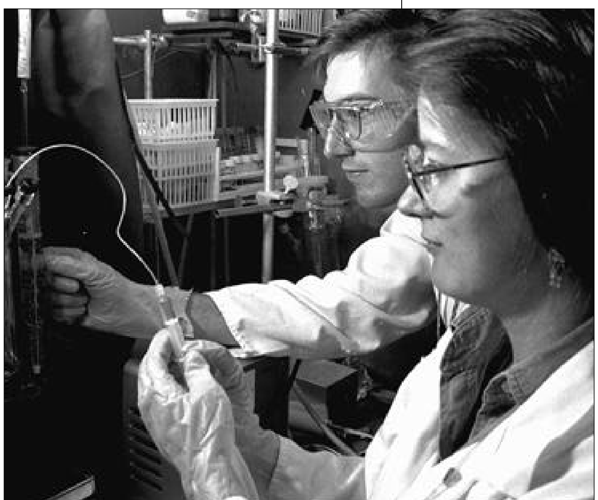
LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE
LOS ALAMOS

THE ALCHEMY OF WASTE

LOS ALAMOS RESEARCHERS DEVELOP NEW RECYCLING PROCESSES FOR DEPLETED URANIUM

One of the country's biggest environmental problems is the waste generated by chemical processing and production plants. Uranium presents a special problem because of the large quantities of depleted uranium stored throughout the Department of Energy's complex as a result of machining bulk materials in research and weapons work.



Los Alamos Researchers Tracey Frankcom (right) and David Pesiri draw a sample of uranyl solution from a photochemical processor. The processor uses ultraviolet light to help organic compounds reduce uranyl, a form of uranium, to a mid-point oxidation state that is suitable for both long-term storage and recycling schemes.

Los Alamos researchers are developing new chemical processes that make it possible to transform depleted uranium into forms more suitable for long-term storage or potential recycling schemes.

Machinists generate uranium chips, or shavings, when working with the metal just as carpenters generate sawdust and shavings when working with wood. The potential hazard of heat buildup and fire — not radioactivity — is the greatest concern in storing uranium chips. Most of the chips currently stored are depleted uranium, which is less radioactive than naturally occurring uranium and contains less than 0.2 percent of the isotope uranium-235. The potential for fire exists because any finely divided metal has more surface area available for oxidation, which generates heat and could ultimately result in fire.

To eliminate the risk of fire, Los Alamos researchers are investigating ways in which uranium chips can be partially oxidized. Oxidation occurs by removing electrons from uranium atoms; reduction occurs by adding electrons to the atoms.

In an ideal oxidation scheme, the reagents, or chemicals, used to oxidize the waste would produce no hazardous waste byproducts; the reaction would leave little or no uranium in solution; and the reactions would occur within a suitable time scale — several hours to a day. The time scale is important because if a reaction occurs too fast there is the danger of a runaway reaction because too much heat might build up too quickly. On the other hand, if a reaction occurs too slowly, it might not be feasible for treating large amounts of waste.

To date, the researchers have developed two oxidation schemes that meet the criteria for a safe, practical, and effective treatment process.

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The first system uses a hypochlorite solution such as household bleach to oxidize the uranium. This system requires three to six hours, it's cheap, and the risk of fire during processing is low. However, the bleach-to-metal ratio is four to one — which leaves a lot of bleach left over for further treatment.

Larger pieces may be treated more suitably with the second system, which oxidizes uranium with hydrogen peroxide in conjunction with bleach. Hydrogen peroxide speeds up the reaction by nearly 50 percent, but managing the process is much more labor intensive. Bleach and hydrogen peroxide must be added carefully throughout the reaction for the system to work.

"Los Alamos researchers are developing new processes … to transform depleted uranium into forms more suitable for long-term storage or potential recycling schemes."

The systems are both adaptable to new, environmentally benign actinide reprocessing schemes. Both systems convert depleted uranium into uranyl, the most highly oxidized form of uranium. Uranyl may readily be dissolved in dilute acids, which makes this a major advantage in formulating recycling schemes.

