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NUCLEAR REGULATORY COMMISSION

ORIGINAL

In the Matter of: ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE ON CLINCH RIVER BREEDER REACTOR

BRIEFING ON CLINCH RIVER BREEDER REACTOR

GEOLOGY AND SEISMOLOGY

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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BRIEFING ON CLINCH RIVER BREEDER REACTOR

GEOLOGY AND SEISMOLOGY

Nuclear Regulatory Commission
Room 1046
1717 H Street, N.W.
Washington, D.C.
Tuesday, June 1, 1982

The Subcommittee meeting convened at 8:40 a.m, pursuant to notice, M. Carbon, Chairman of the Subcommittee, presiding.

PRESENT FOR THE ACRS:

M. CARBON
J. MARK
H. ETHERINGTON
J. RAY

ACRS CONSULTANTS PRESENT:

W. KASTENBERG
P. POMEROY
Z. ZUDANS
W. LIPINSKI
M. TRIFUNAC

NUCLEAR REGULATORY COMMISSION STAFF MAKING PRESENTATIONS:

R. STARK
J. KNIGHT

DEPARTMENT OF ENERGY STAFF MAKING PRESENATIONS:

J. LONGENECKER

BURNS AND ROE, INC. STAFF MAKING PRESENTATIONS:

W.G. BRUSEY
A. DAJANI

WESTINGHOUSE STAFF MAKING PRESENTATIONS:

A. MORRONE
R. MALLETT
T. PITTERLE
G. KRAEUTER

DESIGNATED FEDERAL EMPLOYEE:

P. BOEHNERT

P R O C E E D I N G S

MR. CARBON: The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on the Clinch River Breeder Reactor. My name is Carbon. I am subcommittee chairman.

The other ACRS members present today are: Messrs. Etherington, Mark and Ray. And Mr. Mathis probably will be here, subject to the airlines, and perhaps Mr. Bender.

We also have in attendance ACRS consultants: Mr. Kastenberg, Mr. Lipinski, Mr. Pomery, Trifunac, and Zudans.

The purpose of this meeting is to discuss the seismicity and associated seismic design for CRBR. The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act and the Government in the Sunshine Act. Mr. Paul Boehnert is the Designated Federal Employee for this meeting.

The rules for participation in the meeting have been announced as part of the notice of this meeting previously published in the Federal Register on Friday, May 14, 1982. A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice. Everyone is requested to use a microphone when speaking. We have received no written statements or requests for time to make oral statements from members of the public.

Before calling on Mr. Stark, I would make one or two short comments and ask if you have any comments and/or questions.

I know the purpose of the meeting is fully announced and obvious and apparent. I would comment that we have allowed adequate time to really dig in as deeply as we wish and be sure we get answers to any questions you might have in your minds. Simply from the standpoint of time alone, I would suggest that you need not be particularly inhibited.

Do you have any questions or comments to make about the direction that we should take today?

(No response.)

MR. CARBON: I know that a fair amount of review is accomplished, three or four or five or six years ago, but a lot has changed since that time. And as far as I am concerned, we are starting pretty much from ground zero.

MR. MARK: I have a small comment in connection with your remark that we can be leisurely and take our time. We do have 45 minutes set down for lunch.

(Laughter.)

MR. CARBON: I had not noticed that.

Well, if there are no other questions or comments, we will proceed with the meeting and call on Mr. Stark of the NRC.

MR. STARK: Good morning. The Staff review in the seismic area is currently underway, and the results will be formally documented in our SER which is scheduled to be due next March.

However, the Staff and its consultants, USGS, are present today, and one of the items you will find on the agenda is a discussion of the Staff review status and the review plans. And Mr. Jim Knight, who is also here, will be giving that presentation later on. So unless there are any other items, I guess we are prepared to listen to the Applicant.

MR. MARK: Is the Staff already firm, however, on its estimates of seismicity and seismic input?

MR. STARK: For the most part. We are finalizing the site suitability report, and we are currently reviewing that, which looks at the site and the characteristics of the site. So we are farther along on that item than we are on analysis of seismic restraints of piping, where we have a lot more time to complete that.

Are there any other items?

(No response.)

MR. CARBON: I guess I am not clear there. Are you expecting to have the SSE from the Staff by the end of this month?

MR. STARK: What we are doing is making sure that the characteristics of that site are reasonably well known so that we feel that the site is not a mismatch in that respect. So we have a section that addresses seismic considerations in the site suitability report. It is a general discussion that looks at that particular site.

MR. CARBON: Will it say anything firm about your belief on the OBE in the SSE?

MR. STARK: I have to take a look. I have a copy of it right now that I am reviewing, and I can show it to you later on this morning, and its present status. I will look and see what the words are.

MR. CARBON: Sometime today we would welcome that.

MR. STARK: Okay.

MR. LONGENECKER: Mr. Chairman and subcommittee members, good morning. I am John Longenecker from the Department of Energy, the Applicant in this proceeding. I am pleased to be here today to present to you the details that you have requested on the seismic design for the Clinch River Breeder Reactor Plant Project.

I would like to begin by saying a few words about the agenda, if I may. As I believe you are aware, we have requested some modification to the agenda as originally transmitted. Specifically, I would lile to review the agenda and identify for you who the presenters will be today, at the same time identifying a few small changes.

As noted in the hando t, we will begin with a review of the geology and seismology by Walter Brusey of Burns and Roe. We will then proceed with the seismic Category 1 structural design description by Ash Dajani, also of Burns and Roe.

After the lunch break then we will proceed with the description from four Westinghouse presenters of the seismic design of the mechanical systems and components. The presenters there, the first will be Tony Morrone, as shown on the original agenda.

We would propose reordering the first three presentations such that the one currently noticed as V.d, Electrical Equipment by George Macrae, would be proceed; second, item V.c by Tom Pitterle on Shutdown System Equipment would proceed third; and the final presentation under Seismic Design of Systems and Components, Heat Transport Systems Equipment, would be presented by Bob Mullept of Westinghouse.

We would then proceed, omitting item V on the agenda. We believe that the summary and conclusions will have been given by each of the individual presenters.

The next item then, VII, will be reviewed; that is, the NRC presentation as scheduled there. We would propose at this time deleting item VIII, which is the Response to two previous questions you had asked, one on containment margin and the other on off-site power and defer those until the next presentation we have on site suitability, if that is acceptable.

Okay, any questions on the changes in the agenda?

(No response.)

MR. LONGENECKER: Having said that, I would like to give you a brief overview of what we hope to present to you today. We will plan to show as the day progresses in the two key areas that the seismic design approach that we have used for the Clinch River Breeder Reactor Project is appropriate for this use and is, in fact, quite conservative.

In most cases, you will see that it is quite similar to or identical to that used for light-water reactors. The methodology, criteria, and design results that we have used will demonstrate, we believe, substantial conservatism. And in several important design areas you will note that the SSE is the controlling loading condition.

Again, just as with light-water reactors, we have a substantial margin to accommodate seismic events beyond the SSE. For your information, as we go through today we will try to point out in which cases we are using standard LWR criteria and in others where we are departing from those due to the unique nature of the LMFBR, and we will describe what criteria we have used there.

So having said that, I would recommend that we proceed with the first detailed presentation by Walter Brusey of Burns and Roe.

(Slide.)

MR. BRUSEY: As you have heard, my name is Walter Brusey, and I will be presenting the geology and seismology section of this presentation.

(Slide.)

During this presentation I will be covering the development of the more significant parameters that have been used in the design of the Clinch River project. I will be covering essentially how we got to the location of the Clinch River site, which is shown on Figure Number 1.

Did you all get copies of the vuegraphs?

And I will do that by basically covering this outline. There have been rather extensive investigation programs conducted over a number of years at the Clinch River site.

I will briefly outline what we did in these programs and how we got to arriving at the foundation design parameters of this program. Also I will also cover the earthquake history and then the selection of the SSE and the OBE.

(Slide.)

This is a regional physiographic map of the area. As you can see, the site is located in the valley and ridge physiographic province here (indicating). This particular province is roughly 25 to 55 miles in width and about 500 miles in length.

It is characterized by northeasterly trending boundaries and ridges. Topographic elevations range from about 800 to 1000 feet. Rock formations that have been identified in this province include the Rome formation, the Conasauga, the Knox, and the Chickamauga. The Knox and the Chickamauga formations have been identified at the site.

MR. MARK: Those different areas have different names.

MR. BRUSEY: Yes.

MR. MARK: Those have to do with geologic characteristics? Or is it thought that those are seismic provinces?

MR. BRUSEY: These are just geologic formations, similar stratigraphy and orthology.

MR. ETHERINGTON: What was the radius of the circle?

MR. BRUSEY: The province is roughly about 500 miles in length and about 25 to 50 miles in width.

MR. MARK: No, but on your chart there was a circle which reached out into West Virginia and so forth. That was a 200-mile, 300-mile --

MR. BRUSEY: This slide here?

MR. MARK: The radius of that bit circle.

MR. BRUSEY: That is only about 20 miles.

MR. MARK: No, no --

MR. BRUSEY: Oh, I'm sorry. This is roughly about 200 miles.

(Slide.)

This is a site geologic map which we have obtained from doing a number of site studies. Included in these investigation activities are literate studies, geological reconnaissance and mapping, aerial photographic studies, fairly extensive boring coverage, a number of observation wells that have been located in this general site vicinity, and also extensive geophysical investigations, including refraction and cross-hole.

From this data it is possible to come out with a geologic map of the site. As you can see, we are on a peninsula of the Clinch River. This is actually a Watts Bar lake. There are more levels of course, and the Clinch River on Watts Bar Lake are controlled by dams Lake upstream and downstream of the site.

The dams upstream are Meltons Hill and Norris Dam, and the controlling dam downstream would be Watts Bar Dam. The Knox and Chickamauga formations I identified earlier. You can see the general extent of these formations here. The Chickamauga formations are located in this (indicating) band and, generally speaking we are dealing with interbedded siltstones and limestones, dipping at an angle of about 30 degrees. These identified nonconformities occurred many years ago towards the end of the Paleozoic era, about 280 million years ago.

The site is located roughly here

(indicating). There are some other significant features that probably should be identified. We were a little bit concerned about potential solutioning in the limestone formations, and the Knox of course is quite well known in Tennessee for solutionings.

There are a number of sinkholes and so on that have been identified in this formation. Similarly, in the Chickamauga formation we have other sinkholes and solutioning activity.

The overall thrust of the invesigation was for economic reasons, certainly, to try and locate the plant in an area where we would have minimum solutioning. And this generally meant the upper siltstone stratum in the Chickamauga formations.

We found in our boring investigations that this particular stratum had minimum solutioning. Other features I might want to just point out are the terrace deposits here, which of course are reasonably extensive also on this branch of the river.

(Slide.)

On figure 4 we have just a brief outline of the major investigation programs that are being conducted. Starting in 1972 some initial work was done by TVA to locate the site. And ongoing 1973 and 1974, when fairly detailed work was done to prepare for the

PSAR. In 1975 and 1976-77, some localized investigations were done not necessarily Category 1-related, primarily for balance-of-plant and other problems related to excavation.

We are presently involved in a bedrock verification program which is ongoing. And results, in fact, preliminary results, just arrived recently.

As I mentioned previously, the main thrust of the investigation was to define the interbedded siltstone and limestone strata, the depth of the weathering, to define the depths of the residual soils and terrace deposits; to actually locate the nuclear plant island structures in the area where we had minimum solutioning; and then to carry out a detailed evaluation of the foundations for the Category 1 structures.

MR. MARK: When you speak of borings, are we thinking of 200 feet or 2000 or any particular amount?

MR. BRUSEY: No. Generally speaking, the depths of the borings range from about 100 feet to 400 feet. Most of them are on the order of 200 to 300, but we had a few that extended down to 400 feet.

MR. CARBON: I am curious as to the timing on the bedrock verification program.

MR. BRUSEY: Sure.

MR. CARBON: What is the significance, if any, of that being in the last year or two in contrast to earlier there?

MR. BRUSEY: Primarily schedule. We could have actually conducted this program after we had excavated, but it was felt that by doing it now we might save some time while we are on schedule. In other words, it could be done after excavation, but that would obviously mean a halt in the placement of concrete for mats and so on while we continued the program. But by going ahead now we can hopefully eliminate that gap in the schedule within a 2-or-3-month allowance for that in the original schedule.

(Slide.)

On figure 5 there is an outline of where these borings are located. This is up to the end of 1974. We had about 106 borings completed at that stage. As I mentioned earlier, the main thrust was to identify the area where we had minimum solutioning. Also, there are other investigations conducted primarily to evaluate the sinkholes in the Knox and also for the emergency cooling tower, which is also located on this same band of siltstone.

Also, we did some rather detailed work on this portion of the nuclear plant island, primarily to find out if solutioning, which you will see when I identify the cross-section, any possibility of an encroachment of solutioning below the major nuclear island structures.

The actual investigations of course consisted of borings and the core from these borings were evaluated, and the core recoveries were estimated using of course an RQD determination; and geophysical studies were conducted, extensive studies, by Western Geophysical Company.

And as a result of this work, it was concluded that the optimum location of the structure should be on a band of siltstone which is roughly 400 feet wide. The width of the structures is pretty close to 400, 380 or so, so it was possible to place the structures entirely on the siltstone stratum.

MR. TRIFUNAC: A question. What are the shear wave velcoities in the siltstone?

MR. BRUSEY: I am coming to that. That will be part of the design parameters.

(Slide.)

On figure 6 we have a cross-section through the nuclear plant island and the foundation-bearing strata. You can see that the upper siltstone stratum, which is roughly 400 foot wide at this section, essentially supports the nuclear plant island.

We do have limestones, Unit A limestone and

Unit B limestone bordering the upper siltstone. We were concerned with respect to potential solutioning in these limestones, particularly with the possibility of an encroachment below the nuclear plant islands.

Grade elevation was established at 815; and in reviewing the RQD determinations of the rock, it was concluded that elevation 715 was a reasonable elevation with respect to the finding of the consistent properties of the foundation stratum. So that particular elevation was selected as the bearing elevation for these structures.

MR. ZUDANS: Could you help me understand what RQD is?

MR. BRUSEY: That is the Rock Quality Index.

MR. ZUDANS: Fine.

MR. BRUSEY: That is basically the sum of all the 4-inch segments of rock core occurring at any 5-foot round or 10-foot round.

MR. ZUDANS: And this question of solutioning, can you point with your pointer where these things potentially might exist?

MR. BRUSEY: We were concerned here (indicating), this is unit A limestone, the possibility of solutioning extending down below the structures in this zone here. The same rationale of course would apply to the Unit B limestone with potential encroachment here (indicating). In fact, in the bedrock verification program we are presently checking this limestone layer roughly 100 feet or so into the limestone area to determine whether or not we have any solutioning.

We also conducted an extensive test grouting program in this area to demonst.ate that this problem will not occur in any reasonable time frame.

MR. ZUDANS: What are the consequnces if you cannot prove that this problem does not exist?

MR. BRUSEY: There are no major problems; strictly one of economics. Obviously if you do find this problem, then you have to go through a rather extensive grouting program. But obviously, it can mean a delay in schedule and so on and it also can be rather expensive.

MR. ZUDANS: In other words, the potential solutioning volumes are not too large not to be able to be handled by grouting?

MR. BRUSEY: That is right. That is right.

(Slide.)

Figure 7 shows the location of a fairly extensive test grouting program that was conducted in this area to demonstrate that this particular limestone layer had essentially no solutioning. This program consisted of about 13 borings around boring 55. The intent of the program was to check the representivity of these borings.

Initially, the borings were placed at 20 feet, and water pressure tests were conducted and then grouted. And then we went inside the 20-foot spacing with borings of 10 foot spacing. The overall conclusions were that, based on negligible grout take, foundation treatment would not be required in this zone.

It was also decided to extend the verification program, which we are doing right now, to establish that we do not have a problem across the full length of the structures.

(Slide.)

As I explained, this is just a brief outline of the verification program consisting of about 34 borings. This is an outline of the nuclear plant island excavation. If you will remember the cross-section, we were primarily interested in the first unit, the limestone that dips under the siltstone stratum. So we are extending these borings down roughly 100 feet into the limestone to check that.

The results that I got last week indicates a miminum amount of solutioning. So it looks like we are able to demonstrate that the results of the test grouting programs are confirmed. That is a limiting conclusion, by the way, but we expect it to hold out.

MR. MARK: You have used the phrase "minimum solutioning" several times. What does that approximately mean? That you have not found any caverns bigger than 20 feet across, or what?

MR. BRUSEY: That is right. Generally speak, a small one, 1 foot, 2 foot. If my memory serves me correctly, there are none at all below elevation 715, below the actual bearing elevation we selected for the nuclear plant island.

MR. MARK: But the biggest cavern that you would include in your expression "minimum solutioning" would be perhaps bigger than 2 feet but not as big as 10 or something?

MR. BRUSEY: That is right. That is right. As you get closer to the top of the weathered rock, the voids do become rather significant up to -- I think our maximum size void is about 26 feet. But that is, generally speaking, fairly close to the top of the weathered rock, and it obviously does not affect the bearing capability of the nuclear plant island structures.

But there is obviously a fair amount of

solutioning at the site, and it is not too unusual to find a major sign of voids in the highly weathered portion of the rock.

MR. ZUDANS: On the other cross-section that you showed, I thought you indicated some potential for the other coordinate as well.

MR. BRUSEY: That is right. Yes.

MR. ZUDANS: Now you are exploring this corner and the other corner. What is in between? What makes you sure there are no problems in between?

MR. BRUSEY: We have done some rather detailed work in the siltstone, and as I say below elevation 715 we just have not got a problem. In the unit B siltstone also below elevation 715, no problem. As I say, as you approach the top of the weathered rock of that unit B limestone, you do find rather extensive voids and cavities, but nothing below 715.

MR. MARK: Excuse me. If you have a couple of bore holes of four bore holes on the 30-foot -- these things are roughly 30-40-foot spaces?

MR. BRUSEY: Yes.

MR. MARK: Supposing you have those. It is possible to imagine that all of the middle where you did not bar is empty.

MR. LONGENECKER: Yes. Yes.

MR. MARK: Is there a technique whereby you can use some signals to ascertain that there are not any big holes between this drilling and that drilling?

MR. BRUSEY: Yes. We can use cross-holes techniques to establish whether there are or not.

MR. MARK: Are those used?

MR. BRUSEY: Yes. In the foundation stratum below the nuclear plant island, we did cross-hole work to establish the dynamic properties to be used in the seismic design and the engineering properties, as I mentioned before, were consistent, and the velocities were consistent -- in other words, there was no evidence of solutioning below the structures.

It is quite likely that if cross-hole work was conducted in the unit B limestone above elevation 715, the velocity pattern might be rather erratic and could demonstrate that solutioning did exist between borings. But that is not really of concern with respect to the foundation integrity of the nuclear plant island.

(Slide.)

In addition to borings, there were also some other investigations conducted primarily in the faulting area to check on the possibility of capable faulting. Of course the two major fault lines in this area are the White Oak Mountain fault and the Copper Creek fault. The White Oak Mountain fault is about 1.7 miles from the site. The Copper Creek fault outcrops about something on the order of 1,500 to 2,000 feet from the site.

These faults were investigated. On the Copper Creek fault, extensive work was done, including borings and mapping of outcrops, and samples were recovered which were possible to date. Dr. Wampler of Georgia Tech did the dating, and he found by radiometric methods of testing argon methods, that the age of the Copper Creek fault was on the order of 280 million years old.

This confirms other geological consensus on the age of faults in the area.

(Slide.)

We were also a little bit concerned about localized faulting occurring in the substratum, particularly below the nuclear plant island structure, and from the borings a shear zone was noted. This plane, generally speaking, occurs throughout the length of the nuclear plant island in the Unit A limestone.

Extensive investigations were conducted to establish whether or not there would be any potential for movement of the zone. It was concluded, based on a consensus of geological opinion once again that this is an ancient and rehealed yield zone, and no possibility of movement.

(Slide.)

Another investigation was conducted at the request of the NRC on some injection wells which are located at the ONL site about four miles from the Clinch River site. This is the method that ONL had elected to dispose of radioactive waste. This is mixing radioactive waste with grout and injecting under pressure at depths on the order of 800 feet by hydraulically fracturing the shale formations. It was suggested perhaps by the NRC that the so-called Denver analogium could be applied. Apparently, this particular problem did crop up in Denver when they were disposing of waste, and this created a triggering mechanism which resulted in seismic activity.

The same rationale is applied here, and it was thought that perhaps by injecting this waste, we might be able to lubricate an existing fault plane, thereby triggering activity. Once again, extensive investigations were conducted to establish whether this problem just could not occur. The magnitude of both the pressures and the amount of waste that was being deposited in this area was such that it would just not be possible to lubricate a fault plane and create seismic activity.

(Slide.)

Going to the development of the foundation design parameters that were used for both the static and dynamic design of the structures, as I mentioned earlier we had a rather extensive boring program, and of course the static properties are derived from testing representative samples of the core in the lab, and design compression tests were conducted.

In situ pressure meter tests were also done to establish a range for the static properties. From these properties calculations were done to determine what the acceptable bearing capacity would be, and also what the likely settlement might be. These numbers were more than adequate. In fact, the actual depth of excavation is considerably in excess of the estimated static wave of the plant structures.

It is quite likely that the settlement, which may be on the order of a half inch, may be primarily due to recompression as a result of minor or potential elastic rebound after the excavation has been completed, but of course installing some geotechnical instrumentations, these are electrical extensometers to monitor potential heave and settlement, both during the excavation and also during the actual placement of concrete and the construction of the nuclear plant island.

As outlined here, it is anticipated that the movements will be negligible, something of less than a half inch. As far as the dynamic properties are concerned, as I mentioned earlier, geophysical investigations were conducted by Western Geophysical. This included refraction lines, also cross hole, up hole, and down hole, and also some continuous velocity measurements by Birdwell.

As a result of these investigations, properties were established for the siltstone and limestone strata. In situ velocity measurements generally resulted in a number like 6,200 feet per second as the shear wave velocity for the siltstone. Based on some work that Dr. Hendron had done, who is our rock mechanic consultant, a rock reduction factor was applied to these in situ velocity measurements, resulting in a modulus of approximately 1.5 million psi and a plus or minus 25 percent variation was placed on the modulus. That was the number that is being used for seismic design.

MR. MARK: I believe you said 6,200 fps for the siltstone?

MR. BRUSEY: Right.

MR. MARK: What is the corresponding number in the limestone that seems to also be part of the immediate environment?

MR. BRUSEY: Around 9,000 or so.

MR. MARK: 9,000 in the limestone?

MR. BRUSEY: Yes. And that is by applying a reduction factor and so on. The modulus corresponding dynamic modulus was on the order of 3 million. So there are two numbers that have been used for seismic design: 1.5 million for siltstone and 3 million for limestone.

MR. MARK: Another question. You are only three miles from the K25 plant, I think?

MR. BRUSEY: Right. Three or four miles.

MR. MARK: Is the local geology similar enough that its experience in settlement has any relevance to your estimates here?

MR. BRUSEY: We are pretty sure of our foundation properties, so we are pretty sure basically of our orders of deformation for both rebound and resulting settlement. I can't really say the same for the K25. I am not sure of the order of magnitude you are talking about.

MR. MARK: I am believing they had no trouble at all, and I was supposing you could use that as a parallel statement if the geology had a resemblance.

MR. BRUSEY: That's right, yes.

MR. MARK: But you haven't done that?

MR. BRUSEY: No, we have not checked the actual records of the K25 plant.

(Slide.)

Going on to seismology and the derivation of the values to be used for the SSE and OBE, of course, on Figure 13 is the regional earthquake map. Outlined here, we have seismic events that have occurred in the 50-mile radius and also in the 25-mile radius. Of course, there is the major earthquakes that control seismicity for the site.

The three that are significant are, of course, the New Madrid, the Charleston, and the Giles County earthquake. The New Madrid and Charleston are roughly 300 miles from the site, and of course, based on the attenuation relationships for both New Madrid and Charleston, it was established that New Madrid would have an intensity 6, 7 at the site, and Charleston would have an intensity 6 at the site. These are the maximum historical earthquakes that have occurred at the Clinch

River site.

The controlling earthquake is the Giles County earthquake, which occurred in 1897. That is roughly 220 miles from the site, and this area here, this, of course, is New Madrid, and this is Charleston (indicating).

MR. CARBON: Where again was the Giles County?

MR. BRUSEY: Giles is up here. There is a more detailed vu-graph coming showing the actual location of Giles.

MR. TRIFUNAC: Could I ask a question regarding the preceding vu-graph that had a 50-mile radius?

MR. BRUSEY: Yes.

MR. TRIFUNAC: Are you going later on at some time to tell us what are the recurrence relationships for the earthquakes within this 50-mile radius? What are the A and B parameters for the number of earthquakes with this intensity?

MR. BRUSEY: We are presently not doing any studies in the probabilistic area.

MR. TRIFUNAC: I didn't imply probabilistic. I just asked whether you had A and B's in the relationships.

MR. BRUSEY: We do have them, right. I don't have them with me, but I could get them for you.

MR. TRIFUNAC: Would you get them, please?

MR. BRUSEY: Right.

(Slide.)

This is a tectonic province map of the general area. This particular map was developed by Law Engineering Company. It is quite similar to some of the other maps that have been developed in recent years by USGS and others. The Giles County earthquake, as I mentioned earlier, is roughly here (indicating), the epicenter, about 220 miles from the site, which of course is here (indicating). We, of course, have adopted the tectonic province approach to defining the SSE, which is to define the intensity of the maximum historical earthquake in that province, which of course is the Giles County, and you can move that earthquake to the site. Then, having done that, to define an acceptable intensity acceleration and core acceleration correlation.

There is a reasonable amount of controversy on the intensity for the Giles County earthquake.

(Slide.)

Figure 15 is an isoseismic map of the Giles County earthquake. This map was developed by a combined study of Law Engineering and Burns and Roe to establish, based on felt observational effects, what the intensity should be. As a result of this extensive study, it was concluded that the intensity of the Giles earthquake should be classified as an intensity 7-8. In completing the study, we consulted with a number of recognized authorities on southeastern U.S. seismicity. At the same time, other studies were being conducted by the NRC.

MR. POMEROY: Before we leave that, could I ask you what the consensus is that you managed to arrive at there? It seems to me that there has been a rather definitive study in the literature by Ballenger where he has defined the epicentral intensity as definitely 8. And I noticed in your PSAR also that you use 7 to 8, based on this work, I assume.

MR. BRUSEY: Right; yes.

MR. POMEROY: And I would like to ask you what consensus you developed, because most of the people that I know classify that as intensity 8.

MR. BRUSEY: We consulted with Dr. Ballenger. He was one of the consultants on that study. He originally had written -- classified that as a 7-8. His opinion today may be an 8, but at that time it was a 7-8. We also consulted with Dr. Timothy Long of Georgia Tech, who also did an independent assessment; and a number of other consultants, particularly TVA, who had been involved in many studies in the area. But as I say, it is quite likely that Dr. Ballenger has perhaps changed his opinion now.

MR. CARBON: I am sorry. I can't hear you. Would you repeat your last statement?

MR. BRUSEY: That Dr. Ballenger may have changed his mind relative to the time when we did this study, which was back in '75, '76.

MR. CARBON: And you are saying he may now believe it was an intensity 8?

MR. BRUSEY: Well, I am just assuming from what you just said.

MR. POMEROY: I believe he has published in the Seismological Society of America to that effect. Can I make another comment here?

MR. BRUSEY: Sure.

MR. POMEROY: I also noticed in your listing of earthquakes that you list the Charleston earthquake as an intensity 9 event; and that is based, according to the references in the PSAR, on a telephone conversation with Leonard Murphy who at that time was at NOAA, who is now deceased of course; yet everything that is published on that particular earthquake indicates that the intensities were intensity 10. Would you comment on that, please?

MR. BRUSEY: We have used intensity 10 in our computations for determining what the historical intensity would be for the Charleston at the site; but intensity 10 was used.

MR. POMEROY: So then you don't believe what is written in the PSAR?

MR. BRUSEY: Well, that will be modified.

(Slide.)

On this vu-graph, we have a number of acceleration intensity relationships which were reviewed in order to establish the basis for defining the SSE and the resulting accelerations. As I mentioned earlier, based on our studies, we had concluded that an intensity 7-8 would be satisfactory for the Giles County; and the NRC indicated that in their opinion an 8 was the correct classification. So that is the number we have used in order to come up with an SSE, and also the resulting acceleration value.

Also looking at the various relationships, one can see that a number of them -- these have been used for licensing of other nuclear power plants, including Goltavor on the Rhine and Guttenberg-Richter, and others-- however, the most conservative relationship has been selected, which is Trifunac-Brady, or also Coulter, Waldron and Devine, or Neumann. And based on this relationship here on intensity 8, the maximum acceleration was defined at .25.

Initially of course .18 G is the number that had been selected originally, and this was raised of course to the .25.

MR. ZUDANS: In terms of calendar time, when was this changeover made from .18 to .25?

MR. BRUSEY: I would say around '76.

MR. ZUDANS: That was prior to completion of the design of the structure and components?

MR. BRUSEY: Right. But the .25 was incorporated in the actual seismic design and in fact the OBE controls in many cases, particularly with respect to structural design. And as I point out here, we did select the OBE of approximately a one-half SSE, which is of course a very conservative approach. There have been a number of sites licensed that were evaluated less than one-half SSE. The OBE has selected at less than half the SSE. We could have adopted that approach also I believe in the Clinch River project, but it was decided to stay with the conservative approach of one-half SSE.

MR. ZUDANS: So if I read your comment correctly, the basic design of all the components was done at .25?

MR. BRUSEY: Right.

MR. ZUDANS: In other words, you did not have the design completed already before the change was discussed?

MR. BRUSEY: That's right.

MR. MARK: In '76, when you say the number was chosen, you indicated on the slide you had up that it was done in collaboration to some extent at least or in antagonism with the NRC?

MR. BRUSEY: Yes, right.

MR. MARK: Is that to be taken that the people in the NRC in 1976 agreed that .25 was big enough?

MR. BRUSEY: Yes, yes. That is also the value that has been used on a number of other nuclear power plants in the area, primarily plants presently being constructed by TVA and in fact in operation by TVA. That .25 is the number that is actually being used.

So, just to sum up then, we have done extensive geologic, geotechnical, and seismologic investigations over the past ten years, in order to arrive at the data that you have seen here today. It is believed that there is inherent conservatism because we still feel that intensity 7-8 is appropriate for Giles County. We have elected to use a rather intensive acceleration relationship, and of course the OBE has also been selected at one-half SSE.

That more or less completes the presentation, if there are no more questions.

MR. TRIFUNAC: There are some questions. What is the conservative intensity acceleration relationship?

MR. BRUSEY: I think one has to go over the background and precedent, in that a number of nuclear power plants have been licensed with extensive acceleration relationships, not quite as conservative as the ones that I showed on the vu-graph, such as the Coulter, Waldron and Devine upper rock line.

MR. TRIFUNAC: How conservative is that relationship?

MR. CARBON: Excuse me, Mr. Brusey. Could you move your microphone up closer? I am having great difficulty hearing you.

MR. BRUSEY: Basically on background and precedent, as I mentioned, you are probably familiar with a number of these relationships that have been used in the past. Plants have been licensed successfully using these relationships.

MR. TRIFUNAC: I don't disagree that they have not been using those relationships. You made the statement that they are conservative, and I would like to know now much. Can you tell, for example, what data '. e been used by Coulter, Waldron and Devine? What is the data base for that relationship?

MR. BRUSEY: They did establish three curves related to rock conditions at the site. Basically, low strength, medium strength, high strength rock. So data obviously --

MR. TRIFUNAC: They have established the curves, but have they demonstrated where the data for those curves came from?

MR. BRUSEY: I am not sure. I would have to check on that.

MR. TRIFUNAC: I am not sure either. That is why I would like to know, because in all the years I have never seen the data, and if you say those are conservative, I think we should be able to demonstrate that. I have not seen the data ever before, so I think we should look at that. You have used the curve by Trifunac and Brady. Have you read his paper?

MR. BRUSEY: Yes.

MR. TRIFUNAC: Did you read the statement that the authors suggest that this curve should not be used in this work?

MR. BRUSEY: Yes.

MR. .RIFUNAC: And you think it should still be used?

(Laughter.)

MR. BRUSEY: As you probably saw, there are three curves. They all happen to fall on the same line, the Trifunac, Brady, and Neumann, and also the Coulter, Waldron and Devine. So all three curves indicated that a conservative approach could be taken.

MR. TRIFUNAC: What is the conservative approach, then?

MR. BRUSEY: Well --

MR. TRIFUNAC: If at least one of the three authors suggest that this curve should not be cited, if Neumann's curves recognize that virtually no data was available and Coulter, Waldron, and Devine being a set of curves for which the data was never published, what is so conservative about this kind of procedure?

MR. BRUSEY: Well, obviously, there may be some scarceness of data, particularly for rock site. We obviously have to do a little bit of checking to establish what Coulter, Waldron, and Devine used to develop those curves. I'm not sure, but we can obviously check on that.

MR. TRIFUNAC: Don't you think we should actually check if we are going to base our judgment on that?

MR. BRUSEY: Yes, sure.

MR. TRIFUNAC: Could we see some of the data? Could you check into that?

MR. BRUSEY: Yes, we will check into that and let you know.

MR. TRIFUNAC: You do remember reading the statement that the Trifunac Brady should not be used in this work? You do remember that? So that is assumed not to be conservative, right?

MR. BRUSEY: Well, the data that was used, of course, was soil data primarily, as to how that is applied to the rock site, but based on, as I say, the hard rock data that presumably Coulter, Waldron and Devine has, this curve could be used.

Are there any more questions?

MR. POMEROY: Yes. Could I ask a question with regard to -- there is a statement in the PSAR work that I read having to do with the depth of some of the earthquakes in the area, which establishes the depths at 49,000 to 69,000 feet. Could you give us some idea of the uncertainty that is associated with those depths? For example, because you have used that as an argument, that that seismicity could not be associated with the nearer surface faulting?

MR. BRUSEY: Well, there has been a lot of speculation as to whether or not some of the seismic activity has occurred in the sedimentary rocks rather than the basement rocks, but my understanding is that no legitimate data has been presented that one would reach the conclusion that this seismic activity is occurring at the shallow depths. In fact, the preponderance of evidence is that it is a suppression peak in the basement. I think that is still the present consensus of opinion for that area.

MR. POMEROY: Could you outline what that preponderance of evidence is?

MR. BRUSEY: Primarily geologic opinions by consultants who have worked in the area for many, many years, people like, I believe, Dr. Malichi and others.

MR. POMEROY: There are some other seismic networks operating in the area. There have been some recent instrumentally located events, and those events have a certain depth associated with them and some uncertainty. And what I am trying to explore is the amount of uncertainty and whether some of that activity could have been occurring at shallower depths.

MR. BRUSEY: I believe it is still in the speculation stage. I don't believe any data have actually been produced to demonstrate activity, as I say, at the shallow depths.

MR. POMEROY: And they have been produced at deeper depths by definition. Is that correct?

MR. BRUSEY: Well, that is still the prevailing opinion, certainly, that all activity is occurring in the basement.

MR. POMEROY: Again, and I do have a question about prevailing opinion, because I do not know that that is necessarily the prevailing opinion of the entire community, in view of the fact that there is really -- you are correct, there is very little data, and given that lack of data, there is a great uncertainty as to the actual depth of occurrence.

MR. BRUSEY: Yes. Obviously, the answer is, more data on microseismic networks would help in this area.

MR. POMEROY: Are there any plans to do that at all in this area?

MR. BRUSEY: Nothing definitive. This is still a subject for discussion amongst ourselves. It is quite likely that something like this might evolve in the near future.

MR. MARK: I would like to ask, Pomeroy, would you educate me just a little bit on this possible significance of these things really being at 25,000 feet instead of 60?

MR. POMEROY: Well, yes. There is a statement in the PSAR that it is generally accepted that there is a so-called thin-skinned tectonics in this area, and that most of the ancient faulting that we are observing here, such as the thrust faults that were described, are associated with or are what they call listric faults, that are associated with a large-scale structure at a rather shallow depth.

If all the earthquakes are occurring deeper than that, then they are not associated probably with these nearer surface faults; that they could have occurred at shallower depths, and they may be associated with these nearer surface faults, and there may be some movement occurring on these faults, which then has some implications for what we are talking about here.

MR. MARK: Thank you.

MR. POMEROY: Speaking of that, though, can I then ask a question of where that statement came from, again, that it is generally accepted that that thin-skinned tectonic approach is the correct approach? Again, I know people that are violently opposed to that.

