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IDAHO NATIONAL ENGINEERING LABORATORY ANNUAL REPORT 1986

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"The INEL underwent a year of transition in 1986. Success with new business initiatives, the prospects of even better things to come, and increased national recognition provided the INEL with a glimpse of its promising and exciting future."

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IDAHO NATIONAL ENGINEERING LABORATORY ANNUAL REPORT 1986

The INEL underwent a year of transition in 1986. Success with new business initiatives, the prospects of even better things to come, and increased national recognition provided the INEL with a glimpse of its promising and exciting future.

Among the highlights were: selection of the INEL as the preferred site for the Special Isotope Separation Facility (SIS); a national Strategic Defense Initiative (SDI) conference hosted by the INEL; the first shipments of core debris from the Three Mile Island Unit 2 reactor to the INEL; dedication of three new facilities—the Fluorinel Dissolution Process, the Remote Analytical Laboratory, and the Stored Waste Experimental Pilot Plant; groundbreaking for the Fuel Processing Restoration Facility; and the first IR-100 award won by the INEL, given for an innovative machine vision system.

The prospects of SIS and involvement in SDI are indicators of the INEL's expanded role in programs vital for U.S. defense. The INEL has been assigned project management responsibility for the SDI Office-sponsored Multimegawatt Space Reactor and the Air Force-sponsored Multimegawatt Terrestrial Power Plant Project. New Department of Defense initiatives have been realized in projects involving development of prototype defense electronics systems, materials research, and hazardous waste technology.

While some of our major reactor safety research programs have been completed, the INEL continues as a leader in advanced reactor technologies development. In April, successful tests were conducted for the development of the Integral Fast Reactor.

Other 1986 highlights included the INEL's increased support to the Office of Civilian Radioactive Waste Management for complying with the Nuclear Waste Policy Act of 1982. Major INEL activities included managing a cask procurement program, demonstrating fuel assembly consolidation, and testing spent fuel storage casks.

In addition, the INEL supplied the Tennessee Valley Authority with management and personnel experienced in reactor technology, increased basic research programs at the Idaho Research Center, and made numerous outreach efforts to assist the economies of Idaho communities.

The INEL's reputation for achievement is leading to increased national recognition of the important role the laboratory plays in U.S. technology development. A number of distinguished visitors to the INEL emphasized this recognition, including Air Force General James Abrahamson, head of the SDI Office; Dr. Lodewijk van den Berg, scientist/astronaut; DOE Secretary John Herrington; nuclear pioneer Dr. Edward Teller; and Mary Walker, DOE Assistant Secretary for Environment, Safety, and Health.

With the close of 1986 and the important achievements the year heralded for the future, I look forward to 1987 and beyond. The possibilities are exciting as I contemplate new initiatives such as the superconducting super collider, the electromagnetic/electrothermal launcher national test facility, and numerous other programs. I am confident INEL people will successfully meet the challenges.

Troy E. Wade II
Manager

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The Idaho National Engineering Laboratory (INEL) is a multipurpose, defense programs laboratory. Historically a leader in the Department of Energy's (DOE) reactor technology programs, the INEL conducts applied research and development to support DOE's mission. The INEL also maintains for the federal government the capability to provide independent scientific advice, and technical verification and validation in areas of its expertise. The INEL provides use of its unique facilities for the benefit of members of the technical community, cooperates with personnel in universities and industry to aid in the education of scientists and engineers, and provides technology transfer to the public and private sectors. Major facilities are located in Idaho Falls, Idaho, and on an 890-square-mile tract west of Idaho Falls.

The DOE Idaho Operations Office has three major operating contractors at the INEL: EG&G Idaho, Incorporated; Westinghouse Idaho Nuclear Company, Incorporated (WINCO); and Rockwell-INEL. In addition, two other organizations are located at the INEL: Westinghouse Electric Corporation operates the Naval Reactors Facility for DOE and the U.S. Navy; Argonne National Laboratory-West operates the Experimental Breeder Reactor-II and maintains reactor research facilities.

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Fluorinel Dissolution Process Begins Operating

The October hot (irradiated) fuel startup of the Fluorinel Dissolution Process (FDP) marked a major milestone in nuclear fuel recovery for DOE and the Idaho Chemical Processing Plant (ICPP). FDP, where nuclear fuel is dissolved, is part of the Fluorinel Dissolution Process and Fuel Storage (FAST) facility at ICPP.

Troy Wade, DOE-ID Manager, announced in December 1985 that Phase II hot startup of FDP was DOE's primary goal at the INEL for FY 1986. The challenging milestone was achieved because of the commitment and excellent cooperation among several organizations at the INEL—DOE-ID, WINCO (the operating contractor for ICPP), EG&G Idaho, and MK-Ferguson.

Phase II, finished during October, followed a strict testing program to ensure safety and guarantee operational readiness. One of the major efforts during Phase II was the revision of operating procedures to include new process changes and operational requirements, thereby providing surety of operations.

The FAST facility now makes ICPP a fully integrated plant where highly radioactive spent fuel is safely stored and reprocessed to recover uranium for recycling to various reactors.

Irradiated fuel must be dissolved in acid before chemical separation of uranium-235 from other components and fission products. FDP is the initial element of this process. It is now playing a major role

The FAST control room

Two of the biggest challenges were procuring the necessary hardware and equipment and completing the construction phase on a very tight schedule. Procurement required canvassing the U.S. and Europe in search of needed equipment. In all cases, the needed equipment was found, purchased, and expeditiously delivered to accommodate construction. The tight construction schedule required work around the clock, three shifts a day, seven days a week.

Before irradiated fuel was introduced to FDP, heavy emphasis was placed on surety of operations. This was done in two phases. Phase I required operating FDP with unirradiated materials to find any process and equipment deficiencies that needed correction before full-scale operation. Phase I also established the reliability of plant protection systems and proved the validity of the basic operating procedures.

FACILITY STARTUPS

***FAST Facility with
FDP high bay in
foreground***

in recovering valuable uranium-235 from government-owned fuels for recycling into fuel for government reactors.

FDP, which is next to the underwater Fuel Storage Area, houses a shielded dissolution cell and various support facilities. Concrete walls, five feet thick, protect operators from radiation inside the cell. Shielded viewing windows in the walls and remote television systems provide visual access for remote mechanical operations. This significantly reduces radiation exposure to operating personnel and increases the operating time of the facility. For example, items requiring frequent repair or replacement in radioactive areas are remotely removable, permitting quick changeout of the items without personnel receiving radiation exposure.

Nuclear fuel is transferred underwater directly from the storage area to FDP. This procedure eliminates the need to use shielded casks for loading and unloading radioactive material. Similar fuel-dissolving work has been conducted at the ICPP for over 30 years, but FAST provides an ultra-modern facility with the latest fuel reprocessing technology.

Older fuel reprocessing facilities at the ICPP will eventually be replaced by FDP and other new facilities, which will be capable of handling much larger quantities of fuel. This expanded capability will permit the ICPP to reprocess increasing quantities of government-owned fuels projected for the future. FDP and its associated facilities will allow the ICPP to double its reprocessing throughput capability by 1995.

New Approaches Developed for FDP Operations

New approaches to determine quantities of undissolved uranium and to monitor corrosion were developed for FDP.

New Equation Determines Undissolved Uranium Quantities

An estimated \$3.3 million a year in process and other costs will be saved by using a new equation to calculate quantities of accumulated undissolved uranium in FDP. The accumulated undissolved uranium in FDP is monitored by comparing the amount of dissolved uranium produced with the amount charged to the dissolver. When this difference reaches a specified level, a special step or "heelout" is added to remove the undissolved uranium.

The heelout process is costly in terms of throughput reduction and additional waste generated. The previous equation required knowing certain values relating to the fuel to be processed before the fuel is placed in the reactor.

Because these values were unavailable for Fluorinel fuels, engineers developed the equation to provide the required information and allow the FDP facility to begin operating on schedule. The new approach will ultimately result in much better determinations than the original equation and increased productivity. The costs saved from the use of the new equation do not include repository costs.

Corrosion Monitoring

To allow instantaneous measurement of corrosion rates, a modification of commercially available polarization resistance corrosion probes was developed for use in FDP.

Previously, the only method of corrosion monitoring used at the ICPP was the placement of corrosion coupons in plant equipment. Until the equipment was shut down and decontaminated, these coupons could not be retrieved. In some instances, vessels or piping experienced severe corrosion before the routine inspections.

Now, the probes are installed in all three FDP trains and are operating successfully. They have indicated process upsets caused by improper solution makeup or temperature excursions which, in turn, caused temporarily high corrosion rates. And the probes can trigger alarms if corrosion exceeds a predetermined set point.

World-class Remote Analytical Laboratory Opens

Chemists and technicians at the Idaho Chemical Processing Plant's new Remote Analytical Laboratory (RAL) work in one of the safest, most sophisticated, radioactive chemistry laboratories in the world. Dedicated in July, the laboratory is part of the Idaho Chemical Processing Plant (ICPP) that is operated by WINCO.

Designed specifically for analyses of highly radioactive samples, the laboratory provides analytical support for ICPP's primary functions, reprocessing government-owned nuclear fuel and converting liquid radioactive waste to a solid.

The laboratory contains many features for improved operator safety, product quality, and work efficiency. The heart of the laboratory facility is a 50-by-20-foot hot cell enclosed within three-foot-thick concrete walls. Seventeen master-slave manipulators are used by operators outside the cell to perform analyses of highly radioactive samples inside the cell. Observation of work in the cell is possible through nine oil-filled, leaded-glass windows, each 30 inches thick.

A pneumatic transfer system, similar to those used at drive-in bank windows, moves capsulated samples from other ICPP operating buildings to the cell. Compressed air moves the capsulated sample through overhead stainless steel pipes at speeds up to 50 feet per second, shortening the time between taking samples and receiving analytical results. Inside the cell, samples and supplies are moved between analytical stations on a small cart. A drive system beneath the cell floor couples magnetically to the cart and propels it from station to station.

Analytical functions, such as aliquoting, titrating, weighing and measuring densities, and other chemical operations are performed inside the cell. Results from these analyses are relayed to the operating facilities at the plant by interconnected computers so that rapid adjustment of chemical processing operations can be made whenever variations in process controls are detected.

