barrier if an accident damages the fuel rods. This primary system has several filter systems to filter out any radioactive fission products that are released to the coolant and collect them for later disposal.

Under the assumed condition that the primary coolant system containment barrier has been breached in the design basis accident, three more barriers are provided to contain any fission products that escape from the ruptured pipes. First is the 7-foot to 10-foot thick layer of concrete shielding that surrounds the reactor vessel and the primary coolant system. Next is the containment building, which has two barriers: one is a sealed steel shell nearly 4 inches thick designed to a pressure of 60 pounds per square inch. Outside this shell is more than 3 feet of concrete shielding to absorb radiation.

These barriers are designed to protect the public in the case of the design basis accident. The incident at Three Mile Island was similar to what is called a small pipe break in reactor safety terminology, far less severe than the design basis accident. There was never any danger to the public.

Radioactive fission products give off heat long after the reactor is shut off and must always be cooled. To assure that cooling is always available, engineered safety provides redundant core cooling systems to guarantee that water is always available to the reactor core, even under the conditions of the design basis accident. The back-up core cooling systems are designed to keep the fuel from failing and melting under even these severe circumstances, and if there *is* failure or melting, to prevent so-called core meltdown.

The first line of defense is, of course, the primary cooling system itself. In most loss-of-coolant accidents, as long as the primary pumps (or even one out of the four) keeps running and make-up water is continuously supplied, the fuel will continue to be cooled. The make-up water is automatically supplied to the primary coolant-system by a set of large tanks held at pressures somewhat below normal reactor operating pressure. Thus if a coolant system rupture occurs and the pressure drops, these tanks will automatically inject water into the reactor vessel.

The water make-up system is entirely passive. It requires no pumps or valves to turn it on. The water in these tanks is borated—a boron salt is dissolved in it that absorbs neutrons and shuts down the reactor completely, if for some reason the control rods have not shut it down.

Under certain hypothetical LOCAs, it is necessary to get water into the reactor core faster and at larger volumes than the tanks can supply it. For this purpose there are sets of high-pressure and low-pressure emergency core cooling pumps that automatically turn on when preset pressures in the vessel are detected. The high-pressure pumps are for small ruptures, while the low-pressure ones come on during large ruptures, which require large volume and flows.

The 1979 antinuclear film *The China Syndrome* built an anti-science myth in the tradition of Mary Shelley's novel *Frankenstein*. According to this scare story, in the course of a core meltdown, the molten core forms into a round glob that melts through the reactor vessel, drops onto the concrete floor below, burns its way through more steel and many feet of concrete into the ground below, and defies gravity to emerge in China. Along the way, of course, the fiery glob gives off fission products, contaminating all ground water and everything else it touches.

Such a process is scientifically and physically impossible, as should be clear from the preceding discussion. A core meltdown could happen only if *no* cooling water got into the reactor core for many hours. The fuel would drip onto the massive steel support structure and perhaps eventually the vessel bottom. The splattered fuel would be cooled by contact and conduction of the thick steel walls.

What the experts say

Dr. Joseph M. Hendrie: It can't happen here

Joseph M. Hendrie, former chairman of the U.S. Nuclear Regulatory Commission, is now a consulting engineer. He served on the NRC from 1977 through mid-1981. In this interview he describes one essential difference between the Soviet graphite reactor and light water reactors.

EIR: How would you assess the state of U.S. nuclear safety, compared to Soviet safety systems?

Hendrie: The U.S. water reactors are simply incapable of producing the sort of gross release that has occurred in Russia. We don't have the flammables in core that would provide the kind of driving force they had there in the fire. Our systems are engineered with more extensive safety provisions and we then encapsulate the whole reactor system in a very strong and tight containment structure.

After Three Mile Island we made a very extensive reassessment of the safety of U.S. plants from all kinds of standpoints and all kinds of accidents and found it appropriate to upgrade a number of areas. We have concentrated attention on operator training and expertise and on a drive to achieve real excellence in operation at all U.S. plants. This is reflected in the industry efforts as well as in the regulatory incentives.

Furthermore, we undertook after Three Mile Island, a very extensive upgrading of the ability both on-site and off-site to take emergency measures in the event of accidents. I think those provisions are particularly notable against the background of the Russian accident.