However, uranyl is not suitable for storage. It is extremely soluble and could be leached into the environment if even slightly acidic ground water were to breach the storage containers. This "leachability" is a major disadvantage in a long-term storage form. The trick to producing a suitable waste storage form is to oxidize the uranium — but not too much. The researchers are investigating ways of reducing the uranyl to a form of uranium that is mid-way between the metal and uranyl. Uranium in this partially oxidized form would be suitable for long-term storage or for use in existing recycling schemes.

By combining one of the oxidation systems mentioned above with a photochemical process that uses light to help organic compounds reduce uranyl, the researchers are able to reduce uranyl to a more desirable, mid-point oxidation state.

The photochemical process developed at Los Alamos may also be used to destroy organic compounds in hazardous mixed waste. The researchers currently are refining the photochemical process to improve its effectiveness and broaden its potential applications.

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LOS ALAMOS DESIGNS MOLECULES TO CAPTURE RADIOACTIVE IONS

TECHNOLOGY REMOVES MINUTE AMOUNTS OF TOXIC METALS FROM SOIL AND WASTE STREAMS

A significant portion of the world's environmental radioactivity stems from a class of metals known as actinides. These metals, which include uranium, plutonium, and americium, can cause severe health damage because of their radioactivity and their heavy-metal toxicity. Since the advent of the Manhattan Project in the early 1940s, large amounts of these radioactive materials, as well as non-radioactive heavy metals such as mercury, have been discharged into the environment. These discharges are a result of weapons production, nuclear power reactor operation, and medical applications.

> *"By designing 'chelator' molecules with a strong affinity for specific atoms … researchers are able to capture and remove toxic metals and other contaminants while leaving the surrounding environment undisturbed."*

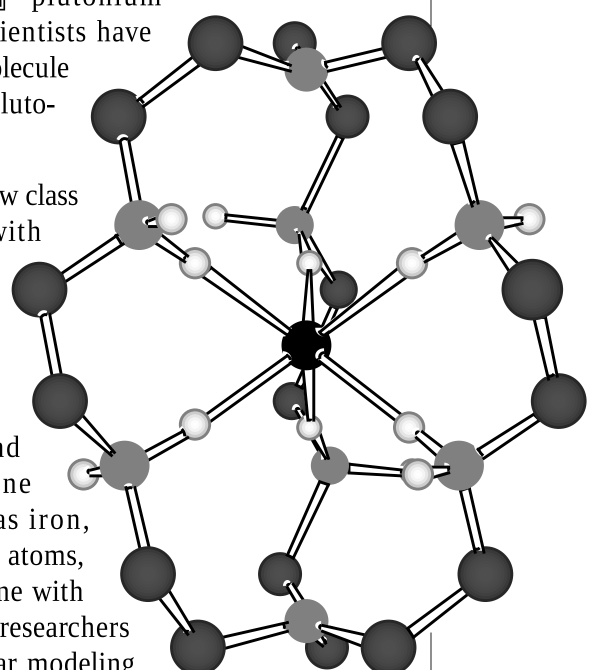
Los Alamos researchers are developing cost-effective chemical agents that selectively remove such contaminants from soil and aqueous-waste streams. By designing "chelator" molecules with a strong affinity for specific atoms such as uranium and plutonium, researchers are able to capture and remove toxic metals and other contaminants while leaving the surrounding environment undisturbed. The word "chelator" comes from the Latin word for "claw." In chemistry, the term refers to a class of organic molecules that can grab and hold metal ions.

Physically, a chelator resembles a tiny cage with an opening on one side. Carbon atoms provide the framework that holds other atoms in ideal positions for forming strong chemical bonds with toxic metals. The number of binding atoms, or teeth, in the chelator is referred to as the chelator's "denticity." In general, the higher the denticity of the chelator, the higher its affinity for metal ions. When designing a chelator with a strong preference for one type of metal ion, scientists take advantage of the differences in molecular structure and chemical behavior of different types of metal ions.

