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U.S. NUCLEAR REG. COMM.
ADVISORY COMMITTEE ON
REACTOR SAFEGUARDS

April 1 1980

Dr. Milton S Plesset
Chairman ACRS

Following our conversation last week and in accordance with your suggestion, I have given some thought to the comparative suitability of the several LWRs for electric power generation. This has turned out to be a useful exercise.

According to my tally the cancellations and new orders for LWRs, over the last seven years, add up to a net deficit of approximately fifty units. This hiatus is bound to have a serious effect on the availability of new plants. At some point there will be a demand for additional units, and it is worthwhile that we consider what these will look like.

Next month the Institute for Energy Analysis will sponsor a workshop to be attended by a dozen or so old timers, mostly retired, to consider the form and characteristics of

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the optimum nuclear unit for the next generation of power plants. It will be possible to take advantage of the present lull to consider what has been learned to date. One concern has been voiced that by the time new orders are placed, the need for additional capacity will be so urgent that the utilities will accept anything that is available. Another view has it that our design teams will have been dismantled, as has already occurred at the National Laboratories, and that we will be unable to produce a new concept. These considerations are arguments that we should establish, without delay, a program looking to the next generation of nuclear plants.

My principle interest in the suitability of a given concept is in regard to controlability. As an example, the submarine reactor employed the fully enriched fuel which was available as a result of the weapons program, and which proved to have optimum control characteristics. The negative moderator coefficient of reactivity made it possible to change load rapidly as would be required for manoeuvering, and without the necessity for moving control rods. An increase in power extracted from the core would cause the moderator/coolant to be returned at a lower temperature which in turn, would increase reactivity and power level until the initial temperature had been attained. As a result, and without control rod movement, the power could go from 20% to 100% in ten seconds in response to the demand.

In 1958 it was elected to use partially enriched oxide fuel for the merchant ship Savannah, and some control problems emerged. The partially enriched fuel brought with it a doppler coefficient of reactivity, which appeared in the form of a power coefficient. Now an increase in power would cause an increase in fuel temperature and a decrease in reactivity. The reactivity loss would be exactly offset by the lower moderator temperature which would stabilize at a lower value. This change in bulk temperature would result in a volumetric change that would appear as a change in pressurizer level. As a result, the plant would load-follow, but it would be necessary to move control rods to maintain a constant pressurizer level. This PWR although not optimum for maritime application requiring rapid load changes, is however admirably suited to stationary power plant operation supplying ba: load.

The BWR on the other hand, has control characteristics that are not optimum for electric power generation. By being connected to the utility grid, the plant is subjected to abrupt loss of load. Unlike the PWR which is decoupled from the grid by virtue of the steam generator which stands between the reactor and the turbine, the BWR moderator is circulated through the turbine in the form of steam. A sudden loss of load would require instantaneous closure of the turbine valve to protect the turbine from overspeeding. This, in turn would impose a pressure transient on the boiling voids that are controlling reactor power. The abrupt collapse of these voids would cause reactor power to reach a peak of 300 to 500% power in less than a second. This brings about the ATWS problem wherein the reactor is routinely subjected to transients where the failure of the Reactor Shutdown System, a single line of defense, would be intolerable.

Again, by circulating the moderator through the turbine, outside containment, it becomes necessary to effect containment by closing the MSIV. This again would subject the reactor to a severe power transient, this time to protect the containment, whereas before it was to protect the turbine. This could be quite unhandy if a local flow blockage were to cause fuel damage. A release of fission products could cause MSIV closure and again subject the core, and the damaged fuel, to a severe power transient. Should control rod insertion be impeded by the damaged fuel, the situation would be worsened.

To accomodate the collection of steam at the top of the core, it is necessary that the control rod drives be located beneath the core. The rods are withdrawn downward to increase reactivity and scram upwards against gravity. Gravity never sleeps and as expected troubles have been encountered. Should a rod become uncoupled from its drive, as has happened repeatedly, and become fully inserted while its drive is fully withdrawn, the rod could then become unstuck and fall at an uncontrolled rate completely out of the core.

In the worst case, the central rod of a freshly loaded core, if alone were to be withdrawn, this single rod would increase reactivity by 4% Δk/k. Inasmuch as the average worth of a single rod is 0.1% Δk/k, this represents a rod worth multiplication of a factor of 40 as a result of the unsymmetrical configuration. It has been determined that during start up and low power operation up to 20% power, numerous rod configurations would make it possible for a single rod, in dropping, to cause vaporization of fuel. As a result of this concern, rod withdrawal sequence patterns have been established which are rigidly enforced by a dedicated computer, the Rod Worth Minimizer, or by hard wired sequencing circuits. These have worked poorly and to recover from a scram it is necessary to check out these devices and then regain criticality by withdrawing a hundred or more rods, one at a time.

This has resulted in excessively long restart times, often up to twelve hours to regain criticality. This in turn has brought about still another problem. The excessively long delay following a scram is just right to allow 135 Xe to maximize, with the result that the reactivity configuration of the core is altered. The rigidly enforced rod withdrawal sequence is now innappropriate and as a result the withdrawal of a single rod by a single notch has resulted in periods shorter than 10 seconds, causing scram and another 12 hours delay.

The defense, of questionable effectiveness, against this relatively improbable event has resulted in a serious impairment of availability which could in turn become a safety problem. Regional blackouts, such as have occurred at New York, can be again expected. Should a blackout occur in a region powered by several BWRs, it would be a matter of concern that these units would be unavailable for a period of up to twelve hours, while being cooled, in the absense of off site power, by unreliable deisels.

In considering the next generation of nuclear plants it would appear that the BWR would be more suited to application to a process where it would not be subjected to sudden loss of load and where it would not be necessary to circulate the moderator outside containment. From the viewpoint of reactor control, the BWR has encountered problems that, after years of effort, remain unresolved. It would be inappropriate however, to judge the suitability of the BWR for electric power generation on the basis of this single argument. It could in fact be said that the existing BWR design would fare better in a situation such as at TMI because the single primary system would be more accessible for cooling. The PWR steam generator, while advantageous in decoupling the reactor from the utility grid, makes it necessary that both the primary and secondary systems be operable in order to remove residual heat.

Again, it would be inappropriate to make a judgement on the basis of this factor alone, inasmuch as both the PWR and BWR would be in serious difficulty in a situation such as the Browns Ferry fire. This single event should make it quite clear that a dedicated system to effect reactor shutdown is not sufficient. After shutdown residual heat must be removed over a long term by the use of systems which, unlike the Reactor Shutdown System which needs only to respond momentarily must continue to be operable. It should not be required of the operator that he use for this purpose the plant systems, which by their failure or malfunction had been the cause of reactor shutdown. For residual heat removal, a dedicated and protected system is needed, as much as for reactor shutdown. Events such as TMI and the Browns Ferry fire are not to be tolerated at 200 reactor year intervals where the operators' struggles, even if always ultimately successful, become media events, invite the evacuation of populations, and destroy public confidence.

In addition to the above considerations, the next generation of nuclear plants will not be able to enjoy the luxury of operating at constant base load, but will need to load-follow, in order that plants now capable of load-following and which consume expensive fuel, can be taken off line.

Today the CRBR team is about the only reactor development team remaining, and the President is determined to dismantle it. It is not additional research that is now needed, so much as the establishment of an experienced team. The knowledge gained through research lives on, but a design team, once dismantled, is gone forever.

E. P. Epler