of its functional defects, I am on much more tenuous ground. There is some evidence that in certain peripheral neuromuscular syndromes the quantal release efficacy of the motor impulse is impaired (*15*), resembling somewhat the experimental condition of low Ca–high Mg, while in other forms of myoneural disease a "packaging failure," that is, insufficient accumulation of transmitter by individual vesicles has been suggested (*16*). It would clearly be of interest to pursue this line and to find out whether there is similarly localized involvement in some central nervous lesions.

Finally, there is the more general question, whether the statistical fluctuations and "uncertainties" which are inevitably associated with the quantal nature of transmitter release, play any recognizable role in the organized function of the nervous system. That there are large quantal fluctuations in the response of unitary synapses in the central nervous system, has been shown very clearly by Kuno (*17*) and others. In many instances, the number of packets released by an impulse impinging on a spinal motoneuron was found to be small, and the predictability of the synaptic response appeared to follow the statistical rules of Poisson's law. In other instances, the fluctuations were much smaller, indicating a greater efficacy of the afferent impulse, so that either a large average number of packets was being discharged from the terminal (*18*), or a small number was being released with high probability. One would presume that in a "fully trained" neuronal pathway, quantal fluctuations become unimportant because of simultaneous involvement of a large population of synaptic transfer sites. The larger the average number, the smoother and more predictable becomes the synaptic performance. However, large numbers and smooth performance may not be the rule at *all* times and in *all* pathways. Experiments on the neuromuscular junction have shown that certain processes of synaptic modification during and after prolonged activity are associated with quantal recruitment, that is, with an increase in number of packages delivered per impulse (*19*). Similar changes would be expected to occur, and make synaptic performance more predictable, during development and "training," while the opposite trend might underlie some forms of pathological and degenerative impairment.

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NEWS AND COMMENT

Nuclear Reactor Safety: A New Dilemma for the AEC

The Atomic Energy Commission has adopted a curious position lately. While assuring the public that the nuclear reactors it licenses will operate safely, a number of AEC officials have been discreetly appealing for more money—preferably much more money—to support research on the safety of conventional, water-cooled nuclear reactors.

For the most part, the money has not been forthcoming. But the appeals themselves have inflamed suspicions among the AEC's numerous critics that the atomic power plants that are blossoming across the nation's landscape may not be as secure from mishap as licensing implies. And thus the AEC finds itself impaled on a new dilemma that may serve to weaken its already shaky public credibility: If reactors are as safe as they are advertised to be, how can a large new safety budget be justified? Or, if new safety research is as urgently required as the AEC indicates, should the construction of atomic power plants (21 are operating, more than 50 are being built) be proceeding as rapidly as it is?

At a time when the AEC's $3 billion program for subsidizing the development of water-cooled reactors is nearly at an end, and when new plants are being licensed in ever-increasing numbers, the commission's appeals to Congress and the Office of Management and Budget for safety funds seem more than a little awkward. Indeed, the AEC's rationale for funds above and beyond its fiscal 1971 safety budget of $36 million rests partly on the premise that significant "uncertainties" in the performance of reactors remain, and that "urgent" work is yet to be done to resolve these uncertainties. For example, Milton Shaw, the AEC's director of reactor development and technology, confides that "At the drop of a hat I can spell out 15 areas where we could do more research in reactor safety. Drop two hats and I'll spell out 30 areas. There's virtually no limit on the work we can do." At the same time, however, commission officials are at pains to deny any untoward implications in such statements. In this context, George M. Kavanagh, the assistant general manager for reactors, told the Joint Committee on Atomic Energy last March that "This does not mean our reactors are unsafe. It means we should be spending more to assure that they are safe. . . ."

