#### Horace Heffner June 2003

The following is a proposed design and some design considerations for a high efficiency electrolyzer, especially one where the cathode and anode gasses can be provided as a mixed product, or gas only evolves from one plate. Further, a means is provided to place ordinary hydrogen electrolysis in these categories by extracting the hydrogen directly through the cathode.

It is well known that reducing plate separation, in order to reduce cell resistance, is required to increase existing cell efficiency. It is also known that slow bubble evolution limits the closeness of plates due to the reduction of plate area and effective current path area. Electrolyzes currently rely on gravity to remove their bubbles using displacement forces, but reduce the bubble formation rate by operating at high pressure.

One method suggested here to solve the bubble problem is to place the plates in a rotatable centrifugal tank as shown in Fig. 1. The plates are thus in annular coaxial form with central circular holes with radial spokes connected to a central shaft, with insulating spacers and/or axial bolts included to hold the plate array together. This use of a centrifugal force on the rotating plates permits the effectiveness of removing bubbles to be increased by two or more orders of magnitude over the use of gravity. The process is made continuous by replenishing the electrolyte and retrieving the evolved gas through a central open space in the centrifuge and/or through piping in a hollow central rotor shaft. During rotation, the electrolyte is pinned to the outer walls of the cylindrical tank by centrifugal force.

	I		KEY:
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===== .	I	. =====	- rotating electrolyzer tank
===== .	I	. =====	rotating electrolyte level
===== .	I	. =====	== - rotating electrolytic plates
===== .	I	. =====	I – central rotor shaft
===== .	I	. =====	-> - direction of electrolyte flow
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#### Fig. 1 - Centrifugal Electrolysis Device

By placing the entire apparatus inside a pressure vessel, with appropriate plumbing and electrical connections, and temperature control, operation can occur at high temperatures and pressures currently in use with high efficiency electrolyzers.

The use of neutral buoyancy dielectric particles in the electrolyte is feasible in this configuration for bubble scrubbing, even without auxiliary pumping, due the pumping action of the electrolyte through the plates caused by the displacement force on and inward motion of the bubbles. The electrolyte flow between the plates is thus toward the central shaft, and the flow outside the plate region is axially away from the central rotor shaft as shown by arrows in Fig. 1. The largest

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dimension of such bubble scrubbing particles should be about one fourth the plate separation distance.

Using the methods described here, plate separation can be made almost arbitrarily close, but plate thickness itself is increased due to the need for plate structural strength and diffusion requirements.

When electrolysing hydrogen, use can be made of a diffuse or porous (essentially transparent to hydrogen) but structurally strong material as a supporting structure for a Pd surfaced cathode in the centrifuge. Such a material can be made by sintering metal or ceramic granules of the size required for the support of the Pd. A gradation of granularity can be made to occur, with the finest granularity located at the cathode surface, just below the palladium surface. The Pd coated cathode's interior would then either be hollow or very porous, so as to conduct the H2 gas away from the electrolyzer directly through the plate interior and then through a hollow supporting structure (e.g. spokes) for the plate, and to a hollow central rotor. In this manner, only O2 would evolve between the plates. The hydrogen principally is driven into the cathode interior by the high operating pressure, but also by the electrolytic potential.

The electrolytic plates in the suggested use act as cathode on one side and anode on the other. Therefore a sandwich style construction is suggested. The anode side might be stainless steal, possibly with an exterior platinum plating for longer anode life. A space between the anode side and cathode side of the electrode can be made by using conductive spacers that permit free flow of hydrogen through the electrode to the central shaft. A seal zone around the perimeter of the electrode, and between the anode and cathode portion, can seal out electrolyte and seal in the hydrogen. Bolts parallel to the main shaft that hold the electrode array together have to be insulated and their entry and exit points sealed from the interior hydrogen space.

If momentary reverse emf pulses are used in order to disrupt the electrolyte interface, then a high enough pressure will have to be used to avoid significant out gassing of the hydrogen from the cathode during those brief periods. It is not known if this specific out gassing prevention method is workable. However, any out gassing at all can be expected to momentarily disrupt the interface, so may assist in providing the intended effect. Operating at high temperatures and nearly boiling conditions further places the interface under disruptive stresses, thus reducing the electrical energy required to achieve electrolysis. It is not known what percentage of the hydrogen can be adsorbed, because a film of water between the hydrogen bubble and the electrode could prevent adsorption. Even though full adsorption may not take place, it would be very useful if enough could be adsorbed that the remaining mixed gas is difficult to ignite or explode.