EIR: Most of the material written in the 1970s on the Soviet safety question indicates that they are scornful of the Amer-

icans for spending so much money on what they consider unnecessarily redundant safety systems.
Hendrie: I think that may have been the attitude in some quarters earlier on. My impression is that in the last five, six, or seven years that there has been a move in the Soviet Union toward safety standards and arrays of safety systems in the plants more like the Western standards. Those are reflected, for instance, in the designs of the new PWR [pressurized water reactor] line, 1,000-megawatt line, which does have emergency core cooling systems similar to U.S. designs and does have containment. Or at least the outline drawings I've seen for what they were regarding as their standard 1,000-megawatt PWR did have a containment on that looked very much like a standard U.S. reinforced concrete prestressed containment. So I think there's been a move in the Soviet Union in the last few years for reactor safety standards more nearly like those in the Western world.

But, of course, these graphite machines are in many ways a design and reactor concept from an earlier time. I think they have a number of features about them which are not desirable from a safety standpoint.

EIR: It's curious, given this, that the Soviets claimed in some of their publications that the graphite reactor was actually safer than the PWR.
Hendrie: I think in part that grew out of a concern on the part of the Soviets that was really one of the bases for the effort they put into the graphite machines: It was a long time before the Soviets were confident about their ability to fabricate large pressure vessels of the necessary quality for a large reactor. That's really a central reason why they went into that pressure tube design—to avoid having to fabricate very large size reactor vessels.

Remember that the 440-megawatt PWR, which has a substantially smaller pressure vessel, and which has been their standard in the water reactor line for many years, and the 1,000-megawatt designs for which the heavy components were to be produced at the Atommash plant (which has so many problems now)—both those designs were early 1980s.

In 1979, after Three Mile Island, I talked to a high-level Russian delegation from the Ministry of Electricity. . . . They showed me a set of drawings of their 1,000-megawatt PWR which they said was going to become their standard power machine. That's the one that had the Western type containment on it and the emergency core cooling systems. But that's 1979. We had been making big pressure vessels since the late 1960s. So, I think that's the reason that they went to graphite.

EIR: So you think that they built the graphite reactors because they did not have the technological sophistication to build PWRs?
Hendrie: I don't know. These graphite machines, even the one at Chernobyl, was finished quite recently. They nevertheless are a design and a concept that is really late '50s sort of thinking. I'm sure there are some upgrades in the recent ones that reflect more recent technology, but they really in many ways are a technology that we ought to have gone beyond. They have positive void coefficients—

EIR: Can you explain that please.
Hendrie: It means that if the power goes up, the reactivity goes up, because the water is a poison in that system. When you raise the power and boil a little more water and reduce the water density in the fuel channels, that's a positive reactivity. That would really panic us. We don't permit machines with positive coefficients.

Sue Gagner: Safety upgrades after TMI

Sue Gagner is a public affairs officer for the Nuclear Regulatory Commission. She discusses how U.S. safety standards were upgraded after Three Mile Island.

EIR: Can you comment on U.S. nuclear safety standards, in particular how they were upgraded after Three Mile Island?
Gagner: We have a "defense-in-depth" system for nuclear reactors in this country: if one system fails, another system would come in. For example, we have the emergency core cooling system, which would cool the core in case the primary system failed. The final back-up system is, of course, the containment, but there is a series of redundancies and systems that back up other systems.

After Three Mile Island, there was something called the TMI action plan, and that resulted in over 6,400 separate action items, and about 90 percent of those had been done by the end of 1985.

EIR: What do you mean by action items?
Gagner: There were different types of things. Some of them were equipment changes, some were procedural changes. For example, we required greater emphasis on quality assurance in building and operating plants, to make sure that the plants were built as designed. . . .

Emergency planning has been significantly upgraded since Three Mile Island with the requirement of emergency drills, evacuation planning, and notification of local and state officials. The training of personnel, particularly control room operators, has been upgraded. The number of resident inspectors, started before Three Mile Island, was increased. Now there is a resident inspector at every operating plant who works at the plant as his primary duty station.