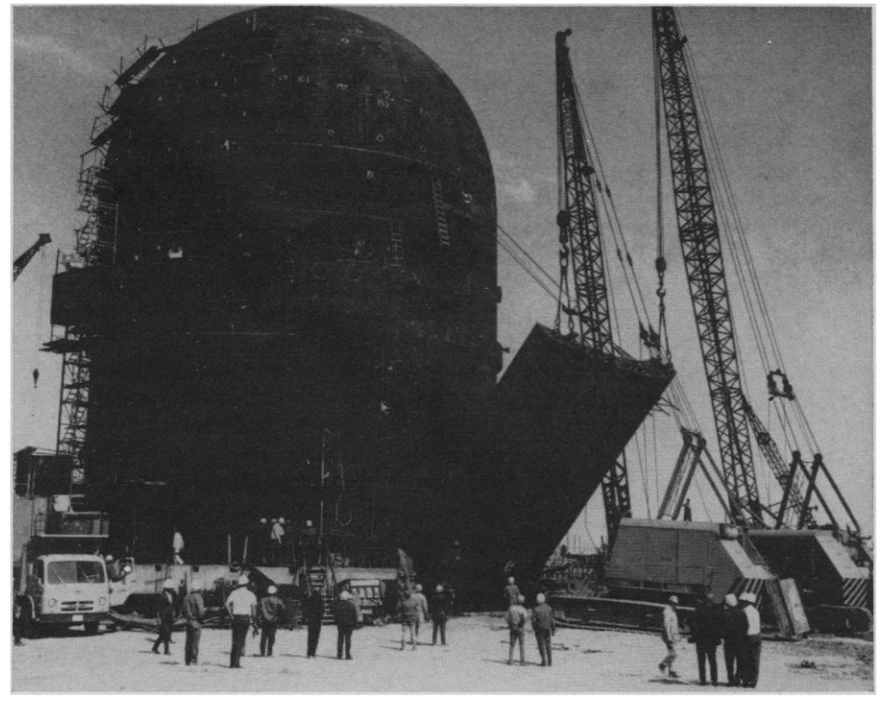
One way out of this paradox is to concede the point, raised by those close to reactor development, that safety research is not a finite task. As reactors age and their designs evolve, so the job

of ensuring that they are properly designed, built, and operated continues. Moreover, there are, in fact, people of influence within the AEC who are given to what industrial sources regard as excessive zeal for perfection in safety.

Nevertheless, the fact remains that a large volume of nuclear safety work —much of it aimed at refining current understanding of normal and aberrant reactor behavior, and much of it aimed at improving quality control in manufacturing—has been cancelled, delayed, slowed, or simply not begun over the past decade. To all appearances, the result has not been to leave key safety issues untouched. Instead, one effect has been to limit the ability to define precise margins of safety in reactor operations. Another has been to impede the development of stringent standards of quality assurance—a primary ingredient in reactor safety.

Conversations with AEC officials and a reading of recent testimony presented to the Joint Committee suggest a variety of reasons for this R & D backlog. Essential projects, for example, have been delayed by inept management, and by design and construction problems similar to those that afflicted the nuclear industry as a whole during the 1960's. There is also reason to believe that program administrators have shown considerable inertia in acting on research suggestions still being pressed by the AEC's safety watchdog, the Advisory Committee on Reactor Safeguards (ACRS).

But the reason cited most often and most adamantly by AEC officials for their burden of unfinished business is a chronically undernourished safety research budget. For instance, Spencer H. Bush, chairman of the ACRS, told the Joint Committee in hearings on 22 June that the safety program's fiscal problems have worsened in the past 2 years. "While progress has been made," he said, "the accelerated erosion of AEC money for water-cooled reactor safety research has resulted in termination of some programs and substantial delays in others."



The AEC's $35 million Loss of Fluid Test (LOFT) facility in Idaho nears completion as two cranes lift a 200-ton door into place on the project's containment building.

A Furor over Safety

The AEC's new dilemma was thrust into prominence recently by a much-publicized controversy over the adequacy of a key accident-control system that is used on nearly every nuclear power reactor—the emergency core-cooling system (*Science*, 28 May). Although the commission's initial reaction to the furor over the backup coolers was to minimize its significance, the AEC's subsequent action was in keeping with its claims of ultraconservatism in matters of public safety. But more important, the controversy has helped point up the safety research program's infirmities.

The backup cooling systems in question are, very simply put, complexes of pipes, valves, and pumps, which are meant to flood a reactor's superheated uranium core in the unlikely event that the core's normal bath of cooling water escapes through a ruptured pipe. Thus the systems are analogous to spare hoses, radiator, and water pump on an automobile—but with a big caveat: Although operating reactors have occasionally sprung leaks from faulty pipes and poorly welded joints, none of these leaks has been great enough to call an emergency cooling system into action. Thus, though backup coolers perform well enough in elaborate computer simulations, they have never been tested in an operating reactor.