Solid wastes from the analytical operations are moved to a waste-handling cell within the laboratory where they are packaged, placed in shielded casks, and transported to another part of the INEL for interim storage. Liquid wastes are stored with other ICPP-generated liquid wastes and later converted to solids at the New Waste Calcining Facility.

The laboratory also contains shielded glove boxes, hoods, and benches where samples having lower levels of radioactivity are analyzed. A conventional cold laboratory with benches and hoods for analyses of nonradioactive samples is also included in the new facility. Offices, locker rooms, and numerous auxiliary systems support round-the-clock operation.

The RAL was designed and constructed with systems to prevent unacceptable releases of hazardous substances during normal operation and during any unlikely natural event, such as fire, flood, earthquake, or tornado. Continuous monitoring systems are installed inside the laboratory and along every discharge path to the environment to ensure that the protective systems are operating normally.

Chemist performs analysis inside an RAL hot cell

Stored Waste Experimental Pilot Plant Begins Operations

The Stored Waste Examination Pilot Plant (SWEPP) began full operation in FY-86 as the first U.S. facility performing nondestructive examination and certification of defense-generated transuranic (TRU) waste. SWEPP, an integral part of the DOE Nuclear Waste Management program for defense-generated TRU waste, will operate for the next 23 to 45 years to examine and certify stored, contact-handled waste for shipment to the DOE Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Shipments are expected to begin in 1988.

Contact-handled TRU waste is material contaminated with small amounts of plutonium and americium. About 2.1 million cubic feet of contact-handled TRU waste now are stored in aboveground containers at the INEL Radioactive Waste Management Complex.

TRU waste planned for shipment and permanent storage at WIPP must meet WIPP waste acceptance criteria. SWEPP capabilities for certifying waste to criteria include weighing, real-time radiographic examination, neutron assay examination, container integrity examination, and radiological surveys.

The nondestructive examination techniques allow waste and containers to be inspected without opening the containers. The radiography system permits identifying materials unacceptable for WIPP storage, such as free liquids, respirable fines, and pressurized items. Assay examination measures fissile material content, thermal power density, and total TRU content.

***Stored Waste
Examination Pilot
Plant***

The container integrity system ultrasonically measures metal wall thicknesses of waste drums to ensure that the drums meet U.S. Department of Transportation safety requirements for shipping radioactive materials. Containers that fail the integrity examination will be overpacked before shipment to WIPP.

Support capabilities include facilities and equipment for retrieving waste containers, venting pressurized containers, overpacking damaged containers, and storing certified and uncertified waste packages.

A specialized sampling program has been integrated into the SWEPP examination process. It is a statistically based program that verifies the accuracy of the SWEPP examination by visual inspection of waste designated for WIPP.

Waste that cannot be WIPP-certified will be handled in three ways. One, waste may be shipped to the Process Experimental Pilot Plant (now undergoing acceptance testing at the INEL), processed to meet WIPP acceptance criteria, and returned to SWEPP for final certification. Or two, the waste may be classified as low-level waste and designated for other handling.

The third type of waste is special case that will be processed in PREPP-II, a future facility planned for this purpose.

THREE MILE ISLAND

TMI-2 Fuel Shipping Program Begins

Five cask shipments, each containing seven canisters of core debris from the Three Mile Island Unit 2 (TMI-2) reactor, were transported to the INEL in 1986. Approximately 30 more shipments will be made during the next two years to transport the remaining debris.

The shipping program has received considerable national attention and DOE and EG&G Idaho personnel have responded to hundreds of inquiries from interested third parties, the public, news media, state officials, and U.S. senators and congressmen. The success of the program in this atmosphere of intense public scrutiny illustrates the INEL's capabilities and leadership role in developing and implementing technology and institutional plans for nuclear waste shipments.

INEL personnel monitor the progress of each shipment as it travels some 2,400 miles from TMI to the INEL. Each shipment is carefully coordinated with rail carriers and officials of the 10 states along the shipping route. At the INEL, the shipping casks are unloaded from the railcars at the Central Facilities Area and transported by truck to the Hot Shop at Test Area North, where the canisters are unloaded for research and interim storage.

The INEL was selected as the site to study and store the TMI-2 core debris because of its extensive experience and capabilities in damaged fuel analysis and nuclear waste management and technology development.

***Fuel cask leaves
TMI***

The shipments use railroads to move two rail shipping casks designed and built by Nuclear Packaging, Incorporated. The casks are designed to survive severe impact and fire accidents without releasing any of the radioactive material.

Core Bore Samples Removed

A significant milestone was reached at TMI-2 in July with the removal of stratified core debris samples from the TMI reactor vessel. Once examinations and analyses are completed at the INEL, the information gained from these core samples is expected to contribute to the resolution of several important research issues.

These issues include improving the definition of current core conditions, advancing the understanding of the accident scenario, and establishing the location and distribution of retained fission products. In addition, information developed during core boring operations will aid core debris removal. This information was developed both from drilling data and from video inspections made through the core bore holes.

The need for a thorough understanding of conditions inside the damaged reactor was recognized during the early stages of the TMI-2 program. More than simply identifying the end-state condition of the core, understanding the thermal, chemical, and mechanical processes that occurred during the accident was established as a priority concern. The amount of release or retention of fission products during a severe accident is the key licensing issue, and was recognized as an important topic for investigation at TMI-2.

Similarly, the events and conditions contributing to the relocation of core materials, as well as the timing of those events, make up the major data points for reconstructing the accident sequence. Vital to all these considerations is the ability to acquire meaningful core samples.

The research community requires physical samples representing the spatial extent of damage or degradation. With analysis, the samples must be capable of providing data to characterize the variations in postaccident core materials present, as well as represent as-built variations in fuel assembly types and locations.

To be meaningful, the samples had to be traceable within the three-dimensional geometry of the core. Similarly, those responsible for defueling plans needed data on the type and distribution of altered core materials, both in the normal core space and in the regions within the lower core support structures. The latter information, to be useful, had to be available shortly after drilling. An overriding consideration was to minimize delays to the plant recovery and defueling operations.

The core stratification sampling project, referred to as the core-bore project, was developed as a coherent approach to the complex task of in-core sample acquisition. Starting with equipment and technology currently available in the mining/geology industry, the system was extensively modified to meet the special operating and environmental requirements of the TMI-2 Reactor Building.

Ten core samples were removed from the reactor vessel and loaded into five shipping canisters for shipment to the INEL. Once received at the INEL, the canisters are remotely removed from the shipping cask and transferred directly into the water pool at Test Area North for storage. Selected canisters are taken from storage and then placed into a hot cell for disassembly. The contents are removed from the canister and transferred into smaller cells for sectioning and detailed examinations.

Video inspections of each core bore hole including the lower core support assembly region were performed. The data obtained from this operation and subsequent analysis of the video and drilling data revealed that:

1. A region of previously molten core materials, estimated to be approximately 122 square feet (about 10% of the original core volume), was confirmed to be in the lower, central region of the core. This solid structure is approximately four feet thick in the center of the core, one to two feet thick near the core periphery, and is roughly shaped like a funnel extending down toward the bottom of the core. Intact rod stubs exist from the bottom of the core up to the previously molten ceramic material.
2. The primary migration path of the previously molten material into the lower plenum appears to be located on the southeast side of the core near the periphery.
3. The core support assembly appears to be undamaged in those areas where previously molten ceramic materials have frozen in place between the core support assembly structural members.

4. The fuel debris resting on the bottom vessel head near the center of the reactor vessel appears to be loose and relatively fine as compared with the larger agglomerated debris existing near the edge of the reactor vessel in the lower plenum.

Based on the success of the core-bore operation, the core-bore machine was used by GPU Nuclear in an attempt to break up the solid, previously molten region in the TMI-2 core using techniques recommended by EG&G Idaho.

Core-boring equipment at TMI

Integral Fast Reactor Research Progresses

Research at Argonne National Laboratory-West focuses on nuclear reactors, with the aim of developing energy technologies that promise high, long-term benefits, but that bear financial risks too great for industry to undertake. Major reactor research facilities of the Argonne National Laboratory are located at the INEL. Argonne-West is operated by the University of Chicago for the DOE-Chicago Operations Office.

One of the most important nuclear power advances in recent years is Argonne's design of a nuclear power system called the Integral Fast Reactor (IFR). The reactor, cooled by liquid metal and fueled by a new metallic fuel, appears to be both inherently safe and less costly to build and operate than other liquid-metal reactor designs. The fuel cycle all but eliminates the possibility of unauthorized diversion of nuclear fuel, reduces the volume of radioactive waste generated, and eliminates any need for over-the-road transportation of radioactive materials.

The IFR concept has three key elements. First, it is a pool-type, sodium-cooled reactor. This means its core, the heart of the reactor where the fission reaction takes place, and other major components are submerged in thousands of gallons of molten sodium. This gives the reactor inherent protection against overheating in case of an accident.

Second, the IFR concept uses a new metallic fuel that enhances core safety and can be easily reprocessed and recast into new fuel. Third, the IFR uses an economical fuel reprocessing method that prevents unauthorized fuel diversion and eliminates any need to transport radioactive materials to or from the site during the reactor's operating lifetime.

Inherent Reactor Safety Demonstrated

During 1986, a major aspect of the IFR's built-in safety was demonstrated at Experimental Breeder Reactor-II (EBR-II). Like the IFR, EBR-II is a pool-type, sodium-cooled reactor. Tests using metal fuel at EBR-II showed that this type of reactor does not need elaborate backup systems to protect against overheating meltdowns.

During these tests, EBR-II operated at full power while pumps that normally circulate sodium coolant were shut down. At the same time, backup emergency systems were turned off. Even under these extreme circumstances, the EBR-II core did not overheat. The reactor shut itself down and kept itself cool through natural convection currents in the coolant pool.

These results suggest that metal-fueled, sodium-cooled, pool-type reactors do not need complicated backup systems for emergency shutdown and cooling. Plant safety appears to be inherent in the basic design.

