

is driven at a frequency of 24.8 kHz. A drill bit is attached to the horn by means of a simple threaded connection: for this purpose, the proximal end of the drill bit is threaded and widened, and the thread on the drill bit matches the thread in a hole on the tip of the horn. The drill bit is tipped with a crown having a cutting edge (which could be toothed) chosen to

suit the specific application. The crown is attached to the bolt by brazing and, hence, can be replaced when it is worn out. The bolt, horn, drill bit, and crown are all hollow so that, optionally, air can be blown through them to remove dust from the drilled hole.

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## Hydrogen Peroxide Concentrator

Water is removed through selectively permeable membranes.

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A relatively simple and economical process and apparatus for concentrating hydrogen peroxide from aqueous solution at the point of use have been invented. The need for this or a similar invention arises for the following reasons:

- The highest commercial grade of hydrogen peroxide has a concentration of 70 volume percent.
- Concentrations of more than 80 volume percent are required in some industrial and some military propulsion applications.
- Prior methods of concentration of hydrogen peroxide are expensive and can entail production of quantities larger than can be utilized immediately. The necessity of storing and handling the excess concentrated hydrogen peroxide poses a safety problem.

The heart of the apparatus is a vessel (see figure) comprising an outer shell containing tubular membranes made of a polymer that is significantly more permeable by water than by hydrogen peroxide. The aqueous solution of hydrogen peroxide to be concentrated is fed through the interstitial spaces between the tubular membranes. An initially dry sweep gas is pumped through the interiors of the tubular membranes. Water diffuses through the membranes and is carried away as water vapor mixed into the sweep gas. Because of the removal of water, the hydrogen peroxide solution flowing from the vessel at the outlet end is more concentrated than that fed into the vessel at the inlet end.

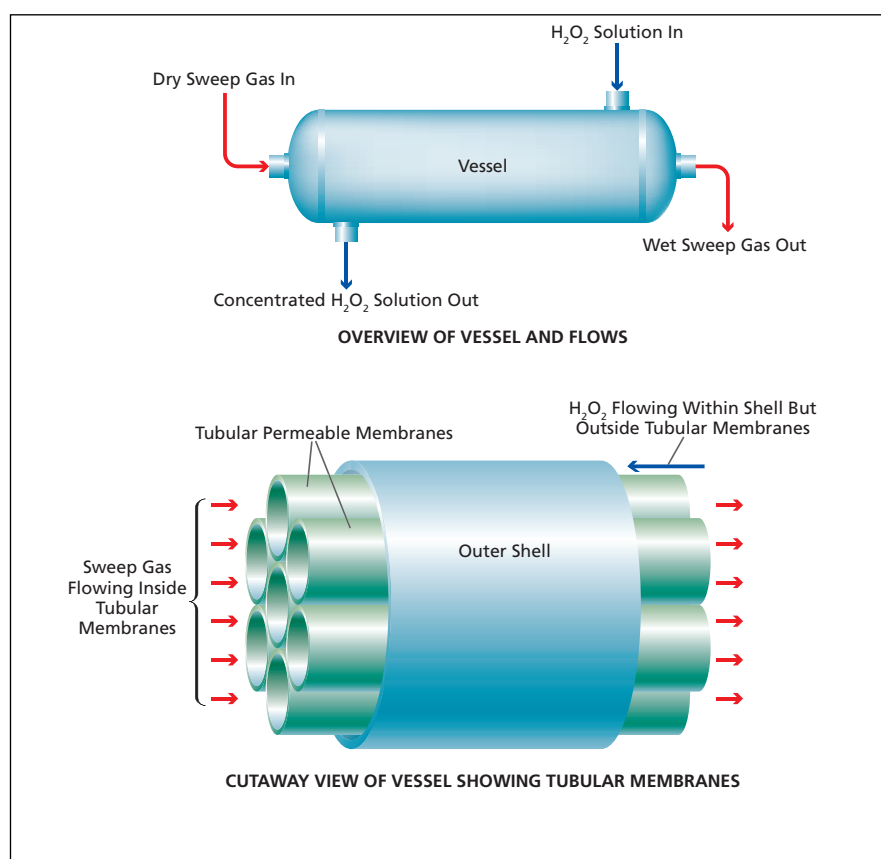
The concentration process as described thus far would ordinarily and preferably be run in a continuous, counter-flow mode. Optionally, it could be run in a batch mode. The rate of removal of water can be increased by increasing the rate of flow of the sweep gas. Also, the water capacity of the sweep gas and, hence, the rate of removal of

water can be increased by heating the sweep gas, taking care to keep the temperature less than the lower of either (1) the boiling point of the hydrogen peroxide solution, (2) the temperature above which the hydrogen peroxide decomposes spontaneously, or (3) the maximum temperature that the membrane can endure without deteriorating. The sweep gas can be air, nitrogen, or any other gas that can be conveniently supplied in dry form and does not react chem-

ically with hydrogen peroxide.

The selections of the membrane, outer-shell, and plumbing materials are governed largely by the following criteria:

- All of the affected materials should be chemically nonreactive with hydrogen peroxide at the highest concentration expected to be encountered.
- The membrane material should be capable of sustaining a high flux of



An **Aqueous Hydrogen Peroxide Solution** flows within the outer shell, in the interstices between the tubular membranes. Water diffuses from the solution into the interiors of the membranes, where the flowing sweep gas carries it away.

water so that the total membrane area needed to sustain a given rate of removal of water can be made as small as possible.

- The selectivity of the membrane, here defined as ratio between its permeability by water and its permeability by hydrogen peroxide, should preferably be greater than 2.

Suitable membrane materials include

polysulfone and perfluorinated polymers having sulfonic or carboxylic ionic functional groups.

The viability of the invention has been demonstrated in tests. For example, in one test in which the membrane material was a perfluorosulfonic polymer, the sweep gas was air at ambient atmospheric pressure, and the temperature was 42 °C, a 69.6-percent hydrogen peroxide solu-

tion was concentrated to 85.4 percent in 80-percent yield.

*This work was done by Clyde F. Parrish of Kennedy Space Center.*

*This invention has been patented by NASA (U.S. Patent No. 7,122,166). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Kennedy Innovative Partnerships Office at (321) 861-7158. Refer to KSC-12666.*