Virtually all facilities that process plutonium or other actinides generate waste contaminated with these ions. Many treated waste streams contain minute amounts of toxic metals and much larger concentrations of non-toxic metals such as iron. Removing a few ions of plutonium from an ocean of iron presents a special challenge because plutonium and iron have similar chemistries. Because of their similarities and the fact that plutonium is not a well-researched metal, scientists have been unable to design a chelator molecule capable of distinguishing between plutonium and iron — until now.

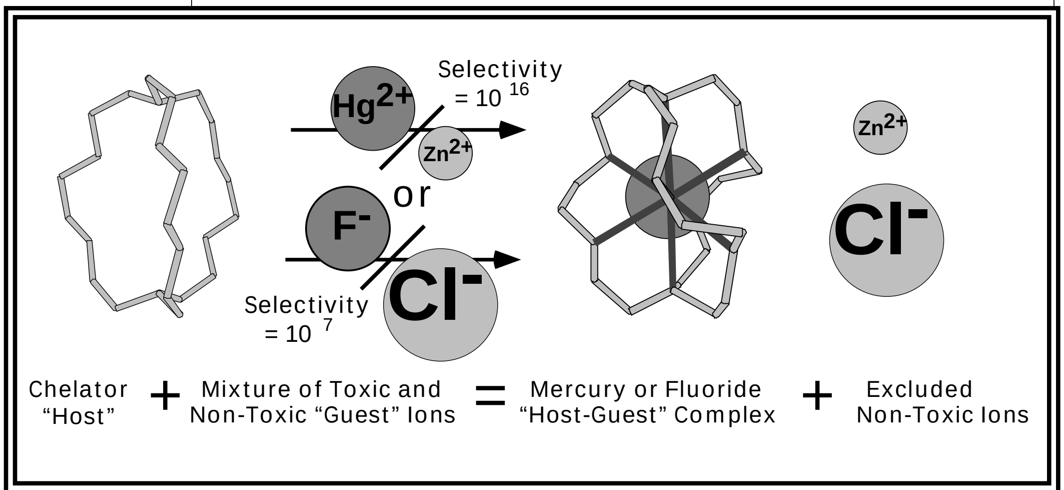
> *"Although Los Alamos research is aimed at developing chelators that treat sites potentially contaminated with toxic metals, the same technology could be used to remove non-metallic elements."*

The researchers have identified a new class of octadentate chelators (those with eight binding atoms, or teeth) that are capable of removing plutonium in the presence of higher concentrations of iron and other non-toxic metals. Plutonium ions are much larger than iron ions and can have as many as eight or nine atoms attached to them; whereas iron, which is normally restricted to six atoms, requires a hexadentate chelator (one with six binding atoms, or teeth). The researchers are using computer-based molecular modeling to determine the optimal metal size for a range of chelators. Once they determine the optimal metal for each and synthesize and test those that show promise, they then incorporate that information into the design of future chelators.



The word "chelator" comes from the Latin word for "claw." Carbon atoms provide the framework that holds other atoms in ideal positions for forming strong chemical bonds with toxic metals. Pictured at right is a chelator designed to grab and hold mercury or fluoride ions.

If a chelator has a strong chemical affinity for more than one type of ion, it will select the ion that best fits its cavity. For example, in a waste stream containing similar concentrations of mercury and zinc, a particular chelator binds with mercury much better than it binds with zinc.



↑ The chemical process by which a chelator molecule selects metal ions. If a chelator has a strong chemical affinity for more than one type of ion, it will select the ion that best fits its cavity.

This is because of the nearly ideal size match between the chelator's cavity and the mercury ion. The zinc ion, on the other hand, is too small to be bound effectively by the chelator.

Once an ion is locked inside a chelator, the host molecule and its guest ion can be sifted out of soil or precipitated out of an aqueous waste stream. The toxic metal ions can then be stripped chemically from the chelators and the chelators recycled. Los Alamos scientists have demonstrated the effectiveness of several chelators in laboratory bench-top experiments.

