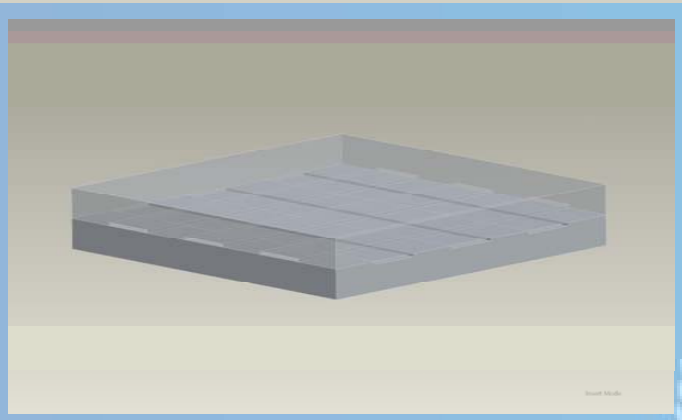
> 10-20 μm Turbulence can develop
A membrane is needed

5-10 μm In a squeezed film can
turbulence not develop

Basic working principle



A number of very vide, but shallow channels are etched out in two silicon wafers.

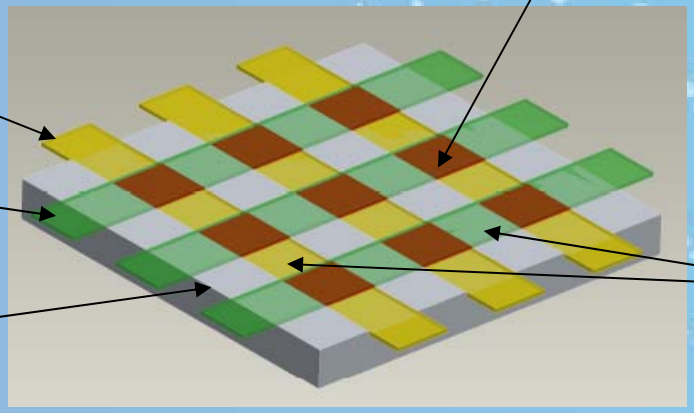


When the wafers are bonded together face to Face, with one wafer turned 90 degrees a number of channels are created.