To rectify that situation, the AEC is preparing an extraordinary series of core-cooling experiments at its National Reactor Testing Station in Idaho. Here, a small reactor enclosed in a huge, dome-shaped shell will be subjected to progressively worse loss-of-coolant "accidents." Each time the reactor will be revived with a spirtz of emergency water, which, in turn, should spare it from destruction. This is the Loss of Fluid Test (LOFT) project—and it was in preparation for LOFT last winter that a series of core-cooling experiments in miniature scale first cast doubt on the adequacy of full-sized backup systems.

The "semi-scale" tests, as the experiments were called, suggested that steam pressure inside a real reactor might prevent emergency water from reaching the core in sufficient time or volume to save the reactor from severe damage or destruction. The tests were aimed at refining a computerized model of the LOFT reactor's behavior and were not meant to simulate events in an atomic power plant. Nonetheless, they did spur the AEC into reviewing the designs of backup cooling systems on power plants now in operation and on several scheduled to "go critical" soon.

After deliberating for 4 months, the AEC issued on 19 June an "interim policy statement" which suggested a slightly diminished confidence in the ability of emergency cooling systems to save a reactor—and perhaps the nearby populace—from the consequences of a broken pipe. Five older reactors, including the San Onofre plant nestled along the California coast not far from the western White House, were ordered to modernize their backup

coolers by 1 July 1974. Until then, the policy statement said, the plants were to triple their inspections of pipes, pumps, and valves, in order to reduce the likelihood of an accident that would require the use of an emergency cooling system. In addition, four new atomic power plants were ordered to hold their peak operating temperatures down to 1260°C, although doing so might decrease their power output. The AEC said that these and other "clearly conservative" guidelines would remain in effect, "pending the development of further data," much of which would presumably come from LOFT during the next few years.

A Dismal History

As an AEC budget summary described the LOFT project last year, it is the nation's "largest and most vital water (reactor) safety project," and it bears on the "most critical safety problem facing all water reactor plants"—namely, what to do when the core runs dry. But none of this urgency appears to have spared the program from a long and rather dismal history, marked at first by poor management, and more recently by a tight budget that has necessitated "terminations" and "reductions" in preparatory work.

The LOFT project has limped along under these circumstances since its inception in 1963. By the time its consummate experiments get under way in 1974 or 1975, it will have consumed more time from start to finish than the Apollo program took to land two men on the moon. "It went along for years with conflicting changes in intent and direction," one high-ranking AEC official said. "Project management in the early 1960's just wasn't that good. With better management it could have gone faster."

How much faster is suggested by the tables that the Joint Committee published in the record of its authorization hearings for fiscal 1971. Begun officially in September 1964, LOFT construction was supposed to have been finished in late 1967, at a cost of $19.4 million. But having since been expanded and upgraded to become the "focal point" of the water reactor safety program, LOFT equipment is not scheduled to begin debugging operations until mid-1972, at a final construction cost of $35 million.

Nor was this pattern of delay and overrun unusual for major test facilities at Idaho in the 1960's. The Advanced Test Reactor (ATR), billed as the world's most powerful reactor for testing nuclear fuels and core materials, suffered a 3½-year delay and a $17.7 million cost overrun that pushed its price to $57.7 million. The ATR finally achieved full-power operation on Christmas Day 1969, but only after "rather severe" construction flaws had required dismantling and rebuilding it. Still another major test reactor at the Idaho site, the Power Burst Facility (PBF), is expected to begin running this year, 4 years late and $6 million, or 70 percent, over its original cost estimate.

The AEC now blames many of these difficulties on the Phillips Petroleum Company's management of safety program operations during the 1960's. In 1969, the commission shifted responsibility for the program to Idaho Nuclear, a composite of Allied Chemical Corporation and Aerojet-General Corporation. Phillips then joined as a minor partner with no managerial responsibilities. "For one reason or another, we were unable to get the LOFT and PBF projects done," Shaw has said. "Phillips as a parent organization did not have that [necessary] kind of power or test reactor design and construction experience, and they were unable to recruit the kind of talent necessary to get the job done right."