Although Los Alamos research is aimed at developing chelators that treat sites potentially contaminated with toxic metals, the same technology could be used to remove non-metallic elements such as fluoride, which can be toxic in large concentrations. Fluoride is a common component of light-industry waste streams. Chelators could also be used by the mining industry to concentrate precious metals.

The technology has applications in medical imaging and treatment as well. Specially designed chelator molecules can carry paramagnetic ions to tumors or body organs for use in MRI, or magnetic resonance imaging. Chelator molecules also have the potential to seek out malignancies and release their radioactive contents inside the cancer cells, killing them without harming surrounding non-cancerous tissue.

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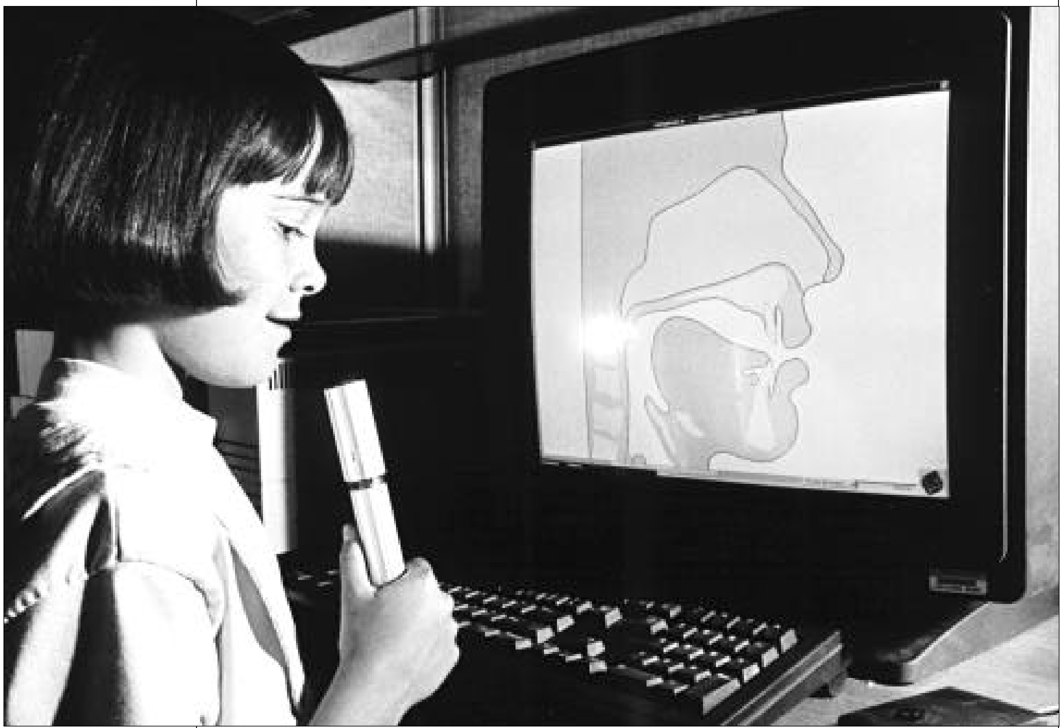
COMPUTER-AIDED SPEECH THERAPY

LOS ALAMOS TECHNOLOGY HELPS HEARING-IMPAIRED STUDENTS LEARN TO SPEAK BY IMITATING MOVEMENTS, NOT SOUNDS

A picture is worth 1,000 words, especially to people who have speech and hearing impairments. That's the basic premise behind a speech analysis technology developed by Los Alamos scientists to help speech and hearing-impaired people learn to speak. The technology was chosen as one of the top 30 entries from 1,500 applicants in the Johns Hopkins University national search for computer-based technologies to assist people with disabilities.

When a user speaks into a microphone attached to a personal computer, the computer screen displays a simulated X-ray image of the speaker's vocal tract. This simulated image is derived from a mathematical



A new Los Alamos technology allows hearing-impaired students to speak. The simulated X-ray image displayed on the screen shows the student what she is doing with her vocal apparatus. By moving her vocal apparatus to conform to a target image of a speech sound, the student learns to make that sound.