MR. BRUSEY: Well, we have used a number of consultants in this area. I believe, Law Engineering and their geologists were in consultation with people like Dr. Kouchi, and that was based on discussions with someone like Kouchi that this conclusion was reached. And also, of course, TVA has done extensive work in this area, and their geologists also have reached similar conclusions.

MR. KASTENBERG: I have a general question.

MR. BRUSEY: Sure.

MR. KASTENBERG: If Burns & Roe were to construct a plant on this site which did not require an NRC license such as a chemical plant or an oil-fired plant, what would be your design parameters in terms of accelerations? How would you arrive at them?

MR. BRUSEY: Well, we would probably use the Uniform Building Code approach which may result in values perhaps on the order of .1g or .12 g, that kind of number.

MR. KASTENBERG: And that would be sufficient to protect the investment in the plant?

MR. BRUSEY: Right. This would be an approach used at, say, for fossile plant design or industrial plants where you are generally speaking on a different order of magnitude when we have to design for a nuclear plant.

MR. POMEROY: I have another question related to that. I am not sure you are the proper person to address it to, but I will. You mentioned the upstream dams. Could you tell us what the design of the seismic design criteria for those dams is?

MR. BRUSEY: I believe analyses were conducted by TVA. They really handled that particular aspect of the work. I understand that they did the analysis for both OBE and SSE, combined with the various flood stages, but I am not really familiar with the details of the analysis.

MR. POMEROY: Could we ask, Mr. Chairman, to have somebody from the TVA to give us that information, as to the design criteria that went into those?

MR. CARBON: Yes, we certainly can. I suspect that information will be presented to us at the so-called site suitability meeting which is later this month. But I see no reason why we cannot ask for it earlier, if you have the information. Is it available at this time?

MR. BRUSEY: I think the information is available I think it is just a matter of content.

MR. GAESER: We would have to get hold of that. I don't know whether we could have it today or not, but we will try to get it and get back to you.

MR. POMEROY: Would it be correct to assume that at the site suitability hearing that we would also hear about possible effects of a failure of that structure, if indeed there were more criteria applied to that structure?

MR. BRUSEY: That is right, yes.

MR. TRIFUNAC: Could I ask one more question, please? Could you put on the viewgraph, I believe, number 13? It is the one that has regional earthquakes with intensity exceeded for MMI. It has a 50-mile radius and a 200-mile radius.

(Slide.)

I think the copy I have is a little bit better than the viewgraph, but working with that difficult, is it reasonable to say that the 50-mile radius over there of the first site appears to have more circles in it than some areas, meaning that more earthquakes have occurred there?

MR. BRUSEY: Intuitively, perhaps, yes. The actual rate is a little bit --

MR. TRIFUNAC: It is a little bit higher?

MR. BRUSEY: Yes.

MR. TRIFUNAC: Would it be reasonable to say that it is higher than perhaps the region where the Giles County earthquake occurred?

MR. BRUSEY: Probably.

MR. TRIFUNAC: I am sorry?

MR. BRUSEY: Probably, I think, yes.

MR. TRIFUNAC: Now, if you ask -- how many years did we have the historic record for, 100, 200, 300?

MR. BRUSEY: Roughly 150, 200 years, yes.

MR. TRIFUNAC: If we have, by some miracle, 500 years, would you still think that 7 to 8 would be a good number?

MR. BRUSEY: Most of the events that have occurred in that area have been very small.

MR. TRIFUNAC: I am aware of that, I agree. But I am asking about your judgment.

MR. BRUSEY: Yes. Obviously, a design basis has to be arrived at, and the approach that has been suggested and the one we followed that is obviously in the Reg Guides and so on, is to select the maximum historical earthquake in the province, and the historical record, of course, was known when that particular approach was suggested.

MR. TRIFUNAC: Does Appendix A say that the largest historical earthquake should be taken as the maximum earthquake to be considered at a site? Or does it say that it should be considered in the selection of the largest earthquake?

MR. BRUSEY: Considered is the word, but in actual practice that is what has been used in nuclear power plant design.

MR. TRIFUNAC: Do you believe this is a good approach?

MR. BRUSEY: Yes.

MR. TRIFUNAC: And you are not disturbed by the fact that this 50-mile radius appears to have a higher seismicity than some other regions on the map?

MR. BRUSEY: No. As I mentioned earlier, the number of events are quite small, and there are obviously many areas where you can have a considerable amount of microseismic activity and get design values less than the SSE that are still lower than the values that we are --

MR. TRIFUNAC: Is this some microseismic activity on the map?

MR. BRUSEY: No, this is obviously not. But it is in the range of low values, 3's, 4's and 5's.

MR. TRIFUNAC: Does that exclude the possibility?

MR. BRUSEY: No, it doesn't exclude it, no. Then you are getting into the probability area, and right now we have we have not done any studies in that particular area that particularly relate to the SSE.

MR. TRIFUNAC: Are you suggesting that taking the largest historical earthquake is not the probabilistic statement? I mean, the way you put it, it appears as though I am not supposed to get into the probabilistic area. Are you saying that taking the largest historic accident for the design basis is not a probabilistic approach?

MR. BRUSEY: Well, it is an approach that as I mentioned before, background and precedence indicates that people should follow, and that is what we have done. Are you indicating that we should arbitrarily go higher because we have some seismic activity that indicates a number of events, small events perhaps, a little more frequently than in another area?

MR. TRIFUNAC: I am not trying to suggest anything in particular. I am trying to understand the distinction between the precedent, historic approach and to me what appears to be the physics of the problem, and

I am trying to see how you reconcile the two. You do feel comfortable with the 7 to 8?

MR. BRUSEY: Yes, yes.

MR. TRIFUNAC: If you do take a probabilistic approach, if you have a pesallia sequence of earthquakes, what is the expected value of the largest number, if you have the largest historical value? Would it be still 8?

MR. BRUSEY: Right. Well, you get into a whole historical area: how many events constitute a data base.

MR. TRIFUNAC: Have you done this?

MR. BRUSEY: No, we have not done any probabilistic studies to the SSE.

MR. TRIFUNAC: Thank you.

MR. CARBON: I would like to ask a couple more questions along that same line.

MR. MARK: I have a very simple one. An earthquake of intensity 4 to 5 -- at what distance can that thing be imagined to be recorded in the last 150 years, or is it only with instruments that you can pick those up anyway, intensity 4 to 5?

MR. TRIFUNAC: Four to five is at the limit of perceptibility. Level 4 is near perceptibility for California; I guess for this part of the country, 3 is nearer that level.

MR. MARK: I am imagining that part of the lack of earthquakes in western Tennessee across the last 150 years is that there was nobody that close to a magnitude, or an intensity 4.

MR. TRIFUNAC: That could be.

MR. MARK: This is Oak Ridge and Knoxville that is in that 50-mile area, and there we will know everything that happened for the last 40 years.

MR. TRIFUNAC: That is quite possible, yes.

MR. CARBON: I would like to inquire a little further on Dr. Trifunac's question of probability. You pointed out that we do certain things a certain way with LWR's and we do something there that I would like to inquire if we are already doing it here.

We do not design on the basis of probability, but nevertheless, there is some consideration that if the return frequency leads us to some acceleration value and then something quite a bit less likely gives us quite a bit higher acceleration, we can take some comfort in the fact that we have a fair amount of safety built into the structure, perhaps, of an LWR plant.

I think it would be appropriate for us to be taking somewhat the same kind of view here, the same kind of question, and then this question of return frequency becomes of importance in that.

Can you -- maybe this is the same question Dr. Trifunac asked you to reply to -- can you give me any feeling at all for what sort of return frequencies we might get into with the magnitude of the acceleration you have assumed here, and then how it would vary as we go to higher intensity or higher acceleration?

MR. BRUSEY: I can't really because as I mentioned, we have not really done any probabilistic studies at all related to the SSE. So I really cannot answer your question.

MR. CARBON: You stated on many of the other things that it has been a matter of people's judgment and beliefs. Would you have any judgment on this question?

MR. BRUSEY: Well, numbers like one times 10 return period, on that order would perhaps be a number that one might arrive at, going through the probabilistic analysis. But as I say, that is just speculation. We have not done the work ourselves yet, and there has been some discussion about doing some study like that but we have not reached any firm conclusion on that.

MR. CARBON: Would your judgment give you any suspicion as to what accelerations you might have with a return frequency of 10^{-5} or 10^{-6}? How much more severe would it be?

MR. BRUSEY: Well, probably higher, but I cannot give you any numbers on that.

MR. CARBON: May I ask, Dr. Trifunac, when you were asking for the As and Bs in the equation, which I do not appreciate, was that aimed at that question?

MR. TRIFUNAC: That would be included there, but this is the basic information on the seismicity of an area. From A and B I can calculate what the return period is, I can calculate how many earthquakes of different sizes one can expect through a given period of time.

It is not really only a probabilistic question; it is a general question of seismicity in the area, and I think this will be very valuable information, especially because usually, intuitively, I do see a lot of little circles in there, perhaps more than in some other places. So it would be good to see how much larger seismicity may be there than the overall uniform average over the entire 200 mile radius.

But yes, you could answer your question if you had As and Bs, definitely.

MR. CARBON: And I guess you indicated you would provide those?

MR. BRUSEY: Yes.

MR. CARBON: What kind of timescale did you mean? Did you mean today?

MR. BRUSEY: I am sure for the site suitability meeting. What date is that particular meeting?

MR. BOEHNERT: The 24th and 25th of June.

MR. BRUSEY: Is that an acceptable date?

MR. CARBON: Yes.

MR. POMEROY: Can I bring up one other question, just following along your question? I would like to see some statement of the amount of uncertainty associated with those determinations, because of the questions regarding the intensities and the basic seismicity information that goes into the calculation of those values.

MR. BRUSEY: Okay, okay.

MR. CARBON: Any other questions? Bill?

MR. KASTENBERG: Yes. In the PRA that is going to be done for the plant, will you be considering the earthquake as an accident initiator in a probabilistic sense?

MR. BRUSEY: I think perhaps I could give this to DOE to answer.

MR. GROSS: We are in the process of

establishing what scope we will have for that PRA right now. We haven't finalized that, but certainly that is one of the things we would consider in seismic as an initiator, obviously.

MR. CARBON: It was my understanding in something that I read that perhaps your PRA study would be broken into maybe three or four phases, and that you have committed to phase one, and perhaps it did not include in phase one anything on seismicity. Am I correct, or do I have things mixed up?

MR. GROSS: We have broken it into several phases, if only from a contractual standpoint. Phase one is preparation based on fault trees and event trees. Seismic is part of that. But phase two is more detailed analysis of the detailed scope for that.

MR. CARBON: And will the seismicity aspect be part of phase two?

MR. GROSS: We haven't finalized that yet. I am sure it would be considered.

MR. CARBON: I guess you're saying you don't know at this time?

MR. GROSS: At this time I don't know. I feel confident that seismic analysis will be a part of the PRA. To what extent we have not finalized yet.

MR. CARBON: Are there any other questions?

(No response.)

Thank you, Mr. Brusey. Mr. Dajani?

MR. DAJANI: Good morning, my name is Ash Dajani, I am with Burns & Roe. I will describe this morning the procedures that we used in the seismic anlysis and the design of the Clinch River plant.

(Slide.)

First, let me describe to you the outline of the presentation. I will first recap some of the pertinent site characteristics that influence the seismic analysis, the applicable codes and standards that we used in the seismic analysis and design, the seismic classifications for the various structures within the plant, then a description of the seismic analysis of the nuclear island, the category 1 structures and the category 3 structures as well. Then an overall summary of conservatisms or margins in the overall situation.

(Slide.)

You saw a viewgraph earlier of the site that showed we have inclined layers of siltstone and limestone. We described on this occasion as well as last week that the finished grade elevation is 815 feet, and the sound rock elevation varies. However, the deepest point is approximately 80 feet below grade.

The nuclear island is founded on a mat that is on elevation 715. The SSE zero period acceleration as we have heard earlier was selected at .25g and the OBE at .125g, half the SSE.

(Slide.)

The codes and regulatory guides that are used are things that you have seen before, I am sure. We used the design spectra from Reg Guides 1.60 damping values, the combination of modes and the rules for that in the response analysis, and the development of the response spectra to be used by equipment from Reg Guide 1.122, NUREG-75-087. Sections 3.7.1 and 3.7.2 are also applicable in this area, as well as Appendix 3.7(a) of the PSAR.

(Slide.)

First, so that we get our definitions in line, just let me describe to you briefly the seismic classifications, seismic category classifications. Seismic category 1 are those structures that either contain and perform a safety function and they are designed for both SSE and OBE. Seismic category 2 are primarily designed for OBE to protect plant investment, and category 3 are those that do not perform a safety function. However, a part of those category 3 structures that are adjacent to category 1 structures and whose failure could jeopardize the integrity of category 1 structures are analyzed and designed for the SSE, and I will describe that a little bit later.

(Slide.)

The main structure that I will cover is first, the nuclear island. I will be coming to that very shortly to describe to you what the nuclear island is comprised of. The other category 1 structures are the emergency cooling tower and the diesel generator building.

The category 3 structures that I will address that are adjacent to the category 1 structures are the turbine generator building and the radwaste building.

(Slide.)

First, a description of the nuclear island. The nuclear island is the one that I will be passing this marker on. It is the reactor service building, the containment building, the steam generator building, the control room building, and the electrical equipment building as well as the steam generator building. This is the nuclear island.

(Slide.)

A cross-section. This would be the nuclear island (indicating). As you can see, the nuclear island is founded on a common foundation mat, and the mat width and length are as shown here, and the mat thickness is as we described last week, about 15 feet.

(Slide.)

MR. KASTENBERG: Before you go on, where do the steam lines come through?

MR. DAJANI: I beg your pardon?

MR. KASTENBERG: The steam lines from the intermediate heat exchanger, from the steam generator.

MR. DAJANI: In this cross-section we show one of the evaporators and a super heater, so it goes from what is not shown here -- here is the steam drum. So the steam flow goes through the evaporator into the steam drum, back into the super heater, from the super heater to the turbine generator.

MR. KASTENBERG: When you say the turbine generator building is seismic 3 and you have a pipe that runs through that building, how do you characterize --

MR. DAJANI: The pipe is anchored at the interface between the two buildings.

MR. KASTENBERG: How do you characterize that, seismic 1 or 3?

MR. DAJANI: The steam line itself, there is an isolation valve that is seismic category 1 up to the first isolation valve; seismic category 3 beyond that; similar to the pressurized water reactor where you have an isolation valve right outside containment.

MR. KASTENBERG: Then where do you find the aux feedwater system?

MR. DAJANI: The aux feedwater system is in this area, I think, on the other side, and there is a tank, protective water storage tank, and three pumps that pump the water into the steam drum. Then you have lines between it and the auxiliary heat removal equipment, which is the protective air cooler condenser and the return line to the pumps.

MR. KASTENBERG: What would that seismic category be?

MR. DAJANI: One. All this equipment in this nuclear island is all seismic category 1.

(Slide.)

The input motions that were used for the seismic analysis are three; three statistically independent artificial accelerations that were synthesized to envelope the design response spectra that is found in Reg Guides 1.16, normalized at the zero period to .25g for the SSE.

The overall duration of the input motion -- and this is just an example of what it looks like --

(Slide.)

-- is 20 seconds digitized at the .01 second intervals. There is a one-second buildup for strong motion, to get to the strong motion, and three seconds for decay.

I have said before that the time histories are such that when you get a response spectrum out of it, it envelopes the NRC response spectrum, and as you can see, generally does that. I will describe now the methods of seismic analysis in the various buildings.

(Slide.)

First, the nuclear island. We used the lumped mass method for direct integration of equations of motion. We characterized the foundation springs and dampers through an analysis first of a static finite element anaysis of the rock/soil characteristics. We used the finite element analysis as well as we checked it against the half-space theory and the results were very much in agreement. The reason we used the static finite element analysis was primarily to take into consideration the inclined layering underneath the plant.

The directional effects were combined by the square root of the sum of the squares, and the degrees of freedom at the response points included translations and rotations in all three directions.

MR. TRIFUNAC: Question. If I understand correctly, you used the finite element program to get the compliances for the foundation materials because there is this inclination of the layers going down, right?

MR. DAJANI: Yes. And --

MR. TRIFUNAC: How was the inclination included in the arrival of seismic waves' program? Was that considered?

MR. DAJANI: How were the waves included?

MR. TRIFUNAC: Let me repeat: How was this inclination of the layering included in the analysis of the wave arrival?

MR. DAJANI: It was not. As I said, what we did was to characterize the -- to get the compliance functions, we used the static finite element analysis. That was, in turn, coupled with the lumped mass model.

MR. TRIFUNAC: I understand. That was quite clear to me. But that tells us what the reasonable values are, numerical values, for compliances.

MR. DAJANI: Yes.

MR. TRIFUNAC: But what I am getting at is the input motion. The input ground motion is obviously also influenced by the fact that these layers are not horizontal, that they are at some angle. What I was trying to find out was whether this was included in the analysis.

MR. DAJANI: No, it was not.

MR. TRIFUNAC: Do you think this might be an important thing? You obviously considered it for compliances. Why didn't you consider it for input motion?

MR. DAJANI: Primarily because the tools and the methods available to us were available to come up with a characterization of the soil characteristics, including the inclination through the static finite element analysis. We did not have the tools to go any further in the area that you are commenting on.

MR. TRIFUNAC: Well, I understand the limitation of the tools, but do you think that this should be considered? Do you think it may be important?

MR. DAJANI: Well, I can say this. We have, in addition to having done it with the lumped mass approach, analyzed in response to one of the staff's questions the entire nuclear island through the finite element analysis using FLUSH, in which we did include the layering -- not at an inclined angling; as you know, the code does not allow for inclusion of inclinations -- but we did include the layering, and the results were shown to be very much in agreement; and in fact, the lumped mass approach was a little bit more conservative.

MR. TRIFUNAC: Well, recognizing the limitation of the tools, LUSH is also limited in telling you a number of other things as well. You are still not answering my question, but perhaps it is not possible.

MR. DAJANI: It is not possible. We haven't done it. You asked me the question how do I feel about it. I do not think it is sensitive, because we have done it through a completely different method and the results were quite close.

MR. TRIFUNAC: Which other method?

MR. DAJANI: The FLUSH.

MR. TRIFUNAC: The FLUSH cannot handle that either. How does FLUSH handle that?

MR. DAJANI: We included the layering of the soil. We included the horizontal. Instead of inclined, we included them as horizontal layers for the different soil properties, so that was included.

MR. TRIFUNAC: Could you please explain?

MR. DAJANI: In the FLUSH analysis, let me see if I can find a backup Vu-graph.

MR. TRIFUNAC: If this is coming later, maybe we can postpone that.

MR. DAJANI: No, it is not coming later. It is just that in order to answer your question, I said in the case of the lumped mass we did not consider the effect of the inclined layers on the response, so I cannot give you a direct answer.

You asked me whether I felt it would be significant or not and I said I don't believe it would be significant, and the reason I say that is because we did model the nuclear island through a finite element analysis using a completely independent method which included the layering effect of the substructure although not the inclination, and the results were very much in agreement in the responses between the two methods.

That is the basis for my saying that I do not believe the inclinations inherently or intuitively would have a big effect.

MR. TRIFUNAC: I understood that perfectly. My question is this: How do you know that they do not have an effect, given the limitations of the tools that you have? That is really what I am getting at.

MR. DAJANI: I do not know.

MR. TRIFUNAC: Does FLUSH handle that?

MR. DAJANI: No, it does not handle inclined layers.

MR. TRIFUNAC: So how do we then conclude that they are not important in determinating the input motion?

MR. DAJANI: You asked for my opinion. I gave you my opinion. You apparently disagree with the way I arrived at the conclusion.

MR. TRIFUNAC: No, I don't. I am just trying to see what the logic is.

MR. DAJANI: That is the logic.

MR. TRIFUNAC: So then, is it reasonable to say that we can't tell, because the tools don't let us decide?

MR. DAJANI: We can't tell but I hate to leave it like that. We can't tell but we don't believe it is sensitive is my judgment.

MR. TRIFUNAC: Can we make judgments about sensitivity if the tools are not capable of telling us whether this is important or not?

MR. DAJANI: I understand you can't.

MR. TRIFUNAC: Thank you.

MR. ZUDANS: Could I bother you with a few more?

MR. DAJANI: Sure.

MR. ZUDANS: You said that the static finite elements analysis was done. Was that a two-dimensional model?

MR. DAJANI: Correct.

MR. ZUDANS: That included the layers. And how did you orient the two-dimensional model on this one, relative to the layers?

MR. DAJANI: The same angle as the 30 degree dip, basically.

MR. ZUDANS: In other words, you made the plane perpendicular to the layer?

MR. DAJANI: Perhaps I can show you a picture of it.

MR. ZUDANS: Yes, because those layers are very steep inclinations, not negligible.

MR. DAJANI: They were at basically a 30 degree dip, if I am not mistaken. Walter, you mentioned that earlier.

(Slide.)

MR. ZUDANS: This is the model, right?

MR. DAJANI: Yes, this is the one direction. The other direction, we have a similar configuration although the reason I picked this one is to hopefully respond to your question of how we modeled the area which has the inclinations. In the other direction, you don't have this kind of an effect.

MR. ZUDANS: Did you have another model transverse to this model?

MR. DAJANI: I beg your pardon?

MR. ZUDANS: Did you have another model that was 90 degrees to this model?

MR. DAJANI: Yes. Would you like to see that?

MR. ZUDANS: No. Just yes or no.

MR. DAJANI: Yes. And we have another one for the torsion.

MR. ZUDANS: Do you have another model that does not include inclination on the static analysis?

MR. DAJANI: Not with the static analysis.

MR. ZUDANS: Just layers? That is what would have given at least some support for your intuition.

MR. DAJANI: I am going to perhaps give you something that is equivalent. While we did not do it with the static finite element analysis, we did another check by assuming homogeneous material, removing the area above the foundation, in other words assuming a half space, and calculated the compliances, and checked those against a half space approach, and the answers were very close and in fact not that different from the one that resulted from the inclined layers.

MR. ZUDANS: Now are these materials properties differences in layers between 6, 7 and 11 great, the differences?

MR. DAJANI: Well, the 11 I believe is siltstone which had a modulus of elasticity of 1 1/2 million. Which other layers?

MR. ZUDANS: Six or seven.

MR. DAJANI: Seven is the limestone unit A which had a modulus of elasticity of 3 or thereabouts.

MR. ZUDANS: Three?

MR. DAJANI: And I am not sure about 6. It is siltstone, the same.

MR. ZUDANS: What about the 5?

MR. DAJANI: The 5 is 3 million.

MR. ZUDANS: So you have a stiltstone 6 and 11, connected by a stiffer layer which is 7?

MR. DAJANI: Slightly stiffer, although as we found, the primary compliance really came from the effect of the stiltstone, which is intuitively obvious since it is sitting on it.

MR. ZUDANS: Now, the portion 10 probably wouldn't affect you anyway. That is outside the scope.

MR. DAJANI: That is right.

MR. ZUDANS: So there might be a way to conclude what you concluded intuitively.

Now the other direction -- there is another question. You said you had three statistical independent artificial earthquake time histories, north-south, east-west, and vertical.

MR. DAJANI: Yes.

MR. ZUDANS: How are those oriented to this cross-section? What is the east-west here? How is this cross-section oriented to east-west?

MR. DAJANI: It is east-west.

MR. ZUDANS: Exactly east-west?

MR. DAJANI: Yes.

MR. ZUDANS: This is how you will apply these?

MR. DAJANI: Yes.

MR. ZUDANS: What would happen if you rotated the earthquake input at different angles?

MR. DAJANI: Well, what we do is we input the motion individually to each of the three models. Then we would calculate the responses and add them up by the square root of the sum of the squares.

MR. ZUDANS: I guess the way you did it wouldn't matter because you assume a homogeneous foundation in this instance.

MR. DAJANI: For this area, right.

MR. ZUDANS: So in reality, it would be different because the layers were affected.

MR. DAJANI: But as I said earlier, it seemed from the calculations and from the results the basic effect is from the siltstone layer which is directly underneath, and the others modify very slightly those results.

MR. ZUDANS: Thank you.

MR. TRIFUNAC: Could I have the same viewgraph back?

MR. DAJANI: This one?

MR. TRIFUNAC: Yes.

(Slide.)

Just so that we don't take the static analysis too far, the dynamics perhaps, you would have the earthquake waves coming from east towards the site.

MR. DAJANI: Yes.

MR. TRIFUNAC: We have made earthquake waves coming from the west over the site. Would the motion be qualitatively the same, do you think?

MR. DAJANI: The motion I would think would not be qualitatively the same because the angle of incidence is different depending on the direction. If we are coming down from this direction it is hitting an oblique line; if you are coming from this direction (indicating), so I would expect reflections and transmission would be somewhat different. But whether or not the results -- which is what we are really after -- after all, the responses would be that different I really cannot tell --all I am saying is that based on the fact that we did it through two different ways, we came up with generally the FLUSH analysis now I am talking about, and the lumped mass approach, we generally came out with the similar responses, very similar responses. In fact, lumped mass was a little bit more conservative.

So I think the effect of the inclination is not that significant. I don't think we are going to necessarily reach a convergence on the answer, because we have not done it; therefore, we don't really know.

MR. TRIFUNAC: Well, using your good engineering judgment, would you be concerned if you looked at this picture and saw that there is a possibility that the incident seismic waves might be focused by the geometry that you have? Wouldn't you be concerned? Wouldn't you want to find out about this?

MR. DAJANI: It depends. To be honest with you, I think, using my good engineering judgment, as you said, I think the approach from A to Z is so full of conservatisms including the analysis and design of the structures that things like that may be nice to find out what the effect would be, but I do not believe that it will affect the final answer in any way, form or fashion.

I will be describing later on some of these consevatisms that are not only found, as you heard previously, in the selection of the earthquakes, but also in the approach of the design of the nuclear structure.

MR. TRIFUNAC: Let me ask you a question about conservatism. I think we are using that word too frequently and in a too liberal way. Do I understand that something is conservative if something is a little bit larger than perhaps it should be?

MR. DAJANI: A little bit larger?

MR. TRIFUNAC: A little bit larger than perhaps it is.

MR. DAJANI: Not a little bit larger; quite a bit larger, I would say.

MR. TRIFUNAC: Is it conservative not to consider something at all? How conservative is something that I do not consider at all?

MR. DAJANI: I really can't answer that question. It becomes very philosophical. I think you cannot draw a conclusion whether it would be conservative if you do not consider it. For example, simplified methods tend to be conservative.

MR. TRIFUNAC: Let me ask a question. You have an engineering structure. Is it conservative not to analyze the stresses or deformations of the forces in that structure that may be physically there? You totally exclude the forces. Is that a conservative action from an engineering point of view?

MR. DAJANI: If your general approach has enough conservatism in other areas, such that such things will not be important, I think we won't categorize it as conservative, but does it make a difference becomes the question. As I said before, we did not analyze the situation. I really do not wish to give you an answer beyond what I just said. You asked me for my opinion and I just gave you my opinion.

MR. TRIFUNAC: I am not looking at this picture at all; I am just trying to find out: is it conservative not to consider something and then argue that because other things are conservative, that something we have not considered is not going to be importnat. Is that a conservative factor?

MR. DAJANI: I can think of many situations where what you said would not mean it is conservative. I can think of other situations where what you said does mean it is conservative. I don't think there is a general answer to that kind of a question.

MR. TRIFUNAC: So then we cannot conclude that this might be conservative, right?

MR. DAJANI: Maybe yes.

MR. TRIFUNAC: Would you agree with that?

MR. DAJANI: I cannot conclude positively that this is conservative or unconservative. I cannot conclude either.

MR. TRIFUNAC: Thank you.

MR. ZUDANS: I am sorry, you won't get away that quickly.

(Laughter.)

MR. DAJANI: Go ahead, Dr. Zudans.

MR. ZUDANS: If you now would have been able to represent this foundation as a continuous foundation, I assume that when you talk about lumped structure analysis, you have just lumped the point of support to the soil. That single point of support for the soil assumes the mat is rigid, and therefore it has its compliances derived from this analysis.

Now if you look from the left corner to the right corner, because of the proximity of this layer number 7, that big piece of foundation might be stiffer than the other corner which is strictly on the siltstone.

Now are you concerned in any way whatsoever about the fact that the mat sees different stiffness foundations that are along the plans?

MR. DAJANI: I don't think that we found that there is a difference, but I can ask the question of George Siegal, from Burns & Roe. Do you know the answer to that?

MR. SIEGAL: When we calculated the functions we considered the properties of all the layers. We found that the effect of the limestone was not significant. The predominant difference was the stiltstone that is immediately under the foundation.

MR. DAJANI: So whether it was here or there (indicating) --

MR. ZUDANS: Looking at your model that you are showing there and seeing that you only have a single element at that corner, or at least I assume that is the finite element layouts that you are showing me?

MR. DAJANI: Right.

MR. ZUDANS: You couldn't really have any decent resolution. If you go steeper in the left corner you only have a single element through layer 7; right?

MR. DAJANI: I am not really sure if this viewgraph --

MR. SIEGAL: Yes, that represents that.

MR. ZUDANS: Okay, so you really do not have any detailed resolution around that corner.

MR. SIEGAL: You are not looking for detailed stresses. What you want is the overall stiffness.

MR. ZUDANS: That is exactly what I am talking about. The 6 and 11 are essentially the same. You have a single element that is much more rigid which connects these. Maybe you get good enough information for all the response. I am not so sure. We will have to look at your numbers.

What you are trying to tell me is there was no variability of foundation conditions from left to right.

MR. DAJANI: To my knowledge, that is right.

MR. ZUDANS: I still have to say that Dr. Trifunac is right. Things that you did not investigate you cannot talk about as being conservatisms.

MR. CARBON: Let's pause at this point and take a break, and at the end of the break, let's interrupt Mr. Dajani's presentation. The staff has seismology and geology people here, both from the staff and from the USGS. Let's address any questions that we have to them at that time, and then they probably will leave by noon and will not be available this afternoon.

So if you would, be thinking of your questions during the break.

(A short recess was taken.)

MR. CARBON: Mr. Stark, I wonder if you could comment on who of your people you have here.

MR. MARK: What would be fair questions?

MR. STARK: We have representatives of the geolog" and seismology review, Mr. Rothman, and McMullen, and I guess they both can kind of make a status report right now very briefly, and then also speak very briefly, Mr. McMullen first.

MR. MC MULLEN: My name is Dick McMullen. I am a staff geologist. I am responsible for reviewing the geology of the Clinch River site. Also here is Mr. Delvicki and Mr. Robert Dowl of the U.S. Geological Survey. We are right in the middle of our review right now, and as part of that review, we are making a site visit tomorrow and for the rest of the week, focusing on during that site visit looking at some of the features in the subregion, looking at some of the core from the site and reviewing the status of the solution verification program around the site.

We will also be looking at some of the high level terraces which may show some sort of relationship with the sheer zones and faults in the area. We have a number of questions which are still outstanding which the applicant is preparing answers to now. These questions mainly are about some of the things Dr.

Pomeroy brought up a while ago updating the PSAR to reflect some of the geologic and seismic work that has been going on in the southeast since publication of the PSAR.

The Geosciences Branch has a great deal of experience in this part of the southeast in the valley and ridge province. We have reviewed at least four other sites there, Phipps Bend, Sequoyah, Watts Bar, and Belafonte. Back in the middle seventies, the staff wrote a limited work authorization report for site suitability report, and we have just completed updating that in the last few weeks. There is still a lot of information out, but based on what we know now there is no reason to believe that the site is not suitable at the present time.

MR. CARBON: Questions?

MR. MARK: In connection with reviews of Sequoyah, I believe the governing earthquake would again have been the Giles County?

MR. ROTHMAN: I am Robert Rothman. I am the staff seismologist reviewing the site. We also have Mr. David Berkens of the U.S.G.S. here to answer questions. We are very early on in our review, but you asked the question about the Sequoyah site.

MR. MARK: I am thinking, not early on the

Sequoyah review.

MR. ROTHMAN: No, we are early on now on the Clinch River.

MR. MARK: But was Giles County not the governing earthquake for Sequoyah?

MR. ROTHMAN: Yes, that was.

MR. MARK: What is its intensity?

MR. ROTHMAN: Intensity 8. During the Sequoyah review, the earthquake was also characterized as a magnitude of 5.8 body wave magnitude and a site specific spectra were used for the Sequoyah site, rather than using the intensity 8 as the design for the site. Actual records were obtained from a magnitude 5.8 earthquake, plus or minus a half a magnitude unit, and these were -- the actual strong motion records were used to compare the design of the site with the ground motion which we believe is expected from an earthquake of that size.

MR. MARK: So it would be consistent with what has happened at Sequoyah and perhaps at a couple of the other plants we mentioned, to define Giles County as an intensity 8?

MR. ROTHMAN: Yes, that's right.

MR. POMEROY: Then would you comment on the question of what the effective design acceleration was for Sequoyah, given the fact that it is a site specific spectrum?

MR. ROTHMAN: The staff compared the design spectra for Sequoyah with the site specific spectra that was obtained, and although there was some excedence at certain frequencies of the design spectra, the staff made a judgment that it was acceptable, and the Sequoyah design was accepted. I believe the Sequoyah spectra was a -- I don't remember the spectrum, but it was less than the Reg. Guide spectrum and it was anchored at at .18 G. It was a modified neumark spectrum, and it was anchored at .18 G, and that was almost equivalent to the site specific spectra as .18 as determined by the TVA.

MR. POMEROY: Could you comment on whether the staff has done any of the calculations that Dr. Trifunac was talking about earlier, specifically return periods and that sort of thing?

MR. ROTHMAN: The staff has not done anything. There was a probability study done during the Sequoyah review, and I am not totally familiar with that because we just don't use probability for determining SSE's. We do use them in a confirmatory manner, but we do not use the probability itself. But I believe, if I remember rightly, the results of the probability study showed that the Sequoyah spectrum was somewhere on the order of 10^{-3} to 10^{-4}. In that range, we looked at it plotted on the same curve with the uniform hazard spectra that was developed under the probabilities. Those are the kind of numbers that stick in my mind.

MR. POMEROY: Is the staff generally in agreement with the listings of earthquakes? Has the staff reviewed those earthquake listings in the PSAR, and are they in agreement with the intensities and completeness of the list?

MR. ROTHMAN: No, the staff has a question outstanding right now about the seismicity to the applicant. We have asked them to update it and look at more recent studies that have been done. We have also asked them to look at some recent work that was done by Professor Ballenger on the Giles County earthquake, and those are still outstanding.

MR. POMEROY: Perhaps this is a question for Dick McMullen, but is the staff in agreement with the structural interpretation that is presented in the PSAR as it is at this time?

MR. MC MULLEN: Yes, generally. Of course, the PSAR has not been updated to reflect the latest information there, including the studies that went on around Charleston, but it essentially comes to the same bottom line.

MR. POMEROY: And would they be in agreement then with regard to the depths of earthquake occurrence and the possible significance of those depths of occurrence as they are outlined in the PSAR? That is probably a question for Bob Rothman.

MR. ROTHMAN: I am not convinced how good the depths are of the earthquakes in that region. I have been talking to some of the people at the U.S.G.S. who have been relocating some of those events, and there is not a local network in that area, so they do not have very much control on the depth. They don't have very much confidence in their depth, so that is the way it stands right now.

MR. POMEROY: So how are you proposing they pursue that question of whether or not the earthquakes maybe associated with the shallower structures on such sonambulistic faults that are drawn in the cross section, or are you questioning that?

MR. ROTHMAN: I haven't raised a question on that. What we have done is asked them to update their seismicity, providing all the information they can, including the best depth estimates on that, but we haven't particularly addressed the thin skin tectonics.

MR. POMEROY: Would you think that association might be significant, though, Bob?

MR. ROTHMAN: Yes, I think it would be, but I am not convinced that we can tie it down just on the data that is currently available. I think we will have to wait until we see the latest relocations to see if they are that way. If we are getting depths on the order of tens of kilometers, then it is on the order of two or three kilometers. It is not clear yet what we are going to see.

MR. MC MULLEN: It might be helpful to add that many of these faults which you are talking about which come to the surface of the valley and ridge province have been dated radiometrically, and at least at the surface where the outcrop there doesn't seem to be evidence of movement, at least since the late paleozoic.

MR. POMEROY: In general, I am aware of that, that there is no surface faulting observed anywhere in this area, but of course we have examples of large earthquakes with significant ground motion, without significant breakage.