LOFT and other projects are said to be moving along "tolerably well" now, but the Idaho site's management ills were cured just as the safety research budget began a slow downward slide. Over a period of several years, expenditures for safety had crept up to a $37 million peak in fiscal 1970, then dipped to $36 million in 1971. As available money declined and inflation rose, a growing new emphasis on breeder reactor safety studies accelerated, thereby putting still more financial pressure on the full range of conventional reactor work, including LOFT and such elements of its supporting research as the semiscale experiments. "My problem," Shaw said recently, "was that I was going to have to phase out some of this work in fiscal 1972 unless we got more money."

The LOFT project won a reprieve of sorts in June, when the Joint Committee approved the AEC's request for $2 million in supplemental safety funds. The emergency core-cooling flap weighed heavily on that decision, and therefore probably benefited the LOFT project as much as it did the safety of the public. (The committee also gave its blessing to the $4 million that President Nixon requested in his June energy message for breeder reactor safety.) But, as Kavanagh had told the committee a month earlier, "I think we could use $30 million or $40 million [more]. . . ."

Certainly LOFT's financial problems have not been unique. To accommodate a smaller budget in 1971, the AEC closed down a small test reactor, the Capsule Driver Core, at Idaho and sacrificed a nonnuclear facility, the Containment Systems Experiment (CSE), at its Pacific Northwest Laboratory in Washington. Both were "producing rather important safety information," Shaw said last year, noting that "These are not facilities we would prefer to have closed down." By mothballing the CSE, for example, the AEC cut short a series of experiments to investigate the behavior of reactors during sudden losses of coolant. It also passed up an opportunity to test the performance of emergency core-cooling systems on a far larger and more realistic scale than it could in the miniature LOFT experiments. "The potential was there, and it could still be done," according to Andrew J. Pressesky, the assistant director for nuclear safety.

Quality Control Impeded

In addition to these closures in fiscal 1971, the safety program sustained "general reductions, terminations, and delays in the initiation and progress" of a variety of projects, officials have said. Of these stringencies, the one that is hardest to justify, in Pressesky's view, was a reduction in support of a cooperative program between the AEC and industry to develop manufacturing standards for the pumps, pipes, and valves used in nuclear reactors. These standards are regarded as the backbone of quality assurance in reactor manufacturing, and in large part their development is the means by which safety research is translated into engineering practice.

Laxity in quality control was, to a major extent, responsible for costly delays in construction and interruptions in operation experienced by numerous atomic power plants during the 1960's. Faulty plumbing and welding still plague the nuclear industry, although to a lesser degree now. But AEC officials, such as commissioner James T. Ramey, are still pressing for improved standards. "Despite the progress that has been made," Ramey told the Joint Committee in June, "even higher priorities and more manpower must be

applied to standards development." Despite such appeals, money for the standards program has declined by about 40 percent since 1970.

Privately, a number of AEC officials blame the safety program's erosion on an insensitive Office of Management and Budget. As one man deeply involved in AEC safety affairs expresses it, "The OMB holds a somewhat simplistic view. Since the AEC has cut back its development work on water reactors, it asks 'why all this talk about more safety research.'" In an apparent campaign to explain why, a variety of safety advisory groups issued a flurry of admonishments in 1969 to the effect that money ought to be going up, not down. In June of that year, an internal AEC study group warned that "The large number of construction permits for . . . power reactors which have been issued in the last several years does not imply there is a decreasing need for water reactor safety research. Rather, because these construction permits were issued on the basis that planned programs would resolve certain safety questions related to these reactors . . . there is an increasing need for safety research." Another internal AEC study in October 1969 urged "a vigorous safety R & D program" and went on to say that "Major efforts are still required to resolve issues currently facing both reactor suppliers and those charged with safety assessment for the surge of light water power reactors announced in the 1965–68 period." In a 12 November 1969 letter to AEC chairman Glenn T. Seaborg, a similar appeal was made by the Advisory Committee on Reactor Safeguards, when it complained that "only small or modest efforts" had been initiated in several key areas of safety and that "many safety research activities have not been initiated, have been slowed, or have been terminated." The letter said that the committee "reiterates its belief in the urgent need for additional research and development" in such areas as seismic safety and the safety of ordinary water-cooled reactors.

