achieved through selection of process parameters, including gas flow, power, and pressure. Such control is not uniformly and repeatably achievable in wet chemical etching. The recipe for the present RIE process is the following:

Etch 1 — A mixture of CF_4 and O_2 gases flowing at rates of 25 to 75 and 75 to 125 standard cubic centimeters per minute (stdcm^3/min), respectively; power between 44 and 55 W; and pressure between 45 and 55 mtorr (between 6.0 and 7.3 Pa). The etch rate lies between ≈3 and ≈6 nm/minute.

Etch 2 — O_2 gas flowing at 75 to 125 stdcm^3/min, power between 44 and 55 W, and pressure between 50 and 100 mtorr (between 6.7 and 13.3 Pa).

This work was done by Tasha Turner and Chi Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20777, volume and number of this NASA Tech Briefs *issue, and the page number.*

Flexible Composite-Material Pressure Vessel

Lyndon B. Johnson Space Center, Houston, Texas

A proposed lightweight pressure vessel would be made of a composite of high-tenacity continuous fibers and a flexible matrix material. The flexibility of this pressure vessel would render it (1) compactly stowable for transport and (2) more able to withstand impacts, relative to lightweight pressure vessels made of rigid composite materials. The vessel would be designed as a structural shell wherein the fibers would be predominantly bias-oriented, the orientations being optimized to make the fibers bear the tensile loads in the structure. Such efficient use of tension-bearing fibers would minimize or eliminate the need for stitching and fill (weft) fibers for strength. The vessel could be fabricated by techniques adapted from filament winding of prior composite-material vessels, perhaps in conjunction with the use of dry film adhesives. In addition to the high-bias main-body substructure described above, the vessel would include a low-bias end substructure to complete coverage and react peak loads. Axial elements would be overlaid to contain damage and to control fiber orientation around side openings. Fiber ring structures would be used as interfaces for connection to ancillary hardware.

This work was done by Glen Brown, Roy Haggard, and Paul A. Harris of Vertigo, Inc., for **Johnson Space Center**. *Further information is contained in a TSP (see page 1).*
MSC-23020

Treatment To Destroy Chlorohydrocarbon Liquids in the Ground

Emulsified iron is injected into the ground and left there.

John F. Kennedy Space Center, Florida

A relatively simple chemical treatment that involves the use of emulsified iron has been found to be effective in remediating groundwater contaminated with trichloroethylene and other dense chlorohydrocarbon liquids. These liquids are members of the class of dense, nonaqueous phase liquids (DNAPLs), which are commonly recognized to be particularly troublesome as environmental contaminants. The treatment converts these liquids into less-harmful products.

As a means of remediation of contaminated groundwater, this treatment takes less time and costs less than do traditional pump-and-treat processes. At some sites, long-term leakage and/or dissolution of chlorohydrocarbon liquids from pools and/or sorbed concentrations in rock and soil gives rise to a need to continue pump-and-treat processes for times as long as decades in order to maintain protection of human health and the environment. In contrast, the effects of the emulsified-iron treatment are more lasting, decreasing the need for long-term treatment and monitoring of contaminated areas.

The material used in this treatment consists of iron particles with sizes of the order of nanometers to micrometers contained within the micelles of a surfactant-stabilized, biodegradable, oil-in-water emulsion. The emulsion is simple to prepare and consists of relatively inexpensive and environmentally acceptable ingredients: One typical formulation consists of 1.3 weight percent of a food-grade surfactant, 17.5 weight percent of iron particles, 23.2 weight percent of vegetable oil, and 58.0 weight percent of water.

The emulsion is injected into the ground via a push well. Free-phase chlorohydrocarbon molecules diffuse through the oil membranes of the emulsion particles to the surfaces of the iron particles, where dehalogenation takes place. The dehalogenation reactions generate hydrocarbon byproducts (primarily ethylene in the case of trichloroethylene), which diffuse out of the emulsion micelles and are benign in nature.

Experiments have demonstrated several aspects of the effectiveness of this treatment by use of emulsified iron:

- This treatment is more effective in degrading free-phase trichloroethylene than is a similar treatment that uses only pure iron particles.
- Emulsions containing iron can be injected into soil matrices, where they become immobilized and remain immobile, even in the presence of flowing water.
- Iron emulsions can exert an effect equivalent to pulling globules of trichloroethylene into their micelles.
- No chlorinated byproducts from the degradation of trichloroethylene pass out of the micelles. The only degradation products that have been observed to leave the iron emulsions are ethylene as mentioned previously,