Does the staff have any information with regard to another question I raised earlier, with regard to the Norris Dam site, the design criteria for that?

MR. MC MULLEN: No, not directly. I understand that those dams were looked at during the CP review for Watts Bar. The hydrological engineering group, I believe, did an evaluation for the staff, not on the seismic integrity, but on what would happen if it would fail.

MR. POMEROY: Again, could we ask the staff to provide us some further information with regard to what has been done, if there are -- if there is any information on the seismic design? Could that be made available to us?

MR. MARK: Is Norris Dam actually relevant? It is on the Tennessee River not on the Clinch.

MR. KNIGHT: Just as a general answer, my recollection is a little foggy. We may well, as we have sometimes, simply assume that the dam failed and looked at flood protection at the plant. I don't know if that is the case. I will check, however. If the information is available to use, we will see that it is made available to the committee.

MR. MARK: Isn't the dam upstream of the site?

MR. GROSS: Yes, it is.

MR. MARK: There was reference to the Charleston. Now, I don't think there has been much change in the estimate of the intensity of the Charleston earthquake, but there has been a new question of whether it should not be cut loose from its moorings and be allowed to wander around the province. That still does not bring it within much closer distance of the site than where it is now, does it?

MR. MC MULLEN: Well, one of the theories about the cause of that earthquake is that it was related to the measure of the sole thrust which there is no evidence that it goes under the Charleston area yet, and these faults that outcrop in the valley and ridge province are related to that master thrust, but that is where the interest with regard to the Clinch River comes in.

MR. MARK: So it is not just that it will wander up and down the coast and plague New Jersey, but it might also run inland?

MR. MC MULLEN: That's right.

MR. MARK: Wow.

(General laughter.)

MR. KNIGHT: This is Jim Knight again. In some additional response to Dr. Pomeroy's question, I have just been handed a page out of the site suitability report. Just for your information, the design basis flood for the proposed site has been determined by the applicant to be caused by the assumed partial seismic failure of the Norris Dam of 62 miles upstream from the site coincident with the standard project flood with attendant failure of the Milton Hill and Watts Bar dams. So, as I say, as many times it is the case we have assumed -- in this case, I am not sure what the word "partial" means. We will have to explore that more fully with the hydrologic folks.

MR. POMEROY: I guess that would be my immediate question, because I have heard that before, and I was concerned about the question of partial failure. Oftentimes structures don't do exactly what you want them to do, and I am curious as to how the partial failure might occur and what happens if a full failure should occur, because of the quirks of nature.

MR. KNIGHT: Yes. That is something we will have to explore.

MR. LIPINKSI: Let me amplify on that. I believe it was about 1977 or so, there was an ACRS subcommittee meeting down at the site, and the presentation was made on the failure of Norris Dam, and the assumption at that time was that the central section for the dam failed, and it simply toppled forward, so that the face of the dam became the base and the base of the dam became an interface, and then Lake Norris went past the structure and ended up downstream, but it was a large segment failure of the dam that just toppled forward.

The gentleman making the presentation said he thought he was being overly conservative in assuming that type of a failure of the dam structure.

MR. CARBON: I would like to go back to the Sequoyah question for a second. The return frequency, I think you are saying there, as best your memory served you, was 10^{-3}, 10^{-4}?

MR. ROTHMAN: That is back in my memory. I wasn't the reviewer for Sequoyah. I just happened to look over some of the work that was done on it briefly, but it seems to me if I remember seeing the Sequoyah spectra plotted on a probabilistic curve with the uniform hazard spectra, it fell somewhere between 10^{-3} and 10^{-4}. That was the best of my memory.

MR. CARBON: Just offhand, could you venture an estimate? Would it be about the same as you expected in the CRBR site, or higher, or lower?

MR. ROTHMAN: The .25 G Reg. Guide, which is the SSE for Clinch River, is higher than the Sequoyah spectrum, so it would have a -- it would be a more conservative or longer return period for Clinch River than Sequoyah.

MR. CARBON: A longer period of time between the recurrence?

MR. ROTHMAN: Yes.

MR. CARBON: Any other questions of the staff people? I think it is appropriate for us to agree for them to leave when we get our questions out of the way.

(No response.)

MR. CARBON: Well, I am sure we will have some about five minutes from now, but I guess that does it. We thank you.

I guess then we will return to Mr. Dajani.

MR. DAJANI: Okay. To continue in the discussion of the method of analysis for the nuclear island, seismic analysis, that is.

(Slide.)

MR. DAJANI: We did an independent analysis for each of the three directional earthquakes. We had four main sticks in the lumpe mass model. There is a picture of it in your handout. We also presented major equipment such as polar crane and the reactor vessel model, and we have accounted for the flexible ties between the confinement building and the adjacent reactor service and steam generator building at all the elevations. We did that. We came up with the compliance matrix, if you will, through a separate finite element analysis to determine what those flexibility springs are, and we included them in the lumpe mass analysis.

The mass points were located at the centers of mass. The massless members were located at the center of rigidity. We did two separate analyses. The first analyses considered the upper bound rock properties. We got the responses. We also did another analysis using lower bound rock properties, and we got another set of responses, and we then enveloped the two. We also generated time histories at the various mass points, and the spectrum, the design spectrum were then widened by plus or minus 10 percent at the peaks, in accordance with the applicable Regulatory Guide.

I guess then we return to Mr. Dajani.

MR. DAJANI: To continue with the discussion of the method of analysis for the nuclear island seismic analysis, we did an independent analysis for each of the three directional earthquakes. We had four sticks, main sticks in the lumped mass model. I think there is a picture of it in your handout.

We also represented major equipment such as the polar crane and the reactor vessel in the model. And we have accounted for the flexible ties between the confinement building and the adjacent reactor service and steam generator buildings at all the elevations.

We did that. We came up with a compliance matrix, if you will, through a separate finite element analysis to determine what those flexibility springs are, and we included them in the lumped mass analysis.

The mass points were force located at the centers of mass. The massless members were located at the center of rigidity. We did two separate analyses. The first analysis considered the upper bound drop properties, and we got the responses.

We also did another analysis using lower bound properties, and we got another set of responses. We then enveloped the two. We also generated time histories at the various mass points. The design spectra were then widened by plus or minus 10 percent at the peaks in accordance with the applicable regulatory guides.

To account for the further moment arm for components that are located away from the center of mass, we have a procedure to account for the additional translations that result from that eccentricity.

(Slide.)

MR. TRIFUNAC: Would you describe upper bound and lower bound drop properties?

MR. DAJANI: Yes. Earlier you heard in the presentation that we boiled down the various data to characterize the site in terms of the modulae of elasticity, and there was a recommendation that we use a certain number of, for example, the siltstone 1.5 million p.s.i. and that we consider a plus or minus 25 percent variation on that. The 25 percent variation is what I am talking about here for the upper bound and lower bound.

In the evaluation of the nuclear island structures we find that, first of all, the load combinations are in accordance with the applicable code for steel and for concrete. We find that, in general, the structures are controlled not by the SSE but rather by the OBE.

We also further find that many of the structural elements of the various buildings are controlled by conditions other than seismic. Last week we talked about the thermal margin beyond the design base. That in many areas controls the design of the rebar. The amount of concrete shielding is another one that controls the thickness of walls, not seismic, as well as the sodium spills, what I call the design-basis accidents in the various cells that contain radioactive sodium.

MR. TRIFUNAC: A question. Was the OBE selected as one-half of SSE on a conditional basis, or was there some kind of probabilistic loss assessments included to see that this is a good number to take?

MR. DAJANI: As was described earlier, it was selected at one-half of SSE based on precedents, but I think the statement was made that we believe that was on the conservative side.

Walter, maybe you want to elaborate on that point.

MR. BRUSEY: Probabilistic analyses were conducted but were not submitted to the NRC. The conclusion was reached that the designer reached the stage at that time that really it was not feasible to change and it was decided to proceed with a half SSE value, which was, of course, .125 g.

MR. ZUDANS: Were you going to plan to show us this model or not?

MR. DAJANI: I had it out of phase in my vuegraphs since we left, so I did not show it.

MR. ZUDANS: Maybe that is the beginning of it.

MR. DAJANI: This is just an example of the-- I have mentioned that there were four sticks and I mentioned that the confinement is connected through flexible ties to the reactor service building and the steam generator building.

This shaded area represents that kind of tie between the appropriate nodes at all elevations. Both the polar crane and the reactor vessel were modeled.

MR. ZUDANS: Where is the polar crane on this one?

MR. DAJANI: It is not shown on this section. I think it is shown -- No, I am sorry, the polar crane -- the polar crane, George Siegal, do we have the polar crane on this one? I'm not sure which nodes are represented, but I think the reactor vessel is this one here (indicating).

MR. ZUDANS: That is a good substitute for the polar crane.

MR. SIEGAL: The polar crane in one direction was rigid in that particular model. In the other direction, the polar crane was flexible and was represented by a mass on the spring that was equivalent to the first moment.

MR. ZUDANS: The way that you support the interpolar crane, since you have a stick model, in the other direction how did you model the polar crane in terms of where the wheels sit on the rail? It is supported at the ends? It spans the entire containment building. How do you --

MR. SIEGAL: We have a simplified representation of the polar crane. We have a complete model of the polar crane, and we found that there was one mode that was predominant, the first mode. So we determined the generalized mass stiffness for that mode and we represented the crane with one mass and one spring attached to the node that represents the polar crane support.

MR. ZUDANS: Okay. Actually, all you considered in this model for the polar crane was its mass.

MR. DAJANI: That is correct.

MR. SIEGAL: Stiffness, too.

MR. DAJANI: It was not intended for the

design of the polar crane; it was simply intended to include the major equipment as it may affect the response of the nuclear island. I believe the effect was very small in either case.

MR. SIEGAL: In addition, there was an analysis of the polar crane by itself.

MR. ZUDANS: I would believe that.

MR. SIEGAL: We determined those weir reactions and those weir reactions were imposed in the crane to find the stresses.

MR. ZUDANS: Now I would like to understand this cross-hatched area. In terms o. what you said, a separate finite elemental model was made for those buildings and there were appropriate stiffnesses developed between different nodal points. Would then in this model the cross-hatched area be an equivalent super-element? Are there cross-couplings between all the nodal points listed on the boundary?

MR. DAJANI: I am getting a nod that that is yes.

MR. ZUDANS: So this is a fully developed matrix between all those nodes connecting the cross-hatched area?

MR. DAJANI: Right. That is why we didn't show them exclusively, but we showed it shaded.

MR. ZUDANS: And that is the mat matter is rigid; right?

MR. DAJANI: Right. And the foundation spring is not shown.

MR. ZUDANS: 326-foot long mat, 15 foot thick; right?

MR. DAJANI: Something like that. 15 foot, yes. I am not sure about the other number.

MR. ZUDANS: That is about a ratio of length to thickness of 20. Now are these stick models attached to the mat at different proper locations where they are?

MR. DAJANI: Correct.

MR. ZUDANS: Well, I guess I understand what you did.

MR. TRIFUNAC: A question on the mat.

MR. DAJANI: Yes.

MR. TRIFUNAC: This was a two-dimensional slice? Or a three-dimensional mat plate? Or what?

MR. DAJANI: For the lumped mass, George, how did we eventually lump the mat in the model here?

MR. SIEGAL: It is three-dimensional. The actual coordinates of the mass points and of the members were taken into consideration.

MR. TRIFUNAC: Okay. And then at the points indicated in the sketch about structural four stick models were attached to the mat?

MR. SIEGAL: As Mr. Dajani said, the location of those members that are supported from the mat coincide with the center of the rigidity.

MR. TRIFUNAC: Then the stiffness matrix of this entire package on this picture included what degrees of freedom?

MR. SIEGAL: The stiffness matrix included the cross-cut between the different nodes for 60 degrees of freedom.

MR. TRIFUNAC: My question was for the mat and for everything above.

MR. SIEGAL: Well, the mat is rigid. So on the mat there was not such a problem.

MR. TRIFUNAC: I thought the mat was flexible.

MR. DAJANI: No, the mat is rigid.

MR. TRIFUNAC: So that means, for example, that in reality part of the foundation under stick-1 moves differently than the part of the foundation of the stick-2. So this is not included in the analysis; right?

MR. SIEGAL: We do not believe that will happen, because first of all --

MR. TRIFUNAC: I am not suggesting it would happen. I am asking, if it were to happen.

MR. SIEGAL: In the model it is assumed it is rigid, so they move the same.

MR. ZUDANS: Now, hold on. I thought that you had one spring constant attached, say, to node 59. Is that a correct statement for soil?

MR. DAJANI: That was soil, but the question was relative to the mat.

MR. ZUDANS: That means the mat rotates and translates; and therefore, the points that are different distances from node 59 moves differently. Was that the assumption?

MR. SIEGAL: Well, they move differently, but consistent with the assumption of a rigid plate for the foundation.

MR. DAJANI: Well, that is all right. In other words, the points of the --

MR. SIEGAL: Obviously if you have a torsion they will not move exactly the same. But if you make the assumption that the plate is rigid, then you would have consistency.

MR. DAJANI: They move consistent with the rigid foundations.

MR. ZUDANS: And the mass and moments of

inertia at the foundation were all lumped at point 59?

MR. DAJANI: For the mat?

MR. ZUDANS: For the mat, yes.

MR. SIEGAL: Yes. All that was lumped at point node 59.

MR. TRIFUNAC: What is the horizontal extent of the mat, the horizontal size?

MR. SIEGAL: The dimensions of the mat? I think that is on one of the vuegraphs.

MR. DAJANI: 320 feet, I think. Dr. Zudans just mentioned that.

MR. KASTENBERG: Before you leave that vuegraph, how do you account for damping in the structure?

MR. DAJANI: We have a damping matrix for each of the elements.

George, maybe you can elaborate on that.

MR. SIEGAL: The damping of the structures are in accordance with Reg Guide 1.61. That means for the SSE in concrete it is 7 percent and for the OBE the concrete is 4 percent. Now, on that basis, the structural damping is considered.

MR. TRIFUNAC: These are the largest allowables. 161 gives the largest allowable for damping; it does not give the recommended highest for the damping. You are to determine the best engineering judgment what the best values are but not to exceed those. Is that correct?

MR. SIEGAL: It says the SSE values are associated with stresses or strains and yields and the OBE values are associated with stresses and strains about one-half of that.

MR. TRIFUNAC: Yes.

MR. DAJANI: These are the values that we believe. Therefore, I believe what George is saying is that they are the reasonable values to be used.

MR. TRIFUNAC: So you are using the largest values allowed?

MR. SIEGAL: We are using the values that we thought were appropriate for our problem.

MR. TRIFUNAC: If you allow me just one brief question, coming back to the mat question, what is the -- for the metal frequency of either of the four stick models?

MR. DAJANI: I don't remember.

George, do you remember the fundamental frequencies of the four stick models, or any of them?

MR. SIEGAL: The fundamental frequency, I would say, is about 5 Hz.

MR. TRIFUNAC: In the range of 5 Hz.

MR. SIEGAL: In the range of 5 Hz.

MR. KASTENBERG: I just wanted to ask one more question on this.

MR. DAJANI: Yes.

MR. KASTENBERG: Please excuse me, I am not a structural engineer; I just want to learn something.

Basically, when you go to solve for the motion, you are solving a typical matrix equation, like an RLC circuit analog, presumably?

MR. DAJANI: It is not within -- we employ the method of direct integration. We just directly integrate the equations of motion, which include both stiffness and damping.

MR. KASTENBERG: Stiffness and the damping and the mass measures.

MR. DAJANI: Correct.

MR. ZUDANS: Your assumption was right.

MR. KASTENBERG: I see. And you do not use some kind of an IGAN vector modal analysis to do this?

MR. DAJANI: No.

MR. ZUDANS: I think you just misstated your answer.

MR. DAJANI: Tell me how I should have stated it.

MR. ZUDANS: You have your model set up. You ignore the damping, you compute natural frequencies in what shapes, which is an analysis.

MR. DAJANI: Oh, I see. You are right.

MR. ZUDANS: Then you go back and combine your IGAN values and get the approximate response.

MR. DAJANI: In the method of direct integration there is a part where you look at the modes and use the modes rather than as the primary way of heading your responses. But the reason I said what I said, Dr. Zudans, is because there is something else, called, of course as you know, the modal analysis technique, which uses --

MR. ZUDANS: Also uses the natural frequency mod shapes because you have to the chart and pick up the accelerations.

MR. DAJANI: True.

MR. ZUDANS: So I would like to ask one more question on this node 59 that seems to be the item that everything else hinges on. You had some damping values for the soil, too. I did not get those.

MR. DAJANI: I mentioned earlier we did the static finite element analysis, which established the compliance values, the stiffness values. We then used the relationships we derive from that the shear modulus which then, an equivalent shear modulus, which then used the half-space equations to derive the damping values.

MR. ZUDANS: I was just going to knock you down on static analysis using damping valuves, but you have got just the soil property from that analysis.

MR. DAJANI: That is correct.

MR. ZUDANS: Then you went back to half-space and computed your damping values.

MR. DAJANI: Correct.

MR. ZUDANS: That would be correct. How did you derive the damping values for each of the mode shapes that you analyzed for, because your different structures have different damping levels. Steel structures have certain and concrete others and soils other ones. Which would you use for mode shape in the analysis?

MR. DAJANI: Do you know the answer to that?

MR. SIEGAL: To determine the damping matrix for the structural feet space we used a weighted average by the strain energy. That means for the different fixed modes, thick-spaced modes, we determine an average damping considering the different elements in the structure. And that way we formulated the damping matrix for the fixed-base structure. Then we combine that with the damping coefficients for the soil dampers. And in that way the complete damping matrix was formluated.

MR. ZUDANS: How did you "combine"? How did you do the last combination soil damping matrices with a fixed-base structure?

MR. SIEGAL: We have a complete formluation of the model. The placement of a node, in general, is a summation of two displacements: one, of the structure by itself, assuming the base is fixed; and plus those displacements that come from the action of the soil in the dampers.

So the whole formulation of the equation of motion was based on that assmumption. Based on that assumption, you could formluate the complete mass stiffness damping matrix for the structure with the soil effects. And that was integrated directly.

MR. ZUDANS: Now you are telling me you did two analyses: one was a foundation with everything assumed to be rigid sitting on it, and that determined certain rigid-body motion on the foundation; then you did another analysis where you fixed the foundation plate and computed the frequencies and watched for the rest of the structure. Is that a correct statement?

MR. SIEGAL: I am saying we did one analysis, but in formulating the model of the structure for the structure itself we developed the fixed-base mode.

MR. ZUDANS: Okay.

MR. SIEGAL: And that way we could represent the structure by the modes instead of in the degree of freedom in the particular modes which is what is normally used to save a lot of computational time.

MR. ZUDANS: That is okay. Yes.

MR. SIEGAL: In addition to that, we coupled the effects that come from the rotation and translation of the base.

MR. ZUDANS: But you had then another model which consisted of rigid-body modes for the base plus the more flexible structure relative to the base.

MR. SIEGAL: We developed the questions accounting for this.

MR. ZUDANS: This is where you had to combine this coming from soils and structures.

MR. SIEGAL: Yes.

MR. ZUDANS: Did you use something referred to as "equivalent modal damping technique"?

MR. SIEGAL: Modal damping was only for the fixed-base structure. For the other it would be the damping coefficients as calculated by the half-space theory.

MR. DAJANI: So we had one matrix that included the damping coefficient for the structures as well as the soil.

MR. SIEGAL: We have the equations available. That is a method that was proposed for the first time to discuss that formulation.

MR. ZUDANS: I am not trying to discredit what you did. I am just trying to understand it.

MR. DAJANI: For the other nuclear Category 1 structures -- we have not completed this analysis, by the way yet -- but for the emergency cooling tower we intend to use the lumped-mass analysis and use the same approach of providing for a range of rock and soil properties. And since there is a basin within that emergency cooling tower with water in it, we will include the effect of the fluid within that basin using Hausner's theory.

The diesel generator building is another Category 1 structure. It is supported on soil. And we will utilize FLUSH to determine the response of that structure. And we will also use a range of soil properties.

(Slide.)

I mentioned earlier that --

MR. TRIFUNAC: Can I ask a question? How is the ground motion coming into FLUSH or the other model?

MR. DAJANI: Which other model?

MR. TRIFUNAC: I thought you were going to do this calculation using FLUSH and also a lumped three-dimensional anlysis. Am I incorrect in that?

MR. DAJANI: Yes. To find the foundation response, we will use FLUSH, and then after that we will take that foundation input motion that we would calculate from FLUSH and apply it to a three-dimensional, detailed three-dimensional lumped model, which is a standard way of doing it.

MR. TRIFUNAC: But then for FLUSH you are going to get only the translational out of the surface motions where surface is in the plane of the two-dimensionality of the FLUSH. What are you going to do about the other components of FLUSH? How do you get torsion into the FLUSH?

MR. DAJANI: That will be included in -- how do we get specifically the torsion from FLUSH?

MR. SIEGAL: FLUSH does not give torsion. We determine rocking motion, and we get translation motion for FLUSH. But torsional effects will be just considered by representing the masses, the proper center of mass, and the members of the model at the center of the rigidity.

MR. TRIFUNAC: I suppose what you are referring to is accidental-type percentage-type eccentricities?

MR. SIEGAL: Not percentage. Actual.

MR. TRIFUNAC: 5 percent, 7 percent, so-called accidental eccentricities. So you are going to ignore torsion, essentially.

MR. SIEGAL: There will be torsional degree of freedom, but there will be no torsional inputs.

MR. TRIFUNAC: Exactly. That is what I meant. Thank you.

MR. ZUDANS: One more question. The soils/structure interaction by FLUSH, is that a time-history analysis or -- and what do you use? Do you use the synthetic time histories?

MR. DAJANI: Correct. We go through the deconvolution process, and then the convulsion.

MR. TRIFUNAC: This input comes from where?

MR. DAJANI: Which input?

MR. TRIFUNAC: The ground motion. Where does it get into the FLUSH?

MR. DAJANI: In the FLUSH we are going to put it at the -- for which question? For which building, first of all?

MR. TRIFUNAC: For all of them. I thought that this is rigid; so the question applies to all of them.

MR. DAJANI: No, but I mentioned that FLUSH will be used for the diesel generator building, which is on soil properties. I am not sure, where do we start our input motion, at the surface or at the top of the rock, George? For that we have not done it, so I am not really sure.

MR. SIEGAL: We are going to put the input motion in this particular analysis at the foundation layer. It is near the surface. There is no embedment.

MR. DAJANI: There is a requirement in the new Standard Review Plan, NUREG-0800, which we intend to follow for this analysis, that the input at the foundation level envelope the design response spectra in the reg guide. So that is what we will eventually have to do.

MR. TRIFUNAC: I understand that. But FLUSH needs to get input somewhere. Where is it going to be put in if you are going to use it?

MR. DAJANI: I am not sure the criterion is to put it at the position at the control point such that we will envelope the design response spectra at the foundation level of that building, which is not yet designed.

MR. TRIFUNAC: Can you answer that question?

MR. SIEGAL: We are planning to put it at the foundation level. That is, we are going to put the input motion at the foundation level.

MR. TRIFUNAC: Does that mean that you are going to take that motion back down to the bottom of the box in which FLUSH is sitting and calculate the motion there and send it back up?

MR. SIEGAL: Yes.

MR. DAJANI: And it has to be at the foundation level such that it envelopes the design response spectra.

MR. TRIFUNAC: That is a consequence of the requirement. But I am trying to understand the physics of the calculation. Are you going to consider the motion coming from one side of the box of the FLUSH? Are you going to consider the input motion coming from one side of the box of the FLUSH?

MR. SIEGAL: No. FLUSH does not allow for that. FLUSH considers vertically propagating motion, so they are going to put the motion -- we will start with the control motion at the foundation level. It will go to the base of the model to the horizontal boundary, and it will solve the problem with that motion. That means that at the site we are going to have energy absorption bounds at both sides of the model.

MR. TRIFUNAC: So you are going to consider only vertically inputting seismic energy?

MR. SIEGAL: Yes.

MR. TRIFUNAC: Do you feel comfortable with that in light of the layers we were talking about earlier?

MR. SIEGAL: I think in this particular case, where we have a rather deep layer of soil, it is very adequate in this case.

MR. TRIFUNAC: Is it possible that the waves coming from below would show up smaller on the surfaces because of the layering? Is it impossible that this inclined layering would scatter a lot of energy out of the structure?

MR. SIEGAL: I would say there are a lot of possible variables. It is a very complex topography, and I do not think you will be able to model perfectly regardless of the method of calculations that you use. So I think we have to try to do a simplified analysis, as simple as we can, but try to create a seismic environment that would be consistent with the area that we have. And we believe that using this method, we will be able to achieve that.

MR. TRIFUNAC: I thought that there were some other later generations of FLUSH. Some of them are called LUSHs and PLUSHs.

MR. SIEGAL: I do not think that they have been introduced or released yet.

MR. TRIFUNAC: They have been released for years. Do either of these allow other types of input so that you might get a better view of the effect of these inclined layers?

MR. SIEGAL: I understand there is a new version of that type of program that considers wave propagation in direction, but I understand they have not been officially released.

MR. DAJANI: For the seismic Category 3 structures adjoining Category 1 structure and whose failure could challenge the integrity of the Category 1 structure, the turbine generator building and the rad waste building, we also did a pretty detailed seismic analysis on those two buildings for the SSE.

(Slide.)

In summary, I will go over the points of conservatism that we have in the seismic analysis. The first two were discussed earlier. The third bullet relates to the fact that the design response spectrum covers a wide band of frequencies, that the fourth bullet relates to the time that the artificial earthquake in general is higher than the design response spectrum when you put it in the frequency domain.

The fifth bullet relates to the fact that the seismic analysis considers linear properties and does not take into consideration or account the nonlinear properties of the structural elements. The fifth bullet is that there are pretty conservative safety factors required by the codes.

The sixth bullet relates to the fact that we are using minimum material properties and as strength properties. And we find that the actual yield strength is actually higher. The second sub-bullet relates to the fact that we use the strength properties of young concrete, 28 days, and we do not take into consideration the substantial increase of that strength with time.

(Slide.)

We also know the dynamic properties, the response of the properties under dynamic conditions yield higher strengths than the ones that we used, which are based on static strength properties. We typically have simplifications in the design itself, the structural design itself, such that we would use similar configurations, equal member sizes even though they are not absolutely needed. Something smaller would be sufficient, but we do that as part of the prudent engineering and standardization of the design.

The next bullet talks about the fact that, in general, the structural sections are controlled by the OBE and not the SSE. And many other sections, as I mentioned earlier, are controlled by things other than seismic altogether. The difference is quite significant.

The last bullet relates to the picture I showed last week. In the containment, for example, below 816 where the cells underneath the operating floor are all interconnected, you have many redundant paths to transmit the loads, and it is not conditional or dependent on one particular load path.

That is the end of the summary and the presentation I have.

MR. ZUDANS: I thought this last statement, that you already told us in the model that all these structures were analyzed by a separate model, and the conductivity of various degrees of freedom was included in the basic structure. So that should not as a consequence represent any other hidden conservatism.

MR. DAJANI: What I am referring to here, Dr. Zudans, is, since you have many paths for the loads, if one of those walls, for example, cracks or gives way, it does not mean a catastrophic consequence. You have many other load paths that will transmit that load.

MR. ZUDANS: That is, of course, correct. I would like to return back to the cooling tower. You said that you would model it as a stick. What kind of a structure is it? Is it a cylindrical vessel?

MR. DAJANI: It is cylindrical. The superstructure is, I think, rectangular, because the fill has to fit, and the basin is the volume that has the inventory water that is required.

MR. ZUDANS: And the superstructure is rectangular?

MR. DAJANI: Yes.

MR. ZUDANS: The crane type structure?

MR. DAJANI: I really don't recall. I thought the outside walls were concrete; inside it is framing, I believe.

MR. SIEGEL: It is more of a shear wall type of concrete structure.

MR. CARBON: Bill

MR. KASTENBERG: I just have a question. Do you ever find that you have conflicting requirements in your bullet? You say many structural elements are controlled by other than seismic, such as the TMBDB or the structural margin beyond the design basis. Do you ever come into conflict where you have a problem satisfying two different requirements, or does one always subsume the other?

MR. DAJANI: It is more the latter than the former. I cannot think offhand of something that says, because of the thermal margin here is what you should do; because of something else here is what you should do, and that those two things are in conflict. Typically, one envelopes the other, and you just have to design for the response that is coming out from the more severe environment, which in many of the cases, as I mentioned here, is not coming from an earthquake from a seismic event. We are talking about a substantial amount of difference between the two.

MR. KASTENBERG: What is the thing that is always controlling in some of these other areas, such as in the thermal margin, that would subsume the earthquake as the seismic consideration?

MR. DAJANI: The thermal moments that are generated that affect the cavity wall, for example, determine how much rebar you are going to have in there, and not the seismic.

MR. KASTENBERG: And questions relating to your ability to take up thermal capacity due to expansion is never in conflict, say, with trying to make a system more stiff or thicker to meet a seismic requirement?

MR. DAJANI: I think the way I will answer that is to say that we have to factor in any requirements for thermal expansion within the range or within the domain, the regime of me trying to design the structure to satisfy several conditions. In that sense, yes, there will be requirements that are perhaps apparently in conflict or one thing requires expansion, the other thing requires rigidity.

A perfect example of that is, of course, the seismic snubbers, but I would not consider those as being fundamentally any different than any other situation we have on any other design. .In this case, if you are asking me, does one set of accidents result in configurations that are required that are in direct conflict, that degrade the effectiveness of that structure for another load combination, the answer is no.

MR. ZUDANS: I think it is probably too strong an answer, because I think I could think of a couple of ways you have a definitive conflict. Let's take the containment shell coming into concrete at a certain level. It sits on the concrete there. Whatever the upper part of the shell wants to do the concrete stops it from doing. Suppose you heat up the upper shell. You have a definite conflict. You go deeper where the shell is embedded in the concrete. Then you heat up the compartments and you start pushing the cell out or preventing it from expansion. That is another conflict. There are many places where you do have a compromise solution.

MR. DAJANI: I thought I answered that in terms of this is the normal stuff, is there anything in this particular situation that is coming uniquely out of TMBDB? That is what I was trying to address. The answer is no.

MR. ZUDANS: I would like for you to qualify also that in general structures are controlled by OBE. It is not the OBE by itself, but it is the way you have to combine it with the other loads.

MR. DAJANI: And the allowable.

MR. ZUDANS: That is right. So it really creates a misconception that OBE is more dangerous than the SSE. That is not the case. It is a code requirement as to how to combine that result and the allowables associated with it.

MR. DAJANI: Let me clarify what I meant. If you designed a structure, you find that the rebar or the amount of concrete you must have is controlled by the OBE requirements, because it has lower allowables and it is combined with other conditions. If you took that structure and challenged it with the SSE, you would find that it has a substantial amount of margin because that design was controlled by the OBE.

MR. ZUDANS: Because the SSE allows you to go higher with stress levels.

MR. DAJANI: Yes.

MR. ZUDANS: That is why a higher stress level, of why the OBE controls, and that is not unusual. That is pretty much just a standard type of view.

MR. DAJANI: Right.

MR. POMEROY: I had one further question. Perhaps I misunderstood your last two slides, but I have always had this question, I think. We have often been told that the earthquakes do not need to have additional conservatism built into them because of the additional conservatisms that are built into the structural analysis and structural elements. Not here, other places. Would I interpret your last two slides to tell me that in fact you believe that the analyses that you have done would allow the structure -- or that the resultant structure would actually withstand a greater acceleration spectrum than the one that the design spectrum is made up of?

MR. DAJANI: Yes.

MR. POMEROY: By what kind of a factor?

MR. DAJANI: It is very hard to tell or to generalize, because as you know, some of these apply in certain areas, others apply in different areas, but I would say it is by a substantial factor. If you look at -- one of the elements I mentioned before is, the design basis accident controls the rebar in many areas, and there is a significant difference between the density of that rebar and the density of rebar found in other areas where you don't have that condition.

MR. POMEROY: Could you give me an order of magnitude perhaps?

MR. DAJANI: Only if you will not quote me on it.

(General laughter.)

MR. ZUDANS: You could answer the question differently in a critical combination where the SSE was the most significant contributor. What fraction of the total allowable did it take?

MR. DAJANI: I think I would rather answer it the first way.

MR. POMEROY: I think I would like to hear the answer to the second one.

MR. DAJANI: I don't really know.

MR. ZUDANS: Maybe Mr. Siegel knows, or he should know.

MR. SIEGEL: I would say that probably the structures will stay standing at least for twice the value we use for the SSE of .15.

MR. ZUDANS: Because of the fact that they take just a little fraction of the total available stress?

MR. SIEGEL: No, because once you consider that they will be cracking and you have some inelastic action, then you see the structure can take a much higher value than you normally assign when you do your analysis, because you have to have the number of redundancies.

MR. DAJANI: George, let's not digress. I just want to try and answer the question to the best of my ability.

MR. CARBON: We weren't digressing, Mr. Dajani. Go ahead, Mr. Siegel.

MR. ZUDANS: I would like to ask a further question. You are giving the right answer. That's the way it is. You do have the margin at that point, but do you offhand remember the worst case where an SSE's contribution was identified quantitatively compared with other loads if you applied the same thing?

MR. SIEGEL: I would say that perhaps the containment vessel would be one case.

MR. ZUDANS: The buckling mode was a key contributor?

MR. SIEGEL: Yes. Even so, I think the OBE was the controlling mode, but that margin was less for the SSE, if I remember.

MR. ZUDANS: When you calculate the free standing shell buckling mode, what other loads induced the compression that you had to live with? Was it seismic alone?

MR. SIEGEL: It was seismic plus the dead load and the external pressure.

MR. ZUDANS: That is three.

MR. SIEGEL: Point five psi.

MR. ZUDANS: Then I guess in this condition seismic probably dominated, right?

MR. SIEGEL: Yes.

MR. ZUDANS: So if you look at that containment --

MR. SIEGEL: I think the containment pressure is a significant factor, considering the buckling strengths of the shell. Perhaps it is not as significant as the SSE, but it is not negligible. I think it is an important parameter.

MR. ZUDANS: So at any rate an SSE produced compressive stress because of the bending mode.

MR. SIEGEL: And also due to the actual load.

MR. ZUDANS: That was significantly higher for any other load than this failure mode.

MR. SIEGEL: Yes, except for the external pressure.

MR. ZUDANS: But that also means that your margin is based on inelastic behavior code by concrete cracking disappeared in this failure mode, and therefore you would be in a worse position in terms of allowing higher SSE accelerations, right?

MR. SIEGEL: Well, but then we can go into the conservatisms that are involved in the design analysis of the containment vessel.

MR. ZUDANS: But that is a different conservatism. I think the key conservatism in the SSE is that in most locations it is not a dominating load, but you can single out few structures and few failure modes which are really dominated by SSE, such as this containment buckling mode, and that kind of determinants, how far you can go, because it doesn't matter how much you can have elsewhere. It matters how much you can have in the weakest link, so to speak.

MR. SIEGEL: But even under the SSE we have conservatisms in the containment vessel. That means we can have an SSE, and even when we meet the allowable limits under SSE, I would say we still have plenty of conservatism in the containment vessel.

MR. ZUDANS: Are we going to hear more specific detail from Bob maybe on how the containment was analyzed, or from somebody else? Have you planned a discussion of this particular buckling mode of the containment today?

MR. DAJANI: Not in my presentation.

MR. GROSS: No, we don't plan on covering that.

MR. ZUDANS: I think the containment shell in my opinion is what I would like to hear about. How did you handle the buckling? What are your allowables there? What design criteria did you use? And what are your so-called design values? Not necessarily going into how much conservatism you have. What safety factors do you use? How do you do the calculation? This is what I would like to hear if it is possible at all.

MR. GROSS: We covered the containment design last week.

MR. ZUDANS: We said we would discuss the details today, because it was seismic. We didn't really discuss the calculations of the containment free-standing steel shell. I don't know who on your team analyzed it.

MR. DAJANI: That's correct. We did not discuss the structural analysis of the containment vessel.

MR. LONGENECKER: We will attempt to treat that on June 24th.

MR. ZUDANS: Who did that analysis? Did Burns and Roe do it?

MR. DAJANI: Chicago Pridge and Iron.

MR. ZUDANS: I would like to hear that, because I think this is a weak link in terms of the SSE.

MR. CARBON: Let's do, Mr. Longenecker.

Harold?

MR. ETHERINGTON: I have often heard that argument that there is conservatism because the strength of the material exceeds the specification. I think that advantage is far more than offset by the defects we expect to find in a gross product which you do not have in the test specimen. I think that is a spurious argument, although it is a very common one.

