After the fun and games came the tests at Harrow. The tests took five hours on each of two days. The first test consisted of three lengthy questions drawn up by the British hosts and the second was administered under lab conditions. Mauskopf wrote the answer to one theoretical question over 20 pages, setting the record for length in this year's Olympiad. He also solved one problem with an elegant use of Lagrangian equations—the only contestant to employ this technique. In one lab test requiring rainbow angles to be detected by spectroscopy in a water droplet, Mauskopf was awarded a zero for measuring the supplements of the angles rather than the angles themselves. Eisenkraft and Edge argued that the answer was absolutely correct for the supplemental angles, and the judges finally gave Mauskopf 25% for the answer.

"We didn't have any notion of how we came out until the winners were announced on the last day," says Sheshan. That ceremony took place in Harrow's New Speech Room, a semicircular hall with stained-glass windows and a pipe organ. It came as no surprise that the USSR took three of the four gold medals, while the fourth went to a student from Romania. The team from China won a silver and bronze. England and both Germanys took silver medals. Graham, Mauskopf and Zucker were awarded bronze medals, while Fukuda and Sheshan missed getting honorable mentions by less than two points overall.

"It was a satisfying, difficult competition," says Mauskopf. "If we had more experience and more training, we might have done a little better. Even so, we were happy to have done so well. To hear the other contestants tell it, in most of Europe, the Olympiad serves as a basis for a rigorous series of physics courses and exams. In our country we do things differently." "I'm glad I went and did so well," asserts Graham. He and Zucker will be attending Stanford this fall; Mauskopf is going to Harvard, Sheshan to the University of California at Berkeley and Fukuda to Carnegie-Mellon University.

Wilson, Eisenkraft and Edge are thrilled by the showing of the US team and preparing for next year's Physics Olympiad, to be held in Jena, East Germany. Says Eisenkraft: "I'm convinced the Physics Olympiad will excite both students and the system to aspire to greater achievements in much the same way that the Olympic games stimulate athletes to compete. In my mind's eye, I see physics becoming as glamorous as any competitive sport."

—Irwin Goodwin

Despite Superphénix startup, outlook for breeders is poor

Back to the Future, last summer's surprise hit science fiction movie, opens with a teenaged boy being carried back three decades in a plutonium-powered time machine built by an amateur physicist. The scientist has obtained the first plutonium fuel load for his machine by working with and hoodwinking international terrorists, who now are in hot pursuit. The boy, finding himself an awkward contemporary of his teenaged parents, plaintively asks the scientist to resupply him with plutonium so that he can be powered back to his own era. "Look kid," the scientist says, "this is 1955 not 1985 when you can buy plutonium in any corner drugstore."

The scene nicely captures a couple of stereotypes about the 1980s that became current in the 1970s—the notions that plutonium would be circulating in very large quantities by now and that it would be increasingly easy for a terrorist gang or wayward government to get its hands on enough to build more or less sophisticated atomic bombs. The realities are turning out to be somewhat different.

It is true, as anticipated, that plutonium has been piling up in alarming quantities. By the beginning of 1985 about 300 metric tons of plutonium had been discharged in spent fuel from conventional reactors in the non-communist world alone, according to calculations by David Albright, a physicist who does research for the Federation of American Scientists in Washington. Of that amount, about 60 metric tons had been separated from the spent fuel at major reprocessing facilities, enough plutonium to build 7500 Hiroshima-size atomic bombs.

Nevertheless, contrary to predictions confidently made in the immediate aftermath of the 1973–74 oil shock, plutonium is not coming into commercial use at anything like the rate expected. A number of major countries already have decided to forgo fuel reprocessing and plutonium recycling altogether, and in a number of other countries that have been firmly committed to the commercial use of plutonium, commitments are increasingly controversial. The case for using plutonium has lost force partly because world uranium prices are currently very low and are expected to remain low for many years, and partly because the technologies that employ plutonium are proving to be more expensive than their promoters had hoped they would be.

The possibility now exists that the use of plutonium will level off at a rather low plateau for several decades, rather than increase geometrically as expected, and that has important implications for energy policy and the international nonproliferation regime.

For those who have been concerned that the growing use of plutonium would undermine the international safeguards system, which is designed to provide the world with timely detection when plutonium or U^{235} is stolen or "diverted" from peaceful uses, it is good news that the plutonium economy is growing much more slowly than expected. For those, on the other hand, who have staked their careers on the expectation that plutonium would soon become the dominant source of cheap electricity, the current situation is a bitter disappointment.