All these admonitions seem to have had little mitigating effect on the OMB's axe hand. It is true that over the past 2 years the OMB has been no more sanguinary than the commissioners themselves in cutting the requests of safety program administrators. Each sliced about $7 million from the $49 million lower-echelon request for 1972. On the other hand, the budget office allowed the AEC to ask Congress for only 40 percent of the supplemental safety funds the commission wanted last May, thus leaving about $3 million worth of high-priority projects unfunded.

It appears, however, that the OMB's fiscal pressure on the program is motivated less by malice or insensitivity than by a desire to force more of the burden of nuclear safety studies onto the nuclear industry. It also appears that AEC earnestly shares this desire. But it has so far achieved only modest success in buttonholing support from reactor manufacturers, who are said to be convinced that they are already selling a safe product, or from the electric utility industry, which is chiefly interested in buying a safe product and has notoriously little inclination toward research in the first place. As things stand, the nuclear industry continues to enjoy a kind of technological welfare that must seem lavish to aerospace corporations.

But from all of this, can one conclude that the safety of atomic power plants has been compromised? Senator

AAAS Names Five to Freedom Panel

The Board of Directors of the AAAS announced on 1 July the appointment of five members, including former Chief Justice of the Supreme Court Earl Warren, to form the association's new Committee on Scientific Freedom and Responsibility. The committee, which the board had formally established last December, was asked to (i) study and report on the general conditions required for scientific freedom and responsibility; (ii) develop suitable criteria and procedures for the objective and impartial study of these problems; and (iii) recommend mechanisms to enable the association to review specific instances in which scientific freedom is alleged to have been abridged or otherwise endangered, or responsible scientific conduct is alleged to have been violated.

Committee members are Chief Justice Warren, Allen V. Astin, former director of the National Bureau of Standards, Mary Catherine Bateson, associate professor of sociology and anthropology at Northeastern University, Walter J. Hickel, former Secretary of the Interior, and John H. Knowles, director of the Massachusetts General Hospital in Boston.

Athelstan Spilhaus, chairman of the AAAS board, explained the 6-month hiatus between establishment of the committee and appointment of its members by saying that it took that long to find public figures "who are of such stature that they would make clear the seriousness of the Association's purpose." AAAS officials also noted that the five members, by and large, have been personally involved in great public conflicts of free expression and responsibility to institutions.

Last December's decision to establish the committee was made partly in response to a request from Senators Edmond Muskie (D-Maine) and Mike Gravel (D-Alaska) to investigate charges that the Atomic Energy Commission had harrassed two dissident scientists, John Gofman and Arthur Tamplin. Officials of the AAAS say that Gofman and Tamplin themselves communicated no such request to the association. However, several other scientists who alleged that their own scientific freedom was in jeopardy have turned directly to the association for help in recent years. These appeals are said to have been an important stimulus in creating the new committee.

"Although very concerned about charges involving abridgment of scientific freedom," Spilhaus said, "the AAAS has lacked a mechanism for considering such questions." He emphasized, however, that it was not the committee's purpose to adjudicate individual cases. Although it may choose to review the Gofman-Tamplin imbroglio, it is not being specifically asked to do so. Its larger purpose, he said, is to suggest guidelines for handling such cases in a way which preserves individual freedom while protecting institutions from "irresponsible individual behavior." The board has not suggested a time or place for the committee's initial meeting, nor has it proposed a timetable for the panel's deliberations.—R.G.

Mike Gravel (D–Alaska), who has become a vocal foe of nuclear power, seems to think so. In a speech to the Oregon State Legislature not long ago he urged that every state "stop all construction of nuclear power plants until the safety problems are resolved and until we achieve the safety-first policies to which we are entitled." Last May, voters in Eugene, Oregon, approved a 4-year moratorium on a nuclear power facility planned for their area. Similar movements are afoot in the Oregon legislature, in Minnesota, in New York City, and in California where a citizens' group has succeeded in placing on the June 1972 ballot a proposal to ban power reactor construction for 5 years.

AEC officials understandably find such activities unjustified. And so, it seems, do the most influential conservation organizations, which say they prefer to weigh the merits of atomic power plants on a site-by-site basis rather than putting up blanket opposition to nuclear power.