MR. CARBON: Yes?

MR. TRIFUNAC: I have a question that deals with this dilemma of exceeding SSE. I thought we just heard that not speaking about general modes of failure, but in general that we might be able qualitively to support forces perhaps a factor of two larger than SSE. Was that what you were saying essentially, not in detail?

MR. SIEGEL: Well, rather than force this, I would say if you do an analysis for a .5 G and consider those effects that are not included in our analysis, non-linearities, things like that, I think you would prove that the structures will not collapse, they will keep the structural integrity at that level.

MR. TRIFUNAC: Yes. Now, in light of that, I think we were talking a little earlier about damping. How do we then justify using the largest allowables, just for the sake of discussion now, 25. percent G, rather than maybe considerinz 7 percent damping for 50 percent G, and perhaps 5 percent G for 25 G?

MR. SIEGEL: If we had 25 G, we would go much higher than 7 percent and 4 percent damping, because you would be well into the plastic trends. You would have substantial cracking of the concrete and I think the losses of energy under those conditions would be much highier, so I would say 7 percent damping would be quite low.

MR. TRIFUNAC: Well, would you expect that the damping is a -- how can I ask this? -- a linearly or monitonically linearly light increasing of the non-linear response, or would you expect it to be changing slowly while you are in the linear range and then going up around the non-linear range?

MR. SIEGEL: Yes. I think once you get into the non-linear range, you will have a sharp increase.

MR. TRIFUNAC: Now, if you take this list from the summary of conservatisms here, a lot of things are stronger than they are calculated for. Would that not suggest the possibility that we will never reach the strains that would support our selection of damping, like 7 percent? If everything were right, we would perhaps reach 7 percent, but because everything is so much better, we say, are we not having too much damping in the system?

MR. SIEGEL: I think the numbers you have in the Regulatory Guide for damping are quite conservative. At that level, you probably can expect more than 7 percent even in the linear analysis.

MR. TRIFUNAC: What is the basis of that statement? Is this a hypothesis, or is this experimental, or a factual observation?

MR. SIEGEL: Well, I don't have any data readily available, but in general I understand the values specified by the NRC are conservative values.

MR. TRIFUNAC: So you are actually working on the confidence that their numbers are good? You don't want to explore that a little bit further, the engineering practice of whether those numbers are too large?

MR. DICKSON: Excuse me, Dr. Trifunac. We are going to get into that, the damping values on some of the components, during Mr. Moroni's classification of criteria a little later.

MR. TRIFUNAC: That is fine. Thank you.

MR. CARBON: Are there any other questions of either of the gentlemen?

(No response.)

MR. CARBON: I guess the agenda calls for our break at noon, and we might as well take it at this time, in deference to Dr. Mark. We will come back at 1:00 o'clock.

(General laughter.)

(Whereupon, at 12:00 noon, the meeting was recessed, to reconvene at 1:00 p.m. of the same day.)

AFTERNOON SESSION

(1:00 p.m.)

MR. CARBON: Mr. Dickson, are you all set?

MR. DICKSON: Yes. Tony?

MR. MORRONE: Good afternoon. My name is Tony Morrone, from the Westinghouse Advanced Reactor Division, and I will be discussing the seismic design criteria for systems and components.

(Slide.)

MR. MORRONE: This consists of the seismic classification and qualification, the seismic input development from the building to the system, and from the system to components, damping valves, basic load combinations, and seismic test requirements and procedures.

(Slide.)

MR. MORRONE: For seismic classification --

MR. CARBON: Mr. Morrone, could you step back, please, so we can see?

MR. MORRONE: For seismic classification, we classify the systems and components in accordance with the importance of their function. These are seismic category 1, seismic category 2, and seismic category 3.

Seismic category 1 system and components are designed for both the SSE and OBE and consists of those safety related systems and components necessary to ensure the integrity of the reactor coolant pressure boundary, provide capability for reactor shutdown, and provide capability to prevent or mitigate consequences of accidents.

Seismic category 2 systems and components are designed only for the OBE, and they are required to permit continued reactor operation and to protect plant investment. Actually, this is an optional classification, and these components may be put with the seismic category 1 safety related components or in the seismic category 3.

The seismic category 3 components are designed to meet local design criteria, standard building codes, and they are required to maintain support of normal operations. Actually, the seismic category 2 and 3 components are comparable to the non-seismic category use in LWR plants.

Additionally, these components must be designed for no gross structural failure under SSE loads to protect the seismic category 1 components.

MR. ZUDANS: Are you sure that that applies in all the cases, or in some cases that you may just separate them from the others?

MR. MORRONE: When applicable.

MR. ZUDANS: So if you design them to a standard, you will be category 1 then.

MR. MORRONE: Not category 1, but with the loads for category 1, not to the criteria category 1.

(Slide.)

MR. MORRONE: Okay. The seismic qualification, is performed by either or both analyses and testing. For seismic category 1 and 2 components, a detailed dynamic analysis is required. This consists of either response spectrum method or the time history method of analysis, and also with conservative simplified methods. This would include designing for a constant acceleration of one and a half times the peak on this response spectrum, which is quite conservative. For seismic category 3, it is only a static analysis, although in many cases they are also designed with response spectra.

For qualification by testing, we have multiple frequency tests, single frequency tests at resonance. We can use either one or both, and I will discuss later how we qualify our components for testing, and the basic criteria is that the test response spectrum must envelope the required response spectrum. Now, the test response spectrum is the spectrum of the shake table motion that is input to the item during testing and the required response spectrum is the spectrum of the motion calculated at the mounting of the equipment.

(Slide.)

MR. MORRONE: I would like to -- I don't know which way to stand here, but I would like to discuss the seismic input that is used for the design of our components. This is obtained from the building analysis which gives responses at nodes located at the center mass of the applicable floor. This figure shows a typical plan view of the nuclear island buildings. Of course, these nodes are not at the same elevation. The responses are obtained from the building analysis in three independent directions.

Now, each node in the building model has three degrees of freedom in the horizontal direction, that is, translation, torsion, and rotation, and in the vertical direction each node has one degree of freedom, translation. Therefore, we obtain seven responses, spectra, and time histories for each node, three translation, two torsion, and two rotation.

Now, when we consider the OBE and the SSE and the upper and lower bounds of soil moduli, we will end up with 28 responses. Now, in accordance with combining the directional effects by the square root of the sum of the square, we must apply for a response spectrum analysis these spectra individually in each of the three directions, apply two spectra in each of the two horizontal, and three spectra in the vertical direction, and basically they consist of direct and cross spectra, so we can keep track of which earthquake causes which effect, and then we can combine the effects by the square root of the sum of the square.

MR. ZUDANS: Could I ask a couple of questions at this point? I assume then that your models for each of the directions in the horizontal direction are two-dimensional or are they three-dimensional?

MR. MORRONE: They can be either two or three. For example, our reactor system model is three-dimensional, but we perform three separate analyses.

MR. ZUDANS: And you perform these three analyses on the same model?

MR. MORRONE: They are different models. In the horizontal direction they are basically the same model. The vertical model would be different.

MR. ZUDANS: So you don't really have a three-dimensional model, even -- if you had a three-dimensional stick model for this system sitting on the map, you can analyze it for a three-dimensional earthquake, but it would remain the same, and you would have in that case still six degrees of freedom per node in principle, but what you are telling me now is that in each of these planar analyses, in essence, you only have two translations, not upper plane, and you also have rocking and the other rotation.

MR. MORRONE: That is the building model that has these freedoms. Our system model has six degrees of freedom. They are basically the same models, except some little variation where we model an important element, a response more in a vertical direction than in a horizontal direction. This is the only basic difference between, in this case, for the reactor system model.

You see, I was going to show you this model later on, and I will tell you that in that case, we would have to input eleven time histories. We have these seven spectra, plus then we have pure rotation and translation, so we have eleven histories input.

MR. TRIFUNAC: Excuse me. But you are essentialliy ignoring the coupling, right? You are assuming there is no coupling?

MR. MORRONE: Coupling between what?

MR. TRIFUNAC: Say, two horizontal components of excitation. You are assuming that coupling is not there.

MR. MORRONE: Yes, but this will be taken care of by the square root of the sum of the square.

MR. TRIFUNAC: Not entirely, because the coupling would equal the differential equation.

MR. MORRONE: Perhaps, but this is the standard methodology to input one earthquake at a time.

MR. TRIFUNAC: Yes.

MR. MORRONE: We can also do it the other way. Our criteria stipulates you can do either, and this is also in accordance with Standard Review Plan and Regulatory Guides.

MR. ZUDANS: That is why I asked you if you used the same model. If you use the same model, you are doing linear analysis, so you can take individual loads seismic in one direction, analyze the results, take the other individual load seismic in the other direction, and then end up with the results either way you want, whether SSR or some other method. But you told me that the models are not quite identical, so I am just wondering how you can combine models that are not identical if they don't represent the same constant system necessarily and they do not represent the same structure.

So, I guess we will have to see your models to have a better understanding.

MR. MORRONE: As I mentioned before, the difference is very small. For example, in the vertical model, the sodium mass is treated a bit differently than in the horizontal model, but we still have the same elements, so that we can combine the effects on a particular element.

MR. ZUDANS: Supposing you modeled sodium in one case with the capability to perform slashing motion, and in the other case you ignored that, and as the vertical motion you took it as the mass and simply anchored it at that nodal point. I don't know. Did you model sodium with a slashing degree of freedom in this system or not?

MR. MORRONE: We have fluid coupling elements.

MR. ZUDANS: Of some kind.

MR. MORRONE: In the model, yes. The elements are given in the answers to the computer program.

MR. ZUDANS: But you did not model sodium as a finite element, not in this model.

MR. MORRONE: Not with finite elements, no.

MR. ZUDANS: Perhaps we will get a clearer picture as time goes on.

(Slide.)

MR. MORRONE: Since it is difficult to have to perform seven spectra analyses, we give the analyst an option to use a more practical, simplified, and conservative method whereby the seven spectra are reduced to three spectra. Now, this is done by initially combining the spectra by the square root of the sum of the square. We combine the two horizontal by the square root of the sum of the square to give us a combined translational and torsional. When we do this, of course, we have to combine the resulting responses by the absolute sum, since we have used up the square root of the sum of the square.

This method has been proved mathematically to be always conservative, and the conservative sum, of course, depends on the effect of the cross coupling concerns. If they are very small, the conservatism would be that which is obtained if we were to add the directional effects absolutely instead of the square root of the sum of the square.

MR. TRIFUNAC: Could you explain this, please? Could you explain the second and the third steps? You have seven spectra. You combine what?

MR. MORRONE: Perhaps I can show you on another vu-graph here. I know it is sometimes difficult using words.

(Slide.)

MR. MORRONE: Okay. First of all, here we have the translation. This --

MR. CARBON: The superscript represents the direction of the earthquake, the subscript represents the direction of the spectrum input as you see here. This is a node, the center of mass. This is the location of our equipment (indicating). In the next direction we have input the translational component plus the torsion times the distance Y. Then we also input the torsional component given by the Y earthquake, okay, and we go through this.

Now, as far as the combination.

(Slide.)

MR. MORRONE: Here we go. We take this here, which is given by the X earthquake, as you have seen before (indicating), added directly, because they are both given by the same earthquake, and then add to that the horizontal component given by the torsion. Now, since this is given by the Y earthquake, then we add them by the square root of the sum of the square. Similarly for the Y and the Z. So --

MR. TRIFUNAC: What then do you operate on with the absolute sum? That is what I do not understand.

MR. MORRONE: When we apply these spectra to a component, you see, now, these are pseudo-earthquakes, okay, so we apply the X earthquake and get responses, accelerations, displacements, whatever. We do each, X, Y, and Z, and then we add them absolutely. Rather, now by the square root of the sum of the square again.

MR. TRIFUNAC: A_X, $_Y$, $_Z$ is now your condensed representation of the X, Y, and Z components of spectral acceleration at the point where you want to analyze something.

MR. MORRONE: Yes.

MR. TRIFUNAC: And then you analyze that something for the absolute sum of these? Is that what you are saying?

MR. MORRONE: We analyze the something with the spectrum input. Let's say we do an analysis in the east-west direction of the component. We input this response spectrum. Then we do an analysis north-south input, vertical, we input this. Now, the response accelerations or whatever that we get from each of these three spectra at a particular node are combined absolutely. You see, this is a conservative method, but it results in three analyses rather than seven.

MR. TRIFUNAC: I understand. Thank you.

MR. ZUDANS: I would like to ask a little bit more. Now I see. What happened to the rotation of inputs at that particular point where this is connected? You just lift them out completely?

MR. MORRONE: The rotation goes into the vertical.

MR. ZUDANS: What you have generated here are the linear accelerations on that point. It is at that point they were connected by a rigid link to your node. The translations are computed correctly this way, but the node or the connecting point also sees the rotations. They transfer in space without any transformation, so you would have to have another three spectra for three rotations identical to the rotations at that particular node, and those seem to be ignored.

Now if you have a flexible joint connection, that would be all right. In other words, this accounts for motion, but it doesn't account for point rotation of the attachment and that could be significant.

MR. MORRONE: You can't input a rotational spectrum.

MR. ZUDANS: Why not?

MR. TRIFUNAC: You have it right there.

MR. ZUDANS: You are using it here to generate that translation. The rotation moves directly to that point. The rotational vector is unchanged. You can move it in space. So at that point you have thetas of X, thetas of Y, and thetas of Z computed, which you didn't. Those rotations are ignored.

MR. MORRONE: They are put in here by multiplying by the moment arm.

MR. ZUDANS: That's correct, but that generates only linear motion. I have a rotation here in a translation (drawing on the chalkboard). This rotation creates additional translation in here.

MR. CARBON: Better use white chalk.

MR. ETHERINGTON: Is that green chalk he is using?

(Laughter.)

MR. ZUDANS: I have a rotation here and a translation. This translation, see, moves this point like that, and the rotation brings it back a little bit. You accounted for this. That is your A_X, but you forgot the fact that this is identical to that rotation at that point. So that point of conductivity sees the same rotation, and that vector moves in space. It is unchanged. If you go back to your cartoon that you had before.

MR. MORRONE: I don't see how you can put a pure rotational spectrum input unless --

MR. ZUDANS: It is a boundary condition, if you analyze it after that.

MR. MORRONE: It is a time history. Let me show you. Perhaps this might explain.

MR. DICKSON: Mr. Morrone, did you not state at the outset that it has been proven mathematically that the resultants of doing it this way are greater, always conservative accelerations and always conservative displacements?

MR. MORRONE: Yes.

MR. DICKSON: If so, I don't think we want to go through that derivation today.

MR. ZUDANS: We do not have to go through the derivation. You cannot prove it mathematically, because you are missing components of motion. It depends upon what you hang on that point. If your equipment is flexible, you don't care. If you have something large and rigid, that rotation might be the critical one. Your displacements may be very small. You just ignore certain components of relative motion.

MR. DICKSON: Could you refer us to the paper in which that is proven?

MR. MORRONE: Certainly.

MR. CARBON: I think we will go ahead with the questions that Dr. Zudans is raising. We would like to understand the physical aspects of this.

MR. DICKSON: I think they are valuable questions, and we need to provide him with the information he needs. I just thought it was a direction where Tony was not going to be able to explain it and derive it this afternoon. It was far too deep.

MR. CARBON: It is not a matter of derivation at the moment, however.

MR. MORRONE: The paper, for the record, is Combination of Torsional, Rotational, and Translational Responses in The Seismic Analysis of A Nuclear Power Plant. This is by me and Mr. Siegel.

MR. ZUDANS: If you, being one author, and the other author, being here, cannot explain it successfully to me now, then it just --

MR. MORRONE: Sir, there is no torsional spectrum as such. Now, for time histories, I think this is what you are talking about, isn't it, the pure torsion and rotation? You see, for the time history analysis, then we do input the three equivalent translations plus now a pure torsion and a pure rotation.

MR. ZUDANS: Supposing my rigid arm to that point was zero lens and I had equipment that touched right to that node. Would you ignore rotations of that node to calculate equipment stresses?

MR. MORRONE: Then if I were concerned about that, then I would ask for different spectra from the building analyst, but because the way they are designed --

MR. ZUDANS: Wait. You have the translations or a rotation in the translation. You use them in the model. I am trying to make sure that you understand what I am asking.

MR. MORRONE: The torsional and rotational spectra are G's per foot of length. Now, if I have zero I cannot use those spectra.

MR. ZUDANS: The thetas are the angles of acceleration at that point.

MR. MORRONE: Yes.

MR. ZUDANS: They are angles of accelerations. And As are linear accelerations. You now connect something by a rigid link to that point where you have thetas and As computed. If you multiply what are the lens of rigid link the thetas which are angles of accelerations, you get linear accelerations at that point.

The problem is that that point still sees the same rotations, the same angle of rotations. Physically if I have a node here, a node like this, and I have a spectra for this point which consists of angle of accelerations and linear accelerations, that point will see that rotation. That is a moment input rather than a force input at that point. It is a bending moment input that will result from it, and it is not necessarily -- it may not be significant in these structures, but you cannot a priori ignore it and tell me that this is always conservative.

MR. MORRONE: I can. I can, because, first of all, the effect of rotation and torsion is extremely small.

MR. ZUDANS: That is different.

MR. MORRONE: Very small. One percent, one and a half percent, based on that.

MR. ZUDANS: That is a different argument. I am not going to contest that argument until I see the numbers, but the other one is not.

MR. MORRONE: Number Two, the way the building analysis is performed, we cannot input the pure rotational spectrum, because they are given in per foot of length, but for the time history analysis we do consider it.

MR. TRIFUNAC: Excuse me just a minute. How do you mean, you cannot when they are right there? You have included them already. The question that Mr. Zudans is asking you is simply what do you do about the dynamic equilibrium equation for a rigid body which has the forces equal to a mass times linear acceleration, but which also has the moment is equal to the mass moment of the inertia times angular acceleration. That is what he is asking you.

MR. ZUDANS: That is exactly correct.

MR. MORRONE: Did you understand or did I explain what these spectra looked like, the ordinates? They are in G's per foot, okay? These are the spectra that are produced from the building analysis.

MR. ZUDANS: That is a correct dimension.

MR. MORRONE: Okay. Now, if I have a certain distance Y. So I multiply that spectrum by this Y to get an equivalent translation. Now, how can I input a pure rotational spectra that is given in G per foot without a length? How can I convert it?

MR. ZUDANS: Well, I think your difficulty I think I do understand, but my difficulty is as follows: If you analyze the structure and you have a two-dimensional model, sometimes you say that model is three-dimensional, but you input one directional earthquake. That is all fine. As a result of that calculation, you came up with the time history of displacements and rotations at different nodes. Wherever you allowed for in-plant rotation, that rotation showed up as a time history. If you take those rotations, they are really physical rotations. The things move, and get rotating. That is what you compute, and you just cannot ignore that, unless you can prove that they are 1 percent or so.

MR. MORRONE: You see, even when we multiply these rotational spectra by the distance, the eccentricity, even so, the increase in the combined spectrum is very, very small, 1, 2 percent. Really, the contribution of these torsional and rotational spectra is not great until you get, for example, in reactor service building or the steam generator building where you have a moment arm of about 100 feet. Then it becomes quite important.

MR. ZUDANS: I don't see how you can have 100 feet moment arm and assume it to be rigid.

MR. MORRONE: No, the equipment is located, for example, on the floor 100 feet away from the node at the center of the mass of the floor, okay? Then we say, since it is not right at the node, we have to give a component of translational motion which results from the torsion.

MR. ZUDANS: Mr. Chairman, may I remark? I think this is such detail that we should have done it in Dr. Shewmon's subcommittee, which is supposed to be structures and components, because this is not a satisfactory -- at least not a completely satisfactory answer. At any rate, one more question along these same lines. When you turned around and did the component analysis, did you consider relative motions of different support points and different spectra --

MR. MORRONE: Yes, sir. Yes, sir.

MR. ZUDANS: You did? Would you explain what you did then?

MR. MORRONE: We do a response spectrum analysis, and then we superimpose on the results of the response spectrum analysis those obtained from the differential motion between the two spectra. We add them absolutely.

MR. ZUDANS: And then that means that you took the time history results and scanned through the entire time history to analyze for differential motions, or did you just take the peak?

MR. MORRONE: Sometimes we just take the absolute sum of the peaks. You can't get any worse than that.

MR. ZUDANS: That would be all right, then. That is okay.

MR. MORRONE: As a matter of fact, this is part of our criteria in our criteria document.

MR. ETHERINGTON: May I clarify my own thinking a little bit here? From a simple mechanics point of view, a motion of a point in space is determined by three components of translation, and three components of rotation. That is correct, isn't it?

MR. MORRONE: Yes, sir.

MR. ETHERINGTON: And for purposes of analysis, these three components of rotation get divided up into two torsional and two rotational components? Is that how it stacks up?

MR. MORRONE: Yes, sir, because in building a model, each node has three degrees of freedom in the horizontal direction: translation, torsion, and rotation. You see, there are three different independent analyses.

MR. ETHERINGTON: You get one extra component of motion. From a mechanical point of view, there are just six components of motion, aren't there?

MR. MORRONE: Seven all together.

MR. ETHERINGTON: A point in space. Isn't this motion governed by three dimensional?

MR. MORRONE: A three-dimensional point in space, yes.

MR. ETHERINGTON: Three translations and three rotations.

MR. MORRONE: Yes.

MR. ETHERINGTON: So we get an extra one in the analysis.

MR. MORRONE: Well, you could look at it this way, because we have three planar models, you see.

MR. ETHERINGTON: Oh, I see.

MR. MORRONE: And we have a torsion and a rotation along with the translation with each of the two horizontal models. If they were fully three-dimensional, then yes, we would get six.

MR. CARBON: Dr. Trifunac, did you get your questions answered a while ago?

MR. TRIFUNAC: Yes.

(Slide.)

MR. MORRONE: Additional conservatism is employed by driving design spectra from the computer developed spectra that we have been discussing. This is done, of course, by enveloping the upper and lower bounds of soil moduli by widening the peaks for uncertainties and frequencies of the building, and by smoothing the spectra to eliminate valleys and various spectral fluctuations.

These now are the spectra that we use for design and result in conservative design spectra. I will show you an example of how these design spectra are derived. We see the lower bound soil modulus spectrum, the upper bound and then the design curve. This valley disappears altogether with this line, and just as an example, at 4 1/2 hertz will have over 15 percent conservatism by using the design spectrum.

(Slide.)

Now for time histories, we also believe we have to do something rather than just using the raw computer drive time history, because of any uncertainties in the frequencies of the building. So one way of doing this is to vary the delta t, the time at which the accelerations are given in the time history. That would be analogous to compressing and expanding the history.

The question here is how much: ± or 10 percent, and is the time history at +10 pecent, -10 percent the optimum, or we may have to search within a 10 percent variation to find an optimum time interval. But with any of these methods here given by this bullet, you can understand that this would result in many time history analyses which, as you know, are very costly.

So to eliminate the need to perform all these time history analyses, we developed spectra-consistent synthetic histories. What this means is we produce a motion whose response spectrum envelops the design response spectrum, a synthetic history.

These next two figures will show you the derivation of this design history. First, this happens to be the spectrum at the reactor vessel supports SSE, east-west horizontal. This is the response spectrum the the original time history by Burns and Roe shown superimposed on a design spectrum. You can see right now how much margin we have between the raw spectrum and the design spectrum.

Then we take the history that gives this spectrum and input it to computer programs, and by a process of amplification and suppression, we obtain a time history which envelopes even this design response spectrum, as shown on this next figure.

(Slide.)

You see, we necessarily have to increase the DBA, increase the peak and the various frequencies. We have quite a bit more.

(Slide.)

Okay. So far we have been discussing the input, the seismic input, for systems or components supported on buildings. For components supported on a system, for example, the drive line, not supported on the reactor system, then we have to go through the same process that is done with the building. We have to make a model and analysis of the system, input the design histories and then output response histories and response spectra for a dynamic analysis of confidence. Then, the resulting spectra are again widened and smoothed to give component spectra another 15 percent or so of valleys eliminated and so forth.

We also do response spectrum analysis on the system model for those components which can be modeled in sufficient detail so that we get seismic loads such as forces and moments, such that we can design the components.

(Slide.)

This is just an example of our system model. As I was mentioning before, it is a three-dimensional model, 6 degrees freedom of movement per node, and consists of many parts, the vessel, the core assemblies, primary control rod system. The response time histories from this system analysis for the primary control rod. Six of them are used as input to a drive line model to perform the scram analysis for that system.

(Slide.)

I would like to discuss damping values.

MR. ZUDANS: Could I ask you to go back to that model a little bit?

MR. MORRONE: Yes, sir.

(Slide.)

MR. ZUDANS: In this model, where do you apply your inputs?

MR. MORRONE: At the reactor vessel support.

MR. ZUDANS: That is the support?

MR. MORRONE: Yes.

MR. ZUDANS: And you only have now three translatons there.

MR. MORRONE: That depends upon which histories we put in. If we put the design histories in, then we have those 11 that I have shown.

MR. ZUDANS: Don't look them up; I remember them.

MR. MORRONE: All the 11 histories that are synthetic that envelop this.

MR. ZUDANS: This model is actually -- the reactor vessel is a cylindrical shell, in essence?

MR. MORRONE: It is a stick. These are all stick models.

MR. ZUDANS: The others are -- ?

MR. MORRONE: They are all represented by sticks and springs like for the plugs, mass springs.

MR. ZUDANS: They all end up being supported against the vessel node?

MR. MORRONE: Yes, sir.

MR. ZUDANS: Did you verify in your own mind that the stick model for a reactor vessel is adequate?

MR. MORRONE: It is adequate for a systm model. Now, for the vessel itself, then, the vendor does a full-blown finite element analysis. This is a system model to obtain -- mainly to obtain spectra and histories to design the components. You see, now for the vessel itself I believe Babcock & Wilcox has the vessel analysis and they take the input that we provide them and do a full finite element analysis of the vessel with their own computer program.

MR. ZUDANS: That would be all right if your attachment points were with some kind of a radial stiff member that prevents the point attachment to the vessel wall which can deflect locally. I would assume you have, of course, a work plate that stretches across the entire vessel. That is a reasonable point of support. Is everything that is attached to the vessel here -- those are the dashed lines you have here, right? You have two of them. One dashed line attaches the core support and the other one higher up attaches the thermal liner.

MR. MORRONE: Yes.

MR. ZUDANS: How is the thermal liner attached on the upper node? It is not attached.

MR. MORRONE: Over here?

MR. ZUDANS: Yes.

MR. MORRONE: No.

MR. ZUDANS: Where is the sodium? Is the sodium represented in here?

MR. MORRONE: Yes, it is. It is represented -- I don't have a viewgraph to show you all of that. I didn't come prepared to go through this presentation, but basically, we use trapped sodium and non-trapped sodium with fluid coupling elements to take care of the hydrodynamic mass effect.

MR. ZUDANS: This model is simply added to the vessel as a mass?

MR. MORRONE: As mass for the non-trapped sodium. For the trapped sodium, there is a fluid coupling element along with the mass.

MR. ZUDANS: You don't show it here?

MR. MORRONE: No, because this is just the schematic of the reason for -- the reason for showing you this is to show that we have a system that we do an analysis to get the load spectra and histories. If I wanted to go through a presentation on our system analysis, I would have much better viewgraphs that would show all these details.

MR. ZUDANS: But at any rate, you do have sodium included in this model in some fashion?

MR. MORRONE: Oh, yes, sir. Yes, sir.

(Slide.)

Okay. Damping values. Remember, there was a quite a bit of discussion earlier. These are the values that we used for our equipment; 2 percent OBE, 3 percent SSE for our system model. Now, these values are quite conservative. They are not maximum permissible; they are values that we can use without justification. Besides, if we have test data that shows higher damping values, we will use the higher damping values. The 4 and 7 percent for the structure are also quite conservative. I have test data that show that these values are smaller than they should be.

Our Westinghouse Water Reactor Division, for example, they use 4 percent for the damping for the SSE for their equipment. Why? Because we wrote a report, a Westinghouse report, on damping values of nuclear power plants' components, and this report justified this 4 percent of critical damping as being a very conservative value. But we still use 3 percent.

This mode says reduced damping value should be used when combined stresses are below one-half yield. We pay quite a bit of attention to that. Also, we use the OBE damping values for the SSE for active components. But these are not maximum, but we believe they are very conservative.

(Slide.)

Just to give you -- you all know this, but just to show the effect on our system design if we were to use 4 percent instead of 3 percent. This is over a 15 percent increase on peak that we are using now.

(Slide.)

I would like to discuss very briefly the basic seismic load combinations. Of course, the seismic loads or stresses must be combined with all of the other applicable loadings. Generally, the OBE is classified as an upset condition or service level feed condition, and the SSE is classified as a faulted or service level D condition.

For seismic category 1 vessel piping and inactive pumps and valves, the OBE load combination basically consists of dead load, plus live, plus operating, plus thermal, plus upsets and normal transients, plus the OBE.

For fatigue evaluation, we would consider 5 OBEs during the life of the plant; each OBE producing 10 maximum peak stress cycles. The SSE load combination includes basically the same loads, except the faulted transients and also a dynamic system loading.

Then, for the active components, we upgrade the faulted condition to an upset condition to allow for more margin.

(Slide.)

Now we come to seismic testing. We are through with analysis. Of course, testing is performed for complex equipment which cannot be analyzed, but most important for that equipment whose function cannot be assured by structural integrity alone. Now, this basically consists of instrumentation and electrical equipment. The qualification is to the IEEE standard 344-1975. We are preparing a new version of this. Basically, the same criteria are given.

Again, the main criteria is a comparison between the test motion and the required motion, which is defined by a response spectra, required response spectra, and test response spectra. There are two main categories of test: single frequency test and multiple frequency test.

As the name implies, in the single frequency test there is a wave form containing one frequency, but this is the frequency of a component. I will explain later on resonant testing. Whereas, with the multiple frequency test, the wave form has many frequencies reproduced.

Now, the single frequency tests are very much applicable when the seismic motion has been filtered by the building soil system. And since these tests are performed at resonance, I believe that they constitute a very severe test where the equipment is most vulnerable at its natural frequency.

Multiple frequency tests are applicable when the seismic ground motion has not been strongly filtered such that it retains its broad band characteristics. However, our criteria on the CRBR stipulates that when single frequency testing is used, we must also test with the multiple frequency motions basically to satisfy the IEEE 344 criterion on full spectrum enveloping; whereas, the single frequency does not develop over the whole spectrum.

When multiple frequency testing is used, it is recommended that it be followed by single frequency testing, but it is not a requirement since the multiple frequency testing fully satisfies IEEE 344.

(Slide.)

Okay. For single frequency testing, we use sine beat motion. This is to limit the resonance amplifications to reasonable values as opposed to sinusoidal or steady state motion. We usually use a trail of five beats with a time between beats, typically two seconds, so that there is no super-position between one beat and the other. The cycles within the beat are 10, and the frequency is made to coincide with the frequency of the equipment to be tested. This happens to be the ZPA on the response spectrum, which is the peak sine beat acceleration. The basic seismic test procedure is shown here.

(Slide.)

The single frequency sine beat tests perform a frequency search from one to 33 hz. Then we do SSE sine beat tests at each natural frequency, and from the frequency search, and also at one-half octave intervals in case we missed a frequency. We use five beats of motion with ten cycles per beat. The shaketable motion maximum acceleration should be equal to the ZPA of the required response spectrum, but in practice, it is usually two or three times as big.

The test response spectra maximum response acceleration is greater than that on the RRS. As a matter of fact, it is one and a half times as large. We performed one OBE test preceding the SSE test at each frequency, and we used independent direction input. Sometimes an item will respond more vigorously to one direction input than three.

Then we follow up with the multiple frequency tests. The procedure for those is basically the IEEE standard 344 with five OBEs preceding one SSE random motion biaxial direction input, horizontal-vertical, and the criteria to envelop the RRS with the TRS.

MR. TRIFUNAC: Could I ask a question?

MR. MORRONE: Yes, sir.

MR. TRIFUNAC: This is sort of a general question based on some past experience. Where, for example, we have a plant designed for maybe 15 percent g or 20 percent g and it turns out we have a very small type earthquake in here of very short duration, the small magnitude maybe has a 30 percent g acceleration, so it would be like a very high frequency burst of energy, having frequencies in excess of 30, maybe even 40 hertz, but only one excursion.

Now, do we have here a test that would possibly model that type of an environment?

MR. MORRONE: First of all, this high frequency will be filtered by the building so you do not see it at the location of the equipment.

MR. TRIFUNAC: Well, yes. If the equipment were high up in the building. But if the equipment were somewhere on the foundation.

MR. MORRONE: Well, if it were on the foundation, no, but as I will show you later on, we do, because it is very difficult to synthesize a shaketable motion that envelopes the required response spectrum without increasing the ZPA two or three times. In that case, you see, it would take care of this particular example.

Of course, our earthquake is designed --

MR. TRIFUNAC: Try to bear with me. I am not trying to talk within the defined earthquake. I am trying to go beyond that. I am saying what if we had a number of cases where we saw a type of a small earthquake that is not of concern to the civil engineering part of the system? It is a very short length of high acceleration type of event, and from the structural point of view, it really doesn't contribute much.

But I am asking about a piece of equipment that may be founded in such a fashion that it will not be filtered through the building.

MR. MORRONE: If this equipment is mounted on a foundation and you have this type of earthquake that you described, first of all, this is a non-damaging earthquake. It is just an impulse.

MR. TRIFUNAC: It is not damaging from, say, the point of view of a containment structure, but it has maybe like five or six or maybe 20 cycles of 40 hertz type of --

MR. MORRONE: Not much amplification if you were to derive a response spectrum.

MR. TRIFUNAC: Right. But it might have a peak acceleration of 20 percent g.

MR. MORRONE: What we are concerned with there is the ZPA, the peak acceleration.

MR. TRIFUNAC: Well, maybe there is a piece of equipment that has a natural of 45 hertz, say, and it would be in the frequency range of that shortlived earthquake from the civil engineering point of view, but maybe not shortlived from the equipment point of view.

MR. MORRONE: Of course, for this non-linear equipment this would be important because the ZPA is important for non-linear equipment. Now you see that the frequency search is done only from one to 33 hertz, but I believe that -- I want to show you some comparisons of TRS and RRS. I believe from that comparison I hope -- to answer your question -- to show you how much bigger the ZPA of the test response spectrum is.

MR. TRIFUNAC: So this is coming out a little bit later?

MR. RAY: Before you leave that diagram, what determines the span of the frequency from 1 to 3 hertz?

MR. MORRONE: That's the magic number here, but I believe the genesis came with the period of .03 gives you 33 hertz -- that is really the frequency, the amplifying power of the earthquake, that beyond 33 hertz it does not produce any amplification.

Now you can see this from the regulatory guide response spectrum, from the criteria response spectrum that goes to 33 hertz and that is ZPA which is the peak in the time history. So the typical earthquakes do not have amplifying power beyond 33 hertz. But 33 seems to be a magic number and it came from the .03.

MR. RAY: What you are saying is this is a natural law, is that what you're saying, a natural phenomenon?

MR. MORRONE: Well, more or less, because a lot of earthquake motions have been analyzed and have shown that beyond 33 hertz they do not have any amplifying power, yes. I guess you could consider it as a natural law.

MR. ZUDANS: It is not the earthquakes that don't have the natural power; it is the structures that do not respond to those high expectations. The structure determines what gets amplified and what doesn't get amplified, not the earthquake.

MR. MORRONE: You wouldn't see very high frequencies above 33 hertz.

MR. ZUDANS: That is correct, because if you don't have the frequencies in that, then there is nothing to respond to.

MR. MORRONE: There are usually not high frequencies in ground motion.

MR. TRIFUNAC: Could I comment on this, because you asked the question I was sort of -- there is no physical law here. Historically, we did not have instruments that were able to record much beyond 20 to

25 hertz. The instrument properties themselves were filtering out the input motion, number one.

Number two, for years, we did not have the ability to digitize those data beyond those frequencies. We had techniques that were, by their very nature, filtering out the motion that may have been there. Thirdly, we never had enough instruments to be really very close to a small earthquake; therefore, just by statistical fact of observation, we didn't record small earthquakes or large earthquakes at close distance.

But nowadays that we can do all of these things, we are discovering that there are very high frequencies with high acclerations for even small earthquakes if we come very close to the source. It is not a physical law; it is just a traditional coincidence of facts.

(Slide.)

MR. ETHERINGTON: Are these very high frequencies of concern from a practical point of view?

MR. TRIFUNAC: Are you asking me a question?