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analysis of the sounds the speaker is making. Superimposed on the screen's image is a picture of the vocal tract configuration that is required to achieve a certain speech sound.

By making the image of his or her vocal tract configuration conform to the target configuration shown, the user learns to make that speech sound. Thus, in contrast to earlier methods that display abstract sound patterns, the Los Alamos approach provides meaningful feedback to users because it teaches them how to place their lips, tongue, and jaw to produce speech sounds. In addition to aiding speech therapy and teaching the deaf to speak, the method can be used by people with foreign or regional accents who want to change how they speak.

In the course of their research, Los Alamos scientists discovered that speaking different languages involves combinations of a small number of basic vocal tract movements that are the same in those different languages. The apparent diversity in the sounds of the languages is caused by the differing ways in which the vocal tract movements are combined, as well as differences in timing and intonation. This spin-off result of the Los Alamos system is important to research in the field of linguistics.

Not only is the Los Alamos technology useful in speech therapy, in teaching speech to the hearing-impaired, and in teaching foreign languages, it can also be applied to talkwriters — machines that transform speech into writing on the printed page. In conventional speech-recognition systems, words are recognized based on discrete units of sound called "phonemes." These systems are limited in recognizing continuous speech (as opposed to isolated words) because in fluent speech many speech sounds are produced simultaneously. For example, a single lip-closing movement is used for both the "m" and the "p" sounds in the word "camper."

Overlaps such as these abound in normal speech, and efforts to recognize discrete sequential units are inaccurate because such units do not exist in fluent speech. Recent research has indicated that the Los Alamos technology significantly improves the accuracy of existing speech recognition systems.

Other potential applications for the technology include identification and efficient coding of speech for telecommunications systems.

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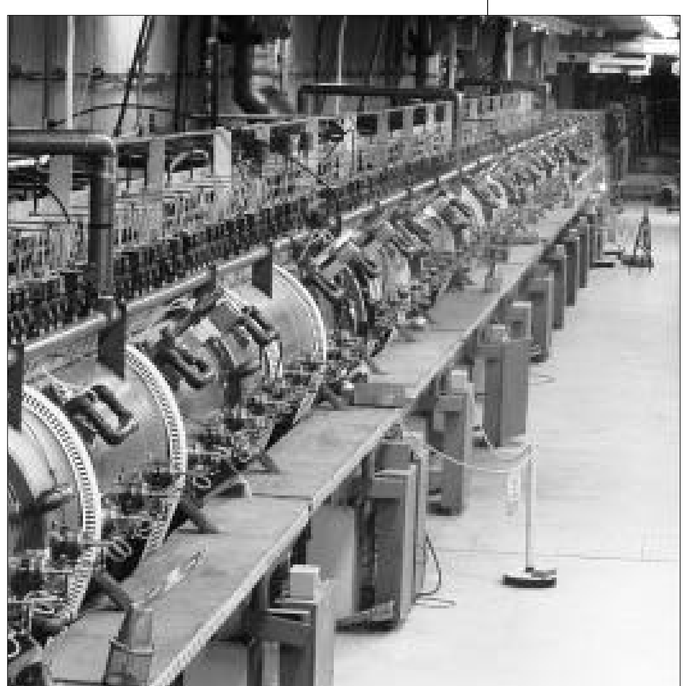
LOS ALAMOS AIDS RUSSIAN EFFORT TO REDUCE DANGERS FROM NUCLEAR MATERIALS

COLLABORATION SHOULD ADVANCE WORLDWIDE EFFORTS TO REDUCE THE STOCKPILES OF NUCLEAR WEAPONS MATERIALS

Under a recently announced international agreement, Los Alamos researchers will help Russian scientists plan, design, and engineer particle accelerators capable of transmuting plutonium from nuclear weapons and nuclear waste into stable elements or species with much faster radioactive decay rates.