For their part, AEC officials say that conservatism in plant design and operation should compensate for any uncertainties that remain in the behavior of reactors.

One AEC authority in reactor safety, and a man who is less reserved in his criticism of the agency than most, sums it up this way:

"I believe that nothing in the water reactor safety program is of low priority. It should all be done. And until these tasks are completed we are going to have to use rather more conservative bases for design judgments on plants, and we are going to have to make decisions with a certain lesser degree of cheerfulness, or confidence, than if we had the results of this research.

"We think we can set boundary conditions, so no matter how a reactor goes we are quite sure it's safe. But I find having to work this way intellectually less satisfying. . . . I prefer to *know*, in a quantifiable way, what the limits of safety are.

"However, I think we're in good shape, and that in the long pull, when we look back, we may see we spent money unnecessarily. At least that's what I trust we'll see."

—ROBERT GILLETTE

Lead Poisoning: Zoo Animals May Be the First Victims

New York. Death and illness as a result of simply breathing polluted urban air is a specter of the future that only the more alarmist environmentalists conjure up from time to time. Nevertheless, researchers at New York Medical College (NYMC) have discovered that a large proportion of the animals at Staten Island Zoo suffer from lead poisoning. And while some of the lead in the animals' bodies may have come from paint in their cages, the major source appears to be atmospheric contamination. In the words of Ralph Strebel, the pathologist who directed the study, "The findings have ominous implications for the people who live in that area of the city."

The first indication of trouble at the zoo came last November, when an 11-month-old leopard became weak, started losing its hair, and refused to eat. The cat was taken to New York Medical College, where sick animals from the city's five zoos are treated under the comparative pathology program. Although Strebel and his colleagues could find no evidence of disease, the leopard died 24 hours later.

Three weeks later, zoo keepers found the leopard's fraternal twin, a black leopard (formerly known as a black panther) named Mr. Leo Pard, lying paralyzed in his cage; he too was taken uptown to the medical school. Again there was no evidence of any known disease. But in response to symptomatic treatment, Mr. Leo Pard survived and regained his muscular coordination. At this point, Dennis Craston, a toxicologist from the city's Medical Examiner's Office and an instructor at the medical college, tested Mr. Leo Pard for heavy metal poisoning and found extremely high levels of both lead and zinc in the animal's hair, blood, and feces. A check of the first leopard's preserved organs also revealed high concentrations of the same two metals.

After 6 weeks of intensive treatment at the hospital's animal facility, Mr. Leo Pard was well enough to return home to the Staten Island Zoo. But once there, the level of lead in his body again began to rise. After he went into convulsions, he was taken back to the hospital, where he is still recuperating.

On the basis of their experience with the two leopards, the NYMC researchers decided to check other animals in the zoo for lead poisoning. They found not only that other animals had high concentrations of lead in their bodies, but that the victims ranged from reptiles to primates.

For some time, snakes at the zoo had been dying after having lost sufficient muscular coordination to slither properly. Sure enough, chemical analysis of the preserved carcasses revealed high concentrations of lead. Hair clippings, along with blood and fecal samples, from a variety of cats and primates showed many of the animals to be contaminated with lead—often in amounts far exceeding the level considered toxic in man. Even a great horned owl, brought to NYMC because it had lost its feathers, was found to be a victim of lead poisoning.

Searching for the source of the contamination, the NYMC investigators first tested the zoo's water, food, and bedding and found them all to be free of heavy metals. An analysis of the paints used in some of the cages, however, revealed that 11 out of 16 paints contained lead in concentrations ranging from 0.01 to 3 percent. This finding is significant in itself, according to Craston, because all of the paints are marketed as lead-free interior paints.

But perhaps even more significant were the levels of lead found outside the cages. Grass, leaves, and soil collected on the zoo grounds contained lead in quantities as high as 3900 micrograms per milligram dry weight—an amount equal to or exceeding that found along the sides of major highways, where automobiles continually spew out lead-containing exhausts. "We can only conclude," said Strebel, "that most of the lead taken in by the animals resulted from atmospheric fallout."

Significantly, the animals kept in outdoor cages, including those in cages