MR. ETHERINGTON: I said are these very high frequencies important in actual structures and instrumentations.

MR. TRIFUNAC: I guess they are not really important for the structures. They are important in the way that they do suggest that the shape of Regulatory Guide 1.60 spectra is not capable to handle that situation. We have had a number of cases in the past that clearly pointed that out. The shake that we are using for 1.60 is not capable of handling that situation from the damage point of view. It may not be important for structures but it may be very important for certain types of equipment, high frequency equipment.

MR. ZUDANS: The kind of building and containment structures we have where all of this equipment is attached do not amplify frequencies beyond, say, 33 hertz roughly. Therefore, you get whatever the rigid body motion of the seismic event is. And if there is equipment like -- I guess that is what Mike is trying to say -- that has natural frequencies, maybe 60 cycles, and gets that excitation, that may be significant.

MR. ETHERINGTON: Yes, I understand that. I was asking really whether there is any such equipment that is important.

MR. ZUDANS: There is lots of equipment that has that natural frequency, but ZPA amplitudes are so small that you don't really care, because what is .25g? It kind of disappears in the noise.

MR. CARLON: Go ahead.

MR. MORRONE: I would like to show an example of a comparison of the TRS, the RRS for tested equipment. This is reactor shutdown on isolation equipment, such as comparators, buffers. These items are housed in cabinets and the whole cabinet is shake-table tested both sine beat unidirectional. And multiple-frequency biaxial motion was employed in these tests. After the test was made in one direction, the cabinet was rotated 90 degrees and rotated in that direction.

The function, the items is a function properly during and after testing, and the test response spectrum conservatively enveloped the required response spectrum. Plus, there was additional conservatism by enveloping the horizontal part of the response spectra. What I mean here is that we have a north-south and east-west required response spectra, so we envelop both of them t provide one horizontal spectrum.

Then there is an additional conservatism given by horizontal RRS 10 percent IEEE 323. And, of course, use of the design spectra.

(Slide.)

The plots are shown on the next two figures. First, for the horizontal motion the solid lines is the required response spectrum; the dashed line the test response spectrum. You can see that the ZPA of the response test spectrum is three times as much as the ZPA of the required response spectrum. And it goes along the peaks, 4.4, for example, versus 2.85 Gs, the same comparison shown for the vertical motion here, where the ZPA again is three times as much.

I think this should take care of that small earthquake, Dr. Trifunac, that you were talking about. Peak, this is more than twice as much.

So these are very conservative tests, and besides, they were done at resonance and with multiple-frequency motion.

MR. ZUDANS: Except for in the case of resonance, you did not look at frequencies beyond 30 cycles.

MR. MORRONE: No, sir.

MR. ZUDANS: That means any frequencies beyond 30 Hz, as you show here, might be different than you would with your PRS.

MR. MORRONE: For sine B, right. But we take care of this with the multiple-frequency motion. So we really catch it both ways.

I would just like to summarize our presentation by showing the conservatism on our seismic criteria. Under simplified spectra we have a conservatism which approaches that given by the absolute sum versus the square root of the sum of the square of directional effects. We have conservatism when we do simplified analysis of 1.5 times the maximum peak.

Under the design spectra we develop the upper and lower bounds of the sound moduli. We eliminate valleys, we widen and smooth the spectra. For design histories we develop the design spectra consistent histories. We conservatively envelop the design spectra, and we combine the translational and torsional design spectra even before we synthesize this design history.

(Slide.)

For a component spectra we additionally widen and smooth the component spectra which were derived with conservative input to begin with. Also, in most cases, we envelop three operating conditions: the normal; preparation for refueling; and refueling conditions.

Under damping we have quite conservative damping values of systems and components. We believe 3 to 4 percent should be more applicable than the 3 percent we are using for seismic testing. We use both single-frequency and multiple-frequency testing, both unidirectional and biaxial, ZPA and peak responses of TRS higher than that of the RRS, as a matter of fact, much higher in the case of the ZPA.

We use the design spectra RRS broadband spectra. We envelop the north-south and east-west RRS, and we have the 10 percent IEEE 323 margins.

Thank you.

MR. ZUDANS: You stated in answer to my question, but I did not see here any place the treatment of relative attachment point displacements. I also did not see what you do if you have piping or something like that that has two points of attachment in different spectra.

MR. MORRONE: We envelop those two spectra.

MR. ZUDANS: Then you do take into account the differential?

MR. MORRONE: Yes. This is part of our criteria in the PSAR.

MR. DICKSON: Most of those are coming later.

MR. CARBON: Are there other questions of Mr. Morrone?

MR. ETHERINGTON: Is there any class of component that comes close to the design limit of the other classes?

MR. MORRONE: Could you repeat that, please?

MR. ETHERINGTON: Is there any class of component that comes closer to the design limit than others?

MR. MORRONE: I do not know. You are giving a margin?

MR. ETHERINGTON: The margin, yes. Is there some that gives no problem at all and others --

MR. MORRONE: Well, yes, but I cannot give you a specific example. There are some components that are so structurally sound that we do not even bother doing a dynamic analysis. We take 1.5 times the maximum peak.

MR. ETHERINGTON: What about the components that are sine beat tested, the cabinets and so on, do some of those create a problem?

MR. MORRONE: To my knowledge, none of them have created a problem. They have all passed the tests with flying colors.

But perhaps Mr. Kraueter, who is going to give the next presentation, can give you some information on that.

MR. CARBON: Thank you, Mr. Morrone.

(Pause.)

MR. KRAEUTER: My name is Gary Kraeuter. I am here this afternoon in the place of George Macrae, who was unable to attend. I would like to give you a little elaboration on how the electrical equipment was tested.

(Slide.)

Essentially, we are governed by IEEE 344. It simply says that we have to demonstrate an equipment's ability to perform its required safety performance during and after an SSE.

How did we relate that to our equipment specification. As Tony pointed out to you a little bit earlier, the equipment specifications allow us through the IEEE 344 to do testing, and we have used both sine beat and random multiple-frequency. We are allowed to use analysis plus some testing, or analysis.

(Slide.)

A typical list of the equipment that has to be tested looks something like that. We have various sensors out throughout the equipment. We have various signal conditioning electronics, logic components, and actuators.

To date, some of this equipment has been tested. That equipment that has been tested appears on that list.

(Slide.)

We have elected to do type-testing or proof-testing on all of it. To give you an example of what that kind of looks like --

MR. CARBON: Excuse me. What does it mean, "type-testing," again?

MR. KRAEUTER: Proof-testing. We have taken it up and provided it to the required test spectrums as opposed to fragility testing where you might take it out and destroy it. We have only taken it to a given limit.

MR. ZUDANS: When you say that, that means you plan to use the same tested components in the plant?

MR. KRAEUTER: By and large; I will not say all across the board. We have used prototype equipment for this.

MR. ZUDANS: And that component, after having been subjected to this test, will be used in the plant?

MR. KRAEUTER: In most cases, no. In some cases, that will be.

(Slide.)

The next piece of equipment, which is the primary reactor shutdown system equipment, that is prototype equipment. Okay. It was mounted on its base and then that base was mountd on sort of a steel channel. It was bolted to itin the same fashion it would be used in teh plant, and then that steel channel was welded to the shake table and then the test proceeded from there.

In this case it was oriented to it was a front-to-back motion and vertical motion. Then it was turned 90 degrees, and that was repeated.

MR. ZUDANS: And this cabinet will be used in the plant?

MR. KRAEUTER: These will not. These have since been shipped to storage. In the case of one, for instance, that was done that way, it is a containment isolation system --

(Slide.)

-- which is that one. This is plant equipment. It was mounted in much the same fashion, however. Everything is much the same way.

MR. ZUDANS: Duringthis test you monitored the functionality of all the pieces that are in this box?

MR. KRAEUTER: During this testing or just before this equipment was fired up electrically, it was tested. Then during each phase of that test, both the sine beats and the random multiple-frequency, it was functionally tested.

This has a scram breaker on it, for instance, logic circuits. Those were functionally operated during that time.

Now, as the sine beats progressed, the number of sine waves that you got in the beat, the time frames kept getting a little bit smaller and smaller. So we ran out of being able to do this switch to do that.

But essentially, every sine beat and throughout the entire random multiple-frequency they were tested electrically.

MR. ZUDANS: Your sine beat test really tests the structure of this cabinet nicely. It tests the relative motion of different pieces of your hardware within it.

But when it comes to the natural frequencies of individual components mounted in it, those 33 Hz are probably far and away from their natural frequencies. So your multiple-frequency load testing becomes very, very important for its functionality.

Are you also testing functionality during that portion of the test?

MR. KRAEUTER: Yes. We ran five OBEs and one SSE on this equipment during the random multi, and during each one of those it was functionally tested.

We also monitored and recorded all of the outputs that are associated with this relay contact voltages, state of the breakers, things like that.

MR. RAY: Can you tell me how closely the equipment was welded to the shake table and conforms with the way it is going to be welded to the channels of the floor of the plant?

MR. KRAEUTER: I think the other slide shows it to you a little better. In the plant this surface right through here is where it will be bolted to the floor in the plant. There are embedmets on the floor in the floor. This particular channel that we welded on, it only actually adds a little bit more to the height of this thing, which, in effect, makes it just a hair more conservative.

MR. RAY: How is the cabinet fastened to those channels, relative to the table?

MR. KRAEUTER: It was bolted to it in the same fashion in the plant.

MR. RAY: So you are really checking the installed condition -- the anticipated installed condition of the cabinet?

MR. KRAEUTER: That is correct. They were torqued to that same value. The manufacturer's specified value.

MR. CARBON: Mr. Kraeuter, what are your criteria for using some of the equipment in plant and some of it just testing prototypes and not using it further?

MR. KRAEUTER: This one was a prototype equipment. At the time it was decided, I cannot tell you that I know who made the decision on that. I was not a part of that decision. I really cannot answer that question, I guess.

MR. CARBON: Is there any general type criteria that you are aware of?

MR. KRAEUTER: No, there are none, as far as I know of.

MR. ETHERINGTON: In sine beat testing, you tested the frequency of the most vulnerable component; is that right?

MR. KRAEUTER: In the sine beat testing?

MR. ETHERINGTON: Yes.

MR. KRAEUTER: I guess I do not understand your question. What we did was we --

MR. ETHERINGTON: How do you pick your frequency?

MR. KRAEUTER: We ran a resonance search on this equipment, found several points that for instance that one had two on it, that were other than the octave points, the partial octave points that are normally done in sine beat, added those to it, and then ran the sine beats including those.

MR. ETHERINGTON: Do you run the sine beat test frequency at two different frequencies to correspond to the two that you found?

MR. KRAEUTER: Yes.

MR. ZUDANS: But those were actually below 33

Hz?

MR. KRAEUTER: Yes. All of the testing was below.

MR. ZUDANS: These are the frequencies of the testing rather than the octave?

MR. KRAEUTER: I can't remember the exact number, but there is on the order of 15 accelerometers throughout this cabinet structure on various shelves and other points. If any of those showed a resonance point above an amplification factor of 2, it was added. That point was added if it was a point other than what was ordinarily planned for, we ran it.

MR. ZUDANS: Those accelerometers were mounted on the cabinet?

MR. KRAEUTER: Yes. That is one there, and there were others throughout the interior of the cabinet also.

MR. ETHERINGTON: What I was getting at, in the sine beat testing, is there any chance that you undertest some component which has a frequency widely different from the test frequency?

MR. KRAEUTER: I do not think so, not to the 33. Not to the 33 Hz.

MR. LIPINSKI: On relay system, do you ever analyze a relay independently for its maximum G forces and resonance frequency with respect to the preferred direction for the armature and the holding force?

MR. KRAEUTER: No, I have not.

MR. LIPINSKI: So you do not really know how far the relay could go or what the resonance forces would be. Two cases: One, energized where I could pull the thing open and reclose it; the other one where it was deenergized, and I could bounce it and cause those contacts to close.

MR. KRAEUTER: In this case, two of the frequencies we tested and to the amplitudes we tested, we had relays that were both energized and deenergized. And because of the nature of the way it was turned, they were at least changed in both horizontal directions.

MR. LIPINSKI: You get your choice of the X, Y, and Z, but that depends on the way your seismic excitation hits those cabinets. But it certainly seems like it would be nice to know what the limits are for these components independently such that you know whether you are a factor of 10 away or you are only 25 percent off.

MR. KRAEUTER: I suppose that would be true. I cannot answer that.

MR. LIPINSKI: Do you propose to do anything to evaluate the relay independently?

MR. KRAEUTER: There are no plans to do that as far as I know.

MR. LIPINSKI: So you do not know what your margins are, you only know that during these tests your tests were satisfactory but what the margin may be as to whether you have an error in the test or not?

MR. KRAEUTER: No, we did not take any of this equipment to a failure mode.

MR. LIPINSKI: What about the big scram circuit breakers? You have to trigger those to deenergized and then have them drop open; right?

MR. KRAEUTER: Yes.

MR. LIPINSKI: And those operate in the vertical direction?

MR. KRAEUTER: Yes.

MR. LIPINSKI: And what do they do when they are excited with a vertical excitation? How much do they dance? At what particular frequency?

MR. KRAEUTER: Again, to the frequencies we tested them, there was no vibration or no contact shatter associated with those scram breakers.

MR. LIPINSKI: They did not reclose once they were there?

MR. KRAEUTER: No.

MR. LIPINSKI: Do you card how much they move or do you just observe them electrically or just observe?

MR. KRAEUTER: We do not record the vertical motion of that contact opening. We only know it opened.

MR. ETHERINGTON: Is sine beat testing proprietary Westinghouse procedure?

MR. KRAEUTER: Not that I know of.

MR. ETHERINGTON: It was developed by Westinghouse, was it not?

MR. KRAEUTER: I cannot answer that question.

MR. MORRONE: It is the method given in IEEE 344. It is a recognized method.

MR. LIPINSKI: Getting back to the scram circuit breakers, you could do an analysis without necessarily a test to try to get some feeling for what that mass spraying system takes in order to get the thing to bounce enough for a reclosure. Have you done an analysis to try to fit it?

MR. KRAEUTER: Not to my knowledge.

MR. LIPINSKI: Do you plan to do it?

MR. KRAEUTER: Not to my knowledge.

MR. LIPINSKI: You do not know what your margin is.

MR. KRAEUTER: As I said before, we did not do any testing to failure or, in this case, a closure that would constitute a failure.

MR. LIPINSKI: It seems like that analysis would be relatively simple for that type of a structure.

MR. ZUDANS: And the test is even simpler.

MR. LIPINSKI: These scram breakers they have for their control rods fit in cabinets of that size are relatively large masses.

MR. ZUDANS: Well, unfortunately, the sine beat does not go beyond 33 cycles. And if the frequencies go higher than that --

MR. TRIFUNAC: What is the frequency if you take the mass and frequency? What are we talking about?

MR. LIPINSKI: That is what I am asking, and they do not know. That would be relatively simple. You know what the masses are, you know what the springs are. You could get a relatively quick determination.

MR. TRIFUNAC: Do we need to know the range? Is it 50, 150 Hz?

MR. KRAEUTER: I do not know.

MR. LIPINSKI: And then with the small relays, that is another question. They have their orientation. That is why the clabbers are going to have to --

MR. DICKSON: Could we add something from back here, please?

MR. MORRONE: Tony Morrone from Westinghouse.

We do not have frequencies of the floor motion in excess of 33 Hz where these devices are located. There is none of that high frequency.

And I must also add that sine beat testing is only done by Westinghouse as an additional test. I do not know other organizations that have performed this test. Sine beat testing was developed by Westinghouse, and we believe that it really proves the capability of our equipment because we test the resonance. But it is not required by IEEE 344. Other organizations do not perform it. So it is something additional to give us more margin, and there are no frequencies beyond 33 Hz on the top floor of the control building where most of this equipment is located.

MR. ETHERINGTON: Is it in all cases additional?

MR. MORRONE: Yes, sir, it is always additional, just to prove the capability of our equipment even more so.

MR. ZUDANS: The statement then that there are no frequencies higher than that floor, of course, has to be qualified with a level of acceleration of amplitude.

There are low amplitudes; whatever comes up from the foundation gets transmitted as a rigid body except it does not get magnified.

MR. MORRONE: It is nonconsequential.

MR. ZUDANS: If you run the sine beat at 150 or 200 Hz with nonconsequential amplitude, prove to yourself that the relay context stay there nicely, then that is it, you would have proven your point.

MR. MORRONE: We basically do that by inputting the very high ZPA.

MR. ZUDANS: Talking about that, the sketches that you showed on the spectra TRS and RRS, you broke them off at some frequency of 100 Hz or so. That is because you just did not plot them further. Were these components excited by higher frequencies?

MR. MORRONE: We were not even required to go to 100 Hz.

MR. ZUDANS: If you had drawn the actual input, analyzed it for higher frequencies, would you have excitations higher than ZPA?

MR. MORRONE: The ZPA would start at approximately 33.

MR. ZUDANS: Not on these that you showed. There is a tremendous amplification on the ones that you showed.

MR. MORRONE: Well, there is not that much. What is it, RRS, 50? That is where the ZPA starts.

MR. ZUDANS: Well, look at your beyond-100-Hz. You have three times your ZPA; right?

MR. MORRONE: Yes. But you have to look at what frequency the ZPA begins. 33 or so, you see for the horizontal motion, so you can draw that to infinity, if you want.

MR. ZUDANS: That is not what I am trying to say. I am trying to help you. Let me just see whether I can manage it. I am saying that if you run your tests and took the input motion an analyzed that input motion for the spectrum beyond 100 or 200 Hz, what level acceleration would you find in that test?

MR. MORRONE: The ZPA.

MR. ZUDANS: It would exist there?

MR. MORRONE: Yes. There is no -- it is beyond amplification.

MR. ZUDANS: That ZPA depends on your input.

MR. MORRONE: And exactly at the input, let us say, there is a not very high frequency content that would cause any amplification.

MR. ZUDANS: Okay. Would that mean that your test was actually performed at ZPA level of acceleration for very high frequencies?

MR. MORRONE: Yes. You could say that, yes, sir.

MR. ZUDANS: So then if you could say that, you test the equipment.

MR. DICKSON: This takes away from the curve you are talking about.

MR. MORRONE: When the motion is synthesized, they do not try to put in very high frequencies, to begin with. So the ZPA ten is constant.

MR. TRIFUNAC: That is right. But I think that the discussion is beyond the present regulations. The present regulations only go beyond 33. I think the question is what if there is an excitation that has frequencies up to 40 or 50 Hz; I think that is the question.

Obviously -- obviously -- if low-pass filter your excitation function, there is no doubt that they should look like this, because the energy is not available for frequencies higher than 33 Hz. But the question is, as I understand it, what if there was an excitation that did have frequencies maybe 40 to 50 Hz?

MR. MORRONE: Then the RRS would not be correct.

MR. TRIFUNAC: Absolutely. There is no question about that. But the question is what can you say about the equipment using these tests?

MR. MORRONE: What I could say in that case is due to the high level of the ZPA, that would take care of the high frequency.

MR. TRIFUNAC: If the ZPA were represenative of the high frequency. But the ZPA is very much dependent on the high-frequency spectrum. So if you low-pass filter the function, you decrease the ZPA; right?

MR. MORRONE: Right.

MR. TRIFUNAC: So the ZPA that you have is not really representative of the hypothetical case we are talking about.

MR. MORRONE: If there is that case, then as I said, the RRS would be incorrect. But I still believe the test would be a good test.

MR. TRIFUNAC: Well, the test is good only as long as it contains frequencies of excitation that are in the pass band of the system you are testing; right?

MR. MORRONE: You are saying if the motion at the floor level of the mounting of the equipment has high frequency and besides if this high frequency matches the frequency of an item --

MR. TRIFUNAC: Yes.

MR. MORRONE: -- then you are saying you may be missing it.

MR. TRIFUNAC: That is right.

MR. MORRONE: If that were the case. But I do not see the case as being very probable, because that motion is highly filtered when it gets to those levels.

MR. TRIFUNAC: That is a hypothesis.

MR. MORRONE: Analysis hypothesis plus some test analysis data shows that.

MR. LIPINSKI: What is missing in this discussion is the components, the relays and the breakers that have spring mass systems that can be bounced around, should be qualified in their own right so you would know what their limits are in terms of frequency and acceleration along that path that would cause them to activate.

Unless we know those numbers, there is no way to tell whether you are equipment-sensitive to the assumptions that we are hearing.

MR. TRIFUNAC: And I think it is not a question of that equipment being damaged; is it a question of whether that equipment would perform what it is designed to do, because it might close or open in a completely elastic response range so the function would be interrupted and there is no damage involved at all.

MR. LIPINSKI: In certain cases, you want to drop a relay out, but if it is bouncing around it may be making intermittently. In other cases, you call for a breaker to go in, and once it is pulled in and locked, and also if the seismic event is in place and you call for it to go, the thing may not want to lock in, it may want to just sit in there and bounce for you.

MR. MORRONE: In all those cases that it was tested, all the relays and that breaker --

MR. LIPINSKI: Yes, based on the assumptions for your excitation. But I don't know what the limits are for the device and what your margin was, whether if you went to 50 cycles you would run into trouble.

MR. MORRONE: But I did the required response spectra.

MR. LIPINSKI: Yes, based on what somebody else told you. Okay. And if what they told you is wrong, you may find you are in trouble when the real event comes along.

MR. TRIFUNAC: That is right.

MR. ZUDANS: Besides, you told yourself when you did the sine beat and you increased the frequency there was not enough time for you to check the functionality.

MR. MORRONE: That is true.

MR. ZUDANS: So you may not even know in this test range that your contacts are closing or opening.

MR. CARBON: I wonder at this point whether we may want to hear from the Staff. Can I ask -- I do not want to break up your caucus, but I think we have carried our point through, and I guess you have heard all of our discussion on it. And I would like to sort of refer to you in the future.

MR. ETHERINGTON: I expect these concerns are not unique to the fast breeder reactor. I think they apply equally to lightwater reactors. I do not know whether they are valid or not.

MR. LIPINSKI: Let me make a comment. There is a big discussion on qualification of Class 1.E equipment, but the seismic testing got divorced from that particular specification so it did not come up in any of our subcommittee meetings until today.

MR. RAY: That is to be developed later as a separate requirement. And the seismic electric qualification Class 1.E mechanical or electrical.

MR. CARBON: Well, I guess we can move ahead here, can we not?

MR. STARK: I guess I was going to make a quick comment. We are certainly aware of some of the conversation that is taking place, and I am not sure we can answer all the questions here today. But the items that the Applicant is talking about in the requirements are the current Staff requirements right now.

What they have presented satisfies the Staff requirements. The Staff requirements are always being looked at, and I cannot shed any light on that right now.

MR. CARBON: Yes. We do not ask it right

now. But we would ask you to take a look at it.

Go ahead then, Mr. Kraeuter.

(Slide.)

MR. KRAEUTER: Just quickly, Tony showed you one of these curves earlier. We will show you a couple of them. These were taken from the actual test report from the vendor showing you the required response spectrum in the test response. That is for one piece of equipment.

(Slide.)

For its redundant second part, secondary system --

MR. ZUDANS: The TRS is the table motion?

MR. KRAEUTER: Yes. This is the table motion located at the base of the cabinet. And then we have another one for the containment isolation system.

And then finally just to wrap it up, all of the equipment that has been tested to this date that we know of has passed its seismic test and has been able to perform its function during that test to the requirements that we have imposed on it. And it has also retained its structural integrity.

That concludes my presentation.

MR. DICKSON: Could I ask a question for clarity, because I am not sure what was going on fully.

It seems to me we did this testing of, I guess, light noise out to about 300 Hz. Are the consultants to the ACRS suggesting that it requires a test of a simusoidal motion out beyond 300 Hz as opposed to a white noise motion?

MR. ZUDANS: I do not think we are asking that. I think the simplest answer to whatever questions we asked is you have to know the limitations of the pieces of equipment that came out in that cabinet. If they are critical at high frequencies, I do not know that -- I am certainly not asking you to modify any of the tests. I am trying to find out whether your tests adequately test the piece of equipment as Dr. Lipinski described, the relays closing and opening at high frequencies.

I am sure you adequately tested the cabinet. I am sure that you adequately tested the functionaoity where you had time to switch on and off.

MR. TRIFUNAC: Just a comment along the same lines. As far as I can see, there is no question that you have performed the tests that were required. There is no question about that. The question is really are the regulations that we are living with adequate to look at all the possibilities?

Basically, I think, what you find is that those of you who work with equipment sometimes have your hands tied by the methodology that is imposed on you by the structural engineers, and the methodology for structural engineers may be adequate as far as structures are concerned, but because of some low-pass filtering equipment for the equipment excitation, it may not be realistic in all cases.

So this sort of goes beyond, I think, the present requirements.

MR. DICKSON: Thank you both for that clarification.

MR. ZUDANS: It is certainly not unique to CRBR.

MR. ZUDANS: Thank you, Mr. Kraeuter.

This might be a good time to take a break before we start the next presentation.

(Brief recess.)

MR. PITTERLE: I am Tom Pitterle. I will be describing the testing being performed in support of a control rod system that is seismically related. In particular, the emphasis in the testing is that in support of scram insertion.

(Slide.)

To help a little bit in understanding the type of tests. it is probably best to visualize the scram functioning in terms of the unlatch function or the mechanism releasing the translating assembly and then followed by the insertion function or the motion of the translating assembly and the control rod into the core.

In particular, in the insertion function, an area of particular concern that the testing is emphasizing is the ability to predict the normal forces of the drag forces that would retard the insertion motion in the seismic event.

So the testing that has been done and future testing in support of the control rod systems is a dynamic friction tests, the PCRS seismic tests, and an SCRS scram valve and cylinder assembly test.

The dynamic friction test is the specific objective of obtaining the effective coefficient of friction in the seismic impact type condition. The test was conducted by dropping a simple rod in three bushings under a vibrational input by measuring the impact forces at the bushings, the normal forces meausuring the drop times, and there is very little hydraulic resistance in this particular test. We are able to extract then an effective coefficient of friction as a combination of the drop times and the normal forces.

The testing was done in air, argonne, water, and sodium. We looked at material couples 304 to 718

The primary emphasis in the testing was done with 718 to 316, and 718 to 718. Inconnel 718 and 316 stainless steel.

Cylindrical and hexagonal test rods were tested with the emphasis being on the cylindrical test rods for the efficiency of testing. The result of the testing gave us the design coefficient of friction that envelopes all the data at a two-signal level of about .45 for all the materials. I will describe the results of this test in considerable detail.

Our specifications would have said we used a value of 1 in the absence of any test data and to use test data that was basic objective was to obtain the test data to be the friction coefficient of unity.

The dynamic friction test also helps us to develop test experience for our more complex seismic testing, which I will describe. The friction coefficients, the dynamic friction test provides friction coefficient for use by both the primary and the secondary control rod systems. So it is supporting both of the Clinch River shutdown systems.

The PCRS seismic test is to test the scram performance under dynamic input conditions. The primary objective is to validate the seismic scram analysis methods. It uses completely prototypic hardware, full control rod drive mechanism, control drive line, and control assembly. We use water as a test medium. And the testing will be starting in calendar year 1983. In particular, this test helps to support the unlatch function of the primary control rod drive mechanism.

The validation of the insertion methods helps to support both the primary and the secondary system because we both key off of the finite element analysis of the normal forces, and that will be validated by comparisons of predictions with this test.

The secondary seismic testing is the testing of the scram valve and cylinder asssembly as done per IEEE 344.

(Slide.)

To describe the facility, this is a picture of the facility for the dynamic friction test. It shows the test vessel and the support structure, big I-beams, a single lateral shaker applied to the I-beams, vibrating the whole structure, media bearings which are barely visible at the bottom of the picture.

You can see at least a little bit in the picture of the three bushin~s, the strain bolt locations for the three bushings, release of the drop rod occurred in the upper end of this test vessel, and that released the rod to drop down through the bushings while it is vibrating back and forth and impacting the bushings.

The drop, in addition to measuring the normal forces, we have position versus time displacements and accelerometers to measure impact levels and give us any indications of abnormal behavior.

MR. LIPINSKI: Are the scram valves electrical solonoids?

MR. PITTERLE: The scram valves were not a part of this test. The scram valves for the secondary, which I will describe a little bit later, are on the mag electrically solonoid.

MR. LIPINSKI: There is an electrical solonoid valve?

MR. PITTERLE: Yes.

MR. LIPINSKI: That is to be sseismically qualified?

MR. PITTERLE: That is correct.

MR. LIPINSKI: That is another spring mass friction with some damping coefficient?

MR. PITTERLE: Yes.

MR. LIPINSKI: So you would know basically what that valve had for its own resonance frequency?

MR. PITTERLE: Some work was done to locate the frequencies, but the testing did emphasizse the similar response spectra-type testing that was previously identified.

(Slide.)

In addition to obtaining friction coefficients from the dynamic friction test, it also provides us with some preliminary verification of the scram analysis methods. Again, the scram analysis methods are the scram insertion part of the scram analysis.

The key, as I mentioned, is calculating the normal forces. Given the normal forces, the friction coefficient attains a drag force, and we can calculate the hydraulic resistance to motion off of codes and then verify it substantially against nonseismic testing.

So we use the ANSYS code for the finite element analysis for the primary control rod system. We are using three withdrawal elevations in the plan modeling as well as this test so that we can account for the effects of normal forces on heights and shifting from one model to another at midpoints between the elevations for which they are calculated.

Impact stiffnesses are calculated with the Herztzian contact method. We found impact damping to be not particularly important. Structural damping was taken at .3 percent based on some general survey work done in the testing for the very rigid test facility for this test.

Fluid coupling is accounted for in the water and sodium testing using the concentric cylinder model of the ANSYS code.

Applying this modeling to the dynamic friction test, we can verify it again and look at the checks against tests in two ways. One is to analytically calculate the normal forces, use those calculated normal forces and contrast it to the test normal forces to extract an effective coefficient of friction. Or we could use those normal forces to calculate an effective coefficient of friction.

So we have really looked at it both ways. We can correct for the hydraulic forces by normalizing through zero G test data so that we are confident of making reasonable corrections for the very small hydraulic forces that existed.

Then we did obtain U by adjusting the calculated normal force calculations against drop times and compared that with the U derived from measured normal forces. We have also compared the average normal force between the analysis and the test.

(Slide.)

This shows some of the comparisons that we have obtained from this test in terms of the friction coefficient and the average normal force analysis and tests. For the three test conditions which we have emphasized, this particular type of comparison.

This was a test in air, inconnel 718 bushings, this should be 22.8 Hz rather than 28 Hz, 1.5 Gs, .5 Gs, then compare it in a water medium in the same conditions as 1.5.

Using the calculated normal forces, you measure drop times. We have obtained what I call the anaylsis, and that yields a .32 coefficient of friction which shows excellent agreement with that derived from the measured normal forces.

We went down to half a G. The analysis of fitting the drop times was very insensitive because there was not enough load to particularly retard the rod motion. You can fit off of a wide range, and we really cannot do an adequate fit in that case.

Under test conditions, we could fit over areas, local areas of the drop time to get an estimate, but with a considerable higher error. We also obtained good agreeement with test in the water medium and as typical of some of the other data I will show you for the impact friction, you find that there is very little difference in the coefficients of friction between air and water.

Comparing the average normal forces, we obtained relatively good agreement at 1.5 G. We did slightly underestimate at .5 G in this particular case.

The instrumentation sensitivity is not as good, and there may be somewhat higher errors in the test value.

MR. ZUDANS: A couple of questions. How did you measure normal forces?

MR. PITTERLE: The srain bolts, three strain bolts, mounted on cylindrical bushings.

MR. ZUDANS: Did I hear you correctly, they had three bushings?

MR. PITTERLE: Yes. Three vertically located bushings..

MR. ZUDANS: How accurate was the alignment of these bushings, or how sensitive would the results be to the alignment of the bushings?

MR. PITTERLE: We looked at it in the early phases of the test. We looked at the alignment of the bushings and even a complete tilt of the vessel with the dynamic conditions, it was not found to be that particularly sensitive.

We looked at it. Compared drop times, for instance, were not very sensitive to that alignment. We did optically align the bushings at the start of testing for this particular test. We knew where they were. But it just has been found experimentally and analytically that this was not very sensitive.

MR. ZUDANS: Was this rods relatively flexible and bending?

MR. PITTERLE: This rod the test rod in here, was -- yes, relatively a little more stiff than a normal drive line would be because we had done some work to embed it with additional instrumentation. But yes, basically, in the plant the drive line is long and very easily moved.

In the test it was easily moved, but we could get some indications of the top part. There was a mass at the top for the coupling, and that was wavering more than the bottom parts.

(Slide.)

So what we have concluded as this preliminary check of the scram analysis methods has emphasized that he complete scram test of the control rod system will provide us with some overall and more complete verification of our methods. We did obtain good agreement on the analytical and test Mu or the drop times.

If we use the test Mu in the analysis, we get a good agreement onthe average normal forces. When we looked at it in more detail, we found that the force and impact frequency dependence on rod position. We used an R-3 model; also gave the general benavior of the test as a function of axial height.

So we did feel that the three-elevation modeling disposition for the test was anticipated to be sufficient for the plant. The test, in fact, should have been more sensitive to axial position because of the mass at the top of the rod than we had anticipated the plant performance supports. We have general support for the methods and the three-elevation model.

We did not see -- and I will show the more direct data in a minute -- but we did not see any strong difference between fluids, air, argonne, and water. And to some extent, we found something in sodium.

Looking at it analytically, with the fluid coupling model, ANSYS, we did not see much difference on the normal forces, and the test did not show much difference.

So what we have recommended from the test is they use Mus of .45 for fluids and .41 for gas. And the seismic scram insertion analysis.

To show you more directly the type of test data that we have obtained, this shows each of the data points in this case is an average of 10 drops. We fit each drop to fit a Mu versus -- based on the normal forces versus position curve average that obtained drop feature of the data point represents an average of 10 drops.

We have looked at in this particular case, comparing the effective rod environment and rod velocity. To get the rod velocity effect, we ran with and without a spring assist. So the speed of the rod going through the bushings would be somewhat different. So the spring/no spring is to look at the velocity effect.

But in general, we found the data was more accurate at 1.5 G and, in fact, tends to show by drooping of the spread of the data there is no identifiable effect of G level insertion of the G level of the excitation when we consider that the standard typical deviation of this data is on the order of about .04 and friction coefficient which would flip us essentially almost one of these lines would be one standard deviation to the test.

We found no identifiable difference between water and air, although the average does tend to be like that .04 identified. We did find in our sodium testing that we found consistently lower coefficients of friction. What we believe part of that is, as much as the medium, is the peculiarity of the way we had to instrument the rod or had some guide rods along the rod so that the top of the rod would not break off of the instrumentation. That limited the top rod motion.

When we ran the sodium, we took the bushing out of that rod, and that allowed somewhat more motion without impacting the guide rod. So if you did not impact the guide rod in this type of testing, you get more normal force at the bushings and, in fact, that increased normal force has led, we believe, to the lower coefficient of friction rather than the sodium effects.

In fact, most likely, although we are not trying to develop the argument to lower the coefficient, the friction at this time, that the guide rod effect is probably the reason that these values are much higher than the sodium values.

We also looked at the effect of bushing material and frequency of impact.

(Slide.)

We again found no difference. 22.8 Hz and 15 Hz, stainless-steel and inconel bushings, again within 1 standard deviation. We could not distinguish any effect of the bushing material or environment.

MR. ZUDANS: Did you establish what were the natural frequencies of this rod in different positions?

MR. PITTERLE: Yes, we did, at the start of the test. A series of sine sweeps. We did some sine sweeps at, I believe, three vertical elevations similar to the three that we have looked at. These two frequencies were picked to give us substantial response.

MR. ZUDANS: So these are close to free-free?

MR. PITTERLE: Away from the rod and away from the structure of the facility.

MR. POMEROY: Again, another question on that same line. What would happen if you had 40 Hz and 10 Hz, say?

MR. PITTERLE: Keep in mind for this test the rod is not prototypic for this test. It is not plant hardware. It is just a rod to give us the effective drive of coefficient of friction. The question may apply validly to the other testing where we tested the complete system and prototypes other than beyond the sine sweep, where plans are to sweep up to the order of about 33 Hz.

(Slide.)

Now I would like to describe the control rod system or the primary control rod system prototype seismic test. This is a picture of the facility. Basically, we are using the silo to keep the weather out.