Oxygen

Hydrogen

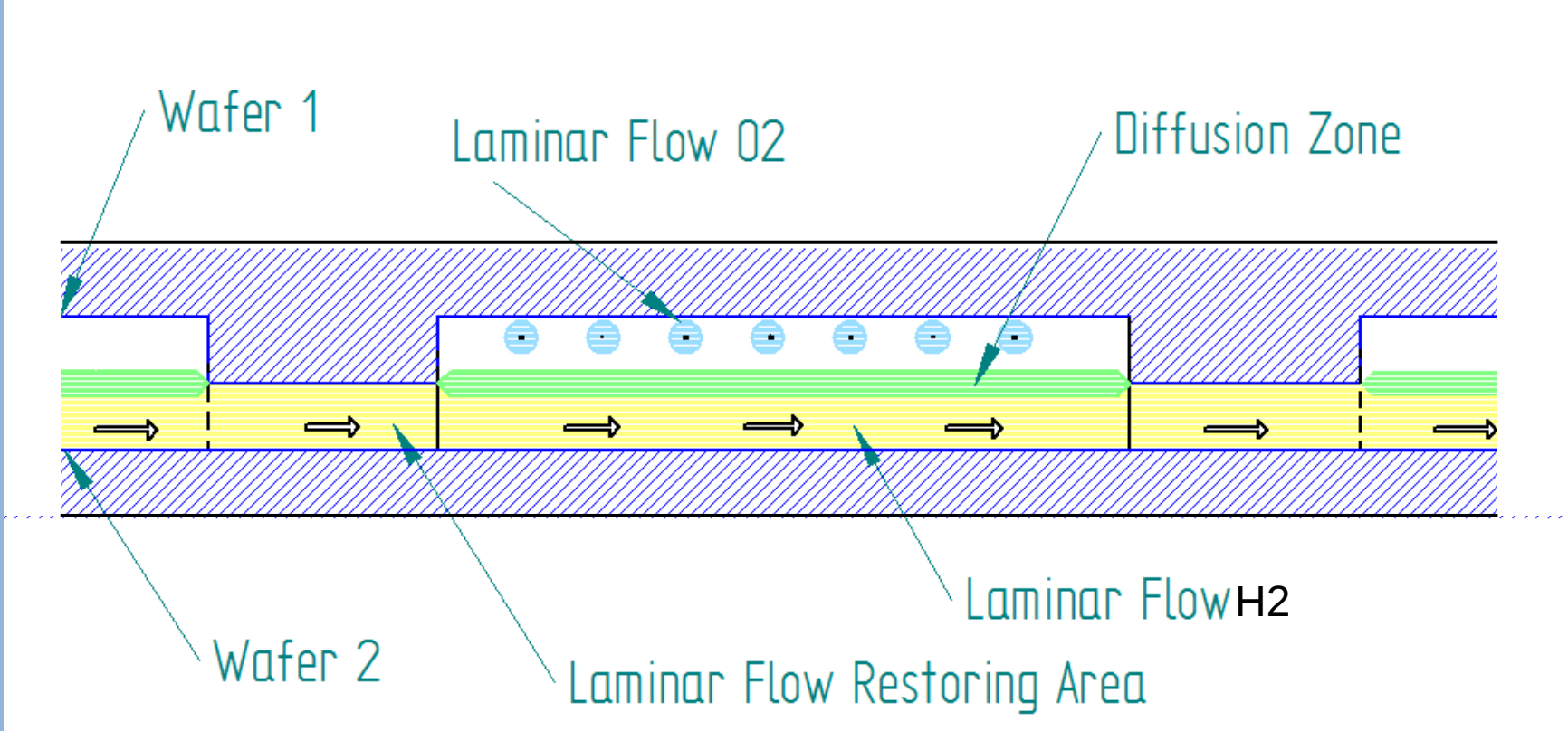
Bond surfaces



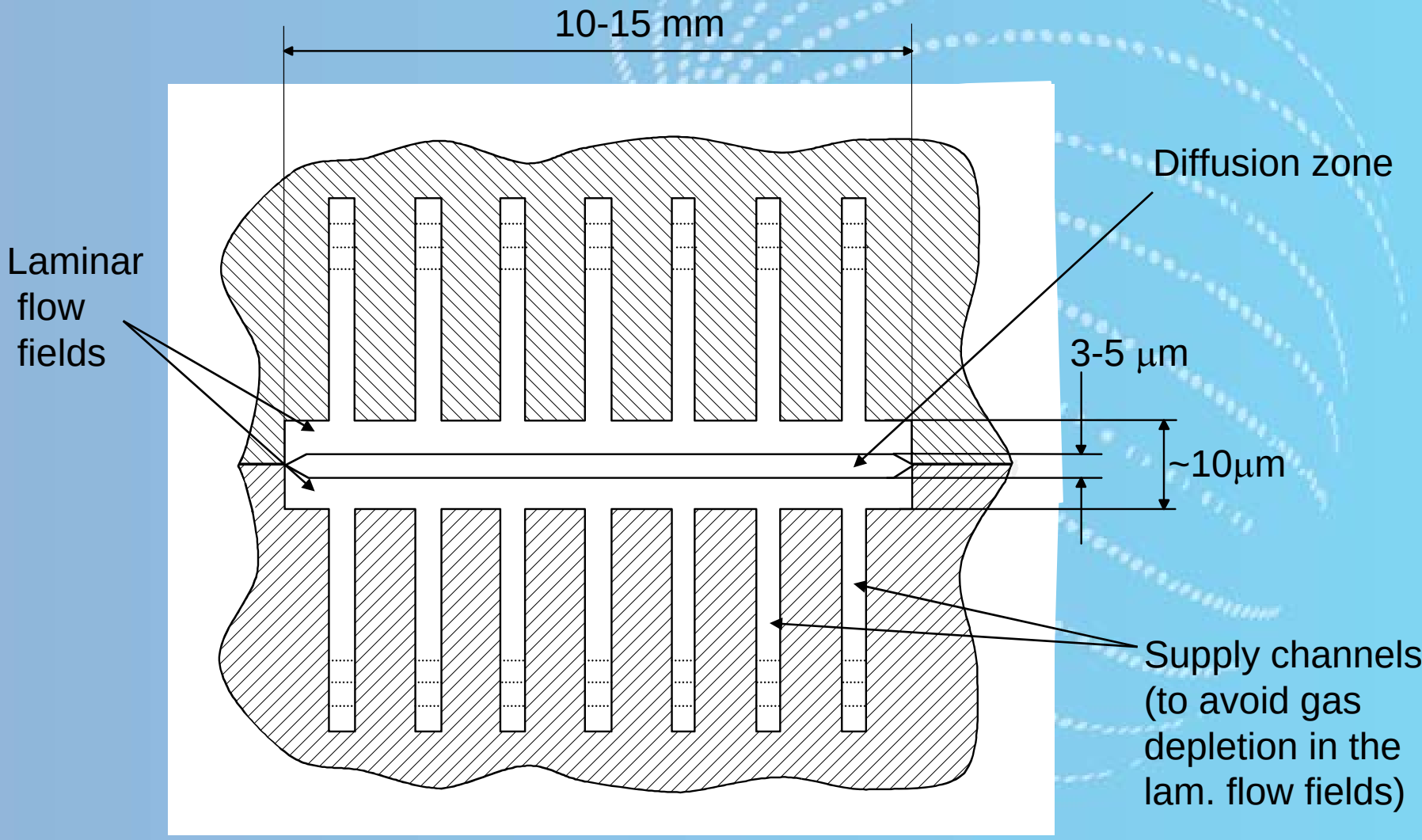
In this area, the gas streams are in diffusion contact with each other without mixing through turbulence.

