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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

April 13, 1979

MEMORANDUM FOR: Chairman Hendrie
Commissioner Gilinsky
Commissioner Kennedy
Commissioner Bradford
Commissioner Ahearne

FROM: Al Kenneke, Acting Director, OPE Dennis Rathbun for

SUBJECT: ANSWERS TO COMMISSIONER AHEARNE'S QUESTIONS: RE FIVE REACTOR SHUTDOWN

Attached are the answers to questions posed in Commissioner Ahearne's memorandum of March 14.

Progress in re-analysis work being done by Stone and Webster (S&W) for the licensee has been much slower than the schedule shown in that memo. Highlights of efforts to date are:

-- The licensees' initial analytical efforts have adhered closely to a narrow interpretation of the Commission's Show Cause Order; i.e. re-analysis using SHOCK 3 or NUPIPE of the specific safety-related piping systems originally run on SHOCK 2. The analytical work is aimed at determining whether or not the pipe stresses and restraints are within code-allowable levels.

-- Where stresses exceeding allowable are encountered, the licensees perform additional detailed analyses rather than commit themselves to any hardware changes. (More apparently is involved than costs of hardware changes per se. They are apparently concerned that the design changes for new hardware would constitute a plant modification which would require a hearing before re-start -- i.e. lengthening of the shutdown.)

-- Substantial effort by S&W and the licensees has gone to verifying that computer input data accurately represents the piping configurations as shown on the engineering drawings.

-- Code verification efforts of the NUPIPE and SHOCK 3 programs by the NRC staff has been underway for several weeks. Among other things, this involves running several benchmark problems (done for NRC using EPIPE at Brookhaven) at S&W using their codes. This work should be done by the end of next week (around 4/20).

CONTACT:
Dennis Rathbun (OPE)
634-3295

-- Although the licensees have pressed hard on what results would be acceptable, NRR's position has been (and continues to be) that the licensees bear the responsibility of proving to the NRC staff the validity of whatever analytical and/or technical fixes they may wish to propose.

-- Neither the licensees nor the NRC staff are examining the broader risk -- cost/benefit question, i.e. analyzing in detail the risks of interim operation taking into acount both the probability and consequences of seismic events weighed against economics and other costs associated with continued shutdown. This is at least in part attributable to the extreme difficult of predicting the actual consequences of severe seismic events.

It appears that there is little that the Commission could do to expedite the process should it choose to -- since the pacing item is essentially determined by the rate of re-analysis of the piping systems by S&W in Boston. According to the licensees' recent submissions, there are over 200 computer reruns involved (there could be more if NRC staff reviews flag additional safety related piping systems). Most of the mechanical operations in re-running the programs are probably done now. However, S&W engineers must review each run in detail; the analyses are also reviewed by the licensees before submission to the NRC staff. At this point, the NRC staff has received and is nearing completion of its reviews for five piping systems packages (those for Maine Yankee). Assuming no major problems in staff reviews, no hearings prior to startup, and no hardware changes (truly "best case"), the following might be the startup schedule:

| | |
|---|---|
| Maine Yankee | -- end of April |
| Beaver Valley | -- mid/late May |
| Surry | -- late May/early June |
| Fitzpatrick | -- late May/early June |

We understand that the NRC staff should be ready to discuss results to date (particularly for Maine Yankee) in a briefing next Friday (4/20). As a contingency that the rough estimates of startup turn out to be overly optimistic, the Commission may wish to discuss two possibilities with the staff at next Friday's meeting:

-- Whether there might be a point in the weeks ahead where staff confidence (based upon (a) results of the code verification work now in progress and (b) completion of a greater number of reviews) might justify recommending interim operation pending completion of the re-analysis efforts.

-- Whether site specific seismic work to estimate earthquake probabilities would be of utility for any of the plants. (Note: In particular, PASNY contends in its March 30 submission that the Fitzpatrick site is "... generally considered seismically inactive," but we understand that the licensee is not now pursuing technical analyses to support this position. This would not necessarily be easy for either the licensees or the staff to do in a short time since we understand significant detailed on-site geotechnical work would be required -- and for this reason not much may be gained from pursuing this course.)