Ironically, the changed prospects for the commercial use of plutonium have become apparent just as the French are commissioning the most advanced piece of equipment based on plutonium, the 1200-MW Superphénix fast breeder reactor, the world's first full-scale commercial breeder. When construction began on the Superphénix ten years ago, its builders thought that it would be the prototype for a series of breeders that would be deployed throughout the European community by the end of the century. As the situation looks now, the Superphénix seems much more likely to stand isolated for some decades, a unique and brilliant feat of

Isotopic composition of plutonium discharges

Reactor type	Plutonium discharged Net kg Pu/GW$_e$-year	Typical isotopic composition % by weight in spent fuel Pu^{238}	Pu^{239}	Pu^{240}	Pu^{241}	Pu^{242}
Light-water reactor	330	2.5	58.5	24	11	4
Heavy-water reactor	650	—	68	24.5	6	1.6
Fast-breeder blanket*	365	—	97	3	—	—

From D. Albright, "World inventories of plutonium," in *Nuclear Terrorism: Defining the Threat*, P. Leventhal, Y. Alexander, eds., Pergamon-Brassey's, McLean, Virginia (1986).

*The numbers do not reflect the burnup of plutonium in the core; taking that into account, a breeder produces about 220 tons of plutonium, net, per GW$_e$ per year.

engineering with some prospect of being the technological basis of our electricity supply in the middle of the next century, but of dubious current value.

The Superphénix, after the Concorde supersonic airplane, has been France's prestige high-technology project *par excellence*. It is the product of the world's most successful program in advanced reactor engineering, headed for three decades by Georges Vendryès (see box). The Superphénix was started up on 7 September last year, Vendryès's 65th birthday, and it currently is approaching full power.

Situated on the upper Rhône River in Alpine foothills one-and-a-half hours northeast of Grenoble by car, the Superphénix makes a striking impression as one approaches on a small road that winds through picturesque fields. In contrast to most conventional nuclear power plants, the Superphénix has no cooling towers, so that one's first impression of the plant complex is that it is relatively small. The containment building, however, is massive by comparison with the compact domes characteristic of conventional nuclear plants and seems very big even against the backdrop of the mountains on the opposite side of the Rhône.

The containment building is large because it contains in addition to the core and breeder blanket, in which U^{238} is "bred" into Pu^{239} by neutron capture, the primary and intermediate pumps, which transfer heat from a pool of liquid sodium via a secondary sodium circuit to a water circuit that powers the turbines in a building adjacent to the containment. The water comes from the Rhône and returns to it, raising the temperature of the river by about 2 °C. "You couldn't do that in West Germany," remarked a reactor engineer, alluding caustically to the neighboring country's powerful environmental movement.

The engineers who built and run the plant take particular pride in the mechanism used to remove and replace fuel assemblies without unsealing the containment and in methods used to guard against a sodium–water explosion. A very severe (non-nuclear) sodium–water explosion in one of five steam generators crippled a 350 MW prototype breeder in the Soviet Union in 1973, setting off a huge fire that was detected by US satellites.

Because the French and Soviet breeder engineers are known to cooperate quite closely, we asked the manager of the Superphénix, Gilbert Labat, whether the French were able to take the Soviet experience into account in designing the Superphénix. Yes, he said, French engineers were at the Soviet Shevchenko reactor very shortly after the accident and they think they know what went wrong. First of all, the reactor was not equipped with sufficiently sensitive devices to detect buildup of free hydrogen. Second, the people running the plant did in fact have some indication of free hydrogen, but the signals were ambiguous, and instead of acting promptly to drain the sodium and water circuits, they dallied until it was too late, discussing whether they might have a problem or not.

Disposition of the plutonium produced by the Superphénix was a matter of some substantial international concern when the reactor was on the verge of being commissioned last year. In contrast to conventional reactors, which produce plutonium with an isotopic composition that is not ideally suited for weapons if the reactors are operated normally, the Superphénix produces large quantities of plutonium that is almost perfectly suited for the manufacture of sophisticated bombs (see table, page 53).