Experimental Breeder Reactor-II

Metallic Fuel Enhances Safety, Economy

The IFR would be fueled by an alloy of the metals uranium, plutonium, and zirconium, instead of the ceramic oxides of uranium and plutonium used in most liquid-metal reactor designs. Because metallic fuel conducts heat better than oxide fuel, it is easier to cool and further enhances the safety inherent in the pool-type design.

Argonne engineers have developed a new metallic fuel design to solve previous swelling problems that limited the use of metallic fuels. As gaseous fission products accumulate inside metallic fuel, the fuel swells and pushes out against the stainless steel jackets that hold it. Too much swelling can rupture the jacket, creating the need to shut down the reactor and replace the damaged fuel.

By redesigning the fuel to allow more room to expand and using the porosity that develops in the fuel, Argonne engineers have created a metallic fuel that lasts much longer before needing to be replaced. Because there is less need to shut down the reactor for refueling, it can operate more efficiently and economically.

Additional IFR fuel experiments were carried out at the Transient Reactor Test Facility, a research reactor at Argonne-West. The facility simulates severe nuclear accidents by exposing reactor fuels, materials, and components to sudden bursts of power.

In IFR physics benchmark tests conducted in the Zero Power Plutonium Reactor, each of the representative states of an IFR core was simulated. Detailed physics performance and safety parameters were measured for each of these reactor fuel compositions. Analysis of the experiments showed that the physics parameters for the IFR metal core can be predicted very well, with about the same degree of accuracy as for conventional mixed-oxide liquid metal reactor cores. These results confirm that the conceptual IFR core designs are evolving on a sound basis.

Fuel Reprocessing is Diversion-Proof

The third key element of the IFR concept is a fuel reprocessing method that appears inexpensive and that should prevent unauthorized fuel diversion. Used fuel would be removed from the core, transferred to a fuel-cycle facility connected to the reactor, reprocessed, and returned to the core. At no time would there be any human contact with the materials, which would remain highly radioactive. The entire process would be carried out by remote control. No fuel or waste would enter or leave the reactor site during the lifetime of the plant.

It is the ease of processing and casting metallic fuel that makes this on-site fuel reprocessing facility possible. The IFR fuel cycle draws on experience with a similar metallic fuel cycle first demonstrated at EBR-II. From 1964 to 1969, spent metallic fuel from EBR-II was routinely removed from the core, reprocessed, and returned. During this period, five complete core loadings—about 35,000 fuel pins—were processed by remote control at the Fuel Cycle Facility next to EBR-II.

Ultrahigh Flux Reactor Concept Developed

An advanced, steady-state neutron scattering facility with a neutron flux level ten times that of existing sources is needed for materials science, isotope production, and fundamental physics research. The research community desires an ultrahigh thermal neutron flux (at least 10^{16} neutrons per square centimeter per second) in a large volume accessible to beam tubes, with minimum fast neutron and gamma contamination. The INEL is developing a reactor design in a double-donut configuration to provide the thermal neutron source for this facility.

As a result of INEL's examination of the constraints and limitations of aluminum-plate fuel research reactor technology, engineers formulated a double-donut core configuration, which is a unique solution to the usual high hot-stripe (the hottest coolant channel) temperature limitation in long, thin coolant channels. To relax the thermal-hydraulic limitations, engineers split the core into two short segments ("donuts") with an interconnecting coolant mixing plenum, which allows the reactor power density to be increased significantly compared with existing plate reactors.

The double-donut reactor concept is illustrated in Figure 1. The core consists of two symmetric fuel donuts. The reactor coolant is heavy water. A coolant bypass annulus is located between the outer fuel region and the pressure vessel. The donuts are separated by a coolant plenum, which mixes the outlet flows from the first donut and bypass annulus before they enter the second donut.

This has two benefits. First, it mixes the hot channel flow with flow from the cooler channels and bypass annulus so that the peak coolant temperature rise through the reactor is greatly reduced. Second, channel-entrance heat transfer effects enhance cooling of the power peak at the entrance to the second donut.

To obtain the required order-of-magnitude increase in neutron flux, approximately an order-of-magnitude increase is required in fission source (power) density compared with current generation high-flux reactors. This increase has been achieved by keeping the heated flow paths as short as possible and controlling surface heat flux with thin fuel plates.

**Cutaway of the
ultrahigh flux
reactor**

The entire reactor and pressure vessel sit in a large pool of heavy water. The thermal neutron flux peaks outside the reactor in the reflector pool. This occurs because fast neutrons produced in the fuel leak through the pressure vessel and into the pool. Heavy water in the pool slows the neutrons to thermal energies (less than one electron volt). Beam tubes placed in the pool will permit the neutrons to travel from the pool to the instruments used in experiments. The split-core arrangement allows direct radial beam access to the resulting high flux environment without exposing the direct field of view of the beam channels to significant high-energy neutron and gamma contamination from the core.

The fuel elements in the double-donut reactor are 10 pie-shaped segments containing 56 thin Advanced Test Reactor type plates. Such a fuel-plate configuration is only one of several that may be feasible. Involute plates or rolled plates that bend circumferentially around the core and are supported by a series of pads or combs are also possible fuel configurations that may improve core performance and reduce cost. The fuel material is a fully enriched uranium (93 percent uranium 235) silicide mixture in an aluminum matrix clad with an aluminum alloy.

The core is attached to an aluminum alloy central support pipe, which also serves as a control rod channel. Thin hafnium tubes placed in the central hole and the coolant bypass annulus control the reactor. A zircaloy pressure vessel is placed close to the core for several reasons. The main reason is that it allows the hot, high-pressure core coolant to be isolated from the reflector pool so that the beam tubes can be operated in a low-temperature, low-pressure environment. This greatly facilitates modifications and maintenance of the items in the reactor pool. The small vessel costs much less than a large pressure vessel with beam tube penetrations.

The core-average power density is 11.6 megawatts per liter, and the 25.8-liter core would produce 300 megawatts (thermal) at the start of the 14-day power cycle. The reactor pressure and coolant velocity are similar to those of the Advanced Test Reactor.

The current design was developed as part of EG&G Idaho's internally funded Exploratory Research and Development Program. A comprehensive plan has been proposed to, and partially funded by, the Department of Energy and Oak Ridge National Laboratory to carry out the research and development necessary to reach a preconceptual design (pre-Title 1) of the Ultrahigh Flux Double Donut Reactor.

Fusion Safety Experiments Conducted

Fusion, a different form of nuclear energy, may offer the potential for producing abundant power in the next century.

INEL is playing an important part in the development of fusion by leading a program to make it a safe energy source with desirable environmental qualities. The Fusion Safety Program at the INEL conducts research on fusion safety and develops new analytical capabilities for safety analysis.

Safety Experiments

Two important fusion safety experiments are being conducted by EG&G Idaho engineers. These experiments are designed to help resolve safety issues early in the fusion energy research and development effort. One set of experiments is studying the potential for release of radioactivity when an accident results in high temperatures such as in a chemical fire. These experiments are beginning to show that only an extremely small amount of radioactive by-products could be mobilized in fusion accidents.

Another experiment is investigating the ways in which tritium (an isotope of hydrogen used as fuel in a fusion reactor) can be kept safely inside the fusion reactor system. It has been found that specialized coatings will be very effective at preventing the escape of tritium.

New Facilities

An unused building at the INEL has been reconditioned and upgraded for use as a tritium laboratory. The new facility contains a fume hood and other specialized equipment for conducting research into tritium safety issues. Experiments that will be conducted in the facility include measurements of permeation of hydrogen isotopes through various materials as a result of ion implantation or exposure to gases containing tritium, permeation barrier effectiveness measurements, and a variety of other experiments that require the use of specialized tritium handling capabilities.

***Fusion experiment
equipment***

***Sample glowing red
during activation
product testing***

Code Development Activities

Development of computer codes to analyze the safety of fusion reactors is an important part of the Fusion Safety Program. Plasma disruptions are a safety concern because if not properly protected against, they could potentially cause damage to a fusion reactor vacuum chamber. The DSTAR code is being developed to model the behavior of the plasma, and nearby objects such as protective tiles, during a plasma disruption. This model includes plasma motion, ablation of the protective tiles, and the interaction of the ablated material with the plasma. DSTAR has been under development for about three years and is presently being used to study disruption data from the Tokamak Fusion Test Reactor (TFTR) at Princeton, and in modeling disruptions for the Compact Ignition Tokamak (CIT) and the Tokamak Ignition/Burn Experimental Research (TIBER) design efforts.

Because fusion experiments require powerful and complex magnet systems to contain the plasma, a code is being developed to simulate transients in the magnets and their electrical supply equipment. This code, MSCAP, the Magnetic Systems Circuitry Analysis Program, models time-, voltage-, and current-dependent resistors, inductors, and capacitors. The magnetic interactions among the coils of the tokamak are also included.

ATHENA, the Advanced Thermo-Hydraulic Energy Network Analyzer code, is a computer program designed to model transients in complex energy producing systems. Because fusion reactors and even near-term fusion experiments will require cooling and cryogenic systems involving many coolants and interconnected flow loops, a computer code is needed to simulate transients before the reactor is built. ATHENA provides that needed capability.

ATHENA, a derivative of the RELAP5 code, has been under development at the INEL for the last six years. In September 1986 it was released to the U.S. fusion community through the National Magnetic Fusion Energy Computer Center in Livermore, California. The code has been used at the University of Wisconsin to model the behavior of liquid-metal-cooled fusion blankets during a fire, in San Diego to analyze the performance of space reactors, and at the INEL to model both fusion and fission reactors.

International Activities

The Fusion Safety Program is playing an increasingly important leadership role in the international research effort to harness fusion energy in a safe and economical fashion. Bilateral cooperative efforts have begun with fusion groups in Italy, West Germany, and Japan. Meanwhile, British, German, and Japanese engineers and scientists have traveled to Idaho to confer with Fusion Safety Program personnel about our research results and future plans. Also, program personnel and the local section of the American Nuclear Society have been selected to host the next major international meeting on fusion technology in October 1988.

INEL Provides Microcomputer-based Decision Aids to the Nuclear Regulatory Commission

Three special-purpose codes—involving probabilistic risk analysis (PRA)—were created at the INEL as decision aids for the Nuclear Regulatory Commission (NRC) and the nuclear community. PRA provides results, models, and tools in a form that can aid plant inspections and audits, decisionmaking, safety issue resolution, formulation of policy, and other regulatory applications. The codes (run on microcomputers) are the Integrated Reliability and Risk Analysis System (IRRAS), the System Analysis and Risk Assessment (SARA) System, and the Plant Risk Status Information Management System (PRISIM).