OGC prepared the answers to questions four and five, in which ELD concurs.

Enclosures:
As stated

cc: Leonard Bickwit
Sam Chilk

1. What will be the impact on each region of this shutdown? The analysis should estimate the length of time the plants will be shutdown to make the fix, if we require the plants be brought back to the original specification; the cost of doing that, both to repair and to purchase replacement power; the impact upon reserve margins in each region; and the increased use of oil. To the extent possible, this impact estimate should include from where the oil would come. In order to prepare this section, OPE should work with NRR and the Economic Regulatory Administration of DOE.

Status

For current plant-specific status report, see answers in question 3.

Estimated Earliest Start-up

Regional impact data are tabulated below. The impacts are expressed in terms of economic costs, oil consumption and reserve margins Also, to give some idea of the time when the adverse impacts would end for the individual plants, estimated startup dates are provided. These estimates are little more than educated guesses based upon the state of progress by the licensees and Stone and Webster in re-analysis with SHOCK 3 or NUPIPE and allowing a period of time for NRC staff review. (This also assumes no major problems in staff reviews, no hearings before startup, and no hardware fixes -- which essentially is "best case.")

Regional Impacts

Information obtained from the NRR's contact with the individual utilities as well as DOE's Economic Regulatory Agency (ERA) is shown for each plant. While some regions such as Central Area Power Coordination Council (CAPCO) may be able to make up energy using coal-fired generation from within the region, ERA's belief is that the total will, in all cases, show up as additional oil consumption for the nation as a whole. This is because reliance on coal within a region will result in less coal-based generation being available for dispatch to other regions -- which will be forced to make up with oil (i.e. apparently ERA assumes that coal-based generation within the U.S. is both fixed and currently fully utilized). ERA believes that the sources for additional oil consumption are either draw-down of domestic oil inventory or imports as available.

- Maine Yankee: earliest start-up around end of April
  - -- Yankee Atomic reports that replacement power is supplied by burning oil costing about 27 mills/kWh compared to nuclear fuel cost of about 3.3 mills/kWh. At a net capacity rating of 830 MWe and a monthly capacity factor of 95 percent, the additional cost of burning oil instead of nuclear fuel is about $450,000 per day.
  - -- Assessment from Economic Regulatory Administration (ERA): Energy make-up from oil-fired units within New England Power Pool (NEPOOL). Assuming 65 percent capacity factor, estimate 23,400 Bbl/day.
  - -- Reserve margins: the April 1, 1979 NEPOOL estimates for the summer, 1979 are:

| | |
|---|---|
| Capacity resources: | 21,164 MWe |
| Demand requirements: | 15,569 |
| Margin | 5,595 MWe |
| (scheduled outages) | 1,909 |
| Adjusted margin | 3,686 |
| (Maine Yankee) | 790 |

Margin without Maine Yankee 2,896 MWe

(Note: A loss-of-load probability estimate to account for unscheduled outage has not been performed for this or other regions potentially impacted by shutdowns.)

- Beaver Valley: earliest start-up probably mid to late-May (dependent on degree of complications in staff reviews arising through soil-structure interaction)

-- According to Duquesne, replacement power is supplied by burning coal or by purchasing power from other utilities; burning oil would be a last resort. Beaver Valley is owned by several utilities; Duquesne obtains 47.5 percent of the unit output. The cost to replace this energy is about $2.4 million/month for coal; $0.4 million/month for purchase power, and $0.25 million/month for increased costs of operation and maintenance (such as additional coal handling, ash disposal, and maintenance of coal-burning plants). Nuclear fuel cost to Duquesne is about $0.8 million/month (3.8 mills per kWh); the net cost of replacement power is about $2.25 million/month. The total cost of replacement power for Beaver Valley 1 is around $4.7 million/month or $160,000/day. (Based upon a 74 percent capacity factor.)

-- ERA Assessment: Energy make-up from purchased power from East Central Area Reliability Council (ECAR); and use of oil-fired units. Exact mix of coal and oil would vary from day to day. If shut-down extended into summer, energy make-up would come exclusively from oil. Oil equivalent is 23,400 Bbl/day.