H2 flows easily through thin Pd foil at a moderate pressure and the high g force of a centrifuge certainly provides sufficient pressure.

It may be that a porous cathode surface provides the best alternative for removing hydrogen directly at the cathode surface, or a combination of adsorption and porous extraction can be used. In this mode, a negative pressure must be applied to the interior of the cathode via the spokes via the central shaft. This negative pressure then sucks both hydrogen and to some degree electrolyte and water vapor or steam through the pores and out the spokes and out the central shaft. Appropriate bearings and fittings are then needed on the shaft to send the hydrogen-electrolyte mixture sucked

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through the cathode interior to an external separator. Alternatively, separation can occur centrifugally in a separator included on a segment of the shaft, and the electrolyte returned to the main electrolyte level via siphoning. In any event, appropriate bearings and fittings are required to continually deliver hydrogen from the shaft to atmospheric pressure. The negative pressure applied to the interior of the shaft can be simply the ambient pressure of one atmosphere, thus the negative pressure inside the electrodes is really supplied by operation of the centrifuge at high pressure. This technique limits the centrifugal force that can be obtained, because the negative pressure must be sufficient to extract the hydrogen against the centrifugal force. It may be that gas-electrolyte separation can be achieved in the interior of the cathode if there is a break in the seal provided on the outermost tip of the electrode for the electrolyte to escape. Operation is then dependent upon a good balance of centrifugal force and operating pressure.

A similar technique of sucking the evolved oxygen into the interior of the anode might be used as well. A barrier between the O2 and H sides of the interior then must be supplied as well as separate paths and liquid-gas separators within or upon the central shaft, and delivery means from the rotating shaft to ambient conditions. If gasses are directly extracted by *both* cathode and anode surfaces, then no scrubber particles are necessary, and even very limited centrifugal force is useful for the gas-liquid separation. Perhaps a useful version requiring no centrifugal force at the plates at all can be implemented (accomplished by suction on the gas side of the electrode.)

One way to get power to the electrolytic plates for the electrolysis is to make a segment, or a segment of the interior, of the central shaft of the centrifuge a (rotating) transformer core, with linkage to it being magnetic from an external stationary "C" core that has a primary coil on it. The linkage between core segments can be achieved by utilizing a small gap between the core containing segment of the shaft and holes in the C core of a size to accept the shaft. A secondary coil can then be wrapped about the segment of the core that rotates, i.e. about the outside of the segment of the central centrifuge shaft containing the rotating piece of core. The secondary coil output can then be fed to rectifiers and then to the plates. As an example, assume a stack of 50 plates and a secondary voltage of 100 V, which gives about 2 V per plate for electrolysis current. There need be no wiring to the individual plates, only to the outermost two. If it is desired to superimpose a HF signal on the high current electrolytic current, then a circuit to do so can be powered by the secondary coil or by another secondary coil in the same location. The rectifiers, circuitry and wiring can all be located inside the rotating centrifuge shaft, thus no brushes are necessary. It may, however, be cheaper and easier to simply use brushes. Such brushes would not be located in the electrolyte, but would be located within an outer pressure vessel, so should work in a normal fashion. If an explodable hydrogen/oxygen mixture evolves from the plates, then brushes are highly undesirable.

If it is desired to create hydrogen from rotational kinetic energy, as from a windmill, then it may be preferable to make a portion of the shaft into a generator armature. No transformer is then required. No brushes are required to or from the armature as the energy is delivered to the shaft itself, though rectification is still required. This approach does give the opportunity for improved DC generation efficiency through use of multiphase rectification.

A good electrolyte for hydrogen evolution is made by making a saturated lye solution and diluting 1 part of that with two parts distilled water.

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If the hollow or porous cathode technique described here proves viable in practice, as combined with high g electrolysis or not, it could have some significance on worldwide energy supplies and the building of a hydrogen infrastructure in particular by providing a low technology means of converting sporadic kinetic energy sources, like wind power, into storable form.

#### Update September, 2, 2007:

For a related electrolysis power supply see:

http://www.mtaonline.net/~hheffner/ElectrolyseAC.pdf