At a recent conference in Las Vegas, the International Science and Technology Center agreed to provide $3 million to seven Russian physics institutes for two years of research and development. The proposal is one of the largest efforts funded by the ISTC, whose goal is to support former Russian nuclear weapons scientists working on civilian projects that reduce the danger of proliferation of weapons of mass destruction. The ISTC was established in 1992. Its board of governors consists of government and scientific representatives from the United States, the European Community, and Japan. Together, the three governments provide $75 million a year to the ISTC to fund Russian scientific work.

As its contribution to the project, Los Alamos will support broad Russian technology



A portion of the proton accelerator — known as a drift tube linac — at the Los Alamos Meson Physics Facility. Proton beams accelerated in the linac are delivered to neutron production targets at the Weapons Neutron Research Facility. Such targets could be used in an accelerator-driven approach to transmutation of nuclear wastes, which potentially can destroy all major types of long-lived radionuclides.

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development that scientists hope will lead to the design of Russian systems for accelerator-based conversion, or ABC, of plutonium from weapons and for the destruction of long-lived nuclear reactor wastes, termed accelerator transmutation of waste, or ATW. Both processes transmute plutonium and other long-lived radionuclides into different forms by bombarding them with neutrons generated by particle accelerators. The radionuclides absorb some of the neutrons, which increases their stability and eliminates or drastically reduces the length of time required for them to undergo radioactive decay.

The technical work will be carried out entirely by Russian scientists working in Russia under Russian project management. Los Alamos will play a key role in planning the work and defining the technical tasks, as well as reviewing the research as it progresses.

Los Alamos researchers predict that the ABC/ATW collaborative project will provide a new, non-defense mission for more than 200 former Russian weapons scientists. In addition, the scientific fruits of this collaboration should advance worldwide efforts to reduce the stockpiles of nuclear weapons materials and nuclear wastes.

Many of Russia's most prestigious nuclear physics laboratories will be involved in the project. These include the All-Russian Scientific Research Institute of Experimental Physics at Arzamas-16; the All-Russian Scientific Research Institute for Technical Physics at Chelyabinsk-70; the Institute for Theoretical and Experimental Physics in Moscow; the Bochvar Institute of Inorganic Materials, also in Moscow; the V.G. Khlopin Radium Institute in St. Petersburg; the Scientific and Design Institute for Power Engineering, also at St. Petersburg; and the Institute of Physics and Power Engineering at Obninsk.

Los Alamos' ABC/ATW proposal was accepted for funding at a June 13–17 meeting of the ISTC board of governors. In fleshing out the ISTC proposal, Russian and U.S. specialists held a number of meetings to discuss potential ABC and ATW systems. These meetings took place in Moscow (November 1992), Los Alamos (December 1992), Chelyabinsk-70 (June 1993), and again at Moscow (May 1994). Further meetings are planned at Dimitrovgrad (September 1994) and at Arzamas-16 (October 1995).

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DATELINE: LOS ALAMOS

PATENTLY CREATIVE

LOS ALAMOS INVENTIONS USEFUL TO INDUSTRY

Patents are a form of "intellectual property" granted by the U.S. government. Patents granted for scientific research and innovation are known as "utility" patents, a category that recognizes inventions useful for industry and commerce. Since its origin in 1943, Los Alamos National Laboratory has garnered more than 1,000 patents.

Basic criteria in awarding patents are novelty, usefulness, and "non-obviousness." Each month, the Laboratory's Intellectual Property Review Board examines reported developments for usefulness to industry.

In considering an invention, the board asks if it is new, different, and useful. Does it show a leap of technical creativity? If the invention is a mere variation of things done before, it will not qualify because it is in all likelihood not patentable. If not of commercial value to industry, an invention will not qualify because it cannot be licensed.

After the patent is granted by the U.S. Patent and Trademark Office, it is often licensed, or "rented," to industry — sometimes with exclusive rights, sometimes with non-exclusive rights. After 17 years, the patent expires and the invention is introduced into the public domain.