EIR: What is the NRC's budget for safety tests?
Gagner: Our budget on research, proposed for the next fiscal year, is $113.5 million.

EIR: Has it been at that level, or higher?
Gagner: The research budget has been decreasing. In fiscal year 1986, it was $207 million. We would like to spend as much in 1987 as we did in 1986, but our budget is being cut, along with the overall budget decreases, and we do have to put emphasis on inspection and enforcement of plans.

Paul North: experiments in nuclear safety

Paul North is the manager of Nuclear Reactor Research and Technology for EG&G Idaho at the Department of Energy's Idaho National Engineering Laboratory (INEL). He discusses the nuclear safety experimental work that he has been involved with for the past 10 years.

EIR: Can you describe the nuclear safety projects at INEL?
North: A substantial program in safety has been going on for a great many years. There are two major research areas at EG&G Idaho. One relates to thermal hydraulics—the flow of cooling fluids within the reactor and the energy transfer associated with those flows. We have operated a number of experimental projects, two of them being the Semiscale project and the LOFT [loss of fluid test] project, which is aimed at getting a great deal of actual physical data concerning the operation of emergency core cooling systems during a wide range of transients.

The second area is the developing and testing of computer codes, which are designed to predict the behavior of full-scale reactor plants. It is through the comparison of those predictive capabilities with the experiment system results that we learn of possible deficiencies in our modeling capability and make improvements, so that we build confidence that we can predict the full-scale plant behavior in transient conditions—transient means that conditions are varying with time and usually implies that things are not normal.

EIR: Was the LOFT project an actual reactor?
North: It was a 50-megawatt thermal pressurized water reactor with a great many scale features. . . . It tested some of the major flows in the transfer interaction that took place in the transients. The other facility, Semiscale, is literally that—a roughly scaled facility. It has an electrically heated core rather than a nuclear core, and was in the most recent version a 2-megawatt electrically heated core. The heights in the system were full heights, so it was a rather long and slender system. It has run a great many experiments and we have learned a great deal out of that system. Both facilities have given us a lot in terms of thermal hydraulic behavior and reactor transients.

EIR: How is the data that you get from these experiments translated into use by the nuclear industry?
North: The data that we provide has been used by them in a variety of calculations. But it is primarily produced for the Nuclear Regulatory Commission—either directly to enhance engineering understanding of the behavior of the systems or indirectly by allowing confidence in the terms of the predictive capability of the computer codes.

EIR: Was LOFT the device used in the experiment showing that a reactor could actually stand up much better than previously predicted in a major accident?
North: You may be referring to experiments on the operation of the emergency core cooling system in the event of a very large break in one of the cooling pipes. LOFT did run some experiments along that line and they were very, very instructive. In terms of calculating the behavior of a reactor under those circumstances, when you do safety calculations, you make what are called conservative assumptions. That means you assume things that make matters worse in order to make very sure that the analyses, if they indicate safe behavior, are indeed indicating a safe system.

There was some uncertainty on just how much conservatism there was in those calculations, and without going into all of the details, when a large break was run in LOFT, it turned out that the emergency core cooling systems functioned very much better and that the peak temperatures were significantly lower than would have been predicted by the conservative kind of analysis that is generally used in that approach.

EIR: Were these projects conceived after Three Mile Island, or had they been ongoing before 1979?
North: The system was in progress in the early '70s and in fact even before that, but it really jelled in the days of the hearings on the ECC—emergency core cooling. Back in about 1972 there were big congressional hearings on whether those ECC systems would be effective. I think that was quite influential on the research that was undertaken in the United States in the following decade. LOFT and Semiscale both did experiments that were related to the TMI kind of transient.

EIR: Are there other safety projects at INEL?
North: The other major area where we have done reactor safety research is in the region of the fuel itself, again in nonnormal conditions. . . . There is another facility here on a standby condition, the PBS, which stands for Power Burst Facility, referring to the ability to raise the power quickly. That has been used to do a wide range of experiments on fuel. It simulated the conditions to some degree in the Three Mile Island accident and it damaged the fuel.

