The stripped uranium was thus concentrated by a factor of 50 to 100. At the same time, the DEPA-TOPO kerosene solution was cycled back to the first step, ready for reuse. The two-step uranium extraction operation was then repeated on the concentrated product stream in a similar but smaller-scale process designed to further purify the uranium and isolate it for sale.

Several United States phosphate companies consulted closely with Oak Ridge National Laboratory while developing specific versions of the process tailored for their plants. Commercial use began in late 1978. By 1983, in addition to having been installed in five commercial plants in the United States, commercial recovery operations, based on this technology, were put in place in Belgium, Canada, and Taiwan.

A patent was awarded in 1973 to the Basic Energy Sciences researchers, F. J. Hurst and D. J. Crouse, who developed the process. They were later honored for their seminal efforts by being selected as finalists for the prestigious Kirkpatrick Chemical Engineering Honor Award in 1979. They also received an "IR-100 Award" in 1980, as winners of the annual competition for the 100 industrial research prizes sponsored by *Research and Development* magazine.

NON-PROLIFERATION

Since the first awesome use of the atomic bomb as a weapon of war on August 6, 1945, the specter of the spread of nuclear weapons has haunted civilization. So it is, then, that more than 135 nations, including the United States and the Soviet Union, joined together and signed the Treaty on the Non-Proliferation of Nuclear Weapons.

This Treaty both encourages the peaceful use of nuclear power and nuclear research activities and deters the further spread of nuclear weapons. Upon ratification, each country which did not already possess nuclear weapons, agreed not to develop or acquire them. In return, all signatories, including the so-called "weapons states," were encouraged to share more freely their nuclear expertise. Importantly, each "non-weapons state" agreed to allow on-site inspection and monitoring of all nuclear-related operations to prove compliance.

The Treaty's mechanisms of enforcement are aimed at safeguarding special "fissionable" nuclear materials, primarily plutonium and enriched uranium. Both are used in or generated by nuclear reactors. If such materials were not carefully controlled, they might be diverted to make a bomb or otherwise be used illegally.

Basic Energy Sciences research developed a practical technology that now serves as an important method for keeping track of these special nuclear materials and validating reports of their movements. This technology, known as resin bead technology, is used by the United Nations' International Atomic Energy Agency, headquartered in Vienna, Austria, to maintain an accurate accounting balance on material flows. Any discrepancy in this balance would signal a possible diversion and alert the authorities.

Of particular concern today is the fact that maintaining this material balance is more complicated than simply counting the fuel assemblies that go in or come out of a reactor site. A growing number of nations now recover plutonium and enriched uranium by "reprocessing" the highly radioactive spent fuel from nuclear power plants.

In reprocessing, the spent fuel is cut into little pieces and dissolved in an acid solution. The plutonium and uranium are then chemically extracted from this solution and refined.

Once the spent fuel is cut up and dissolved in acid, the methods for monitoring plutonium and uranium must shift from item counting to chemical analysis. By knowing the volume of each batch and measuring the concentrations of all relevant species (isotopes) of plutonium and uranium in solution, the material balance can be inferred. To detect cheating, concentration measurements are performed independently at laboratories operating under the auspices of the International Atomic Energy Agency. In the past, this procedure required a large sample from each batch of acid solution. The sample, like the spent fuel, was intensely radioactive.

The heavy shielding required for safe transport to the laboratories in Vienna was expensive. With thousands of shipments per year anticipated, the cost of transport alone would amount to millions of dollars. Moreover, compliance with all local and international restrictions on the shipments of highly radioactive materials was becoming increasingly complex.