Patents serve as important historical documents. They are part of a worldwide system for identifying and distinguishing advances in science and technology. They are also a way that Los Alamos National Laboratory can provide a competitive advantage to U.S. businesses in the international market.

Some of the patents granted to Los Alamos researchers in 1994 are as follows:

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AEROSOL CHEMICAL VAPOR DEPOSITION OF METAL OXIDE FILMS

One of the initial stages in making computer chips and other electronic devices is chemical vapor deposition, the process of converting volatile molecular compounds to a thin film of a material such as silicon or aluminum. Chemical vapor deposition is also useful in depositing thin films of materials used in superconductors. A major problem in the deposition process is the difficulty of controlling the rate of evaporation of the volatile compound. Any variability in the evaporation rate results in a film with less than optimal properties. The Los Alamos process of aerosol-assisted chemical vapor deposition operates by generating an aerosol of a solution containing the precursor compound in such a way as to reduce the potential for compositional variation of the resulting film. The result is constant composition and better performing thin films.

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AUTOMATIC FEED SYSTEM FOR ULTRASONIC MACHINING

Ultrasonic machining is used in fields as diverse as jewelry making and electronic-parts manufacturing. Los Alamos scientists have developed a method and apparatus for ultrasonic machining in which the feeding of a tool assembly — with the tool toward a workpiece — is accomplished automatically. A delicately vibrating tool located directly above the workpiece is used to shape and “fine tune.” The Los Alamos method makes it possible to cut pieces as small as one-half of a millimeter square. The tool assembly has a very light “overbalance” or inequilibrium adjusted so its downward force is minimal, and the tool overbalance force is equal to the force of the grit as it rebounds from the workpiece back up to the tool surface. Besides prolonging the life of ultrasonic machining tools and increasing production, the Los Alamos method is useful for cutting small details into hard, brittle materials such as ceramics and glass.

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CLAMSHELL MICROWAVE CAVITIES

Numerous military and civilian electronics applications require advanced microwave technology. The Los Alamos clamshell design for a cavity oscillator started as a cylinder (the traditional shape) and was

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elongated by pulling at the equator from opposite sides. An oscillator is the component that sets up electromagnetic waves that resonate at a fixed frequency. The oscillator literally "sets the pace" for other components in a device, thus establishing its primary frequency. In microwave cavities constructed from copper, the clamshell design results in lower phase noise. Because radar range is limited in part by phase noise, the use of the Los Alamos design has the potential to increase the range of any radar system, including air-traffic control radar, air-to-air radar, Doppler weather radar, and satellite communication systems.

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CONVECTION TOWERS

The Los Alamos convection tower is capable of cleaning pollution from large quantities of air while simultaneously generating electricity. Sea water or other water in the form of fine mist is sprayed downward into the interior of tall cylinders. The mist cools the air and washes out particulates from air in the tower. Wind turbines at the skirt section of the tower generate electrical power. In August 1993, a model of the convection tower was successfully demonstrated to the prime minister of Malaysia and his cabinet ministers, and earlier this year, Los Alamos scientists presented a proposal for further research. If the project is approved, the Malaysian government plans to build convection towers to clean air and generate electrical power in Kuala Lumpur, the country's capital.

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FANLESS LONG-RANGE ALPHA DETECTOR

The fanless long-range alpha detector developed at Los Alamos can be used to detect alpha radiation in the soil near any facility with a history of using nuclear material. The list includes gas refineries, mining fields, hospitals, and the Department of Energy's nuclear facilities. The Los Alamos detector can also be used for interior surfaces of old and contaminated buildings. The conventional methods of alpha detection are limited in speed and sensitivity. The new method employs an electronic plate attached to a battery to attract ions. It measures an area 30 times larger than do traditional monitors, and it costs hundreds of dollars less per measurement. Additionally, scientists can get answers right on the spot rather than sending samples to distant laboratories for analysis. Commercial versions of the fanless long-range alpha detector are available through Eberline Instruments in Santa Fe, New Mexico, which has entered into a cooperative research and development agreement with Los Alamos.