The first two codes, IRRAS and SARA, were designed as risk-based, decision-making tools for PRA analysts, regulators, and decisionmakers. Analysts will use them to build and evaluate probabilistic models, and regulators and decisionmakers will use them to evaluate different alternatives proposed for plant risk and reliability improvement.

IRRAS gives an analyst the capability to create, modify, update, and reanalyze a plant PRA to keep it current with the plant's configuration and operation. IRRAS also contains a graphical fault tree editor that allows the analyst to build a system fault tree from scratch or modify an existing fault tree already in IRRAS.

The results of the IRRAS analyses can be loaded into the SARA System for further analyses. SARA uses the dominant core melt or consequence sequences for a plant to evaluate proposed changes in terms of their impacts on the core melt frequency or risk to the public. SARA has been designed to evaluate generic changes to a group of plants, as well as specific changes to a given plant.

The SARA data base contains information at the plant, system, component, and basic event levels for each plant loaded. NRC generic issues information about each plant is also included. Displays of this information can be called up for any combination of plants or for a single plant. Most information is in tabular form, however, plant drawings, fault trees, and event trees are presented graphically.

The third code, PRISIM, contains functions to help NRC inspectors in allocating their efforts towards those areas of greatest impact on plant safety. It is designed to run on a computer located at the plant site. PRISIM is based on a plant-specific PRA and a detailed analysis of an NRC inspector's actions in implementing the most important inspection procedures for which he is responsible. The first installation of PRISIM at Arkansas Nuclear One, Unit 1, was completed in 1986 and two more plants will be evaluated in 1987.

INEL Projects Support SP-100 Space Nuclear Power Project

Several projects at the INEL—lithium removal research, low-pressure lithium condensation experiments, and benchmark physics tests—are supporting work on the SP-100 space nuclear power project.

Research and development activities supporting space nuclear power (or any other high-temperature liquid metal research) require a way to remove the alkali metal from the cooling system internals to allow disassembly, inspection, or disposal. While many methods have been used to remove residual alkali metal from stainless steel systems, the most common and effective methods usually employ a reaction process with water or alcohol. However, these reaction processes produce hydrogen, which is very damaging to refractory metals.

Another method, vacuum distillation is virtually nondamaging, but—in the case of lithium—the temperatures required to produce adequate vapor pressures for distillation are prohibitive. Therefore, INEL researchers looked for a method that removes lithium by solution. They found that liquid anhydrous ammonia, used as a solvent, was such a method.

Researchers ran a series of lithium boiling and condensing experiments that indicated that lithium appears to be an efficient energy transport mechanism at low, less than atmospheric, pressure.

For space applications, the use of low-pressure lithium would reduce the probability of leakage, while saving weight and enhancing the safety of the system. Lithium is superior to other liquid metals as a space reactor coolant because of its wide range of operable liquid temperatures and excellent thermal-neutronic properties.

Benchmark Physics Test

In late 1986, physicists at Argonne National Laboratory-West used the Zero Power Plutonium Reactor (ZPPR) for benchmark physics tests for the SP-100 space nuclear power project. Design concepts for 300-kilowatt (electrical) space reactors, developed by Los Alamos National Laboratory and General Electric, were tested in the ZPPR-16 program. Safety of the General Electric design in the event of a water splashdown accident was verified in a final experiment that “flooded” the assembly with polyethylene, to simulate the effects of immersion in water.

One application of the ZPPR test results will be to set the fuel enrichments for the SP-100 ground engineering tests that will be conducted at Hanford, Washington. Follow-on ZPPR experiments in 1988 will be used to verify all physics performance and safety features of the final ground test reactor design.

Pulsed Laser Moire Interferometry Measures Deformation of Materials Under Stress

Moire interferometry is not new, but engineers at the INEL are improving the technique, making it portable, and using it in a new way to obtain valuable information about the behavior of materials under stress—information extremely useful in materials research, quality assurance, and stress monitoring.

Using pulsed lasers, the new technique can examine how materials deform in a plane under stresses such as high pressure, temperature, weight or tension, and sudden impact. The innovative technique developed by EG&G Idaho engineers moves moire interferometry from the laboratory table, which must be totally isolated from vibration, to the work place. And the system provides more accurate information from a larger area than strain gauges can deliver.

***Traditional coarse
moire***

The new technique can reveal developing weak spots in a ship's hull, a nuclear reactor vessel, welded joints, bridges, ceramics, or around aircraft rivets with an accuracy greater than that of strain gauges by at least an order of magnitude. Further, the technique can make quantitative, full-field gradient measurements in an area about four by four inches instead of the single point-by-point measurements of a strain gauge that leaves gaps between measurement points.

The moire effect occurs when two sets of closely-spaced lines or gratings are superimposed. The slightest movement or distortion of one grating relative to the other causes a new visual pattern, a moire pattern, to appear. The new pattern is, in effect, a map of the distortion, and the distance between the visual fringes formed is a quantitative measure of displacement. Using this principle, material deformation associated with strain fields that occur near crack tips or on flat surfaces can be measured.

**Split laser beam forms
interference patterns on
photographic plate**

**Developed and dried
photographic plate
becomes reference
grating mold**

Preparing mold of reference grating

**Reference grating mold
mirrored with thin
film of aluminum**

Specimen surface
is coated with
adhesive

Mold is pressed
into adhesive

Adhesive pulls metallic
film from mold

***Replicating mold
onto specimen
surface***

Traditional, mechanically produced gratings typically have no more than 1000 lines per inch. Because measurement accuracy depends on the distance between the grating lines, the accuracy of measurements using these coarse gratings is limited to 1/1000 inch.

Researchers have produced a much finer grating by using two collimated laser light beams (actually a single split beam) intersecting at a specific angle to record fine lines on a glass photographic plate. Because both light beams have the same frequency and oscillate with the same timing, their wave peaks reinforce each other where they coincide and their valleys cancel each other, producing a very fine moire grating of alternating black and white lines. Line spacing can range down to a half wavelength of light, or 100,000 lines per inch for blue-green light.

When the photographic plate is developed and dried, the unexposed portions of the image shrink, leaving a series of peaks and valleys. This is called the reference grating. To replicate this grating onto the surface of a specimen to be examined, a mold is made by coating the grating with a very thin layer of aluminum. This mold is pressed onto the adhesive-coated surface of the material specimen. The adhesive pulls away the aluminum film, leaving a mirrored replica of the reference grating on the specimen surface.

Then the split beam of collimated intersecting laser beams, which was used to make the reference grating, is directed onto the mirrored specimen surface grating. The surface grating diffracts and interacts with the reference grating image, producing a moire pattern to be photographed and examined.

At the INEL, moire interferometry is combined with lasers that can be fired in a single 20-billionth-of-a-second pulse to eliminate the effects of vibration, and can also be pulsed 100,000 times per second to obtain stop-action photos, or movies, of stress waves resulting from an impact.

Proof-of-principle tests have been completed and a semiportable unit has been designed, making use of fiber optics to conduct laser light to locations some distance from the lasers. The researchers are extending their work to curved surfaces and high-temperature applications, and are investigating the feasibility of using a digitizer/camera/computer system to record and automatically measure deformation patterns.

Photographing moire pattern

Die-target Aids Dynamic Behavior of Materials Studies

Welded region

A newly patented die-target design that allows crack-free monolithic plates to be produced for complete examination and testing is contributing to a better understanding particle interaction, deformation, and bonding during dynamic consolidation. The purpose of dynamic consolidation of rapidly solidified powders is to develop a method that permits powder consolidation without requiring high bulk temperatures. This approach is attractive for materials that are sensitive to high temperature exposures.

The dynamic behavior of materials is an active area of research at the INEL, with EG&G Idaho taking a primary interest in consolidation and welding of rapidly solidified metals.

The design of the die-target controls the shock waves from an explosion to consolidate the metal powders into a form that can be manufactured into a machine part or a workpiece. The shock wave from the explosion of a measured charge of high explosive subjects the alloy powder in the die to a brief, strong, high-pressure compression. While shock-wave consolidation has been tried before, the die-target minimizes the effect of reflective shock waves that can cause tensile cracks in the consolidated powder work piece.

The high compression stress causes high rate deformation among the particles, and the surface of the individual powder particles — where the deformation is the greatest — heat up and soften enough so that they “glue” themselves together. The event occurs so quickly that the interior of each particle remains cool enough to preserve the unique microstructure.

Most rapidly solidified alloys begin as powders that must be compressed or consolidated into the desired form using high temperatures. However, high temperatures can greatly alter the microstructure of the alloys and reduce the benefits gained from rapid solidification.

Many of the alloys currently being studied at the INEL are produced by rapid solidification. The fine-grained, homogeneous microstructure of rapidly solidified alloys can give the alloys more strength and corrosion resistance.

Tensile/fracture surface

Rapidly solidified Type 304 stainless steel powders have been consolidated at the INEL, using the die-target, to produce crack-free plates. Type 304 stainless steel normally consumes about 40 percent of the chromium used in the U.S. Chromium, a strategic material, gives stainless steel corrosion-resistant properties. Other alloy powders with lower chromium amounts now are being evaluated at the INEL using dynamic consolidation.

***Explosion near
bunker***

For the research efforts, a dedicated site has been acquired on the INEL reservation, and includes a bunker to house instrumentation and personnel during testing.

The experimental efforts have also been aided by hydrocode modeling. A micro model at the particle level has been developed at the INEL. The model predicts that regions associated with high deformation and deformation rate of the particles produce high localized temperatures. These temperatures can cause the particles to weld at certain areas around the particle perimeters. The strengths of the dynamically consolidated monoliths are observed to be very high. The heat from the localized regions of high particle deformation is readily extracted into the particles, and as a result the bulk temperature remains low.

Beneficial Inert Gas Behavior Found in Rapidly Solidified Metals

In conjunction with INEL research on dynamic consolidation of rapidly solidified powders, consolidated forms of the powders are quantitatively examined and tested for structure-property behavior.

