reservoir to prop open the cracks. But water causes clay in the shales to swell, and the formation can eventually plug, throttling the flow of hydrocarbons.

A relatively new technology, however, offers an alternative to conventional aqueous foam, but for more than a decade after it was first developed in Canada, few U.S. producers had sufficient confidence to try it. A series of Department of Energy-sponsored field tests in the 1990s changed that.

The technique is called CO_2-Sand Fracturing. It uses liquid carbon dioxide rather than aqueous foam. Liquid carbon dioxide is a reservoir-friendly substance. It provides enough force to create long, propped fractures, and the absence of water or oil-based fluids offers a near damage-free way to enhance oil and gas production.

A CO_2-Sand fracturing operation produces four times the production rates of wells fractured with conventional foam.

Petroleum Consulting Services of Canton, OH, with support from DOE, used the technique to get four times the production rate of wells fractured with nitrogen foam. Although more expensive than conventional treatments, the increased production rates typically give paybacks in around five months. *Hart's Oil and Gas World* magazine was so impressed by the results of the DOE-sponsored tests that it gave the CO_2-Sand Frac technique its distinguished *"Best Technology in the Northeast"* award for 1994.

The [DOE-sponsored] tests demonstrated that slant hole drilling is commercially viable in tight gas reservoirs since the added drilling expenses were more than offset by the resulting production.

Drilling "Sideways" for Natural Gas

High-angle or horizontal wells have restored new life to many aging oil reservoirs in Texas and elsewhere, but until DOE began an R&D project in western Colorado, the technique had not been tried by many western natural gas producers. It was considered too risky, especially in low permeability (dense) gas reservoirs. In 1990, DOE funded CER Corporation to begin a field research project that led to a new level of confidence in the effectiveness of slant hole drilling in these reservoirs.

During five months of well testing, CER's test well (#1-SHCT) produced over 150 million cubic feet of natural gas including five weeks at a steady rate of 3 million cubic feet per day. A gas deliverability test predicted an "absolute open flow potential" of 19 million cubic feet per day. More importantly, the tests demonstrated that slant hole drilling is commercially viable in tight gas reservoirs since the added drilling expenses were more than offset by the resulting production.