Vendryès, pioneer in breeders, regrets their cost

From the mid-1950s, when France launched its fast-breeder development program, until last year, when the program culminated in the startup of the Superphénix, Georges Vendryès presided over advanced reactor development. In an interview conducted on 5 March, first at the Edison Hotel in New York and then around the corner at a Thai restaurant, where we were joined by his wife, a perfume company executive, Vendryès reminisced about his career and brooded over the changed outlook for breeders.

Vendryès said he first heard of fission right after the war when he was working as a civil engineer near Nice, where he happened to hear a talk by a person who had worked in the Canadian branch of the Manhattan Project. Vendryès returned to school to study nuclear engineering and received a doctorate in 1951, after working with Frédéric Joliot-Curie. He joined the Commissariat à l'Énergie Atomique, where his first work involved calculation of neutron cross sections.

In 1956 Vendryès was put in charge of the startup of France's first plutonium-production reactor, G-1, at Marcoule. Because this reactor was to provide the plutonium for France's first nuclear weapons (even though the official decision to build weapons had yet to be taken), this was a project of very great importance to the French military. The reactor also was designed as a pilot plant to produce electricity and so it also was of great interest to Électricité de France.

Vendryès assembled a team of about 20 physicists and engineers, and as they managed the startup successfully, he began to think about how he could keep them together. After moving back to Saclay in 1956, Vendryès started to work on breeder concepts and managed to persuade CEA to launch a breeder program based on experimental work done with sodium–graphite technology.

The decision to build Rapsodie, the first French breeder prototype, was helped along by a request from EURATOM asking CEA to develop some joint programs, Vendryès recalled. He said he convinced the French that the breeder was so distant, of such little immediate economic importance, that it could be safely launched as a European project despite President Charles de Gaulle's distaste for involving France in European programs.

Once the agreement was signed with EURATOM, with the Europeans covering


VENDRYES

35% of the breeder's expenses, Rapsodie was "unstoppable."

By this time, CEA had opened new breeder research centers at Grenoble and Cadarache, where Vendryès concentrated his team's activities. The facility was built, he noted, as a completely autonomous facility, with full support of the directorate and with lots of space in an attractive part of the Provence. "There was a danger of being located on some terrible desert or military base," Vendryès observed wryly. To avert this danger his team invented a complex series of site-selection criteria that only one place in the world satisfied—Cadarache.

Rapsodie went critical in 1967, de Gaulle visited it and liked it, and after that Vendryès never worried about money again. The Phénix and Superphénix were next.

Contemplating the near-term economic prospects for the breeders, Vendryès was plainly disappointed. "The problem is that they are simply more expensive than pressurized water reactors," he said. Asked how long he expected that to be the case, he said at least 20 years.

Turning to what is for him a more cheerful subject, Vendryès noted that he is on retainer to the Indian atomic energy authorities and regularly visits India. He is impressed by the technology they have developed to produce fuel pins, using zirconium rods made from scratch from ore. When he first saw India's breeder, an almost exact clone of Rapsodie, it brought a bit of a lump to his throat. If we will see an economy based on breeders, Madame Vendryès remarked wistfully, maybe it will be in India. —WS

At a time when the French are energetically modernizing and expanding their arsenal of warheads while commercial demand for plutonium is slight, arms control specialists naturally have wondered whether the French would be tempted to use plutonium from the Superphénix for military purposes. Such use would violate the spirit of the nonproliferation regime, which seeks to establish a clear and sharp division between civilian and military uses of plutonium, and it would set a bad example that near-nuclear countries might be tempted to follow—India, for example, or in the more distant future, Pakistan, Brazil, Argentina, Israel or South Africa, none of which are parties to the Nonproliferation Treaty.

The Superphénix is a joint French–German–Italian project, and each partner is entitled to plutonium recovered from the reactor and electricity produced by it in direct proportion to its investment in the design and construction of the reactor. The West German Green Party, which has made a major political issue of plutonium, raised the question in the German parliament of whether the French would have the right under EURATOM safeguards to divert plutonium from the Superphénix blanket to their military programs. The German government answered that the French would in fact have the right to make military use of their share of the plutonium if they wished to do so and that Germany would have no legal basis for challenging such a move.

The US State Department, according to Albright, asked the French for assurances that they would not make military use of the plutonium. Albright's understanding is that the French insisted on their right to do so but said they had no intention of doing so, and that the State Department is choosing to regard that statement of intent as binding.