The structure-properties of the consolidated powders have shown some superior features when compared with similar conventional ingot metallurgy alloys. In particular, the consolidated rapidly solidified metal powders exhibit substantial microstructure stability, as illustrated in Figure 1 for the grain growth behavior of Type 304 stainless steel. Similarly, significant improvements in strengthening have been observed (as indicated in Figure 2) for extrusion-consolidated Type 304 stainless steel rapidly solidified powder in comparison with a conventional Type 304 stainless steel.

It has been discovered that substantial quantities of inert gas, i.e. helium or argon, have been entrapped in the powder during the atomization process and are retained during consolidation of the powders. The entrapped inert gas is believed to play a significant role in improving microstructure stability and strength.

The common perception of the role of gas species in metals is one of a detrimental influence on properties; particularly in terms of promoting embrittlement. From the INEL studies done by EG&G Idaho, there is no significant evidence of loss in ductility for the rapidly solidified alloys containing significant quantities of helium or argon.

Observations of irradiation effects indicate that implanted helium can promote microstructure stabilization. This premise is the basis for the INEL research efforts on the potential benefits from

entrapped gas acquired during powder processing. The current research efforts involve determinations of the mechanism for gas entrapment during powder processing, gas-vacancy interaction and bubble growth, gas content and thermodesorption, microstructure behavior, and mechanical properties. To support the research on entrapped gas influences on structure-properties of rapidly solidified alloys, collaborative arrangements have been established with several powder producers, including Sandia Livermore Laboratory (California) and the University of Wisconsin, Madison.

Vision System Created for High-luminosity Processes

A new vision system that incorporates lasers, fiberoptics, and image-intensifier tubes has been developed at the INEL to produce high-quality images of industrial or research processes that are otherwise difficult or impossible to see because of extremely bright plasmas or flames.

The new system, invented by an EG&G Idaho scientist, is especially useful in electric arc welding, where a better view of the solid-liquid interface and other welding site features allows an operator to see problems and correct them before they cause weld defects, thus improving quality and productivity and reducing costs. This innovative system is receiving enthusiastic response from welding engineers and technologists.

Conventional weld viewing techniques usually involve using the traditional hood and filter. The filter must be very dark to suppress the intense fireball of the arc. Details near the arc cannot be seen clearly because of the extreme contrast between the arc and the nearby area.

Standard video vision systems have the same limitation—if details near the welding arc are to be clearly seen, vision in the less brightly illuminated areas must be sacrificed. On the other hand, if filtering is removed to allow the camera to record details in the low-brightness areas, the brighter areas of the image become badly overexposed.

The new vision system uses a xenon flash or pulsed laser to produce an extremely bright stroboscopic light that illuminates the area of interest. Images are formed (or detected) by a small solid-state video camera positioned behind an image-intensifier tube. The tube is electronically shuttered and synchronized with the light source, which flashes once or more per video frame. The shutter speed of 0.1 to 1.0 millionth of a second is much shorter than the normal 33-thousandth of a second frame rate of the conventional video camera.

This very brief exposure is synchronized with the laser light pulse that overpowers light from the welding arc or plasma to produce an image that is superior to existing vision systems. The extreme brightness variation across the picture is removed and the image is much clearer for interpretation by human eyes and by electronic image processing equipment.

Schematic of vision system

The vision system could be extremely useful in remote welding applications where only limited access is possible in the hostile environments of many advanced welding tasks. For example, automated welding machines that are controlled remotely could be used in welding applications where generation of fumes during the welding process would endanger nearby personnel. The clear image obtainable using the vision system makes it possible for the welding process to be monitored from a safe location.

Although the system was developed primarily for welding applications and research, it is well suited for research and quality control in any area that could benefit from visual observation of any brightly-lit process such as is used in the ceramics industry for sintering. Ceramic parts could be examined while

being fired to obtain information useful in developing new products or in quality control. High-temperature combustion technology is another possible application for this innovation. Furnace or engine components could be inspected during operation to avoid costly shutdowns or to diagnose problems in real time.

Proof-of-principle tests on the system are complete, and three systems have been operated successfully as diagnostic tools in laboratory experiments characterizing weld pools and details of the welding process. One system is being built for the U.S. Navy and another for a private company. Fully automatic and mechanized welding applications are being developed.

This vision system won an IR-100 award from Research and Development magazine. Each year, the magazine selects 100 products developed in the U.S. as the most significant new technical products of the year.

New vision system

***Ordinary video
camera***

Experimental Method Developed for Measuring Weld Pool Surface Temperatures

To measure the surface temperature of weld pools, an engineer has developed an experimental technique called the optical spectral radiometric/laser reflectance method. Measurements will be used to aid in determining the controlling heat transport phenomena in the weld pool, such as surface tension and electromagnetically driven convection.

Surface tension (which is temperature dependent) can have dramatic effects on weld pool width and penetration depth, making accurate predictions of weld pool surface temperatures very important.

Arc-side surface metal vaporization and condensation within and around the plasma arc, which can significantly alter the electrical conductive properties of the arc and thus the arc surface heat flux distribution received by the workpiece, also depend on weld pool surface temperatures.

The weld pool surface temperature measurement technique has been successfully demonstrated for thin plate gas tungsten arc welds on Type 304 stainless steel. High-resolution (60-micron) temperature contour and topology maps were generated under various welding power and welding speed conditions.

The adjacent temperature topology plot for a welder current of 38 amperes, a welder voltage of 8.0 volts, and a welding speed of 0.423 millimeters per second (1 inch per minute). Note that the electrode and its reflection off of the weld pool and the plate are also apparent in the figure, for which temperatures are fictitious. The peak weld pool temperature, which is located between the electrode temperature peaks, is near 2530° Celsius.

The ultimate purpose of such measurements is for developing and verifying theoretical thermal models that would be used for real-time interactive control of the welding process. Such thermal models are used for determination of the weld thermal cycle, which is in turn used for weldment micro- and macro-structure metallurgical and mechanical property predictions.

Weld temperature topology plot

Biodegradation of Phenolic Toxic Wastes Successful

Biorings in a bioreactor

Phenol is a common, toxic chemical used in many industries. As with any toxic waste, disposal of phenolic waste is a major problem. Biological treatment, allowing certain microorganisms to consume and metabolize the chemical, is a common way of rendering phenol harmless, but is usually effective only when the concentration of phenol is less than about 200 parts per million (ppm), a very weak solution. There are other methods to accomplish the same purpose, but they all have disadvantages.

In commercial "trickling filter" systems, the solution of phenolic wastewater is allowed to trickle through a filter in which microbes grow and feed on the phenol in the solution. The microbes have a short life and must be continuously replaced with new ones purchased from a vendor, which can be expensive.

Another method of treating phenolic wastes is the activated charcoal system, which costs more than trickling filter systems and also requires microbe replacement. Incinerating the toxic waste uses a fair amount of energy and contributes to air pollution, making it an undesirable choice.

INEL researchers, however, found a way for microorganisms to metabolize as much as 2100 ppm of phenol—more than ten times the amount removed by commercial trickling filter systems. The only waste products are carbon dioxide and biomass (the remains of dead microbes) that can be disposed of easily and harmlessly. The microbes multiply and need not be replaced. Also, the biomass may contain chromium, cadmium, or other metals that could have value if reclaimed.

The INEL researchers operated a pilot plant at the Worldwide Landing Gear Overhaul Facility at Hill Air Force Base (Utah) for about nine months to determine the feasibility of removing phenol from phenolic wastewater and spent paint stripper solution, using microorganisms already living in the facility's feed and drain lines.

The entire pilot plant was contained in two trailers that housed a liquid storage tank, a computer monitoring system, various chemical analytical instruments and equipment, and two 600-gallon tanks called bioreactors that contained three vertical feet of biorings (small ceramic cylinders). One bioreactor was operated at a set of "optimum" conditions as a check against results obtained from the test bioreactor.

Part of the process in the landing gear overhaul facility consists of dipping the parts in a tank of concentrated phenol (50 to 70 percent phenol), then rinsing them with water in a rinse tank to wash off the paint, grease, dirt, and phenol solution. The phenol concentration of these wastes varies from 200 to 5000 ppm of phenol in the rinse water, and from 250,000 to 350,000 ppm in the paint stripper. For the pilot-plant tests, the stronger solutions were diluted with water to the desired concentrations.

In the pilot plant, phenolic solutions of waste water and spent paint stripper from the landing gear overhaul facility were sprayed over the bed of biorings. The microorganisms present in the facility's waste lines attached themselves to the biorings, and their reproduction replaced those that died, eliminating the need to purchase replacements. The solutions were heated to various temperatures for different tests, the flow rate was varied, and the effects of adding nutrients and oxygen to the solutions were checked. In some tests, treated waste streams were run through the bioreactor again to see how much more phenol would be removed.

The lowest phenol concentrations were achieved in a single pass at a flow rate of 1/2 gallon per minute (gpm), but the rate at which the microbes consumed phenol was faster at flow rates of one and three gpm. Operating at flow rates of one and three gpm removed less phenol per pass, but the solution can be recycled through the bioreactor, removing more phenol. Using the multipass process and faster flow rates, it is possible to use a smaller bioreactor than that required for a single-pass operation. The pilot plant produced no liquid waste—only carbon dioxide gas and biomass.

The bioreactor's 600-gallon capacity, originally intended only for small-scale testing, proved to be large enough to treat all the phenolic waste produced by the landing gear facility. This means that a permanent installation would require little space. And if a portable plant is desired for short-term operation, the system can be accommodated by trailers that can be moved and set up quickly at little expense.

The phenol treatment system tested by the INEL researchers is superior to activated carbon systems because microbe replacement is not required and the system costs less to purchase, install, and operate. Also the system requires less energy than incineration systems because the only energy needed is for pumping and monitoring. The system and process are computer controlled, so only a minimum of human attention is required.

Although the system proved feasible in the application tested, additional testing would be needed in other waste streams to determine its usefulness in other industrial applications.

Bioreactors

Microorganisms Help Coal Desulfurization and Ore Recovery

Microorganisms also are being studied by biotechnology specialists at the INEL for use in coal desulfurization and extraction of metals from low-grade ores.