But then we mount the shakers and control rod to a reaction mass, which is 140 tons, 50-foot elevation. We are using a triaxial shaker table, shown here, which simluates the closure head of the reactor vessel for purposes of the test. That has two directions, X, Y, and vertical input capability. And the control rod drive mechanism is mounted on that much like it would be mounted on the closure head in Clinch River.

The three different triaxial shaker table was emphasized to test the unlatch or scram release part of the mechanism. It is a collapsable rotor roller mechanism, so the rollers are relaxed out, pushed out away from the lead scoon, and you drop the lead scoon in the control rod system.

That permits us to test our design basis for designing that release function against triaxial input. For the insertion function, the scram motion is dominantly a one-dimensional effect. And that would be -- the testing for that would emphasize one-dimensional effects, and that is for these additional five shakers here together with the one shaker as a part of the triaxial table, which gives us a total of six shakers to input for the scram insertion function.

Now, we can get some idea of coupling between X and Y directions in a limited sense when we change from X to X and Y on the table. So at some low level of excitation we will get some checks on the additional summations of the X and Y direction effects.

Basically, it does test the mechanism control rod drive line, and the in-core control assembly. The location of the shakers are such that they represent typical locations for input from the balance of the reactor system. For example, the control assembly has an input through the core support structure at the inlet nozzle through the core restraint system through the load path and the top load path. The drive line, the shroud tube which envelopes the drive line, the excitation comes through the upper internal structure, and these two shakers simulate that type of input, and the triaxial shaker mocks up the closure head input.

(Slide.)

So in the testing we will do sinusoidal and time-history input at acceleration levels which are typical of OBE and SSE levels. But I do want to emphasize that the purpose, the primary objective of the test is verification of the design and analysis method.

This shows a picture of the triaxial shaker table partially assembled. Here is the shaker. This shows the X direction motion. You can clearly see across here one of the Y directional shakers. The mechanism then is mounted on this table. It does not show the vertical direction in this .

particular picture.

Now I would like to describe the secondary control rod system, scram valve testing. In testing the scram valve for the pilot valve part of that is part of the plant protection system falling within the IEEE Class 1.E definition.

The applicable reg guide IEEE requirements are here (indicating). The reactor system seismic analysis, as previously described, provides a response spectrum input, and it is obtained at the location of the scram valve.

MR. LIPINSKI: This is the electrical solonoid you are talking about now?

MR. PITTERLE: Yes.

MR. LIPINSKI: I would like to emphasize again you do not know its basic characteristics based on its spring mass damping.

MR. PITTERLE: To a complete extent, that is true. There have been in prototype some sine sweep type-testing done to look at the response frequencies up to 100 Hz, and there has not been anthing particularly alarming from that. But the predominant part of the verification testing is still consistent with that which you have heard today.

MR. LIPINSKI: Because you did actually take the single component and subject it to a test?

MR. PITTERLE: And the prototype.

MR. LIPINSKI: Okay. But as a component alone?

MR. PITTERLE: As a component of a valve assembly.

MR. LIPINSKI: But you did not put this as a component on the shaker table and excite it and its vulnerable axis to determine what it could take.

MR. PITTERLE: No, not to the limits, no. No test to failure.

(Slide.)

The scram valve seismic test, I will show a picture of what was actually the typical hardware tested. The valve and cylinder subject to the requirement of five OBEs and one SSE simulation multi-axis excitation. I will describe that in more detail. It was functionally tested during and after each OBE and SSE simulation, and I will describe the test results in more detail, that basically it has met all functional and strutural requirements.

(Slide.)

To give you an idea of what is meant by the scram valve and cylinder, this shows a picture of one of the prototype units. The cylinder is shown at one end which is a pressure pneumatic piston. The tension rod shown coming out of the cylinder comes across here, actually connects with the latch and the control assembly part of the reactor that releases the rod for scram.

So the solonoid and pilot valves are the part that trigger the release of the pressure that permits a tension rod which is downward-loaded to release by venting the pressure from the piston.

Three solonoids can be approximately visualized as one here, one here, and one behind (indicating). The pilot valves, pocket valves are shown here (indicating), as well as opening and close instrumentation for the pocket valve.

That was just meant to give you some idea of what we are talking about with this type of testing.

(Slide.)

To give somewhat more detail on that test, the methods are pretty straightforward. Let me emphasize the test sequence. The preseismic test was functionally tested before the event. Then given five OBEs -- and, in fact, the way the prototype was tested was really ten OBEs -- five and then it was rotated 90 degrees and given five more OBEs.

This statement is slightly misleading in the sense that it was really repeated twice. So there are a total of ten OBEs, counting the rotation of the equipment. There is going to be scram during and scram after each OBE.

The SSE was then simulated in a manner with three earthquakes, three SSE inputs. The first one was 30 seconds followed by two five-second SSE simulations.

During each of these simluations, two out of the three logic trains of the cylinder was tested in different sequences. This particular bullet here (indicating) should really be above this post-seismic test. So two SSEs then were done in one reference equipment on a biaxial shaker vertical and horizontal shaker, and the third one had the equipment rotated 90 degrees.

Then again after the seismic testing, another functional verification test was performed.

(Slide.)

The criteria for this test was that the scram time for the control rod movement occurred within the control rod release delay time of .1 seconds. And there would be no visible or functional damage to the component. The results of the prototype test showed no damage. The actual test values range between a minimum of 50 milliseconds to 62 milliseconds, and exceeded the criteria and were not really significantly different from nonseismic earthquake times that had been measured.

(Slide.)

So just to summarize a little bit what I have said and what we use this type of data for and the application of these results, the dynamic friction test provides the friction coefficient for use in the primary control rod system and the secondary control rod system seismic scram insertion analysis. So it is supporting both systems in the use of that dynamic friction coefficient.

Similarly, the preliminary verification of the scram insertion analysis methods that I described supports both systems. This is the key to the finite element analysis. The overall PCRS seismic test provides a confirmation of the unlatch basis for the mechanism and also will be used to validate the insertion times against prediction. And that again is time-history type methodology that is used for both the primary and the secondary control rod systems in terms of its validation.

The secondary scram valve test is unique to the verification of that scram actuator and is qualitatively in general terms roughly equivalent to the unlatch test function of the primary control rod system.

(Slide.)

For conclusions from what we have done to date in terms of the completed tests, they show that we have satisfied all of our design requirements for what has been completed to date. In the dynamic friction test we take the test coefficients of friction, perform the seismic scram insertion analysis, and the seismic scram speed requirements would be met for both the primary and secondary control rod system.

For the secondary prototype scram valve test, the functional requirements have been satisfied, and in place for plant testing in the primary total prototype system, plus the test of one of the valves of the secondary -- the plant's unit group -- we feel that we do have the tests plans in place to define confirmation for both the primary and secondary seismic scram capability.

MR. LIPINSKI: I have a question on your primary systems. It's a roller nut design, right?

MR. PITTERLE: Yes.

MR. LIPLINSKI: What drives the nut apart when you take the power off? Are the springs internal?

MR. PITTERLE: Yes. There are segment arm springs. It's very similar to -- it's virtually identical to the FFTF and very similar to the Naval reactor program.

The segment arm springs force the segment arms out from the -- the rollers of the segment arms out from the lead screw.

MR. LIPINSKI: There is a pair?

MR. PITTERLE: There are four pairs. Upper and lower pair on each side of the lead screw.

MR. LIPINSKI: Are they all all on the same axis, or are they rotated 90 degrees with respect to each other?

MR. PITTERLE: They are all driving two segment arms, all on the same planes.

MR. LIPINSKI: They may have a spring mass system. What's the resonance frequency for those segment arms with their springs?

MR. PITTERLE: We will in the test, through a sweep of -- we haven't defined the upper magnitude yet, but I am thinking in terms of 50 hertz. We are going to have an accelerometer mounted on the segment arms.

MR. LIPINSKI: This is a paper exercise I'm talking about. You know what those nuts weigh, you know what those spring forces are and you can come up with the resonance frequency rather quickly.

MR. PITTERLE: I am nor sure whether it has or has not been done. I think it may have been done but I can't cite any values.

MR. LIPINSKI: Once again, if that comes out to be a couple of kilohertz you know you are well out there, and your testing would just verify statistically what you want to observe.

MR. PITTERLE: That is basically -- we do not have a strong reservation on it, but I don't recall whether we have calculated the natural frequency of the segment arms by its support. I suspect so.

MR. LIPINSKI: It would be nice to have that number.

MR. PITTERLE: We can look.

MR. KASTENBERG: Do you worry at all about the core itself being distorted in an earthquake so that the rod can't go in, in terms of any of these tests?

MR. PITTERLE: Not in terms of any of these tests. There have been separate tests done in support of the core assembly designs where there have been looked at the loads required to deflect and to form ducts.

For this type of testing I think the only thing that would be relatively relevant would be if there was signficant deformation that could add to the misalignment. We can simulate in this test facility moving the components laterally analytically, and in a few scoping analyses it really does not make a whole of differences. You have a less sensitive scoping analysis and then you are in the normal scrams just because the thing is flopping back and forth as you go in.

But the core assemblies are designed for sufficient margin. They really lock themselves up. They really can't deflect very much. You push them over to one side, you've got a solid mass of hex assemblies, so that deflection is pretty small.

MR. KASTENBERG: I notice that so far in none of the presentations, and I guess not on the agenda, a discussion of the core and reactor internals with regard to seismic. Is that to be covered somewhere else, or is that not important or -- ?

MR. PITTERLE: The modeling is similar to that of -- well, at least for the internals -- to that of Tony Morrone, using a combination of time history and response spectra. That is used on many components, both, but no, there has been no planned specific agenda item because we felt it fell under the general methodology that was talked to by Morrone before.

MR. KASTENBERG: Is it something we should be looking at in detail under seismic?

MR. PITTERLE: Are you addressing that to me?

MR. KASTENBERG: Yes. I guess going back to one of our earlier meetings, we were talking about design basis and events beyond the design basis, and one was a reactivity excursion caused by a seismic event in which you have 60 step reactivity.

MR. PITTERLE: And that dictates feed of response.

MR. KASTENBERG: And somewhere along the line we would hear about how one arrives at reactivity insertions as a result of core motion due to the earthquake. And I thought today was the place we would hear it and I have been waiting to --

MR. DICKSON: This is Paul Dickson of Westinghouse. I believe we are planning to do that as the core restraint design, and I don't know when it is scheduled. But Tom is not prepared to talk to it. Do you recall when it's scheduled? I don't recall, but I do think we discussed having a meeting at sometime in which we would discuss the reactivity input as a result of seismic and other events as part of a core restraint meeting.

We certainly cover it if you wish. We are prepared to do so. It was just not a part of this meeting.

MR. CARBON: You mean you're prepared to cover it some other time?

MR. DICKSON: Yes.

MR. CARBON: Well, I'm not sure where it fits in our schedule. I guess we are going to have to get back to you on that because we are very much interested in that.

MR. DICKSON: That was my understanding, that it was planned to be inserted.

MR. CARBON: Let's be sure to do that.

MR. DICKSON: It was suggested that I should give you the bottom line, that it is physically designed so that it cannot input more than 60 cents, which is the design basis event. But that's a whole day's story before you believe that.

(Laughter.)

MR. CARBON: We will welcome that whole day's story.

(Laughter.)

MR. LIPINSKI: Your roller nut system operates in a gas, is that right?

MR. PITTERLE: Yes. It's an argonne fill gas, not separated from the cover gas by bellows.

MR. LIPINSKI: The point I would like to make is the spring mass system has very little. All I have to do is hit the excitation frequency and I get full amplitude of that response. That goes back to the conversation before. All you have to do is find out what the excitation force is.

MR. ZUDANS: I would like to continue that line. I do not visualize exactly how the details fit together, but I assume those springs preload the balls, right?

MR. PITTERLE: The springs will push it apart upon loss of magnetic field.

MR. ZUDANS: The magnetic field pretty well loads the balls against the magnetic springs.

MR. PITTERLE: The preload collapses the springs.

(Slide.)

This is a picture of the basic features. Mounted externally to the rotor part of the mechanism is the motor tube and then the stator outside that. You have the picture right there. A motor tube and a stator. You apply electrical power to the stator, providing that magnetic pull that is pulling the upper end of these two segment arms, pivoting about these pivot pins and engaging these rollers into the lead screw.

The segment on springs that we are talking about are shown here. There are two pairs, then there are another two pairs on the back side,.so that you have the -- and each of them is a pair of springs so there is a total of eight springs capable of pulling it apart. It will, in fact, not seismically test it, but in the normal scram it will scram even without the segment on the springs.

MR. ZUDANS: So there is actually a positive compression because of the magnetic item?

MR. PITTERLE: Yes. If you lose power, you will push the lower ends of the segment arms and you push the rollers out from the lead screw.

MR. ZUDANS: You actually then could not develop anything like a free vibration if it is not free. You would have to overcome the compressive force before it gets free to begin with.

MR. PITTERLE: Right.

MR. ZUDANS: Except that for the upper portion of those arms that have some elasticity about the pivot point.

MR. PITTERLE: Not really very much. They are pretty massive. I don't know exactly the size. This is pretty rigid about these pivot points. I agree with you in principle but I do not think they are very sensitive.

MR. ZUDANS: It is not a high frequency?

MR. PITTERLE: It is pretty well a hollow cylinder of some five inches in diameter hollowed out, and it is a pretty massive structure.

MR. ZUDANS: At any rate, the arms don't touch anything; they are sitting in a magnetic field free, so that is your spring mass system. And the other is essentially rigid at that point in time.

MR. PITTERLE: That is correct, with this being a very stiff member and held out against -- there are some stops. It is pulled out as -- I forget the terminology for it, but there is like guides that will bring the two segment arms into synchronous positions so that they do collapse and move out synchronously with each other.

So you are really holding them out against the flange and the stop up at the upper end, and you are holding it against that. It is not really hanging there loose to flap around. You are pulling it out until you engage in that synchronous bearing at the top, so it is not free to flap per se.

MR. LIPINSKI: What happens if you have a porous excitation in the direction of the axis label magnetic pull? One-half goes out and one-half goes in? Are they mechanically interlocked so that they have to be out and in togethe, or can I have them synchronously?

MR. PITTERLE: That is the purpose of the synchronous bearing. They are free to rotate if I release a field.

MR. LIPINSKI: What you just described was a limit stop of out and in. When they come in, they are touching each other effectively. When they go out they are separating, so you don't have that mechanically interlocked to synchronize them, to separate and come in together.

MR. PITTERLE: I am not sure we are quite picturing it the same way.

MR. LIPINSKI: Can I have one pushed in and one out simultaneously?

MR. PITTERLE: No.

MR. LIPINSKI: How do you prevent one from going in while the other is coming out?

MR. PITTERLE: Well -- okay. I guess in theory it is possible, yes. But the fact is the springs are tending to push both of them out, and then they are both guided so that they come in. I can't quite see the failure mode that would have coming in and one going out.

MR. LIPINSKI: The excitation along that magnetic pull axis.

MR. PITTERLE: I don't believe if the design basis is right, this is going to overcome this excitation, even if it were along this direction. You are saying along this direction?

MR. LIPINSKI: Right.

MR. PITTERLE: The springs are design basis so that they will take account of any of that excitation and then force them out with time to spare.

MR. LIPINSKI: At what frequency?

MR. PITTERLE: That I don't have the answer to right off, as to what frequencies have been looked at.

MR. LIPINSKI: Because again, you don't have any damping in that system. It is strictly spring mass. If I get the excitation frequency it will take very little force to get those halves to slam back and forth, unless there is something in there that prevents them from being non-synchronized. And I don't know what is in your mechanism that would cause them to have to be synchronized or separated or pulled in together.

MR. PITTERLE: Yes, except that with that force -- it is a pretty rigid system. I don't know the answer, but I suspect the frequency is high enough that it is not of concern. But I am speculating.

MR. TRIFUNAC: What is the strength of the magnetic pull? Do you know the force level?

MR. PITTERLE: No, I don't know offhand. I don't have that number.

MR. ZUDANS: Could you describe how it functions normally? What drops? The lead screw drops?

MR. PITTERLE: Yes. When you scram, you are pushing the rollers out from this lead screw. The lead, screw, which is in this point, is located above the top of the reactor head. The lead screw of that drive line connects it to the in-core control rod, and all of that is scrammed in the primary system.

MR. ZUDANS: When you want to move it out, what do you do?

MR. PITTERLE: You engage the rollers and then you pulse the fields of the stator.

MR. ZUDANS: This is what rotates them?

MR. PITTERLE: Yes. The lead screwup, and that is key to the that is it is all rigidly modeled into the mechanism part. I will briefly give you a picture of the overall part of the mechanism.

The upper mechanism -- what we were looking at before is essentially just this bronze-colored section (indicating).

(Slide.)

This extension nozzle is mounted rigidly to the closure head. The motor tube shown coming down in here is mounted by a hold-down ring. The nozzle and the stator is mounted over that, and clamped to the nozzle with the hold-down clamp. So this is the part you are releasing when you are reacting your forces through the nozzle.

MR. ZUDANS: That means that the flat part can go in in any position when it is rotated? It can stay in any unknown position?

MR. PITTERLE: Yes. It is 15 degrees, I think 15 degrees position is possible to get the time to steps that we are trying to get. It is a very small step, .025 inches per step vertical motion. I think it corresponds to 15 degrees stator rotation. Field rotation.

Are there any other questions?

MR. ZUDANS: Do you have similar pictures for the other systems?

MR. PITTERLE: Only to show how the -- well, let me perhaps give you a general schematic of the other system first.

(Slide.)

Although it is in the cartoon type pictorial. This is a core assembly, the reactor closure head. Then everything that is between the reactor closure head and the bottom of the upper internal structure is cut away. It is a twin ball-nut drive mechanism. The carriage and then the solenoid that we just pictured, the piston and valve solenoid is shown schematically here, mounted to that carriage. We have over-simplified it here.

There is a very slight motion of this piston, about a quarter inch motion of this piston where the rod releases the latch in the secondary system which is located within the control assembly itself. It is contrasted to the primary, where the whole translating assembly is going its full 36 inches.

During the scram the latch function here releases the latch and the whole control assembly travels 36 inches. The assembly is designed to give a fluid or hydraulic assist to the downward motion to assist the scram insertion into the core. The latch is shown in somewhat more detail over here. It shows the tension rod coming down the middle. A sensing tube that indicates coupling to the structural member of the drive shift.

This piston then permits loss of pressure to the piston and permits this latch to open up and release the control rod coupling head and lets the assembly scram into the core. So all the 36-inch stroke of the core is within the core region itself.

Just to orient you a little bit now with that upper mechanism part, the scram valve cylinder -- this elevation here --

(Slide.)

-- is about elevation 80 above the top of the head. We have the shielded seismic support that comes in, gives the general location would go up to on the order of 70-some inches. The cylinder is located here (indicating). The three solenoid valves. And this shows the tension rod. This piece through here is what we had the actual picture of, previously shown. It is supported off the carrier rod, rotor tube, and the support rods are shown here. It is off the support tube from the carriage up to the location of the cell.

That is about all I have in terms of detail. This at least gives you a general orientation of where it is in the reactor.

MR. ZUDANS: It gives an idea of the level of complexity.

MR. PITTERLE: Any other questions?

MR. SWITICK: Thank you, Dr. Pitterle.

MR. MALLETT: Mr. Pitterle has talked. I am Bob Mallett. I am going to address that same topic more specifically for the case of the heat transport system components.

These are the questions that I will address.

(Slide.)

The first is: what is the arrangement of the HDS? Here I will remind you of what it contains and mention some of the parameters of the heat transport system. Then I will identify some of the conventional conservatisms that are in the seismic design process that Mr. Morrone spoke about earlier today. Then we will consider a review of a portion of the information that is on the docket on seismic margin capability. Then I will turn to the two most important ones here, I believe. We will consider some of the differences, some of the specific attributes of the CRBR plant. And last, the development, the verification, the coordination that has been done to be sure that there are no oversights.

Based on the review of this material, it is our judgment then that the seismic safety levels for the Clinch River plant and the light-water reactor components are comparable. This is based on the observation that where things are common, they are handled similarly, and where things are different, that difference tends to be one of strength rather than of weakness.

(Slide.)

This is from the design lab showing of the plant. It shows a plant inside the three-loop for containment. This is the reactor vessel with a 36-inch diameter pipe that goes around the loop to the primary pump in the hot leg.

Here is what we call the crossover leg that goes from the pump to the IHX and the cold leg then returns the coolant back through a check valve in the cold leg back through the reactor vessel.

Two additional runs of ppe that you see here are the cold leg, which brings the coolant in through the IHX and the hot leg, which takes it back through containment penetration.

(Slide.)

The equipment that is inside containment is an inerted cell. I have included this vuegraph because it gives a clear indication of one of the principal effects of temperature on the arrangement of the plant. What you see here along the edge is where the coolant exit containments in the hot leg, it comes down here, it has one expansion loops, three expansion loops, goes into the steam generator building, and another expansion loop there where the corresponding cold leg which is bringing the coolant back to containment has a single expansion loop.

So there is, as I say, a clear indication of an effect of temperature of the plant where the temperature ranges are large pipe thermal piping expansion loops are long.

These are parameters for a typical loop in the plant.

(Slide.)

Temperature is about 1000 degrees for structural evaluation. This is about a temperature that brings creep into play in a substantial way. Creep begins to play a very important role.

You can also see a 24-inch diameter half-thickness is the size of the pipe. In fact, the size of much of the pipe that we have in the main heat transport system is 24-inch diameter pipe with about a half-inch wall.

That half-inch wall is thin. It is permitted to be thin by the fact that the plant is a low-pressure plant. That again is a key attribute or charcteristic of this plant relative to, say, a light-water plant.

(Slide.)

The low-pressure condition gives us a low sustained primary stress. Low pressure comes into play also in connection with the components, not just the piping. Here is a long, slender component about 12 feet in diameter and about 50 feet long. Normally, the wall thickness in this component is about an inch and a half.

The component is top-supported type supports to the building, carefully engineered, down through this cone to the shell. The design of the support is for stiffness, and one thinks of the available margins for a strength-type loading.

It is useful to observe here the nature of the seismic-induced response under seismic loading. One can imagine a wag-type motion of this component. When that happens, two things come to mind. One is that the way the component is challenged is by a buckling, bending, buckling type load in this upper cone. In this particular configuration, it is a failure mode that is not particularly catastrophic.

Another noteworthy aspect of that wagging-type behavior would be the nozzle motion. So you have displacement imparted from the nozzle to the piping characteristic of the top-mounted component.

(Slide.)

Let us look more at the piping. One's reaction in looking at this piping as it, say, exits the reactor vessel here for the pump, it is not a short straight run, it is a long and circuitous run. In order to provide the thermal expansion loop.

Given that the piping is 24 inches in diameter and a half-inch thick and it is relatively long, one's first impression can be that the piping is a vulnerable component in this type of a plant. Because of that first impression, in going through here, I will use piping principally as the example in illustrating that, in fact, that is not the case, that the flexibility in that piping is a beneficial attribute because it is long, though the supports of the piping become very important. We have more of them because the piping is long, and the response of the piping system is very much an integral response of the supports in the pipe.

In view of that importance of the supports, they very carefully engineered items on this type of a plant. You can see here a typical support configuration for main piping. The pipe itself is a cross-hatch part.

The green I colored in is a load-bearing installation. It is kind of a pad between the pipe and the clamp. The clamp itself runs cold.. The two halves of the clamp are held together by Bellville washers. They are springs essentially to hold the two halves together.

So the stiffness design component and it, too, has reserve strength.

One of the aspects that is interesting is illustrated by this load displacement plot in this upper corner under extreme loadings, one can see that this curve bends over at events beyond the design basis. There is a softening here that corresponds to a pulling away of one clamp half of the other under extreme loading. Under all design bases conditions, the pipe clamp stays snug to the pipe. Actually, we have gotten pretty good at designing clamps like that.

We then tested them to the point where the German reactor were designed here in this country.

Based on that overview, a reminder of what the components in the plant look like. It is our conclusion that the seismic design problem is essentially the same except for the differences due to higher temperature and pressure. Due to higher temperature we see longer piping runs. We see top-mounted components. Due to lower pressure we see thin wall.

(Slide.)

Let us move to the second question that I indicated we would address; that is, do the seismic methods and criteria that we use include the conventional conservatisms? To illustrate that they do, we will look at models. We will look at the methods and at the criteria.

MR. ZUDANS: Bob, before you finish the talk, may I ask you a question? You showed those clamps. You said they showed the load displacement diagram. That was intended to be for the clamp motion, the displacement diagram, where it gets softer as it goes by?

MR. MALLETT: Yes.

MR. ZUDANS: At what point will the pipe wall collapse?

MR. MALLETT: Pipe wall will not ever collapse.

MR. ZUDANS: It probably will buckle it, say?

MR. MALLETT: Well, we can overload it, certainly. What we do is we design the wall of the pipe like we were designing a vessel. We take care of the detailed stress distribution under that clamp. And it is that detailed design according to the stresses and strains under the clamp that set the load gradient for the plant.

So we have designed it essentially like it was a vessel wall, and then we go test it at SSE levels.

MR. ZUDANS: So you have tested it at SSE levels?

MR. MALLETT: Yes.

MR. ZUDANS: So your plant would be the one that would open -- reach the design limit before the pipe begins to collapse inward?

MR. MALLETT: That is true. Beyond the SSE, beyond clamp load ratings, what you would find is the forgiveness of the springs and bolts, yes.

(Slide.)

This is the portion on the conventional conservatisms. What I have shown here is the seismic model. What you see when you look at this one is one just like every other one you ever looked at for piping. The piping model is constructed of a string of finite elements, straight and elbow elements, that make up the piping system itself. It is connected on its ends to STIKK model, the components, and it is supported along its length by seismic snubbers or elastic rods at various locations.

In fact, we use the same computer program for Westinghouse that is used in the design of our light-water plant. So the differences in the number of elbows that you see and the thermal expansion loop in the pipe perhaps and the number of supports.

MR. ZUDANS: Bob, on this model, where the V model, the pipe connects the RV model. What do you do for that local load? This is relatively hard pipe in that direction.

MR. MALLETT: That is right. We have a local flexibility for the shell.

MR. ZUDANS: You have it?

MR. MALLETT: Yes, we do. We pay a lot of attention, Dr. Zudans, to the supports in this piping. These are springs and local shell flexibilities. There are other things because it is such an integral part of the response.

MR. ZUDANS: So it is really not necessarily a linear model completely? Or is it linear? Or you do not go to high deformations?

MR. MALLETT: Generally, it is linear.

MR. ZUDANS: I presume that this pipe goes into a vessel. The vessel is what is threatened, not the pipe.

MR. MALLETT: Oh, no, no.

MR. ZUDANS: Not so?

MR. MALLETT: No.

(Slide.)

Elbows in the pipe do not permit you to

exercise a vessel nozzle.

MR. ZUDANS: And supports do not stop the pipe from moving; right? At least that is an assumption that the support allows the pipe to move axially at that point?

MR. MALLETT: That is true. It is engineered that way, and ther are things like guard vessels around many of the components that require that the supports be backed off behind an elbow.

MR. ZUDANS: And these legs are short, the legs next to the vessel are short?

MR. MALLETT: Yes. Especially in the primary system where there is a guard vessel, you have to come out and go up.

Continuing on the conventional conservatisms motion, here is one I call to your mind. The actual data carries you around a curve such as is indicated in green here, and the area inside that curve is a measure of the damping in the design of the piping we wash that damping out in design and neglect that damping, adding then into the process a conservatism that is especially important for the LMFBR plant where we tend to have a lot of snubbers on the run of pipe.

(Slide.)

That was a review of the models. This looks at loads. Here again it is a very familiar process. There is a calculated response spectra, say, at the center of the building up at the support elevation.

Now, in the case of piping where the supports for that piping are at different elevations and at different locations from the center of the building, we would superimpose on a plot like this the spectrum that applies at each of those snubber supports and then the spectrum used in the design and applied at every support is the envelope spectrum. So there is another conservatism that is customarily embedded into the piping design analysis.

MR. ZUDANS: Do you really believe that that is strictly conservative? I do not know the answer, so do not be too hesitant. If you take different point supports and have their own spectrum generated, do you turn around and say, I am going to use single-input spectrum now for all support points because that is what is simpler to do in terms of analysis? And even if you took the envelope, I am wondering whether that would be a conservative result. It has never really been proven, but that is the way it has always been done. And it is bigger, but it is the same at every point.

MR. MALLETT: Yes. But you are not using time phasing in the sense that you took a time-history analysis and made them all the same in phase. Then perhaps this might not be conservative.

MR. ZUDANS: Maybe we will talk about that some other day.

MR. MALLETT: Yes. We worry some about that. There are various things a person does from the selection of the snubber down through preoperational testing, in-service testing, and additionally at this stage, some evaluations. And we have done some. What we find is some snubber failures can be postulated fail-free.

The integrity of the pressure boundary is not really challenged. That is a beyond-design base condition using nominal limits rather than lower-bound allowables. But for a nominal evaluation for that nominal condition, it is not catastrophic; we can accommodate it. I will show some things a little later that will tend to explain why that is the case.

(Slide.)

In addition to those things on loading, we followed the practices mentioned by Mr. Morrone for accumulation of the various modal contributions and accumulation of the directional responses as well. This is the third leg of the thing of the things to review under the conventional conservatisms notion.

This is one that was mentioned this morning that is worthwhile repeating here. What we are looking at here is a table where for the OBE limit enough snubbers have been placed on the pipe to bring the primary stress on this 36-inch hot leg in under the allowable. Here is the allowable 19.44. Enough snubbers are in place to bring it down to 5 percent below its allowable.

Once you have done that, in satisfying the OBE stress limit condition, you can look across here on the other pair of columns and see what that has done for you regading the SSE. A 5 percent margin embedded in the design here results in a 45 percent margin for the SSE level of earthquake. So here is the specific numerical illustration.

MR. ZUDANS: Is that 15? Is that a yield point at that temperature?

MR. MALLETT: No, that is above. That is above. That would be room temperature.

MR. ZUDANS: Room temperature.

MR. MALLETT: But this is not a room temperature calculation.

MR. ZUDANS: It is above the fuel point?

MR. MALLETT: It is above the fuel point.

This is where we have come to with the

conservatism. We have said components. We have had components that were not strange. We have used methods that were customarily used, and here the methods and criteria include the conventional conservatisms to the point of using the same computer programs.

Now, the next area that I would like to suggest that we step past, what it says is this. The question is: do we have inherent size margin capability? The components are familiar, the methods are the same.

What we have on the docket is a generic type of evaluation that says nominal yield stress is 25 percent above minimum yield stress, and considerations such as that lead us to a -- we step to a process that leads us to a conclusion that we should have about the same margin from this type of evaluation that any other structure designed using the same methods and criteria would have.

(Slide.)

If I do step past that question, because it really does not add any light on what has been said here previously today or add any information on the docket either, then that will bring me down to the question what are some of the things that are peculiar to the LMFBR type of plants that warrant mentioning in considering the tolerance of this plant for extreme seismic events?

Here I would like to look at three things, look at loadings, flexibility, and consequences.

(Slide.)

MR. MALLETT: This is a viewgraph that I have included to make the point with respect to loading. The point is that there are other loads in the plant that often are the determining basis for design. In the case of the piping, we look here at the intermediate heat transport system piping. The basis for design of this piping for this type of a dynamic event is more the sodium-water reaction, SWR, than it is the SSE. To illustrate that, what I show here is a number of support loads on the intermediate heat transfer system, hot leg piping. What is noteworthy here is this: at the -- in the first row, a snubber which happens to have a 201 has the maximum reaction of any support location on that piping, 60,000 pounds. At that location the corresponding SSE load is 21,000 pounds.

If we look down at a different point along that same leg of pipe, the maximum SSE load that occurs anywhere is, say, 30 pound load at that point, the sodium-water reaction load is 45,000 pounds. So it is the nature of the plant and its conditions that lead to loadings other than the SSE to be the determining factor in the design of much of the equipment.

Now, this happens to be the intermediate heat transport system. Essentially the same thing is true in the primary heat transport system where in that case the water hammer type of event that is evaluated is the HCDA, or water we call the SMBDB. The water hammer event meets the larger loads than does the SSE.

(Slide.)

MR. MALLETT: Now, this is the point that I found difficult to say, but it is a very important one and it is worthwhile, my having a go at it. It has to do with the flexibility that is inherent in this piping and the capacity of that piping to accommodate deformation. I have to begin here. Remember, in the ASME code we had what is called a primary stress which is the type of stress that can fail with one application of the load. And we often also talk about the secondary stress where it is not a single application but it is cyclic loading that causes a problem.

I have illustrated that here below. Here is the primary stress case on the left. Suppose we have a beam. Suppose that stress on that beam is about the yield stress. So there is a primary load situation. The secondary load situation would be where you push the tip of the beam down one inch. You do the same analysis, you calculate that you have a reaction that would rise. It would be ten kips, and the stresses here on the beam would be the same. This is a load control situation. It is a dead weight. It leads to a primary stress. It is just a displacement control situation that leads to a secondary stress.

The difference is when you are asked the question what if you are wrong? Suppose you are 50 percent wrong? If you are 50 percent wrong in this case, the load is actually 15, then you can go to collapse. If you can go to immediate collapse of this beam.

Over here, if you are 50 percent wrong in what that displacement was and it is actually down an inch and a half, the reaction is up a little bit, but you really have no failed the beam.

Inelastic deformation in the structure does not relieve a primary stress. It does relieve the secondary stress. The significance of this is that the seismic stress limits that we design to in the ASME code are set assuming seismic stresses are primary stresses. You see, the stress limit, you can go to collapse in a single application. The fact of the matter is it does not really work that way, especially in the LMFBR case where the piping is a very highly redundant structure.

(Slide.)

MR. MALLETT: This kind of illustrates the same point. I think it is worth showing it also. This says this is a load versus displacement type plot, but you could think of it as stress versus strain. Let's say the material is initially elastic. We will take it right past the elastic limit, and we come up here. Once we arrive at this point, then we can see this is due to the fact that the material is really nonelastic. It exhibits inelastic behavior, plasticity.

We could move off in this direction, then we see it is very important to provide a substantial margin here because the primary stress would be carried to failure. If we admit to plasticity, we come down that line, that is what happens if it is a displacement control situation or secondary stress.

This is the kind of thing that happens in the LMFBR pipe. It tends to come down in this direction due to an inelastic deformation in the piping. Don Landers of Teledyne mentioned in a report recently that in his experience he has seen cases where elastic calculations would carry you to five times the design limit and yet on inspection of the pipe, after the event, there is only moderate inelastic deformation. The redundancy of the pipe and its flexibility gives it a remarkable capacity for shedding load from the high load region to the low load region.

Let me carry this a little bit further. This is test data for an elbow of the type that we used.

(Slide.)

MR. MALLETT: In our piping, an elbow is about 20 times more flexible -- that's not always the case. Let me take a specific leg. The 36 inch hot leg out of the reactor vessel, the length of the pipe and the elbow, what that means is that all of the deformation occurs -- all of the deformation occurs essentially in the elbows. The straight sections aren't challenged. They are not severely stressed. So the way the deformation takes place, then, we collapse a single elbow in the test here, versus a change in the angle of the elbow.

Here is the OBE limit. Here is the SSE limit. Up here is the actual collapse load. So there is this enormous margin that is built into the process because it is a primary stress.

If you look up here at the collapse load, what you find is the strain, even at that level, is only about a 1 percent strain. The nature of the deformation is a relatively benign deformation. Here we have taken an elbow that we have collapsed. This is a 16 inch diameter, I think. We have collapsed this elbow.

(Slide.)

MR. MALLETT: You can see the way the piping system performs is that the cross section of the elbow is ovalized. The straight pipe really doesn't get bent a lot. The flexibility is in the elbows.

(Slide.)

MR. MALLETT: The important thing is that an elbow like that be able to accommodate a lot of strain, and in fact, it can. As I said, here at the peak this is only about 1.2 percent strain. It is already at a change in angle of 4 degrees, so you must imagine you have two long straight sections of pipe. The elbow is changing four degrees, or out to the right 8 degrees. There is implied in that enormous motion down at the other end of the straight section, and it really can't happen that way.

When you get into large motions like that and these beyond design basis accidents I am imagining here, you will run to the limit on travel in snubbers and hangers and such things. So for the beyond the design basis accident, there are mechanisms there that provide for shedding of loads.

MR. CARBON: Would you put the other elbow back up there?

I didn't have time to really study that.

Would you go through again what I should get out of that picture?

(Slide.)