-- Reserve margins: The April 1, 1979 report of the East Central Area Reliability Council shows the following data for the CAPCO plants:

| | |
|---|---|
| Capacity resources | 15,147 MWe |
| Demand requirements | 11,451 |
| Reserve margin | 3,696 MWe |
| (Beaver Valley) | 852 |
| Margin without Beaver Valley | 2,844 MWe |

- Surry: earliest start-up late May/early June (dependent upon degree of complication in staff review due to analysis using soil/structure interaction)

-- VEPCO indicates that replacement power is supplied by burning 30,000 Bbl/day of oil (assuming 100 percent capacity factor) for one Surry unit. Oil cost is expected to be $15 to $18 per Bbl. -- latter is more likely. The net cost of replacement power is then about $450,000/day; or roughly $340,000/day at a 75 percent capacity factor. The cost of additional O&M activities are not expected to be substantial, although there are some costs associated with shutting down and re-starting the reactors.

-- ERA Assessment: Energy make-up within the region from oil-fired units with VEPCO purchase power (oil-fired) from Pennsylvania-Jersey-Maryland (PJM); purchased power (coal-fired) from ECAR; and/or purchase power (coal-fired) from TVA. Oil equivalent per Surry unit is 22,100 Bbl/day at 65 percent capacity factor.

-- Reserve margins: The April 1, 1979 report of the Southeastern Electric Reliability Council shows the following data for the Virginia-Carolinas Subregion (VACAR):

| | |
|---|---|
| Capacity resources | 36,003 MWe |
| Demand requirements | 28,182 |
| Margin | 7,821 |
| (scheduled outages) | 1,104 |
| Adjusted margin | 6,717 MWe |
| (Surry 1 and 2) | 1,576 |
| Reserve without Surry 1 and 2* | 5,141 MWe |

- Fitzpatrick: probably down until late May/early June (although incomplete information on state of progress in re-analysis)

  -- According to PASNY, replacement power is supplied by burning 32,000 Bbl/day of oil at about $16/Bbl or $512,000/day. The cost of nuclear fuel not consumed is 4 mills/kWh or $77,000/day. The resultant net cost of replacement power is around $435,000/day at a capacity factor of 100 percent. Operating reports to NRC give capacity factors of 72 percent for January, 1979 and 91 percent for February, 1979.

  -- ERA Assessment: Energy make-up from oil-fired units within PASNY. Assuming 65 percent capacity factor, estimate 22,750 Bbl/day -- sources are draw-down of domestic oil stocks or imports as available.

*Note: OPE understands that North Anna 1 should be up for August peak; but North Anna 2 (907 MWe) may not -- in which case the VACAR reserve would be 4,234 MWe.

-- Reserve margins: The April 1, 1979 New York Power Pool estimates for the summer, 1979 are:

| | |
|---|---|
| Capacity resources | 30,410 MWe |
| Demand requirements | 21,450 |
| Margin | 8,960 MWe |
| (scheduled outages) | 1,500 |
| Adjusted margin | 7,460 MWe |
| (Fitzpatrick) | 821 |
| Reserve without Fitzpatrick | 6,639 MWe |

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2. What degree of relaxation from our standards might be allowable, based either on NRR's best judgment or previous compromises? This should be by particular plant, based upon the likelihood of earthquakes in the region, and should also include an assessment of conservatism embodied in the new code being used by Stone and Webster (which apparently does not incorporate the time history but merely takes peak values of all shocks).

Relaxation of Standards

NRR is not proposing to reduce the margins of safety on which basis the plants were originally reviewed and licensed. However, staff has indicated to licensees that they may use as an approach an amplified response spectra (ARS) employing the new technique of soil/structure interaction; but, then licensees must do a comparative analysis including other current practices: notably use of response spectra and damping values specified in Reg. Guides 1.60 and 1.61.