A problem with using coal as an energy source has been that all coal contains sulfur, which is released in burning as sulfur dioxide, and later becomes sulfuric acid, a possible culprit in acid rain. It has long been known that it is possible to remove the sulfur through bacteriological means. Biological desulfurization of coal may be cheaper and is theoretically easier than chemical or physical methods.

The process involves grinding coal into powder at a fossil-fuel plant, mixing it with water and sulfur-digesting organisms to create a slurry, and waiting a predetermined time. After separation processes, the result would be desulfurized coal powder ready for use as an energy source, sulfur to be reclaimed for industrial use, and water for recycling through the system.

The problem is that coal has never been treated biologically on this large a scale. But because it is theoretically possible, EG&G Idaho scientists now are developing large-scale processes.

Another project, using microorganisms to mine important minerals and metals, is being done for the Bureau of Mines of the U.S. Department of the Interior. In the past, such techniques were not widely used, but needs have changed. The use of microorganisms for mining and mineral processing is becoming increasingly important because of possible future shortages of strategic and critical materials. Microorganisms can be used to recover valuable minerals from low-grade ores and to recover toxic or valuable metals from waste streams.

Much of what was once considered waste rock left after mining operations is really low-grade ore, still containing valuable minerals. Miners spray huge rock piles with thousands of gallons of water, and a biologically mediated leaching process takes place that results in a pond of metal-laden water. The minerals are retrieved by electrolysis and the water recycled.

For example, bacteria will grow on sulfide ores, which may contain manganese, iron, copper, and cobalt. Through oxidation, the bacteria make sulfuric acid and ferric ions that dissolve the metals out of the rocks. About 20 percent of the copper mined in the United States in 1985 was produced by this method.

Mining with microorganisms saves energy and money. These bacteria work at ambient temperatures and pressures; they are common organisms, nearly free for the asking; and specific results are achieved, with no unwanted by-products.

Research Yields Better Membrane Technology

Membranes are very thin films of semipermeable material that allow one or more components of a fluid to pass through (permeate) while retaining the other components of the fluid (retentate). Synthetic membranes, prepared from organic polymers, have been used for many years for such applications as water desalination and kidney dialysis. Their application, however, has been limited because of their instability at high temperatures (above 90°Celsius), their low resistance to organic solvent attack, and their instability at pHs that vary much from neutral.

Most separation processes require a change of phase and, thus, a large expenditure of energy. These phase changes include distillation, freeze crystallization, and evaporation. Membranes can perform these separations without phase change. It is estimated that the application of membrane technology in the chemical and food processing industries alone could save approximately two quads of energy per year.

These polymers are composed of alternating nitrogen and phosphorous atoms, held together by a system of alternating double bonds. Various organic components can be attached to the phosphorus atoms which permit the synthesis of an extremely wide variety of compounds. These substituted phosphazene polymers can be made stable up to 500°Celsius; they are stable in most organic solvents and over essentially the entire pH range.

During FY-86, inorganic membrane research was done in four separate areas: (a) polymer synthesis, (b) membrane casting, (c) physical property studies, and (d) study of separation processes. The polymers were synthesized by chemical techniques using procedures found in the literature and by procedure modifications developed in INEL laboratories. The initial linear polymers prepared were the trifluoroethoxy derivative and the phenoxy derivative of polyphosphazene.

Because currently available organic membranes are not stable in the harsh environments normally encountered in chemical and industrial processes, the INEL has undertaken a research program to develop inorganic polymers as membrane materials. The inorganic polymers chosen for study were the polyphosphazenes.

These polymers were cast into membranes approximately 0.1 micron thick, using such techniques as dip casting, spin casting, and blade casting. The base polymer and resulting films were characterized using instrumental techniques. The instruments used were infrared spectroscopy, digital scanning calorimetry, scanning electron microscopy, and optical microscopy.

The membranes to be studied were cast onto porous Inconel support plates and tested in a dynamic system that is unique to the INEL. This system is capable of testing membranes up to 350°Celsius and 3000 pounds per square inch (psi) and with a pressure differential across the membrane of up to 1000 psi.

The membranes have been tested in two different regimes. In one regime, the test media was a dilute aqueous solution containing methanol, ethanol, and isopropanol. The objective was to determine the diffusion coefficient and activation energy for methanol, ethanol, and isopropanol diffusion through the membranes. The results of this study have been published in the Journal of Membrane Science.

During FY-86, emphasis was placed on a second regime which is a dilute aqueous solution of cobalt, manganese, and chromium nitrate. This study was undertaken for the Bureau of Mines with the same objective as for the alcohol solution.

Initial data with the metal ions showed that chromium could be separated from cobalt and manganese. It is hypothesized that at the low pH of the solution, the hydrated form of chromium polymerizes, forming a large bulky molecule that allows the cobalt and manganese to pass through the membrane while retaining the chromium.

An interesting aspect of this study was the difference shown between the separation characteristics of poly trifluoroethoxyphosphazene (PTFEP) and a film prepared from poly phenoxyphosphazene. Figure 1 shows a maximum separation of chromium at approximately 100°Celsius when using the poly phenoxyphosphazene membrane. This particular polymer has a glass transition point at about 107°Celsius which could account for the increased separation. At the glass transition point, there is a change in crystallinity of the polymer material.

Membrane test equipment

The trifluoroethoxyphosphazene polymer has a glass transition point at approximately 80°Celsius. However no peaks were observed and the ratio of diffusion coefficients was linear from 25 to 150°Celsius. This indicates that modification of the chemical structure of the polyphosphazenes can be made to optimize the separation of chromium from cobalt and manganese.

The long-term objective of this program is to study the mechanism of diffusion of material through a variety of phosphazene membranes with the eventual development of a predictive model that will allow the tailoring of a phosphazene membrane to a specific application.

ASSISTANCE TO THE ARMED FORCES

Pioneering the Cockpit of the Future through Brain Wave Research

Thought-process control of a fictitious fighter jet like "Firefox" may seem futuristic, but INEL is supporting current research efforts that may lead to such a reality. During FY-86, EG&G Idaho engineers, working with the U.S. Air Force Aerospace Medical Research Laboratory, designed and built a special magnetic field shield room that makes it possible to take direct low-level magnetic measurements of a pilot's brain.

The laboratory, located at Wright-Patterson Air Force Base (Ohio), has been conducting advanced research in the area of magnetoencephalography (MEG), or the study of the brain's magnetic fields. By studying how the brain processes information in response to various stimuli, the researchers hope to improve cockpit displays, simulators, workstations, and conceivably, aircraft control functions.

Before development of the magnetic field shield room, the modulation of the earth's strong magnetic field and man-made noise sources made it necessary to use signal-averaging techniques to extract useful biomagnetic data. The signal strength of human body magnetic fields is on the order of 1×10^{-9} gauss—about one-billionth of the earth's magnetic field. If measured inside the magnetic shield room, however, the signals can be interpreted directly by using a sensitive detector known as a superconducting quantum interference device or SQUID.

The INEL magnetic shield room was designed to provide the necessary attenuation of the earth's magnetic field and other background magnetic noise to allow direct measurement of MEG signals. The room's inner dimensions are a 7-1/2-foot cube. Shielding performance has exceeded the expectations of the research personnel. The pilot, SQUID, intercom, and test display are inside while the data acquisition system, supporting electronics, and supporting research personnel are outside.

Current INEL efforts to support the laboratory's brain wave research include the design of a MEG data collection and analysis system. It is hoped that in the future the entire MEG system can be miniaturized for installation inside a cockpit, or better yet, inside a pilot's helmet.

Magnetic field shield room

Built-in Test Equipment Technique Reduces Maintenance Costs

The term "user friendly" has become increasingly important when dealing with the maintenance of sophisticated military systems. The need for fast, cost-effective maintenance and simplified personnel training has prompted the expanded use of built-in-test equipment (BITE) for mission-critical systems. Researchers at the INEL have developed a diagnostic technique that enables a microprocessor-based electronic system to test all or part of itself with little user interaction and without the need for external test equipment.

The technique is called microdiagnostics, or smart BITE, and is presented as a set of design rules and guidelines to assist the design engineer in integrating automatic fault diagnostics into a design. When an electronic system has been designed using this technique, maintenance personnel can easily locate and repair hard system faults. Microdiagnostics assists the troubleshooter by stimulating the circuit under test, compressing the resulting test data, and presenting the test results to the user in simple and meaningful messages.

The central processing unit of a system provides the resources to make all test decisions. These decisions are based on a data compression technique known as signature analysis. Fault location consists of comparing good signatures obtained from a known good circuit with measured signatures of an identical circuit under test. If signatures do not match, a fault backtracing algorithm is automatically executed to isolate the fault.

Microdiagnostics does not use an external signature analyzer, but uses signature analysis as part of the system software. This method of signature analysis is called software signature analysis.

A BITE system using microdiagnostics becomes an "expert system" that automatically directs a user through the fault-detection process until a fault is isolated. Microdiagnostics frees a user from dependence on schematics, wire lists, and signature tables. Microdiagnostics can be built into a system to improve reliability, availability, and maintainability; reduce downtime; extend operational lifetime; lower maintenance costs; and eliminate the need for an expert to make repairs.

Empirical fault-coverage data show that about 95 percent of the single-stuck-at faults and open-circuit faults can be detected by using microdiagnostics.

Continuing INEL research will apply microdiagnostics to systems that perform mission-critical functions in such areas as military weapons, reactors, and space systems. User-friendly microdiagnostics show that technically sophisticated systems can be maintained with simple, low-cost methods.

Team Skills Support Improvements in Army's Scheduling System

INEL personnel helped the U.S. Army resolve technical and managerial difficulties with an ammunition program planning and budgeting model, the Plant Job Scheduling Model (PJSM), developed earlier by the Army at the Rock Island (Illinois) Arsenal. Although some new data base and graphics software was developed at the INEL, the project emphasis was on the transfer of planning and scheduling skills and technology to arsenal personnel.

In the first phase of the project, personnel from EG&G Idaho prepared prototype computer graphics programs designed to work with an existing planning model. Recommendations were made for short-term technical improvements to the system, long-range information systems planning, and systems management.