Also, under the international program in LOFT, the last experiment was one in which a large fuel module was raised to very high temperatures and damaged. It was the last experiment in the system; the reason is obvious—we burned up the center fuel module in the core, very deliberately and in a controlled way. Then we shut the thing down, recovered, and we gained a lot of information on fission product release and transport as a result. . . . The international community was very pleased that we were able to conduct the experiment and able to get data that would shed light on the subject.

Richard Wilson: No lethal leaks even in a meltdown

Richard Wilson is Mallinckrodt Professor of Physics at Harvard University. He chaired the Nuclear Regulatory Commission-sponsored study group of the American Physical Society on "Radiological Consequences of Severe Nuclear Accidents," which released a report in February 1985. Here he discusses what happened at Chernobyl's graphite reactor and compares this to a worst-case accident in a U.S. pressurized water reactor.

EIR: What do you see as the major differences between the U.S. and Soviet approaches to nuclear safety?

Wilson: There are two things one should comment on. Firstly, a crucial thing is the different type of reactor the Soviets have. They have a pressure tube reactor with 1,100 or so independent pressure tubes inside a big 5,000-or-so-ton charcoal matrix. They regarded that as fairly good from the point of view of safety, because the whole thing can't get out of control at one time. However, their pressure tubes have a very large amount of zirconium on them, and the reactor has a very large amount of graphite. If they get out of control, and if they are starved of coolant, then they get two very important exothermic chemical reactions that are worse than any we get in our plants by quite a bit.

First is the zirconium-water reaction, meaning hydrogen and zirconium oxide. This also happened at Three Mile Island, but Chernobyl has more than five times as much. The second reaction is the uranium oxide and carbon reaction, meaning uranium-carbon, carbon monoxide, which is also exothermic. So both of those would heat the thing up, and then the hydrogen gas and carbon monoxide gas would put pressure that might explode further up in the system. This would then break open the individual fuel channels, with about 14 pounds per square inch of pressure. That would very quickly blow up the roof of the building.

Something did blow up the roof of the building, so you know that something like this must have happened at one o'clock in the morning on Saturday. That probably could not have happened, according to very rough calculations, with one fuel channel alone going. . . . About 10 of these fuel channels have to go; the hydrogen/carbon monoxide from 10 fuel channels would be enought to cause the roof to blow, by my rough calculations. They presumably thought it was very unlikely that you would get that at any one time. I suspect there was some operator error allowing that to happen.

The main difference here is that our plants have the big pressure vessel that contains the hydrogen. At one time our pressure vessels were heavily criticized; the question was, would the pressure vessel fail catastrophically. The people who 15 years ago were arguing that it could . . . are now arguing that it can't, having seen the new information on vessel tests. . . .

But the second thing that we have, surrounding the whole reactor vessel, is a containment vessel, which will handle 200 pounds pressure per square inch. It is sufficiently large, a huge volume, so that the pressure [from the chemical reaction] will already be reduced and diluted from the volume. That can hopefully contain everything. And if a fire begins, you would soon exhaust all the oxygen so that it would self-extinguish.

The crucial thing about our reactors then, is will that containment vessel hold in an accident, and for how long? The "how long" gives you time to do all sorts of things—for example, finding a way of boiling water inside to cool things down, to reduce the pressure, and to get some standard things going. The worst moment, according to all the things we calculate, is if you have a meltdown of the reactor that melts through the reactor vessel at the time that it's still at high pressure. You get all this molten fuel, 400 tons of it, and some molten iron and whatnot, all dumped into the containment vessel at the same time. And that is much more pressure than the 200 pounds per square inch; we're talking about several hundred pounds. It will heat up the air very rapidly, and the question is how high.

Fortunately, we don't have as many energy sources as the Russians do. We don't have the uranium-carbon reaction and not as much zirconium. The maximum we think that could possibly go is about 60 or 70 pounds per square inch, and our containment vessels will hold 150 to 200 pounds per square inch. That means that at the critical moment—when all the fuel is molten, when all the aerosols are being released—that the containment vessel will hold. There will be several tons of aerosols released in the vessel, some of them radioactive. They will all be initially produced at the smallest size, a tenth of a micron. If they were produced in a dilute area, out in the air, they would immediately float with the air, because the settling velocity of these aerosols is lower than ordinary wind speed.