Laminar flow is restored Between each active zone.

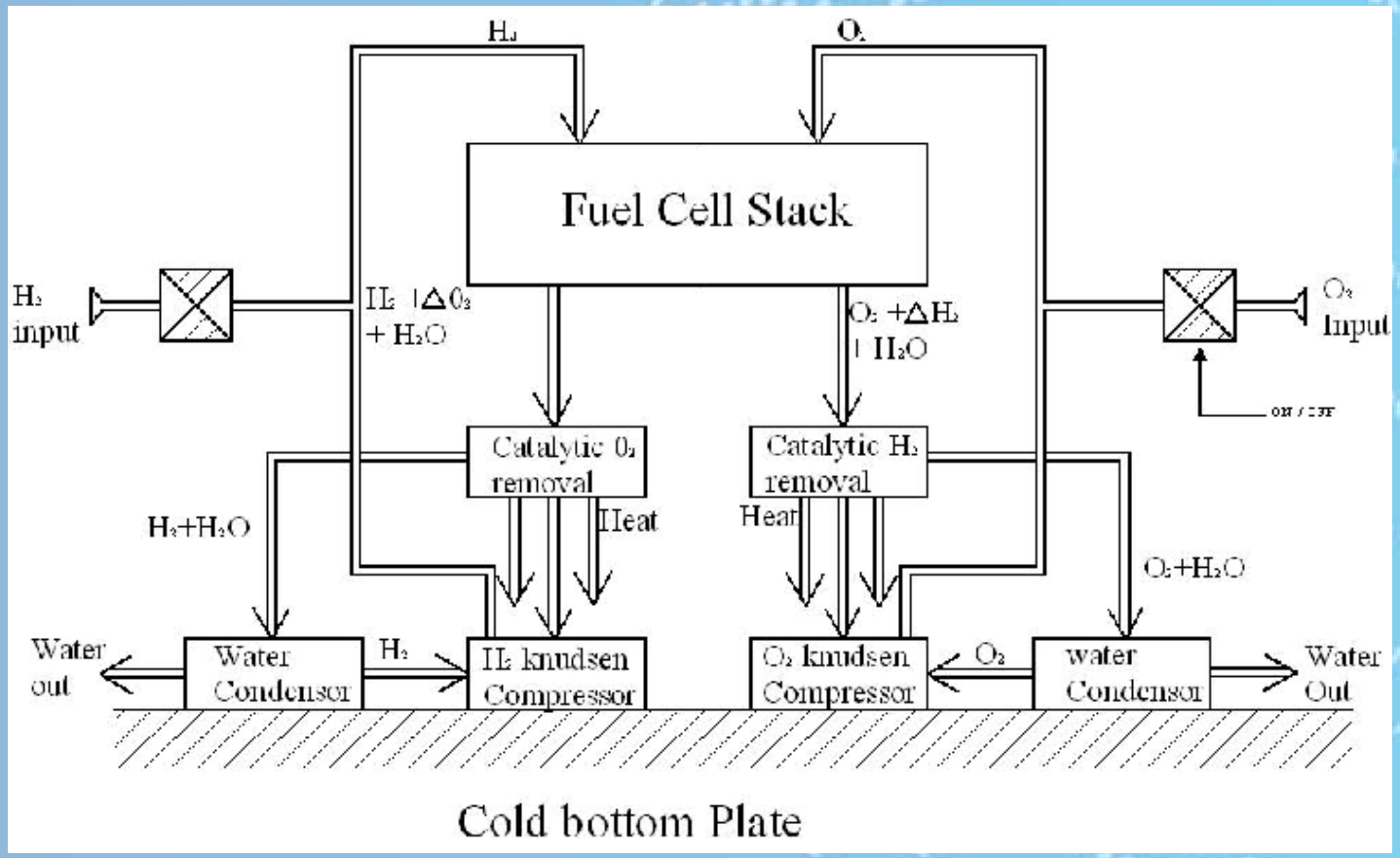
Basic working principle – cross section



Integrated supply channels



Re-Circulation System for Hydrogen/Oxygen



Conclusions

- Water is a true multifunctional liquid with high performance in several interesting application areas in new spacecraft designs.

- Water is the “greenest”, most user-friendly liquid imaginable, with absolutely no handling risks involved.

- Water is available everywhere on Earth, as in the Universe. There is definitely no risk for shortage in supply, now or in the future.

Månbas Alpha

End

For more info, see www.manbasalpha.se or contact Lars Stenmark, Box 99, 619 22 Trosa. E-mail: lars.stenmark@manbasalpha.se