Work in the second phase of the project included specific software development tasks for the INEL as well as further assessment and assistance in systems management and planning. Tasks included graphical display programs, data base design and documentation, and recommendations on applicable computer modeling approaches. Also, assistance was provided for information systems planning, project management, technical training of personnel, and installation of high-speed communications between the INEL and the arsenal.

Spent Fuel Consolidation Saves Storage Space

A technique for repacking spent fuel rods for dry storage has been proven in trial tests at the INEL. Successful duplication of the process in a hot cell, using real spent fuel rods, could alleviate storage problems for commercial nuclear utilities that now are running out of storage space.

EG&G Idaho engineers developed a remotely operated system for horizontally extracting spent or used fuel rods from rod assemblies and consolidating the rods in storage canisters for eventual long-term storage. The goal for fuel rod consolidation is a two-to-one volume reduction.

The INEL technique of horizontally extracting the rods and performing the function out of water in a hot cell allows greater direct visual observation of the consolidation process. Previous consolidation efforts extracted the rods vertically and manipulated the rods under 30 feet of water.

The remotely operated system developed at the INEL removes the top end box of a fuel assembly, grasps the end of a fuel rod, pulls the rod from the bundle, and places it in a storage canister. This takes about 45 seconds per rod.

Because the rods are stacked horizontally (similar to stacking a cord of wood), rods are more easily fit into a storage canister. In trial or cold tests with simulated fuel rods, engineers achieved a fuel rod consolidation of greater than two to one. With actual fuel rods, the consolidation ratio is expected to be lower because of rod diameter changes that may result from reactor operations.

The consolidation project has three goals: demonstrating the feasibility of horizontally removing and packaging fuel rods in a dry environment, developing the technology for a two-to-one consolidation, and obtaining technical data that DOE can use for spent-fuel-storage-method decisions.

Glass-ceramic Product Formed for Management of High-level Waste

A glass-ceramic waste form was developed at the ICPP as part of a continuing effort to minimize the volume of high-level waste sent from the ICPP to a Federal repository. The glass-ceramic immobilizes the same amount of waste as would another glass form under consideration, but would use 58 percent fewer canisters for disposal (700 instead of 1,700 per year from projected annual waste generation).

Reducing the number of canisters is essential because of a projected three- to four-fold annual increase in defense nuclear fuel reprocessing rates in the next 10 to 15 years.

The glass-ceramic product is formed in an isostatic press that applies a uniform high pressure while operating at temperatures of 1000 to 1100°Celsius. The glass-ceramic takes advantage of two chemical compounds present in the waste — zirconium dioxide and calcium difluoride — to immobilize most of the radionuclides in the waste. Because the waste also contains compounds of sodium, boron, and aluminum, glass-forming additives (such as silica) are added to form a durable aluminoborosilicate glass to immobilize the remaining radionuclides.

After forming, the glass-ceramic product contains 70 to 75 weight percent waste at a density of 3.2 grams per cubic centimeter, compared to a glass waste form that contains 30 to 33 weight percent at 2.6 grams per cubic centimeter. Work on the glass-ceramic form will continue with studies of process concepts before small-scale equipment testing begins on the process.

IET Stack Buried

Demolition engineers used a series of sequentially timed explosive charges to topple the Initial Engine Test (IET) exhaust stack into a burial trench. The demolition of the landmark stack was part of a plan to decontaminate or demolish contaminated structures and equipment at the IET facility, located at Test Area North.

The IET facility was once used for the Aircraft Nuclear Propulsion (ANP) Project. Begun in the 1950's and discontinued in 1961, the ANP Project developed a series of air-cooled reactors that proved the feasibility of operating an aircraft turbojet with nuclear heat.

The cleanup project used major cost saving techniques. For example, the stack was buried in place, instead of being dismantled and the debris hauled away. A concrete test pad was decontaminated by scabbling several small areas instead of demolishing the entire pad.

To demolish a stainless steel exhaust duct (6 feet in diameter and 150 feet long) explosives were used to cut ductwork into more manageable pieces for disposal.

Other structures and equipment demolished or cleaned up included a monitoring vault, a hot waste tank and associated hot waste pipelines, and a concrete test pad. Some contaminated soil was also removed. Afterward, grass was placed in the area and a marker placed over the buried stack.

DECONTAMINATION AND DECOMMISSIONING

Test Assembly Removed from LOFT Facility

The test assembly at the Loss-of-Fluid Test (LOFT) Facility was removed from the LOFT containment building as part of the LOFT inactivation project. EG&G Idaho, operator of the facility, completed the inactivation project 21 weeks ahead of schedule and saved \$5 million over the original projected cost.

Workers removed the test assembly, which held the test reactor and its systems, including shielding tank, piping, blowdown valves, pumps, and generators. The test assembly had originally been mounted on a double-width railroad flatcar to allow for movement to hot shop facilities. During the inactivation project, the reactor vessel was sent to the INEL Radioactive Waste Management Complex for disposal. The rest of the test assembly is in interim storage pending final disposition.

An international consortium, the Organization for Economic Cooperation and Development, sponsored eight loss-of-coolant tests in the past four years. The final LOFT test involved the intentional and successful partial meltdown of the reactor core. This test was conducted to provide research data on the release and transport of fission products that might occur during an actual reactor accident, which could lead to severe fuel damage within the reactor core.

The LOFT Facility will be turned over to the Specific Manufacturing Capability Project after the inactivation work is finished.

LOFT test assembly removed from containment

Over a 12-year-period, 40 nuclear reactor safety tests were conducted at the one-of-a-kind facility for the Nuclear Regulatory Commission. Test data are being used to develop and enhance safety codes for U.S. nuclear reactors.

Special Isotope Separation Project to Use Laser Technology

The INEL has been selected as the preferred site for the Special Isotope Separation (SIS) Project. The SIS plant—the only one of its kind in the world—will process DOE-owned, defense-program plutonium using the atomic vapor laser isotope separation (AVLIS) process. The process uses laser technology to separate the isotopes of plutonium while the metal is in a metal-vapor state.

Separator System

The SIS plant will contain separator lines, with independent separator units in series. The isotopic separation process takes place in the separator units where the laser light and plutonium vapor interact. Each unit, enclosed in its own vacuum chamber, is housed in a glovebox to provide an inert nitrogen atmosphere, which prevents the formation of

Schematic of the separator demonstration facility

With SIS, the INEL will be an international leader in laser-separation technology. WINCO will manage the SIS Project for DOE. Construction of the plant, to be located at the north end of the ICPP, is expected to start in January 1989. Production should begin in December 1993.

Design and generation of the SIS plant is based on a pilot plant that is being operated by Lawrence Livermore National Laboratory.

Following are some of the technical details about the SIS process.

Laser System

The laser system supplies light beams that selectively photoionize plutonium isotopes. Copper-vapor lasers that operate in a pulsed mode provide a primary light source. Chains of dye lasers amplify the beams to the required power levels. An extensive optical system is used to transport the laser beam to the plutonium separators and in the laser power amplification steps.

unwanted plutonium oxides. The laser light passing through the vapor stream photoionizes the unwanted isotopes. These laser-produced ions are removed from the vapor stream by an electrical field.

Chemical Processes

Several other chemical processes are used to support operation of the isotope separators. These processes include recovery of plutonium from the separators, and purification of the enriched product. Recycle streams are also processed to maximize plutonium recovery and minimize waste volumes. SIS will generate very little waste because it is essentially a plutonium "refinery."

Work Begins on Fuel Processing Restoration Project

A groundbreaking ceremony held in April for the Fuel Processing Restoration (FPR) Project. This new, major facility is designed to expand DOE's ability to recover and purify uranium-235 from government-owned nuclear fuel to meet future needs.

The FPR is located at ICPP, which is operated by WINCO. FPR construction is scheduled for completion early in fiscal year 1993 and will be followed by extensive operability testing. Actual plant startup with irradiated material is planned for early 1995. Initial construction in 1986 included an excavation four stories deep and pouring a thin concrete pad in the bottom of the excavation. Other work included installation of utility headers and construction of on-site construction buildings, including a warehouse, craft building, substations, and pipe fabrication shops.

The engineering design will allow FPR to meet several basic objectives:

1. Dispose of future fuel receipts safely and cost effectively
2. Provide safe and reliable uranium recovery for the federal government at least until the year 2035
3. Reduce risks for all uranium recovery operations
4. Minimize chances of plant personnel receiving radiation exposure
5. Further reduce the risk of releasing radioactive materials to the environment.

Many of the existing uranium separation facilities at the ICPP were designed and built in the early 1950's, using techniques and technology available at that time. The ICPP was originally constructed as a five-year demonstration project, but instead has evolved into a mission for over 30 years as a production plant. FPR will replace the uranium extraction and denitration systems of the existing facility.

Facilities at FPR will receive dissolver product solution from the new Fluorinel Dissolution Process (FDP), as well as other fuel dissolution systems at the ICPP. The uranium-bearing solutions will be processed through solvent extraction systems to recover and purify the uranium. During purification, the uranium is separated from fission products and other materials. The purified uranium is then processed through a fluid bed denitrator to produce a granular powder that is shipped to other DOE sites for reuse.

The new fuel processing facility will consist of 12 individual shielded cells containing process equipment. These cells, located below ground level, are surrounded by operating corridors. A shielded pump and valve corridor on one side of the cells contains equipment items subject to frequent removal for repair or replacement. As with other modern facilities—the New Waste Calcining Facility and FDP—replacement of these items will be done remotely, using the latest handling techniques. Design of all remote activities is evaluated and verified in a mockup facility.

Above-ground features of the facility include a high-bay area to permit insertion and removal of equipment into and from the cells through hatches, utilities and mechanical equipment, and a control room.

FPR is an important addition to the ICPP because future uranium needs are expected to increase. When completed, FPR will substantially improve the ICPP's ability to provide all processing services for both naval and other spent fuels through at least the year 2035. The increased fuel reprocessing capacity will also prevent potential fuel receipt storage capacity problems.

The new project will complete the upgrading of major facilities at the ICPP. Total uranium-235 recovery by FPR during its projected 40-year lifetime is now anticipated at over 80,000 kilograms with a current value of more than \$3.5 billion.