Because the situation continues to cause concern, we made a point of inquiring into France's plans for the Superphénix plutonium. Conversations with Labat and Vendryès indicated that the issue is unsettled—but that there still is ample time for firmer agreements or understandings to be reached.

They said that because there is currently a surplus of plutonium, the spent fuel from the Superphénix will not be reprocessed at all for several years and probably not until the 1990s. A special reprocessing plant will be needed for the "driver" or core fuel (but perhaps not the blanket fuel, which is richer in Pu^{239}) and it remains to be decided where and when the new facility will be built.

Because the Superphénix proved somewhat more costly to build than hoped, additional breeder reactors like the Superphénix are not expected by the French to be competitive with light-water reactors for decades, at least. Electricity produced by the Superphénix is about 2.2 times more expensive per kilowatt than electricity produced by French light-water reactors, Labat said, taking care to note that the French reactors produce electricity a good deal more cheaply and efficiently than the US reactors they are modeled on. Labat estimates that they would have to get the cost of breeder electricity down to about 1.2 or 1.3 times light-water electricity if breeders were to become competitive under any plausible economic scenarios.

The French have prepared a design for a second breeder the size of the Superphénix that would be, they believe, about 30% cheaper. Much of the saving would be achieved by means of a redesign of the containment based on experimental results indicating that violent reactions between molten fuel and sodium would not release as large amounts of energy as previously believed.

A less conservative design might conceivably be selected for a second breeder in France. But Électricité de France reportedly has no interest in building one any time in the foreseeable future, and it is scarcely imaginable in the wake of Chernobyl that such a design could be sold in West Germany, which regards itself as entitled to build the next full-scale breeder. The world outlook for breeders and closely related reprocessing technology will be the subject of a followup story.

—WILLIAM SWEET

Education

Application deadline nears for senior education fellowship

The American Institute of Physics has established a new position, Senior Staff Education Fellow (PHYSICS TODAY, June, page 85). The activities pursued by the fellow will depend on the fellow's background and interests and could include pre-college physics and other introductory physics programs.

Fellowships will be for one or two years, and fellows will be based at the new AIP office in Washington, DC. The search committee has established a special application procedure to be used by applicants and nominees. The committee especially encourages colleagues in the physics community to help identify the best person by submitting nominations to the committee chairman, Gerald F. Wheeler of Montana State University.

It is anticipated that the fellow generally will be a person on sabbatical, leave of absence or retired. The Senior Staff Education Fellow will be paid a salary corresponding to the individual's regular pay.

The deadline for final submission of all materials is 31 October 1986. For information on procedures and instructions write to Gerald F. Wheeler, Department of Physics, Montana State University, Bozeman MT 59715.

AIP will start magazine–journal on computers and physics

The executive committee of the American Institute of Physics, acting at the recommendation of the publishing policy committee, approved a proposal in mid-June to establish a new journal on computers and physics. The new journal will start to appear in 1988 and will combine elements of an archival journal and a magazine.

In a memorandum to the executive committee, AIP Director of Publishing Robert H. Marks said that the new journal would resemble PHYSICS TODAY in some ways and the *Review of Scientific Instruments* in other ways. Marks mentioned the American Chemical Society's *Environmental Science and Technology* as an example of the type of journal–magazine that has been successfully published.

According to a proposal prepared for the AIP subcommittee on journals by a special task force headed by Howard G. Voss of Arizona State University, the journal on computers in physics could include regular columns on hardware and software as well as research and instructional materials, news reports from laboratories and supercomputer centers, reviews, editorials and letters to the editor, and a large section devoted to archival articles. The journal will be aimed at the upper-level undergraduate physicist and above, including graduate students and professors, and government-laboratory and industry physicists. Libraries also should be an important part of the market.

The exact design, content and character of the new journal are expected to depend heavily on the individual selected to be first editor-in-chief. Voss has been named chairman of the committee to propose an editor for the journal. The other members of the search committee are Enrico Clementi, Don R. Hamann, Scott Kirkpatrick, Robert H. Marks, Edward F. Redish, Larry L. Smarr and Donald C. Wells.

Nominations for the editor-in-chief should be addressed to Howard G. Voss, Department of Physics, Arizona State University, Tempe AZ 85287; telephone (602) 965-7147 or leave a message at (602) 965-3561. □