Earthquake

Both the earthquake recurrence interval and its consequences need to be defined in making an overall risk assessment. NRC's seismologists judge that the recurrence interval for operating basic earthquakes (OBE) in the eastern U.S. is generally every 200 to 400 years per site -- they have not studied detailed differences in recurrence intervals for OBE's at these individual plants.

Under the Commission's show cause order, however, the focus of efforts by Stone and Webster and the licensees has been on re-running the piping analyses using acceptable methods.

Conservatism

The licensees are proposing to the NRC staff that they meet the design criteria established in their respective FSAR's. In instances where the re-analysis using acceptable methods (i.e., SHOCK 3, NUPIPE, etc.) yield stresses over code allowable, the licensee may employ more sophisticated analytical approaches and/or current design criteria -- with particular emphasis on known sources of conservatism in seismic design. Some possibilities which might be considered by the licensees are:

-- Soil/structure interaction: a possibility for plants built on a thick soil layer (i.e. Surry units and Beaver Valley). Use would potentially reduce the estimated floor response spectra which drive (that is to say, are input to) the calculation of stresses.

-- Time history response: a possibility which could result in lower calculated stresses by assuming time histories for forces and not assuming a worst case combination (e.g. simulatenous occurrence of peak forces).

See attached discussion of conservatisms in seismic design (taken from Denton's Congressional testimony of March 21, 1979 before the Subcommittee on Energy and Water Development).

## General Description of Seismic Design Requirements

The seismic design of nuclear power plants involves two principal considerations: (1) the definition of the seismic effects to be designed against, in terms of intensity and characteristics of shaking, and (2) the design of structures, systems and components to resist the defined seismic shaking.

The definition of seismic risk involves consideration of the geologic features of the plant site, observed ground motions related to these geologic features, and observed structural response to earthquakes. The information available from historic records, measurements recorded in more recent years, insights that can be gained from analyses, and damage assessments following earthquakes have been synthesized to arrive at the engineering methods used to define the seismic hazards for nuclear power plants, dams and other public structures.

The seismic input, once defined, is used in a mathematical process to determine how the structure would vibrate in response to the seismic shaking. Through this process very complex natural phenomena and the responses of complex structures and equipment are idealized so that common principles of applied mechanics and mathematics can be employed to determine the response of each of the major portions of the structures and equipment.

To compensate for these idealizations, the engineering practice involved in seismic design for nuclear power plants generally incorporates conservative design considerations at various stages in the analytical process. This process proceeds from the specification of a design earthquake that is severe enough to exceed any likely possibility of occurrence during the lifetime of the facility, though a combination of conservative assumptions at many points in the design. The final design resulting from compounding of the individual conservatisms of the various steps is therefore judged to be conservative.

Once the maximum peak acceleration level is chosen for the design earthquake, conservatisms are provided in the definition of other seismic input parameters, such as the definition of wide band response spectra and the use of synthetic artificial time histories which envelop the response spectra.

Conservatisms are also provided in the seismic analysis and design for structures, systems and components in the following areas:

(1) Elastic-dynamic analyses are performed using conservatively low damping values in either a time-history or a response spectrum method of analysis.

(2) Soil-structure interaction which can have a significant effect on reducing seismic response is conservatively considered. The behavior of the subgrade area during seismic excitation is represented in a soil-structure interaction model. As an example of such conservatism, in both Beaver Valley 1 and Surry 1 & 2, the subgrade area was

modeled using a half-space lumped mass and spring system with damping values limited to no more than 5 to 10% of critical damping; whereas, soil-structure interaction studies have shown that actual subgrade damping can be as high as 30 to 50% of critical damping.

(3) Three input components of an earthquake (two horizontal and one vertical) are considered with both of the horizontal components considered to be of the same intensity.

(4) For cases where piping materials are subjected to small excursions into the inelastic range the dynamic response is reduced as a function of the amount of inelastic action. This can be represented by a ductility factor which is 1.0 for purely elastic behavior and increases with increasing inelastic behavior. A ductility of up to 1.5 can be assumed for vital piping. This would have the effect of reducing accelerations of elastically calculated response spectra by as much as 1/3.