Funds Authorized for Additional LOFT Fuel Module Studies

The OECD LOFT (Organization for Economic Cooperation and Development Loss-of-Fluid Test) management board has agreed to provide \$3.8 million over a three-year period for nondestructive and destructive examinations of the damaged LP-FP-2 experimental fuel module. The fuel module was intentionally damaged during a severe accident experiment in the LOFT reactor on July 9, 1985.

The additional studies will provide information to characterize the condition of the damaged fuel module, to establish peak temperatures, to determine present chemical forms, to show the extent of oxidation, and to show the amount of fission products that were retained in the fuel.

Nondestructive examinations are being done at in Argonne National Laboratory-West facilities, using neutron radiography. EG&G Idaho will perform sectioning and cutting of the fuel bundle in INEL hot cells.

Information from the studies will be used to verify computer codes that predict core behavior during severe reactor accidents. LP-FP-2 was the most severe fuel damage test ever conducted in a nuclear reactor. The test simulated a loss-of-coolant accident in which emergency core cooling is delayed. Extremely high temperatures in the experimental fuel bundle led to melted fuel rod cladding, dissolved fuel, and the release of fission products from the fuel rods.

Multimegawatt Reactor Project Office Established

The INEL was designated as the project integration office for the Multimegawatt Space Reactor Program, a program jointly funded by DOE-HQ and the Strategic Defense Initiative Organization of the Department of Defense. The assignment is the first substantive SDI program assigned to the INEL.

EG&G Idaho is managing and coordinating this work with many other national participants — including Sandia National Laboratories, Los Alamos National Laboratory, Oak Ridge National Laboratory, Argonne National Laboratory, Pacific Northwest Laboratory, Lawrence Livermore National Laboratory, and many industrial companies. DOE-ID will issue a concept request for proposals in July 1987.

Important interface areas include the SDI space-based weapons interface studies, safety methodology, and technology development. Innovative breakthroughs need to be explored in several areas such as high-temperature materials, advanced heat rejection systems, and power conversion techniques.

The long-term objective of the multimegawatt program is to develop at least one feasible space nuclear power system by 1992 that can meet the SDI space-based power demands — an increase of at least four orders of magnitude over previous space power systems.

TVA Assistance

At DOE request, EG&G Idaho personnel from the INEL are conducting a weld evaluation project at the Tennessee Valley Authority (TVA) Watts Bar Nuclear Power Plant Unit 1. The project will provide TVA with an independent assessment of the quality of safety-related welding done during construction of the plant. A work force was established at the facility in December 1985 and weld inspections started in April 1986. So far, personnel have inspected approximately 1740 components, which represent the inspection of more than 12,000 individual welds.

The project is the most comprehensive statistical evaluation of welding quality conducted to date at a commercial nuclear power facility. The component groups to be examined were selected to provide a general assessment of weld quality as well as to investigate specific employee concerns.

A consistently conservative approach was used for engineering evaluation of deviant welds. At the same time, project procedures for analyzing deviant welds were devised to minimize efforts expended on investigation of insignificant quality problems discovered during the evaluation, yet provide a comprehensive investigation of significant quality problems.

Assistance with DOE-Headquarters Security Upgrades Begins

At the request of DOE-Headquarters Office of Safeguards and Security, the INEL began providing project engineering and project management services for continuing overall physical security upgrades at DOE facilities in Washington, D.C., and Germantown, Maryland. INEL experience with security upgrades led to the DOE-Headquarters request.

Teams from two INEL contractors are working together on the upgrades. WINCO personnel are providing project engineering work and designing needed security systems. EG&G Idaho personnel are performing architect-engineering services and cost estimating. The multiple-phase project includes installation of metal detectors, x-ray equipment, alarms, and vehicle barriers.

The work began in January with one person each from EG&G Idaho and WINCO, who were assigned to Operation Cerberus. That operation was to upgrade physical security at DOE's Forrestal Complex in Washington, D.C. The security upgrade work later was expanded to include DOE Germantown facilities.

ICPP Security Rated Superior

The ICPP received two superior ratings—the first given to any DOE facility—after an inspection and evaluation by DOE-Headquarters safeguards and security personnel. The ratings covered physical security and systems for materials control and accountability (MC&A).

All physical security systems were tested for efficiency, effectiveness, and compliance with DOE requirements. The MC&A systems were tested for

completeness, accuracy, timeliness, and adequacy. The evaluation also included a first-of-its-kind accountability exercise to study system and staff functions under emergency conditions.

In a separate two-month review, the New Brunswick Laboratory gave the ICPP an overall rating of excellent for nuclear materials accountability measurement practices.

Advanced Test Reactor

For the first time, the Advanced Test Reactor (ATR) had more on-stream time available than was requested by test sponsors. This was achieved primarily by early completion of a scheduled long shutdown to replace the irradiated core internals, which had reached the end of their useful lifetime. The core internals were replaced and the reactor returned to full power 14 days ahead of schedule.

The ATR is a highly-enriched, thermal, light-water-cooled and -moderated test reactor rated at 250 MW (thermal). The reactor is designed to provide a high neutron flux to a relatively large experiment volume. The primary mission of the reactor is to provide an intense radiation environment to support the development of advanced reactor fuel systems for the nuclear navy program.

To enhance the capsule irradiation capability, eight new 1.5-inch-diameter holes were added to the new reflector during the changeout. Addition of these holes represents an increase in prime irradiation space of approximately 20 percent.

During 1986, irradiation experiments were conducted to demonstrate ATR capability to produce the following radioisotopes:

- Gadolinium-153 for use in dual-photon absorptiometry diagnostic equipment, primarily used in the diagnosis and monitoring of osteoporosis
- Cerium-141 and tellurium-123m for potential use in Compton-backscatter diagnostic equipment, primarily used in monitoring fluid buildup in the lungs of stationary intensive-care-unit patients
- High specific activity cobalt-60 (300-400 Ci/gm) for use as cancer teletherapy sources
- Nickel-63 for use in the production of "beta cells" for long-lived, more reliable power sources for control circuits.

The reactor also experienced the fewest number of power reductions due to system failures in the history of the ATR, primarily because of productivity improvements in the areas of operations, maintenance, training, and technical support.

First Acceptance Test Series Finished at PREPP

Engineers completed the first of six planned phases in a testing program that will lead to nonradioactive operation of the Process Experimental Pilot Plant (PREPP) in late 1987. The first phase consisted of 125 acceptance tests.

PREPP will demonstrate different experimental approaches for processing transuranic waste into a form acceptable for disposal. Processed waste will be taken to the Stored Waste Experimental Pilot Plant at the INEL Radioactive Waste Management Complex for final certification before shipment to the DOE Waste Isolation Pilot Plant (WIPP) in New Mexico.

When PREPP operations begin, waste containers will be fed into a low-speed shredder. The shredded wastes and containers then move to an incinerator where combustible materials are burned. Ash and noncombustible materials are separated using a rotary screen. The coarse material is placed in steel drums and the fine material is mixed with cement, sand, and water to form a grout.

The grout is added to the drums of coarse material. The result is a waste product in a stable concrete waste form that will meet WIPP waste acceptance criteria and achieve a 3-to-1 volume reduction.

Ascension Island Geothermal Resources Explored

The INEL, in cooperation with the University of Utah Research Institute, is exploring for geothermal resources on Ascension Island in the southern Atlantic Ocean. The U.S. Air Force is sponsoring the exploration as part of a program to provide secure power sources for remote base operations.

An exploratory well was drilled to a depth of 8,706 feet near the center of the island. A well production test provided information about the geothermal resource characteristics, including temperature, chemical composition, and flow rate. The information is being combined with geologic data to develop a model of the island's geothermal potential and to plan further exploration and drilling plans.

INEL to Manage Geothermal Technology Organization

The INEL was assigned to manage the Geothermal Technology Organization, a group formed to advance technology in the exploration and uses of geothermal resources. The organization, under a cost-sharing agreement with DOE, will develop specific technologies. The INEL will be responsible for performing the research either directly or through subcontractors.

The organization expects to reduce the economic risks associated with the development and commercialization of potentially valuable innovations. More than 50 firms and persons involved in geothermal resource development and use have expressed interest in the organization.

DOE-ID Sponsors SDI Conference

DOE-ID in June held a strategic defense initiative (SDI) conference that drew 125 persons for three days of presentations and discussions. Among those attending the Idaho Falls sessions were Dr. Edward Teller; Air Force General James Abrahamson, director of the SDI office; Sylvester Foley, DOE Assistant Secretary for Defense Programs; Roger Batzel, director of the Lawrence Livermore National Laboratory; Sun Chun, manager of the DOE Pittsburgh Operations Office; and Daniel Denning, Deputy Assistant Secretary of Defense.

Classification Conference

In June, DOE-ID sponsored a DOE-wide classification officers meeting. More than 80 persons attended the two-day conference.

New SMC Contractor Selected

The Rocketdyne Division of Rockwell International was awarded a five-year operating contract for the Specific Manufacturing Capability Project. The operation will be called Rockwell-INEL. The previous contractor, Exxon Nuclear Idaho Company, Incorporated, declined to renew its contract.

EG&G Idaho Contract Renewed

DOE renewed the EG&G Idaho operating contract at the INEL for another five years through 1991. EG&G Idaho took over an INEL operating contract in 1976.

DOE and Contractors Sponsor Quality Month Activities

The theme for Quality Month at the INEL was "Quality Plus Productivity Equal INEL Excellence," sponsored by DOE and INEL contractors. Quality Imperative, as the event is now known, was held October 8 to observe National Quality Month. Outstanding quality efforts by individuals from INEL contractors were also highlighted during the day-long program. The keynote speaker for the event was Philip Crosby, a nationally known quality management consultant, writer, and authority on human behavior.

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The DOE Idaho Operations Office has three major operating contractors at the INEL: EG&G Idaho, Incorporated; Westinghouse Idaho Nuclear Company, Incorporated (WINCO); and Rockwell-INEL. In addition, two other organizations are located at the INEL: Westinghouse Electric Corporation operates the Naval Reactors Facility for DOE and the U.S. Navy; Argonne National Laboratory-West operates the Experimental Breeder Reactor-II and maintains reactor research facilities.

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