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METHOD FOR REMOVAL OF METAL ATOMS AND EXPLOSIVES FROM AQUEOUS SOLUTIONS USING SUSPENDED PLANT CELLS

Organic removal of toxic metals from contaminated liquids is now possible. Los Alamos scientists have developed a process that uses cells from different plants to purify liquids tainted with heavy metals. The cells remove enough barium, iron, and plutonium ions so that concentrations are less than one part per million, well below Environmental Protection Agency standards. Jimsonweed cells grown in waste streams that contain munitions manufacturing effluent remove TNT and other explosives from solution. Los Alamos researchers have also found that dead, dehydrated plant cells are useful in treating metals-contaminated waste directly.

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OPTICAL AMPLIFICATION AT THE 1.3-μM WAVELENGTH

Fiber-optic networks, because of their low cost and high information-carrying capacity, are rapidly overtaking electrical telecommunication technologies. Information propagated in glass fibers as light pulses must be refreshed every few miles due to inevitable fiber losses. Whereas conventional fiber-optic networks accomplish signal refreshment by complex electronic detection and retransmission at regular intervals, industry is seeking technologies that optically amplify signals in a single pass. Researchers at Los Alamos have developed a technique that amplifies pulses at the most commonly used signal wavelength (1.31 micrometers). The Los Alamos approach, which entails “energy-transfer” and the absorption of light at a more convenient wavelength than ever before used, may lead to the first practical fiber-optical amplifier at the 1.31-micrometer wavelength.

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ORGANIC CONTAMINANT SEPARATOR

A major task in our country's environmental cleanup effort involves analysis of water — drinking water, rivers, lakes, and even waste water.

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Los Alamos scientists have developed a method of extracting organic contaminants from water samples that is more efficient and environmentally sound than traditional methods. The old method extracts contaminants with a solvent in a flask, working much as a coffee percolator. After "perking," the method leaves a half liter of the solvent and more than a liter of contaminated water. The Los Alamos method passes water through a plastic tube. Because the waste and the inner walls of the tube have an affinity for each other, organic contaminants adhere to the walls of the tube. The Los Alamos method uses 95 percent less solvent than the old method and takes less time — two to four hours instead of overnight. It is part of a cooperative research and development agreement between the Laboratory and Restock Corp., makers of chromatography equipment.

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RADON DETECTION METHOD

Radon detection is an important concern in environmental monitoring, and Los Alamos' new device that "vacuums the air" has made detection more efficient. Radon gives off alpha particles, creating ions that are collected in a large bottle. These ions are detected to give a signal proportional to the amount of radon in the bottle. The Los Alamos method is faster, allows for the collection of larger volumes of air, and can be regulated more easily than traditional detection methods. The Los Alamos method can be used to monitor both outdoor areas and enclosed sources of radon such as granite buildings.

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RECOVERY OF NIOBIUM FROM IRRADIATED TARGETS

Proton-irradiated molybdenum targets designed to produce strontium isotopes used for cardiac imaging in heart patients contain radioactive niobium isotopes. This leftover material is potentially valuable for geochemical research. One of the niobium isotopes can be used to eliminate measurement interferences by isotopes of zirconium and molybdenum. Los Alamos scientists have developed a new method for recovering these niobium isotopes. The recovery method employs a unique production and separation technique for niobium isotopes.

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Dateline: Los Alamos

BRIEFLY ...

MICHELINE DEVAURS IS LOS ALAMOS' NEWLY APPOINTED PROGRAM MANAGER FOR POLLUTION PREVENTION. She is responsible for developing programs designed to reduce the amount of several types of solid waste produced at the Laboratory, including low-level hazardous and mixed waste. According to Devaurs, mixed waste is the most problematic to deal with because of regulatory constraints and because there are few technologies available today to effectively handle mixed waste. She is also responsible for developing programs designed to reduce all waste emissions, including air emissions and waste-water discharges. "The main thrust of these programs is to focus on source reduction, followed by recycling and reuse," Devaurs said. "If that isn't feasible, then there is waste treatment and final disposal."

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