MR. NALLETT: What I would like to have you understand from this is that the fairly benign nature of the deformation that has to take place in the piping system, it is not a question of bending the straight piping section. What large displacement of this piping system leads to are simply polarization of the cross section, and in this case it is a complete collapse, ovalization for purposes of illustration, but even at OBE levels for dead weight stress, the nature of the deformation of these piping systems is one of essentially ovalization of the elbows in order to accommodate the motion from straight pipe.

MR. ZUDANS: Bob, the other picture that you showed, the low angle curve, it really didn't mean that the walls collapsed, just that the load capability in bending reduced because of the ovalized cross section.

MR. MALLETT: Yes.

MR. ZUDANS: You still had the low passage in the elbow. It wasn't closed off.

MR. MALLETT: Oh, yes. This is after the test of what we call an elbow collapse. This is what it looks like. This is far removed from any actual design basis type load.

MR. KASTENBERG: I have a question.

The comment you made before about the long run of pipe, does that argue then for having a more flexible piping system with less snubbers in it and letting piping take up in a large earthquake, taking up energy via an elastic deformation?

MR. MALLETT: We have a very flexible piping system here, and the nature of the behavior is one which shedding loads to snubbers which are down in the straight sections and that works well. I think that is a beneficial process.

MR. ZUDANS: I think your advantage is derived from the fact that you have large diameter, thin wall pipe. If you took the large diameter PWR pipe, there are much thicker diameters. While they still have the same tendency to ovalize, but they are much thicker, so in response to your question, this is correct. It is reasonable for more flexible piping, and it is not unreasonable to think of that for LWRs as well.

MR. MALLETT: I had some points I wanted to make here on special attributes. The load flexibility -- this was one I have called consequences. Here the attribute I want to talk about here for a minute is the failure of the piping is not catastrophic. We have done testing such as that indicated here. This is a straight section, an elbow and a straight section. We have applied a moment to that elbow by changing the length here, and we got an initial defect in that elbow, and then we pump up the internal pressure to cause a failure to occur.

Now, I will show you next the figure for the failure looks like for the case of the 16-inch diameter elbow. This is the most highly stressed region. We cut a through-wall crack there equal to the length of about the diameter of the pipe, a 16-inch diameter pipe, a 16-inch through-wall pipe. We put a bladder through that pipe and then pressurized it up to a pressure that is twice the design pressure present, and the cross-over leg in this piping, this is what the failure looks like.

(Slide.)

MR. MALLETT: That is, it is such a low energy system that it is just not possible even for these thin wall pipes to open up the crack. This is the initial crack. No extension of the crack occurred, and we could not get it open more than about that much and still keep it sealed at twice the design pressure.

So the low energy system does not give a violent destruction with the failure and of course does not leave any system dryout because it is below the flash point of the coolant.

(Slide.)

MR. MALLETT: We have studied that process a good bit. We have been here before and presented what we called our piping integrity activity. It included the tests I just showed you, and it included the three tier process. First we looked at ASME type evaluation of the piping. Then we postulated flaws in the piping, worse case location, orientation, such things. We tried to see what would happen to that flow when the duty cycle was applied to the plant. The answer is almost nothing. The cracks don't grow for the combination of conditions that we have and the material that we use, almost negligible cracks.

Then we add a third layer on this evaluation of the integrity of the piping where we set aside the duty cycle of the plant and force the crack to grow. When we did that we found that the crack penetrated the wall at a fairly short length of pipe. A part of this last activity here was a test that I just showed you. Even when we took the pipe, put a very long crack in it, tried to open up an abrupt, large hole, it just does not happen. The energy is just not there.

So from the picture that I showed you and your arguments that are on the docket with respect to these activities, we conclude that abrupt gross failure of this piping is not credible, and that is a noteworthy attribute of this type of system.

(Slide)

For this segment, then, I conclude that the Clinch River plant is designed to beyond the design basis.

MR. ZUDANS: Bob, did you ever experience an indication of buckling collapse in the compression zone?

MR. MALLETT: The pipe is not that thick. It is thin compared to the light-water plant, but if I would bring a piece here --

MR. ZUDANS: It is half an inch thick. We can visualize it, right? So it is not paper thin.

MR. MALLETT: That's right. It is heavy. You saw reaction loads of 60,000 pounds of pipe out of this strong pipe.

MR. ZUDANS: You do have strong relative motion. Supposing you just inconveniently selected support that froze up on you, and you had to go several inches. Did your test reach that kind of arrangements, or do you have such geometric configurations?

MR. MALLETT: We tested the geometry, both short-term loads and in fact creep tests. The only buckling that occurs for the parameters that are relevant here is the ovalization. That is all we see. They are just not thin enough to get us down to the interesting piping problems.

(Slide.)

MR. MALLETT: What special things have we done in view of the fact that this does not have the extensive prior operating history of a reactor? Well, we have done a number of things. We have done things in the development area, in the verification area, and in the coordination area, and let me mention some of those. I have come back here to the clamp case again because supports are so important. This is a plan view of the section of pipe. This is a 24-inch diameter pipe. It is full scale tests where we put a piece of clamp on the pipe. We insulate the pipe. We snub it to ground, and put three thrusters against it. This is really all the horsepower we had to put against that.

We took that to temperature and seismic loadings, and simultaneously we took it through temperature changes and seismic loading. This is an end on view of essentially what the plant looks like. I have a photograph of the test setup that takes this view. From such developmental programs as this, various kinds and many in number in this program, we have established the integrity of the important pieces. This we took through a number of SSE's. We took it apart, inspected it for damage, and it wasn't damaged, and that has helped us to qualify the clamp. This is looking back over the three thrusters. This is a pipe and here is the plan.

(Slide.)

MR. MALLETT: This is an example of the type of developmental testing that had been done as a part of this program. It has been done not only on the large clamp, but also on the small clamps.

(Slide.)

MR. MALLETT: This is more of the same development type confirmation of what we are doing. This is representative of a one scale third of the cross over pipe between the pump and the IHX. We have been very careful in this test to design prototypic supports along this piping, and have a prototypic thinness in the pipe. We will be subjecting this this summer to a seismic load to confirm that what we are doing in representing this thin wall pipe and its associated piping hardware is an adequate model and an adequate method.

Now, with respect to -- I guess the difference between verification and in the actual plant, this is the HDRD contamination project that led to a number of seismic -- a number of vibration studies of the piping. We have pulled these two results from that too as an additional confirmation that the methods we are using are getting the job done. If we look at frequencies for one of the legs in this plant, for one of the three modes I have shown here, what is measured in the field is in the same ball park as what is protected, or vice versa, perhaps I should say.

So, for these loads down at these frequencies, the correlation between analysis and test is pretty good. If you look in terms of peak acceleration response at a place along the pipe due to this excitation, this particular case was a charge set off outside the reactor in the ground. We have ordered here the test measurements along this piping leg from the maximum value to the smallest value, but what you want to look at is in this region where the response is the highest. How is the correlation between the analysis and the test? It is pretty good.

Here, where the responses are strong, the correlation is good, and where the correlation is less accurate, plates out here, plates out here, the analysis is usually more conservative than the test. The analysis is conservative relative to the test, I should say, so this is a confirmation of an actual light-water reactor hardware. The methods that we used are reasonable.

Now, this is a verification that has been done for the FFTF plant on the cross over pipe, that is, the pipe between the pump and the IHX. The excitation in this case is the pump itself. The question, of course, is whether or not the natural frequencies that are predicted are close to those that are observed in the plant. Well, for the zone of pump speed that is shown across here, one can see a peak of 12.4 and another peak down here at 12.0, and 15.0.

The frequencies predicted for that pump are very close to the frequencies actually observed in the plant. This is for the FFTF.

MR. CARBON: These analyses were done with the pipe filled with some fluid? Because you have to have that.

MR. MALLETT: Yes, yes, you have to have that. The accuracy in that case was better than you would expect.

(Slide.)

MR. MALLETT: We have an extensive program of technology exchange with other countries, especially the Japanese. This vu-graph shows a test that is being run by the Japanese. This is their Monju hot leg where it comes out of the reactor here, off the ground here, up around, and back into their IHX. It is a test very much like the test that I showed you earlier in blue, which is the test being run in this country. They have run this particular piping through thermal expansion type testing. They have run it through seismic testing, and they are also going to be doing water hammer testing with this piping. It is an example of the type of program where we have stayed in touch with the Japanese to follow what they are doing. They follow what we are doing, because neither of us wishes to have any important oversights.

(Slide.)

MR. MALLETT: This is a specific quantitative benefit from that exchange. They have done in situ verification of Joyo piping dynamics. This is done by shaker siting force in three places, X, Y, and Z, from a piece of pipe that runs from their IHX out to their penetration. What you see from these in situ test results are here, the first four test frequencies are shown here, the corresponding analysis frequencies are shown here. The two differences and analysis results here. One case they run with the rigid, assume a rigid support. That is the way we used to do analysis in this country, the way they used to do it. We don't do it that way any more, we do it with spring. With springs the correlations on these loads are very good for tests against the installed piping in the Joyo plant.

I have tacked on the end here just for your information damping that has been measured in these tests. They say the damping is quite high. The first load is up to 17, 18 percent, down to the fourth node, higher frequency. The damping is down four to five. This is just an indication of our interest in what is going on elsewhere in the development of these LMFBR reactors. This is where I have come to from this presentation.

(Slide.)

MR. MALLETT: The methods we used are the conventional methods and have conventional conservatisms. I didn't go through the inherent margin business. It is on the docket, and there is nothing special to the LMFBR. We ran through the special attributes that reduce the risk associated with high seismic events, and finally, I pointed to in a summary fashion the number of activities that we have in place to help verify the designs.

It is our judgment based on activities and evaluations such as these that seismic safety levels for LMFBR and light-water reactor components are comparable. We have done them similarly where they are different, we see strengths in the features of the LMFBR plant.

MR. TRIFUNAC: I have a question regarding your loop that you showed very early about the snubber resisting force. If I look at, say, a complicated three-dimensional regiment of the pipe I can envision a situation, and if I suppose it is attached to a relatively rigid structural system, I can imagine a situation where the deformation of the pipe is such that in one case the snubber is pushed in and in other cases it is pushed out, so if I don't have the linear approximation of the spring, equivalent spring for the snubber, but rather look at the actual force that is in the snubber, that I could have one snubber somewhere lagging, and in the other case advancing relative to the force that it should be experiencing from the deformation of the support points. Are you with me so far?

MR. MALLETT: I think so.

MR. TRIFUNAC: So with this hypothetical case, then I am getting into a situation where I can envision that the forces that go into that three-dimensional pipe arrangement have essentially introduced phased delays by virtue of the fact that not only in the area of the snubber response. Do we consider that?

MR. MALLETT: Let me answer it this way. The snubber is quite a complicated device. It differs from a linear spring in several ways. One is the damping.

Another is, there are small gaps, and impacts in snubbers. So we have undertaken to study it a great deal. It continues, and we are going to carry it so far as to actually run piping systems like that that I showed, where we have designed a piping system with prototypic supports and characteristic thinness in piping to confirm what we are doing, but so far we have done it analytically. We have run very careful time histories with one type of model, and another we have run with small gaps and we have run with different stiffnesses.

Frankly, it doesn't turn out to be the problem that we thought it might be. What we are finding is confirmation that the simplified linear response motions that we use are pretty good, pretty good.

MR. TRIFUNAC: I am not sure you can find out, because, for example, in this case, the geometry is so simple, and the length is relatively short. It is difficult to imagine the experimental vibration that you would see that would even bring what I am talking about as a possibility. If you have a long pipe, a real pipe, could you not get a somewhat enriched vibration spectrum mode that you don't see because you impose linearity on the snubbers?

MR. MALLETT: I say again, not as significant as we thought, because the pipeline I showed you there really isn't terribly simple. That is a three-dimensional pipeline. It will be given a complex seismic excitation. We have already run complicated situations and analyses, and I showed you this one from the Joyo actual plant. These complexities are actually there, but apparently really are not all that significant.

MR. TRIFUNAC: How would we test that? This we cannot test in the framework of my hypothetical question. We would have to have the supports of the snubbers moving the way they would, say, during an earthquake, and creating those out of phase motions. How would we test this except perhaps during the computer simulation?

MR. MALLETT: The snubbers are out of phase. We use various models. I think the complexities that you are interested in are already in analyses we have done and test results we have, and we are pleased to learn that they really are not as complex as one might hypothesize as significant.

MR. TRIFUNAC: I think what I am getting at is, I am wondering whether there are some three-dimensional shapes of vibration. I am not using the word "node" intentionally, but we eliminate the phase of the real snubber by linearization.

MR. MALLETT: I can say again we have done analyses of the various snubber models.

MR. TRIFUNAC: Non-linear models?

MR. MALLETT: Absolutely.

MR. TRIFUNAC: Not damping, gaps, theoretic delay, all the complexities that we can imagine might actually be there we have looked at, and it is in the open literature at this point. It is published.

I am talking about histioratic delay. The damping is just going to be a 90 degrees out of phase thing. The stoppage is going to change the stiffness. I am talking about the delay with which the force of the snubber responds in a non-linear fashion.

MR. MALLETT: We have been through that. I say again, we have very complicated snubber models to test the sensitivity to such things. I say again, it has turned out it is not a problem.

MR. TRIFUNAC: You don't find a case where the delay would bring about an unexpected distribution of forces and an unexpected form of vibration?

MR. MALLETT: I can give you some general comments. If the gaps get too big, they are a problem. That is one of the things that happens. I can also say, when you work with such things as the damping that you talk about, you can change the response. Usually you do not have much effect on the largest response. The smaller response, the peak boundary.

MR. TRIFUNAC: I am not talking about damping. I am talking about phasing of the forcing function.

MR. DICKSON: Could I rephrase it, possibly, Bob? I think he is worried about snubber 1 getting hit with a force and snubber 2 getting hit an instant later. Then when snubber 1 is coming back snubber 2 is going forward on the same length of pipe. I think that is what is his concern.

MR. TRIFUNAC: What I am looking at is a situation where they are not all in phase because they are non-linear, so one is pushing, one is pulling. That may be 90 degrees out of phase, or 180 degrees out of phase. So in linearization in the dynamic model eliminates that. That is what I am looking at.

MR. DICKSON: Is that eliminated, or is that factor accounted for?

MR. MALLETT: Every study we have done to look at these interesting aspects of how responses may be replaced have indicated they are not as important as they would be --

MR. ZUDANS: The kind of analysis you did by taking all the response spectra and adding them to the response supports, the kind of question Mike is asking you cannot answer without analysis. It is really a question of, can you really excite the motion parametrically, so to speak, by this fact that they do not linearly react to the portion of the ends.

MR. MALLETT: I do not know what it takes to be helpful. We do a nozzle excitation where one end moves, the other doesn't. So that is a case where the supports aren't all going similarly.

MR. TRIFUNAC: Let me explain why I am asking the question. I have done analyses of bridge type structures where in the response moving phase I get one response, but I just slightly change the phase of the support motion, then I can excite vibrations you have never seen before, and I was wondering if you have ever seen historatical. That is why I am asking the question.

MR. MALLETT: We have excited snubbers with the non-linear historatic. Our time history seismic analyses have all had similar motion and support. Our nozzle has not.

MR. TRIFUNAC: That is a limiting factor.

MR. DICKSON: The sodium/water reaction for the intermediate heat transport is time phased, so that is time phased and when a nozzle is excited, that is time phased.

MR. MALLETT: The structure is very complex. A bridge is more susceptible to being excited in a way so that it has a response particularly to the excitation. The modes in this three-dimensional piping to participate from -- they all participate from any directional.

MR. TRIFUNAC: I was thinking about that, but mechanically it was the same thing.

I just had one other question. You had a table. You showed some very long time pegs. Is that like I take the pipe experimentally and I displace it and I let go and I see how it dies out? How was this actually done?

MR. MALLETT: The Joyo test that showed very large damping, I think it is very large pipe that was excited at the location shown. The question is whether that was a sinusoidal excitation or whether it was a snapback. I don't know. I don't know.

MR. ZUDANS: That damping included all the snubbers as well.

MR. MALLETT: The supports, yes.

MR. TRIFUNAC: That is why I was asking the question. In the first mode it is higher than the higher frequency, so you are more or less structural damping.

MR. TRIFUNAC: So perhaps the fourth or the fifth mode might be representative of the damping in the pipe.

MR. ZUDANS: Oh, yes.

MR. TRIFUNAC: And the second mode is indicative of the energy absorption of the snubbers.

MR. ZUDANS: There is no question about that.

MR. TRIFUNAC: That is why I asked the question.

MR. ZUDANS: It is 17 percent.

MR. TRIFUNAC: So using 17 percent would be misleading in the analysis of the structural model of the pipe.

MR. MALLETT: Clearly, I wasn't recommending that we use 17 percent.

MR. CARBON: Are there other questions?

MR. KASTENBERG: Max, I have a general question for the group of speakers, but it is brought on by this particular presentation. Suppose you find in the PRA that you are about to do that external events such as seismic is the dominant risk contributor which would lead you to core disruption or core melt, and you had some systems which you may rely on, and are either not seismic category 1 or just seismic category 1, and you want them to function in the case of this large accident.

The one I thought of was the one we were presented with at our last meeting, which was the containment event and purge system, which I think goes out into the auxiliary building. Would such a system hold up in a large earthquake? Have you looked at that? Are there other systems that you might rely on in a large earthquake that might not hold up, but you would like to have available?

MR. MALLETT: I would like to ask my spokesman back there.

MR. GAESER: If your question is, having done the analysis and finding that seismic as an example is the dominant risk contributor, and then finding that there is some link within the chain of connection that is weak against that in the higher range, particularly weak, think about the draining lake analyses, you have got something sticking up, then I suspect the project would take some action with respect to that without knowing what the weakness was, how much it was. It would be difficult to predict in advance what you would do about it.

Clearly, the PRA would provide an indicator of where you are headed, and I used the term earlier, a weak link in the chain of protection, and then you would have to evaluate that. Right now, those features that we are counting on are all designed to ride through the seismic event, and all of those, one would expect to have some margin beyond that, and present at least in my mind, not each one individually quantified.

MR. KASTENBERG: Is that system we saw last time seismic 1, the purge system that went out into the aux building?

MR. GAESER: The purge system, the filters, the cleanup system, and the purge system, the buildings those are located in are all seismic 1.

MR. CARBON: Carson?

MR. MARK: This is totally out of ignorance. I have heard that snubbers are one of the main sources of snubbers. That is, they seize up or they lose their fluid or something goes wrong. Inspection is a great pain and not very reliable. You have spoken of needing to restrain these pipes, and yet these pipes are a little more something like an earthworm that I think needs to be restrained at many points. What would be the consequence of just slinging this thing in a hammock and attaching the continuous hammock to beams at a suitable number of points and letting the pipe ride away?

MR. MALLETT: It is true, to fail something you need to tie it down some place. If it is not tied down any place, you can't hardly fail it. Once you begin to tie it down to a nozzle of the component and then another nozzle at the component of the other end, then --

MR. MARK: I could see that that would be true for maybe the last half dozen feet or something.

MR. MALLETT: It is a good idea to have flexible systems. You won't find snubbers like this in fossil plants, old plants.

MR. MARK: You are saying that the snubbers you are proposing to use are going to be less affected by the traditional problems that you would buy from the guys who now make and sell snubbers?

MR. MALLETT: We are going to buy mechanical snubbers which are -- for this piping we talked about here today, which are very well studied items in recent years. That is true. I do not have some of the failure modes and some of the hydraulics numbers handy. We have used vendor data, and we have developed our own data. We have spent a lot of time trying to engineer those supports, trying to get them right, and as you know, we will be involved in inspections and confirmations later.

MR. ZUDANS: Typically, what kind of thermal expansion motion do the scrubbers allow, in inches?

MR. MALLETT: You can specify what you want.

MR. ZUDANS: What do you need, for example, in the piping that you discussed?

MR. MALLETT: We will buy ones that are frequently, say, six-inch travel.

MR. ZUDANS: Six inch travel for slow motion?

MR. MALLETT: Yes.

MR. ZUDANS: The leg that comes up on the reactor vessel goes up a couple walls and goes up. Where is the first snubber located on that line? On the vertical leg someplace?

MR. MALLETT: No, we have no snubbers in the reactor cavity. It is up, out, over and through the wall and then it is over there (indicating).

MR. ZUDANS: And then you have a great number of elbows, at least two more elbows before you hit the first snubber. So that means the reactor vessel expands six inches, you really don't care. You can fully accommodate it. It is not a single support that would freeze up on you and stop the wall from expanding.

MR. MALLETT: Yes. We have done beyond design basis accident analysis, so to say we can withstand circumstances like that.

MR. ZUDANS: Does the compartment head up in the case of spill? I guess you really don't care; when you spill, you spill. Okay, that's a superfluous question.

MR. CARBON: Thank you, Dr. Mallett. Mr. Thornberg?

MR. KNIGHT: I guess the next item on the agenda is the status of the staff review, and I can be very succinct at this point. In addition to the -- this is Jim Knight from the staff.

In addition to the report that we had this morning from the people in geology and seismology, we are in the midst of our review in our areas, and in particular, the structural people will be performing an audit at Burns & Roe on June 22nd and 24th, in which we will be looking at a number of the areas discussed here today, such as modeling and various parameters used in the seismic analysis.

And we have the mechanical people looking at piping and components that are being assisted in this particular case by EG&G, partially because of the shortage of personnel available to perform the review and partially because we were looking at -- for additional expertise. Not so much in the seismic area, although we will be benefiting by the EG&G personnel there, too, but also in the area of high temperature technology in the application of the high temperature code cases and the code.

There we have a subcontract that makes Dr. O'Donnell available to us as the staff consultant and assists us in our review. I would hope we would have a draft SER on the mechanical side probably mid-July. That will be the first item we will set forth as areas where the staff has concerns and expand on that in the question and answer process.

That pretty well is the status of the staff review at this moment.

MR. CARBON: Questions of the staff?

MR. MARK: Will the staff probably have solidified its conclusions on the acceptability of some number for SSE and OBE by the site suitability meeting time?

(Pause.)

MR. KNIGHT: I would characterize the staff's present posture as one of working at this moment to assure ourselves that the conclusion we reached some years ago still holds, and I don't believe as of this moment we see any strong influences that would have us tend to change our mind. We may not -- by the time of the site suitability meeting.

I would presume we would like to reserve a little bit of flexibility to look at some other information that might be available, but by and large, I think we are already at the point where, as I said, barring some unique piece of information, we are satisfied with the seismic design level.

MR. ETHERINGTON: Does this mean that starting today you would reach the same numbers?

MR. KNIGHT: I think that is a fair characterization at this time. We do reach the same numbers. We do have questions that are outstanding, and I do not want to disarm the applicant. We do have questions that are outstanding. They wouldn't have been asked whether they were serious questions, and it is the type of question I think we need to update, our understanding of the geology of the area and to assure ourselves and the applicant that there are not factors that would cause us to change our minds. But it is an attempt to give you the best feeling I can for the moment.

I thin we are not, at this moment, anticipating a signficant change.

MR. MARK: A thing that could make a significant change in principle would be the redefinition of the locale, within which the Madrid earthquake structure exists. Now, I presume that has been looked at and it does not make a change, it does not make Madrid controlling. The boundary of that rift or fault or whatever you call it has been expanded within the last, what, year or two years from what it was when this was first looked at.

If it came far enough in the right direction, then it could become controlling, and that would change your SSE numbers in principle. It could potentially. The same thing would happen if Charleston were allowed to migrate 100 miles inland; then it would be at the 200-mile distance.

MR. KNIGHT: Yes. I guess certainly, if what I would consider signficant events of this type were to occur -- and one might even say if we had another event, significant event somewhere closer by -- it could change. But we have put a fair amount of effort into reviewing the work that we have done over the past, and at this point, with the exceptions of the questions which are now outstanding, we have not felt the need to modify our position.

MR. MARK: That is likely to be rather a central point, is it not, in site suitability discussions ultimately, if not this month? Certainly it is the basis of all we have heard today, that this is the SSE and this is the response.

MR. CARBON: I don't know whether Mr. Check might want to respond to that comment or not.

MR. CHECK: I don't know how much more can be said. There is always an element of risk. If it is important, do things happen, they are going to be accounted for, up to an including changing the game. But if things hold together, right now there is a growing confidence that the conclusions we have reached before about the capability of this site for a reactor of this general size and type are going to hold up.

MR. MARK: I couldn't ask for more.

MR. CARBON: Are there any other questions?

MR. KASTENBERG: Yes. I would ask the staff: in what context will the staff handle earthquakes more potentially severe than the SSE?

MR. KNIGHT: That is a very significant and difficult question. I cannot give you a prescription of what the staff will do. Our response in the past -- and this is a subject which is occurring with increasing frequency -- has been that we believe that the process that is now in place, the designation of the SSE and the OBE, leads us to an adequate design basis with margin that gives a significant, I believe, degree of confidence in an ability to withstand an earthquake greater than that for which we have explicitly designed.

As a matter of fact, I think everytime we look at it, it is virtually impossible for us to design just up to some level. We always end up with capacity greater than our design. Even when we go back and retrofit a plant, we end up with something greater than what we retrofit for. It is just the state of the engineering technology.

Once you decide that you want to enter this question -- and this may or may not have been this type of a question -- once you decide you want to enter the sphere of a discussion on larger load capability of greater magnitude events, the engineer has a rather significant problem, and the regulator along with him, in that if one were to say: I want some definitive response here, it seems to me that the next thing you want to do is define that larger event, define it in a way that you can enter the standard methodology with it.

Having done that, now I should decide on perhaps acceptance limits for stresses and this kind of thing. So one possible avenue seems to be opening an entirely new branch of progress, I might say. The other is to perhaps look more closely at the question of margin and where it exists and what confidence we have in it.

There has been a suggestion, I believe, from time to time that perhaps we should increase the level of seismic input just to gain some of this additional confidence. I have, I know, a very personal feeling and it is shared by others of the members of my staff, that this may be just the very wrong way to go.

A lot of things we are talking about here today, adding stiffeners, snubbers, complicating systems, it would seem to me that a very careful study would be in order before we decide that we really have made a net gain in safety by somewhat arbitrarily increasing the level of seismic input, either because we really are convinced that we have not defined an adequate -- unless we are convinced that we have not defined an adequate seismic basis initially.

MR. KASTENBERG: Let me see, does this mean that during the next year before issuing the CP, you will try to arrive at some resolution, or will you just discuss it over coffee and let it go at that? I am not asking for exactly what the answer is going to be, but just in the context of how you will approach it, because I am sure the question will come up again.

MR. KNIGHT: You are certainly right. The direct answer is that the staff at this time has no plans -- we have no activity underway to either redefine the seismic design basis or, in some way, I suppose you might say come to grips with that question, other than to look at it from the standpoint of the so-called traditional standpoint: are we, in fact, correct that significant margin exists beyond our signficant design levels, and are there soft points, are there areas where that thinking is faulty if something of this type is not a rigorous program or misleading.

But there is no formal distinct plan in progress, then, to address that question other than by coming back to the question of margins.

MR. CARBON: But coming back to that, will you, as an example, be asking the applicant to carry through analyses to find which are the weakest points in terms of added or extra capacity?

MR. KNIGHT: I doubt, at this time, that we would be asking the applicant to do analyses to specifically -- to address -- I think your direct question, to do unique analyses to particularly find soft spots. We would certainly, in our reviews such as the audits we are performing and the reviews that we would be subsequently performing with the Branch, be looking at the work that has been done, with the purpose of assuring ourselves that at this point, -- I suppose one might call it the contention offered by the applicant -- that the margins which exist in this plant are comparable to those which we find in the light water plants.

Whether or not at some point, based on what we learn, it becomes useful to ask for some particular piece of work is another question. I certainly do not know of any at the moment.

MR. ETHERINGTON: Do we have adequate data on the cycle fatigue, elevating temperature? You can just say yes or no.

MR. KNIGHT: Not really.

MR. ETHERINGTON: Thank you.

MR. POMEROY: I would like to ask a quick generic question not directly related to this, but I do remember that at a January meeting of Dr. Okrent's Subcommittee on Extreme External Phenomena, we were told that the Geological Survey was in the process of re-evaluting its position on the Charleston earthquake, and I believe at that time we were told that there would be a report out in late March having to do with that determination.

I wondered if the staff has any late word on when that determination might be available?

MR. KNIGHT: I don't. We have been in communication with the USGS. All indications are now that that report will be delayed. It is not available now. It seems unlikely it will be available within several weeks, extending perhaps into several months. It is rather nebulous. That is the best we have.

MR. CARBON: Can you add anything further to that? Does the reason for the delay have to do with big uncertainties of a particular type, or -- ?

MR. KNIGHT: Well, it is still -- the matter is very firmly internal to USGS, but clearly, the reason for delay is that there is -- and I may be guilty of giving a flavor that is somewhat personal, but it seems clear that the evidence necessary to change the present position is certainly not overwhelming. I don't mean to demean the efforts of those involved, but it certainly was not sufficiently compelling to cause a change to be made quickly, and in fact, is apparently -- the question is sufficiently difficult and the information is sufficiently vague that attempting to develop a consensus, they have really been unable to do so.

MR. CARBON: Is your knowledge of that situation such that it would appear that when they do come to a consensus, it probably will not have any bearing on the CRBR, or might there be a big enough change?

MR. KNIGHT: Either it will not have any

significant bearing on the CRBR, or it -- it is probably not a very good answer to your question. Probably it won't. I think the probabilities are reasonable that it won't or there will have to be rather significant reconsideration for across the board.

I think the trend would seem to be at the moment that we would not see a large impact. That even if there should be some movement, as it were, that the probability of a large event would be quite low.

(Pause.)

MR. CARBON: Are there any other questions anyone wishes to raise?

(No response..)

MR. CARBON: I guess if not, I would propose to adjourn the meeting and ask the subcommittee members and the consultants to stay and talk for a little bit. We will end the recording at this point.

We thank the people from the DOT and the project for your time and effort here today, and we thank the staff likewise. I guess with that, we will adjourn.

(Whereupon, at 5:26 p.m., the subcommittee was adjourned.)

* * *

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

ACRS/Subcommittee on Clinch River Breeder Reactor

in the matter of: Briefing on Clinch River Breeder Reactor Geology and Seismology

Date of Proceeding: June 1, 1982

Docket Number:

Place of Proceeding: Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Jane W. Beach

Official Reporter (Typed)

Jane W. Beach

Official Reporter (Signature)

BRIEFING FOR
ADVISORY COMMITTEE ON
REACTOR SAFEGUARDS (ACRS)

GEOLOGY AND SEISMOLOGY

Presented by

W.G. BRUSEY

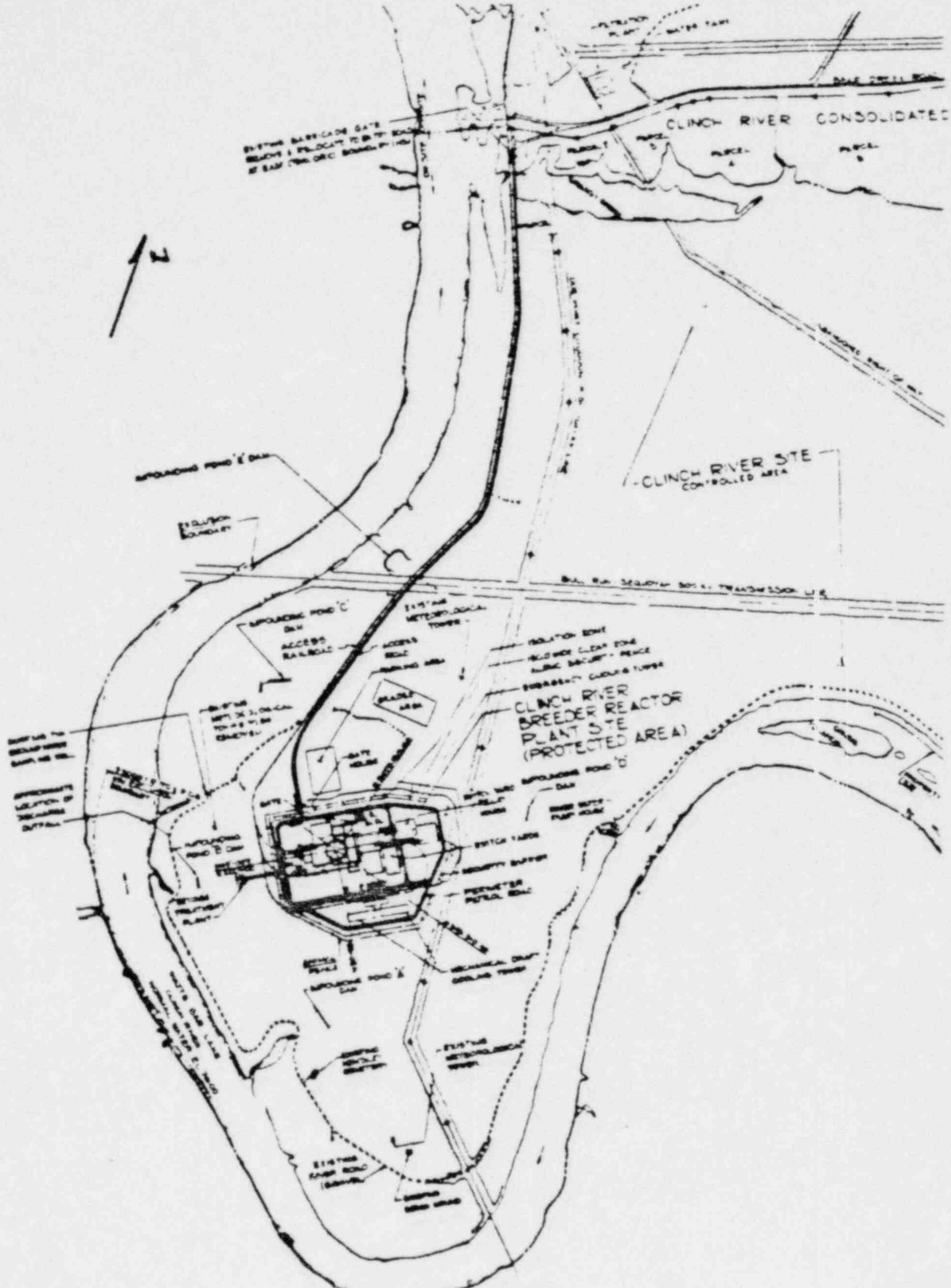
Geotechnical Consultant
CRBRP Project

BURNS AND ROE, INC.