In the design of structues and equipment, it is convenient to assure that all elements of the structure or equipment are designed to stress levels well below the actual strength of the materials so that any permanent deformation is small. This approach eliminates the need for complex and costly inelastic analyses. Actually, from the standpoint of functionability, major structures and components in nuclear plants, as well as other industrial equipment, can tolerate deformation and usually even the failure of some structural members. This deformation and loss of structural members can be sustained because of redundancy; i.e., there is more than one path available to carry loads, and load sharing results so that the load formerly carried by a failed member is redistributed to other members.

(5) Stress limits, whether elastic or inelastic, are based upon material behavior under static loading conditions. Since dynamic loads contain a limited amount of energy, the margin (between the stress limits and failure) under dynamic loading is greater than under static loading, if elastically calculated peak response is compared with the stress limits and strain-rate effects are neglected.

(6) The design of the structural elements is such that the capacity usually exceeds the requirements called for by the analyses. Much of the actual structural design is controlled by the availability of standard structural members such as beams and piping sections, so that larger sizes than those prescribed by the analyses are often used.

(7) Engineering codes specify "code minimum strength" for materials.

These code minimum strengths are in turn specified by the applicant when the materials are ordered; any material found to be under that strength is rejected. The result is that the material supplier, in order to assure that he stands no risk of having costly material returned, provides material of higher strength than specified.

Additional conservatisms for equipment and piping can be found in the following areas:

(1) When the floor response spectra are developed for the design of components located at different locations in the structure. the peaks in the individual floor response spectra are broadened in order to yield responses that account for uncertainties.

(2) Where the system has multiple supports, the staff requires that the maximum response spectra be applied to all support points to account for uncertainty in the seismic loads.

(3) In calculating the seismic loads for these components, the damping values are applied several times (first, to major structures, then to the intermediate structures and finally to the equipment itself). The multiple application of these low damping values compounds the conservatism in the seismic response for which the equipment is designed or tested.

(4) Even identically designed redundant systems may not always experience identical seismic excitation becuase they are mounted in different locations in the structure, with different structural filtering effects. Thus the loss of one system may not mean a loss of function if the other redundant system remains intact.

(5) For simplicity of calculating, assumptions of rigid boundaries are made in many places (e.g. at nozzles, restraints and snubbers). Consideration of the actual flexibility of the boundaries would tend to reduce the calculated loads.

The end result of applying these conservatisms is that structures and components have seismic capability in excess of the established design goal. There is normally no motivation to go back and assess the true as-built strength of various structures, systems and components, because the costs of reanalysis and time lost would swamp any reduction in building size or equipment capabilities that might be gained. The specific information necessary to quantify these conservatisms in the licensing process is therefore not usually developed.

By way of comparison, hospitals, schools, major apartment complexes, large structures that house many people, and essential facilities that have to be designed to resist extensive loss of life are designed to criteria that are, for the same earthquake exposure in terms of acceleration, from 8 to 20 times less conservative than those applied to a nuclear power plant, when the total design process is considered.

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3. Based upon the Stone and Webster calculations and the answer to No. 2, can modifications be done over an extended period of time, rather than all at once? For example, would it be reasonable to do most during routine maintenance or reloads and for some of the more immediately required, is it possible to do them during non-peak times? For example, over weekends?

Extent of Modifications

There is still no firm information on whether or not hardware modifications will be required for the individual plants. Rather, the licensees are continuing to devote substantial effort to re-analyze the affected piping systems -- in particular, with a view towards demonstrating to the NRC staff that the plants are adequate as currently designed and built. The first level of re-analysis is that which was specified in Step (1) of the order (i.e. re-run on SHOCK 3 or NUPIPE); before committing to hardware modifications, licensees will go to a second level of analysis (as a fall-back) such as soil/structure interaction (for Beaver Valley and Surry). (Note: Based upon some past experiences for other plants, licensees have come to NRC and proposed "beefing up" piping supports rather than go back to do additional detailed analyses on piping systems. Concern that hardware changes would be a plant modification requiring a hearing -- and extended shutdown -- might be a driving factor in this regard.)