The point is, that if the containment vessel is not broken, the aerosols inside, including the radioactive ones, will collide with each other, coagulate, and then settle out. So, if you wait 5 hours, most of those aerosols will be deposited all over the surface inside the containment vessel and are no longer available for release. However, if you do nothing, the heat will still go up in that reactor. The uranium will be interacting with the concrete and liberating hydrogen from it and raising the pressure. Therefore, at some unknown time, maybe 8 hours, maybe 16 hours, maybe four days, or possibly never, the containment vessel may crack open. Some critics will then say, "but you don't have containment." But, yes you have: you have it for the crucial period for forcing the settling of the aerosols.

The crucial thing about our reactors then, is will that containment vessel hold in an accident, and for how long? The "how long" gives you time to do all sorts of things.

EIR: So, if there is a crack in containment after that crucial point, you are saying that the radioactivity released would be greatly lessened?
Wilson: A lot of the radioactivity will be unavailable for release; not all of it—you never get all of anything anywhere—but you will be down by enough of a factor to make it safe. You wouldn't even bother to evacuate anybody. . . .

I am hoping, and expecting to be invited to visit the Soviet Union. . . . They have that American bone man in there, who will probably be able to save a fair fraction of the ill people. We call the lethal dose of radiation 500 roentgens. You can give a whole body dose of 1,000 roentgens and save three-quarters of the people. That's been done, because people have been cured of leukemia that way. You kill the leukemia with that high dose, replace their marrow, replace their blood, and three-quarters of them survive, and that's quite remarkable.

Walter Loewenstein: Containment is key

Walter Loewenstein, is deputy director of the nuclear power division at the Electric Power Research Institute (EPRI) in Palo Alto, Calif., with 30 years' experience in nuclear development and nuclear safety. EPRI's statement on U.S. versus Soviet nuclear safety stressed the limited redundancy of Soviet back-up power systems and the limited oversight of quality checks and operator training.

EIR: Was there a change in Soviet nuclear safety practices after Three Mile Island?
Loewenstein: I really don't know if there was a change. . . . The obvious point is that they have a very large reactor with what appears to be no containment, which is quite a departure from the normal practice in the Western world.

EPRI's general statement [on the accident] I think certainly points out one of the major differences between safety measures employed most widely in the United States—the presence of containment. This means a substantial structure with 5-foot-thick containment walls and steel liners.

EIR: What has been the general role of the EPRI Safety Analysis Center, in particular since TMI?
Loewenstein: There were a couple of very important reports and guidelines that emerged from TMI. The first one was the Kemeny Report. Then there were two major reports for the Nuclear Regulatory Commission. These required a number of things, involving modifications in plants, training, and hardware, which were generally implemented throughout the country. For example, one of the things that EPRI did, was to develop basic hardware to enable you to see what was going on in the plant. There was also an extensive program testing the nature of the release valves, providing insights on how to make them operate more reliably.

There are multimillion dollar expenditures every year by the industry and by the Nuclear Regulatory Commission to develop the safety procedures and hardware to make plants function more safely.

Dr. Petr Beckmann: Why did it take 36 hours?

Petr Beckmann is a professor of electrical engineering at the University of Colorado at Boulder. He came to the university in 1963 as a visiting lecturer from the Czechoslovak Academy of Sciences, and he did not return to Czechoslovakia. The author of nine books, he publishes a pronuclear monthly newsletter Access to Energy. *He comments here on how the accident reflects the defects of Soviet culture, which places human life at low priority.*

EIR: Can you comment on the concept of Soviet nuclear safety?
Beckmann: The Soviets have a full-fledged civil defense system in place, with shelters, instructions on radioactivity, chemicals, evacuation plans, etc. Yet it took them 36 hours to put the system that's already in place, to put it in operation.

In 36 hours, you understand that what endangers people is the dose. The dose is directly proportional to the time that you spend there: roentgens per hours times the hours. In those 36 hours, probably hundreds of people will die a death that was definitely avoidable. That means it's not just that they don't care about human life—which they don't—it means that the system is so bureaucratic that it can't even use what's at its disposal. That system will work for war, because it's meant for war. It will not work for another emergency because some bureaucrat failed to think, which is the job of bureaucrats.