Status for Individual Plants

- Maine Yankee: Licensee indicates that an appropriate method has been used to re-analyze safety related piping systems which were initially done with SHOCK 2 (five analyses runs were involved -- the smallest number for any of the plants). The licensee's re-analysis shows that no modifications to the facility piping systems are necessary, and the licensee has requested that operation of Maine Yankee be permitted. The system analyses have been submitted to the staff and they have begun review of the Stone and Webster report; the review is now expected to be completed by next Friday's meeting (4/20). Assuming the licensee's re-analysis is acceptable to the NRC staff, restart of the plant should be end of April.

- Beaver Valley: Duquesne's response to the show cause order indicates that re-analysis of the piping systems is well along. Some 69 piping systems were identified which were analyzed using algebraic summation (i.e. SHOCK 2). Computer runs on SHOCK 3 should be completed now. Packages for the individual piping systems are to be submitted to NRC during April 10-24. Assuming at least several weeks for staff review (and no complicating problems arise in the course of the review), mid to late May might be an earliest startup date for this plant.

- Surry: VEPCO has indicated that 48 separate computer analyses are involved. Of these 37 analyses are required for safe shutdown systems originally done using SHOCK 2 and safe shutdown systems affected by valve weight change. These systems will receive priority treatment over other systems analyzed with SHOCK 2, but not required for safe shutdown. VEPCO plans to use soil/structure interaction concepts for piping runs which, in cases where re-analysis according to FSAR criteria, are found to be over-stressed. The staff is examining soil/structure interaction analytical methods used by VEPCO for the Surry 3 and 4 CP review. Dependent upon the time required for completion of the re-analysis, and the complications in staff reviews due to using soil/structure interaction, earliest startup date for Surry may be late May/early June.

- Fitzpatrick: The licensee estimates that there are 95 computer analyses that must be made which involve a number of piping systems. Also, the licensee indicates that the input data must be verified to insure that it accurately represents the piping configurations as shown on plant drawings. Only 14 computer runs had been made (as of 3/30 PASNY submission). PASNY has requested an immediate rescission of the Commission's order to shutdown the plant -- citing no undue risk to public health and safety due to continued operation, seismic inactivity in the region of the Fitzpatrick site, adverse impacts due to continued shutdown, and empirical evidence on the seismic performance of Japanese BWR's. Fitzpatrick seems to have the most to do -- and perhaps has made the least progress. A judgment for earliest startup date for this plant might be late May/early June (very uncertain).

4. Given the current regulations and Stone and Webster calculations, what legal flexibility does the Commission have to allow either continued operation or operation during peak periods (for example, can we require the plant to shut down during the Spring and the Fall but remain running during the summer and winter)? In developing this section, OPE should work with OGC and OELD.

The NRC has great latitude in setting a repair schedule if it should determine that the plants may operate without creating undue risks to the public health and safety, even though all necessary repairs have not been completed. The Commission could, for example, (a) order the repairs to be completed by a set date -- giving the licensee discretion when to shut down the plant for the repairs; (b) order the repairs to be made the next time a plant is shut down; or (c) order the repairs to commence immediately if necessary repairs can be made without shutting down the facility. Thus, the Commission could issue an order permitting operation of the reactors during periods of peak demand.

5. In light of the answers to question 4, what amount of flexibility can be used by the Commission in balacing in the public interest increased demand on oil and increased costs of power versus requirements for the Commission to assure public health and safety?

This question is addressed in some depth in an attachment to a memorandum OGC sent to the Commission on March 16, 1979, entitled "Economic and General Welfare Considerations Under the Atomic Energy Act." As shown in the memorandum, the answers to these questions are by no means clear. However, OGC and ELD concluded that the Commission's licensing and regulatory decisions under the Atomic Energy Act are to be based primarily upon considerations of matters of public health and safety and that the Commission has no authority or competence to consider broad economic factors, such as the increased demand for imported oil caused by shutdowms.

This does not, however, totally preclude consideration of economic factors in the regulatory process. Once minimum safety standards are established which adequately protect the public health and safety, we think that the Commission may reject on economic grounds additional safety measures if they have very high implementation costs, yet provide only marginal increments in safety.