T1 + T2

OUTLINE

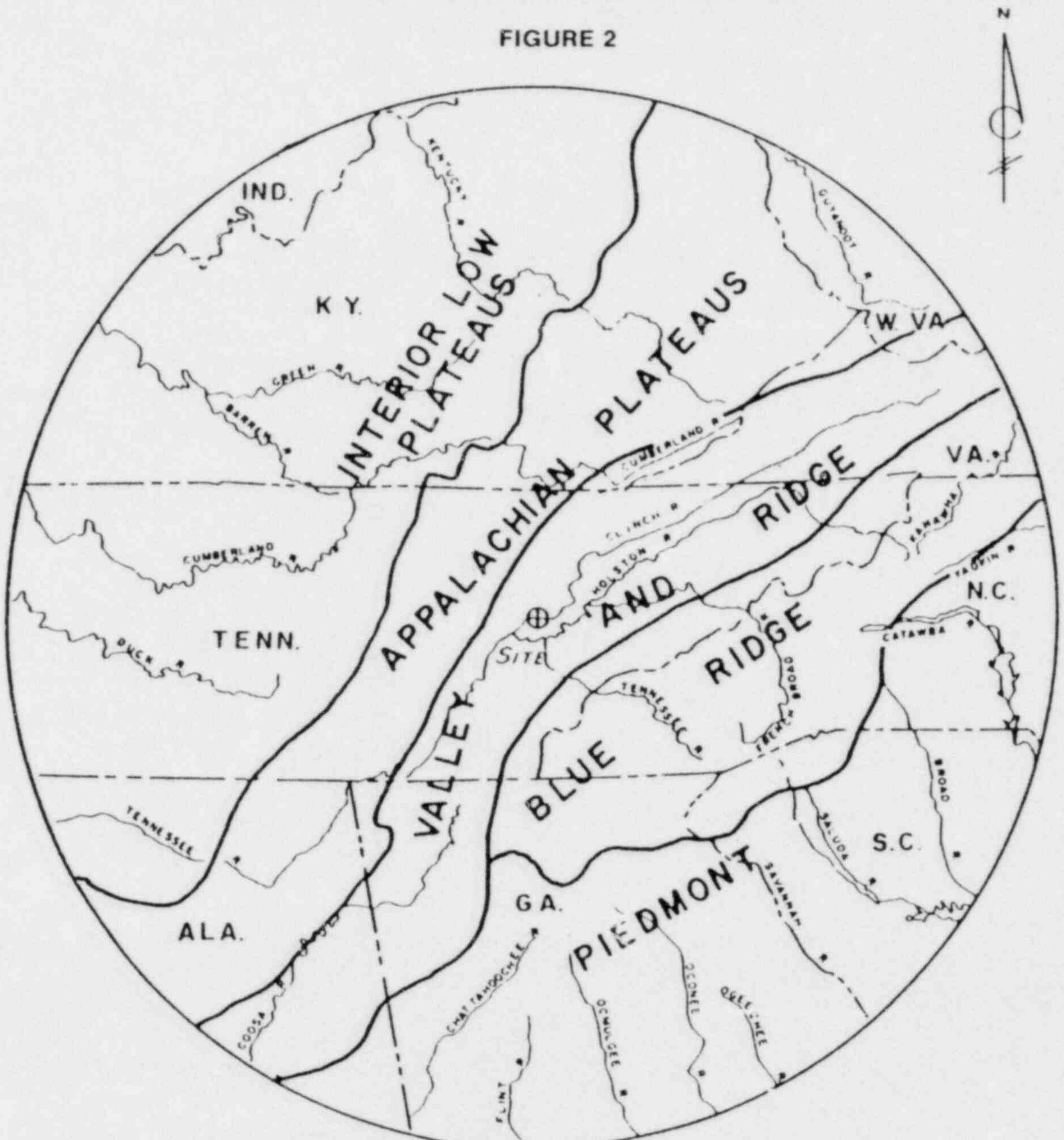
- SITE INVESTIGATION PROGRAMS
- DEVELOPMENT OF FOUNDATION DESIGN PARAMETERS
- EARTHQUAKE HISTORY
- SELECTION OF SSE ANL OBE



Plant Location on the Clinch River Site

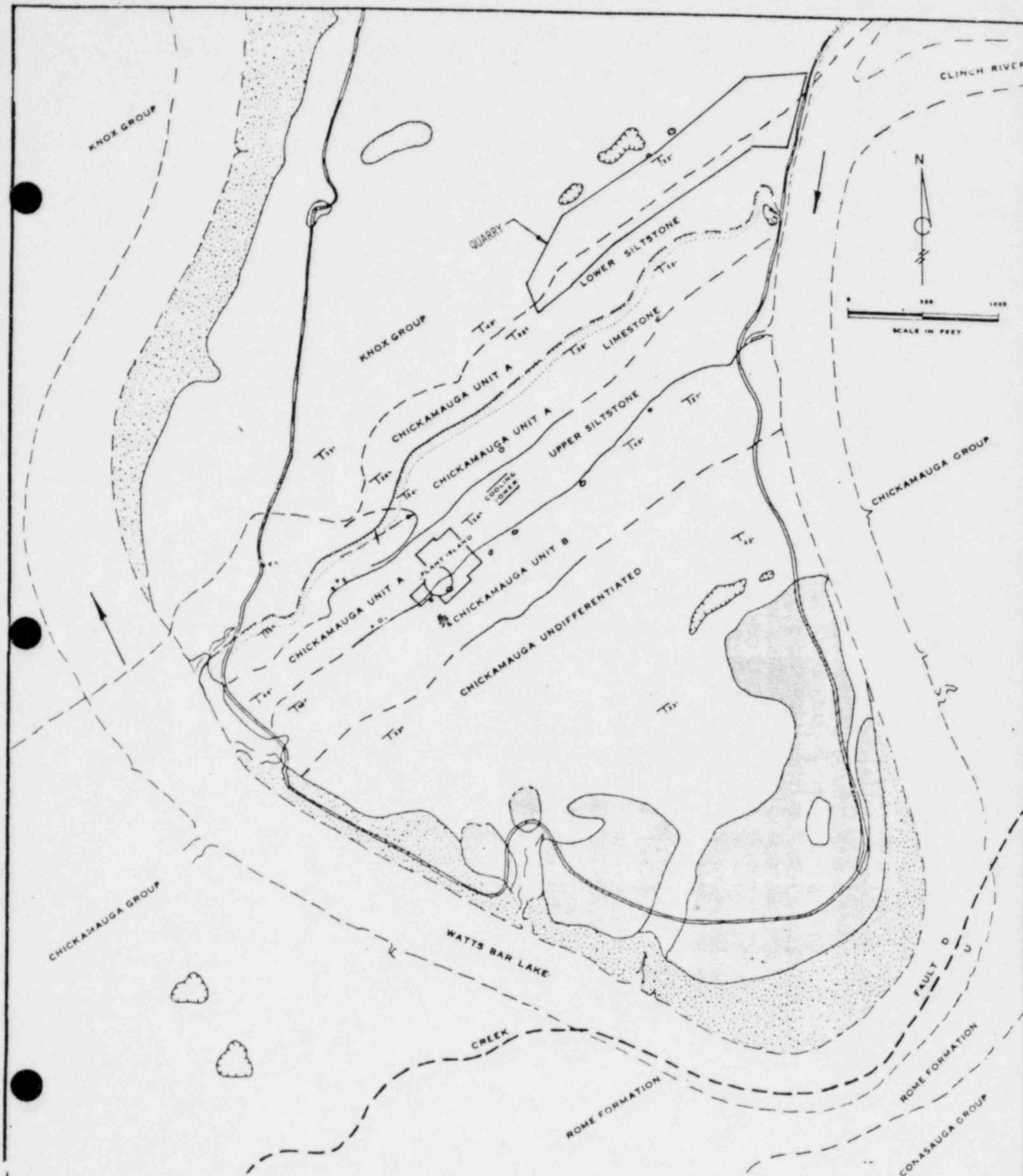
REGIONAL PHYSIOGRAPHIC MAP

FIGURE 2



SITE INVESTIGATION ACTIVITIES

- LITERATURE STUDIES
- GEOLOGIC RECONNAISSANCE
- GEOLOGIC MAPPING
- AERIAL PHOTOGRAPHIC STUDIES
- BORINGS
- MONITORING WELLS
- GEOPHYSICS



GEOLOGIC AND PHYSIOGRAPHIC MAP

FIGURE 3

OBJECTIVES OF INVESTIGATION PROGRAMS

- DEFINE INTERBEDDED SILTSTONE AND LIMESTONE STRATA
- DEPTH OF WEATHERING
- RESIDUAL SOILS AND TERRACE DEPOSITS
- PREFERRED LOCATION OF NUCLEAR PLANT ISLAND STRUCTURES
- DETAILED EVALUATION OF FOUNDATIONS FOR CATEGORY I STRUCTURES

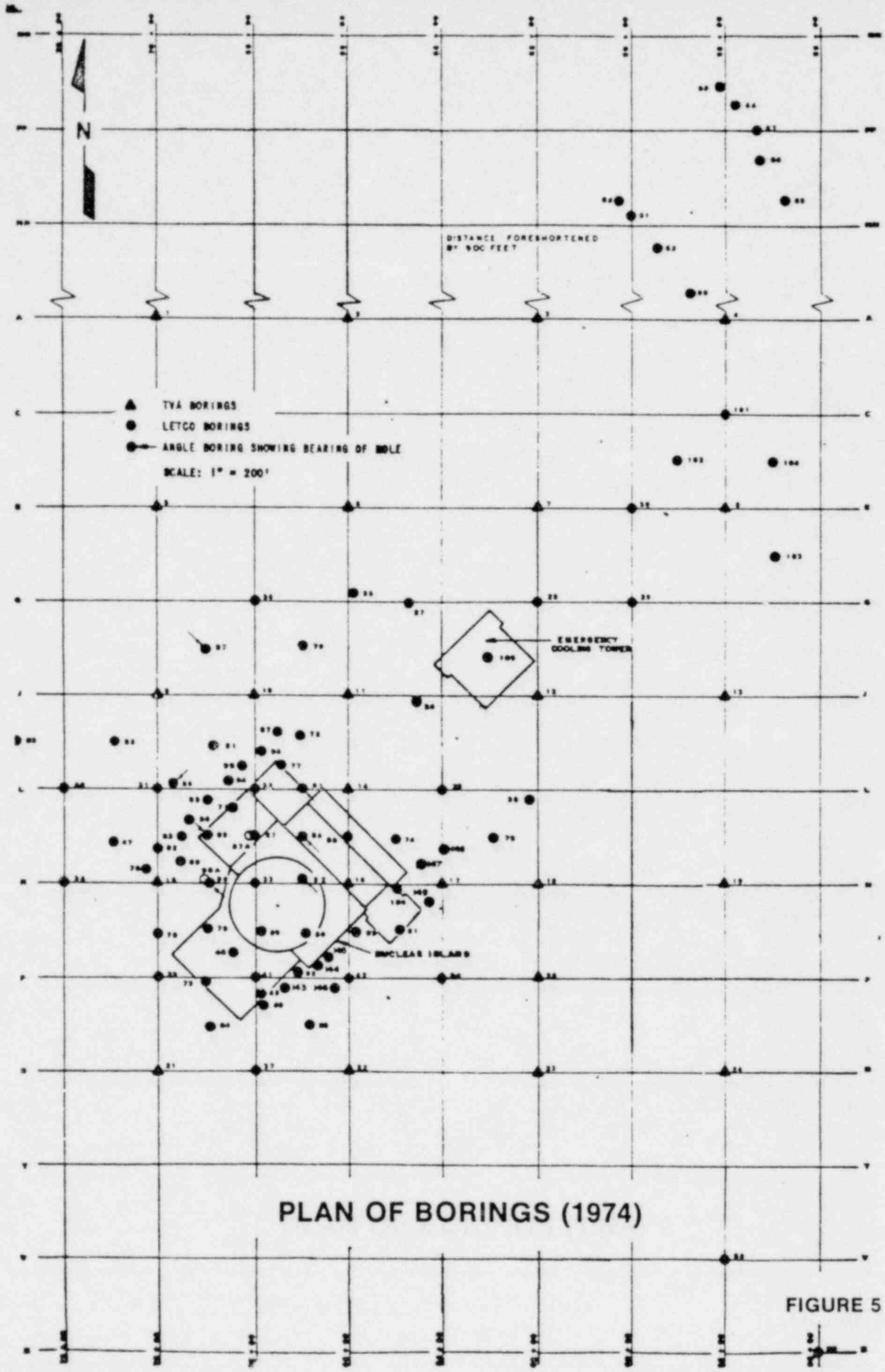
BORING PROGRAMS CONDUCTED AT SITE

DATE	PURPOSE	NUMBER OF BORINGS
2/72 TO 12/72	SITE EVALUATIONS	24
6/73 TO 12/73	SELECTING OPTIMUM SITE LOCATION	42
12/73 TO 4/74	DETAILED FOUNDATION EVALUATION	40
11/74 TO 2/75	BALANCE OF PLANT INVESTIGATION	95
9/76 TO 6/77	LOCALIZED INVESTIGATION OF EAST FACE SOLUTIONING	23
1/81 TO 5/82	BEDROCK VERIFICATION PROGRAM	34
		258

FIGURE 4

DETAILS OF BORING PROGRAMS

- DEPTH OF BORINGS RANGED FROM 100-300′
- EVALUATION OF CORE (RQD DETERMINATIONS)
- GEOPHYSICAL STUDIES
- CATEGORY I STRUCTURES LOCATED ON UNIT A UPPER SILTSTONE

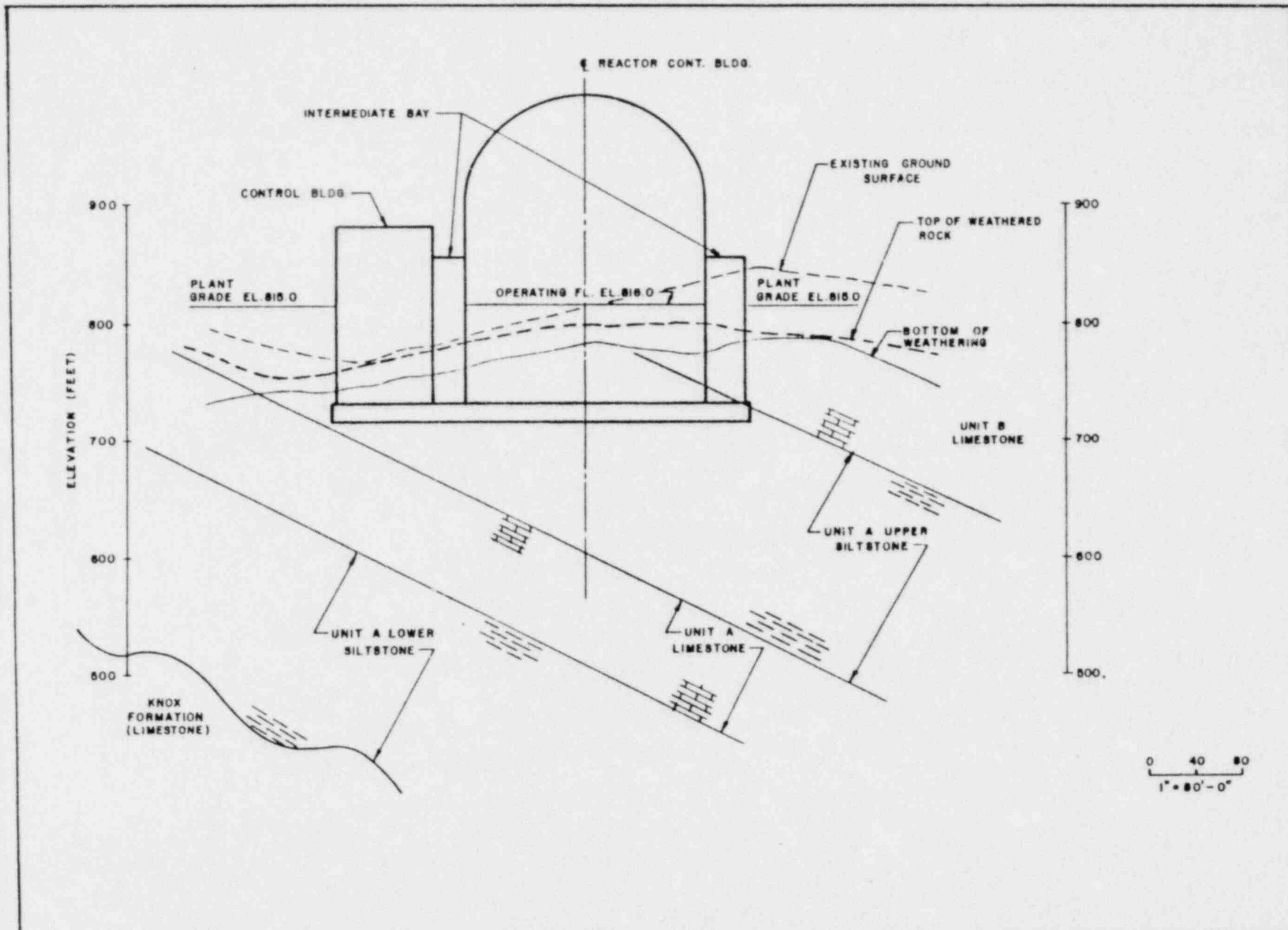


PLAN OF BORINGS (1974)

FIGURE 5

SIGNIFICANT INVESTIGATION PARAMETERS

- DEPTH OF WEATHERING
- INVESTIGATION OF POTENTIAL SOLUTION ZONES IN UNIT A & UNIT B LIMESTONES
- SELECTION OF FOUNDATION BEARING ELEVATION

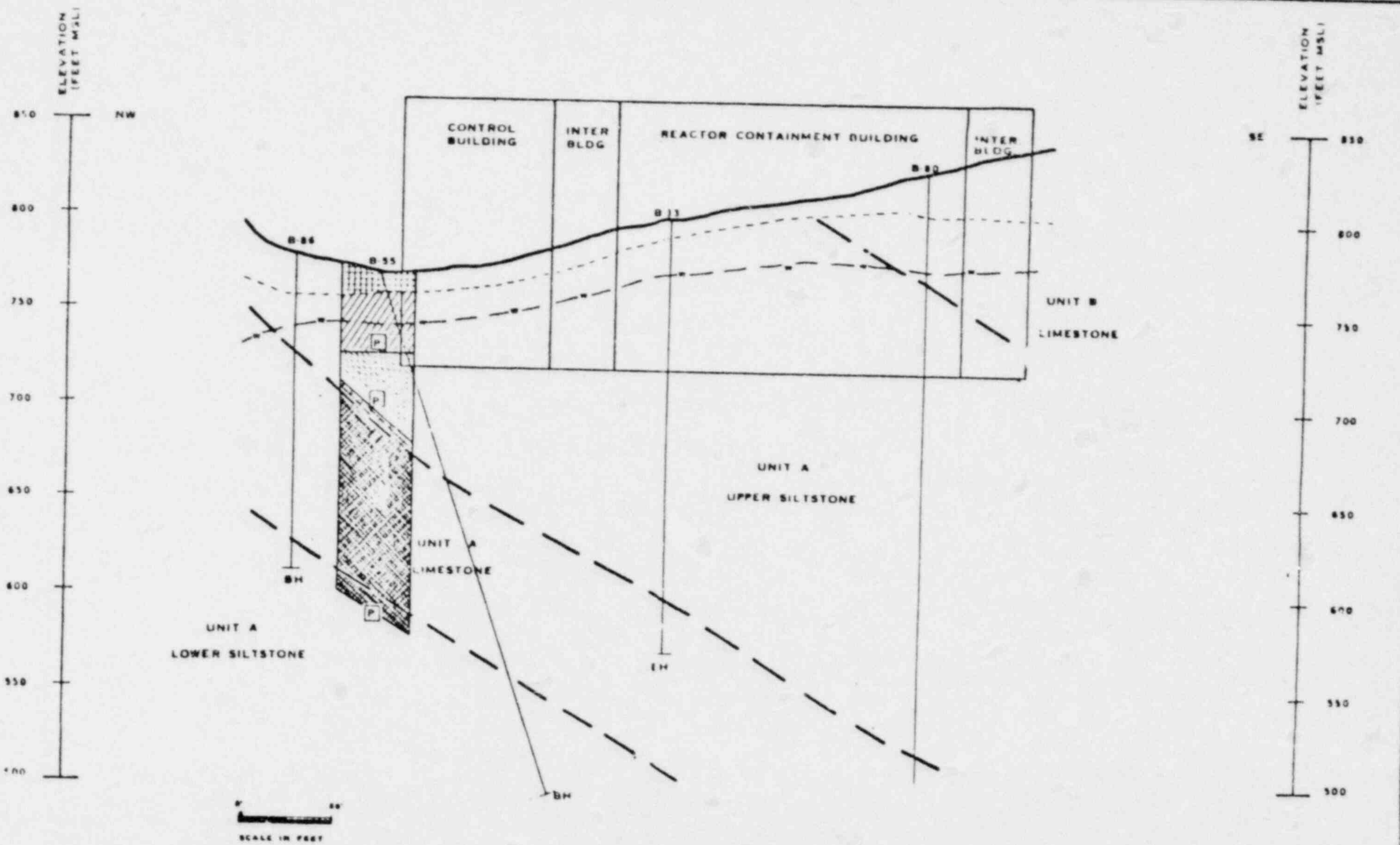


CROSS SECTION — NUCLEAR ISLAND

FIGURE 6

DETAILS OF TEST GROUTING PROGRAM

- CHECK REPRESENTIVITY OF BORING 55
- BORINGS SPACED AT 20′ AND 10′ INTERVALS
- WATER PRESSURE TESTS
- NEGLIGIBLE GROUT TAKE
- FOUNDATION TREATMENT NOT REQUIRED

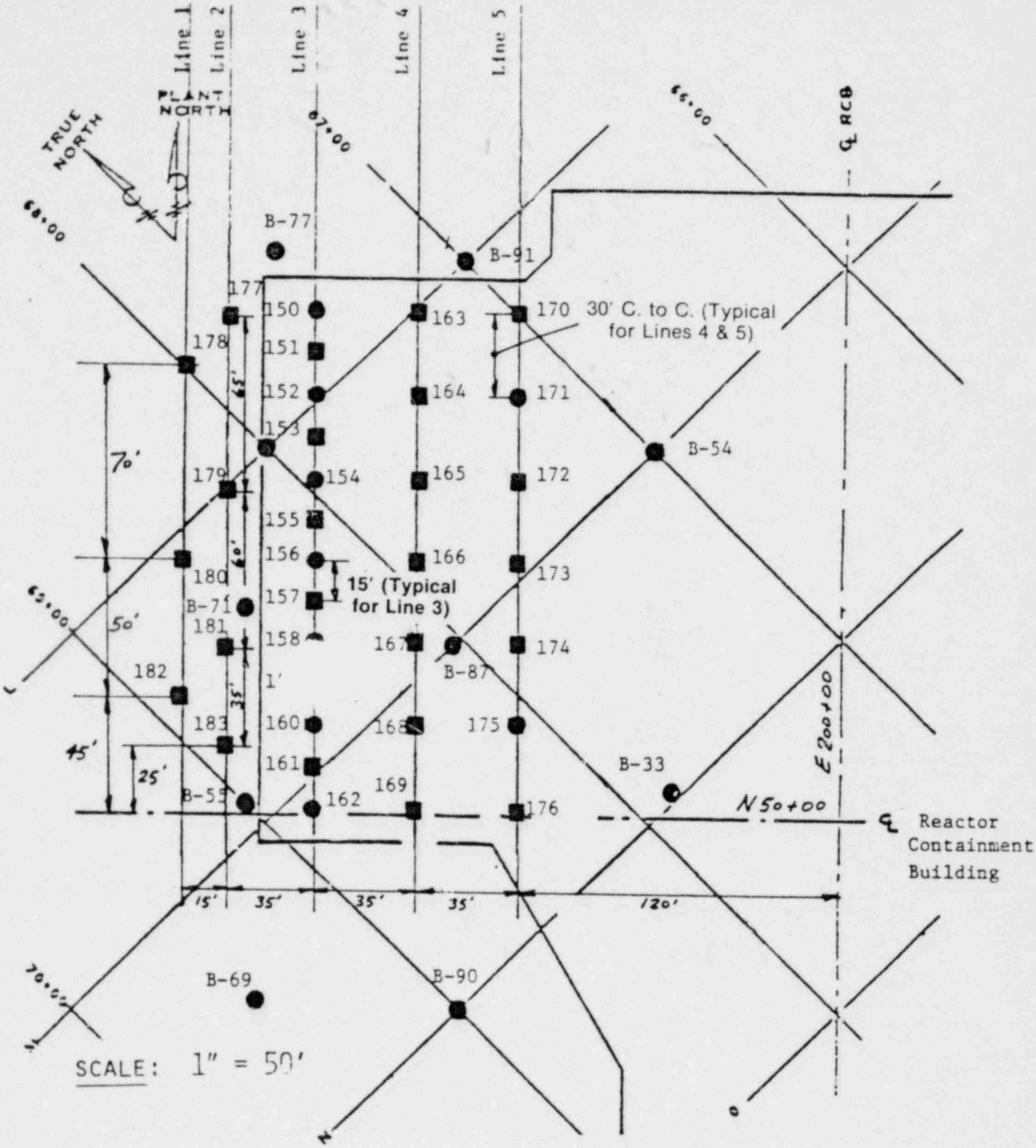


CROSS SECTION — TEST GROUTING PROGRAM

FIGURE 7

DETAILS OF VERIFICATION PROGRAM

- DEPTH OF BORINGS EXTEND 100′ INTO UNIT A LIMESTONE
- PROGRAM ONGOING
- RESULTS ANALYZED TO DATE INDICATE NO FOUNDATION TREATMENT REQUIRED



LEGEND:

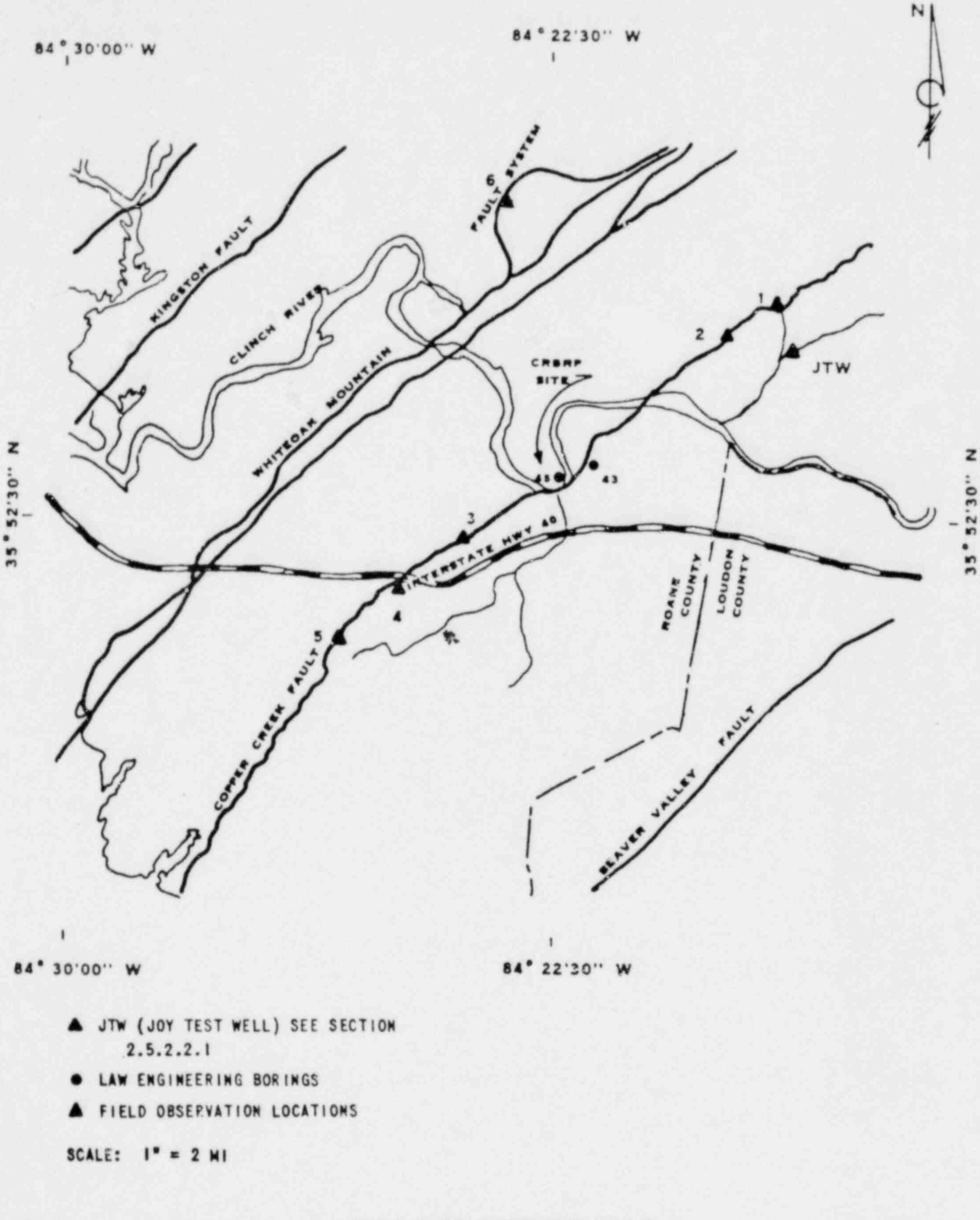
- ● CORE BORINGS
- ■ AIR TRACK (ROTARY PERCUSSION) BORINGS

VERIFICATION PROGRAM BORINGS (1982)

FIGURE 8

FAULTING INVESTIGATIONS

- IDENTIFICATION OF MAJOR NON-CAPABLE FAULTS
- GEOLOGICAL INVESTIGATION OF COPPER CREEK FAULT
- AGE OF FAULT DATED AT 280 MILLION YEARS



▲ JTW (JOY TEST WELL) SEE SECTION 2.5.2.2.1

● LAW ENGINEERING BORINGS

▲ FIELD OBSERVATION LOCATIONS

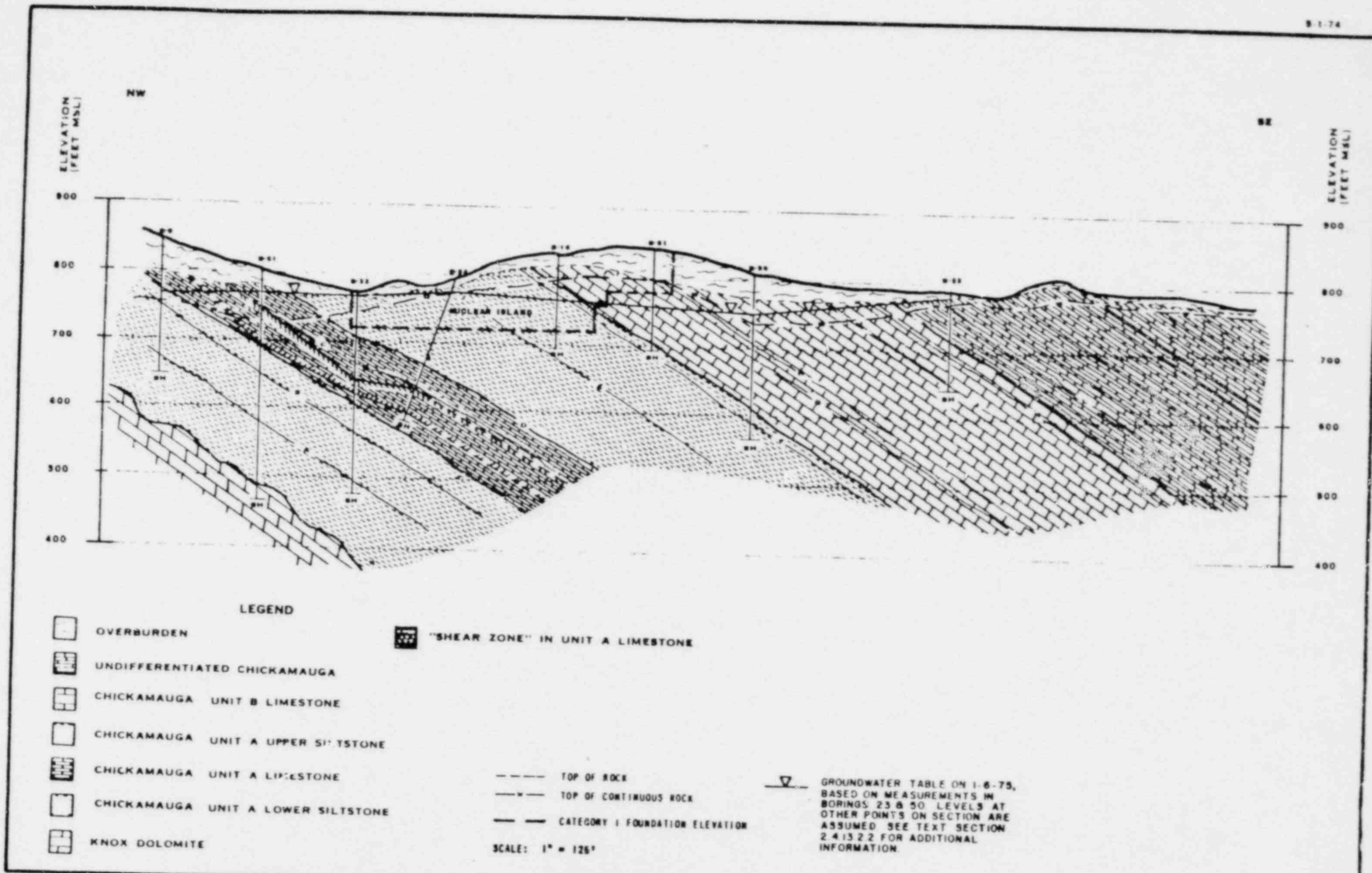
SCALE: 1" = 2 MI

AREA STRUCTURE MAP FIGURE 9

INVESTIGATION OF SHEAR ZONE

- IDENTIFICATION OF SHEAR ZONE IN UNIT A LIMESTONE
- EVALUATION OF CORE FROM BORINGS
- CONSENSUS OF GEOLOGICAL OPINION THAT SHEAR ZONE FEATURE IS ANCIENT AND REHEALED

T2

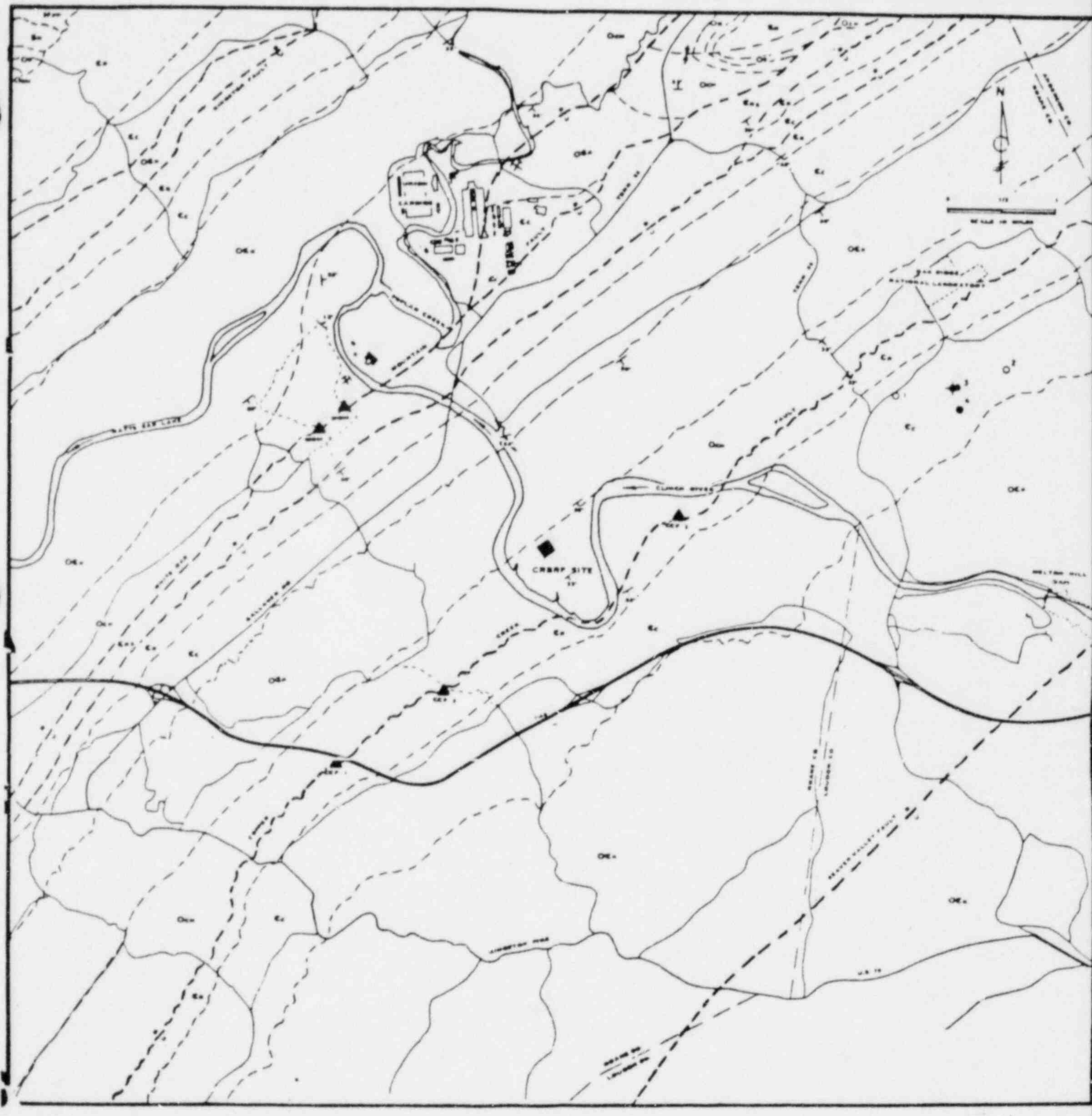


SITE GEOLOGIC PROFILE (SHEAR ZONE)

FIGURE 10

WASTE DISPOSAL AT ORNL SITE

- LOCATION OF INJECTION WELLS
- DEPTH OF INJECTION ($\approx$800′)
- ANALYSIS OF DATA INDICATES NO IMPACT ON SITE



AREA PLAN SHOWING INJECTION WELLS

FIGURE 11

EVALUATION OF PARAMETERS

STATIC

- BEARING CAPACITY AND SETTLEMENT
- GEOTECHNICAL INSTRUMENTATION TO MONITOR POTENTIAL HEAVE AND SETTLEMENT
- ANTICIPATED MOVEMENTS WILL BE NEGLIGIBLE

DYNAMIC

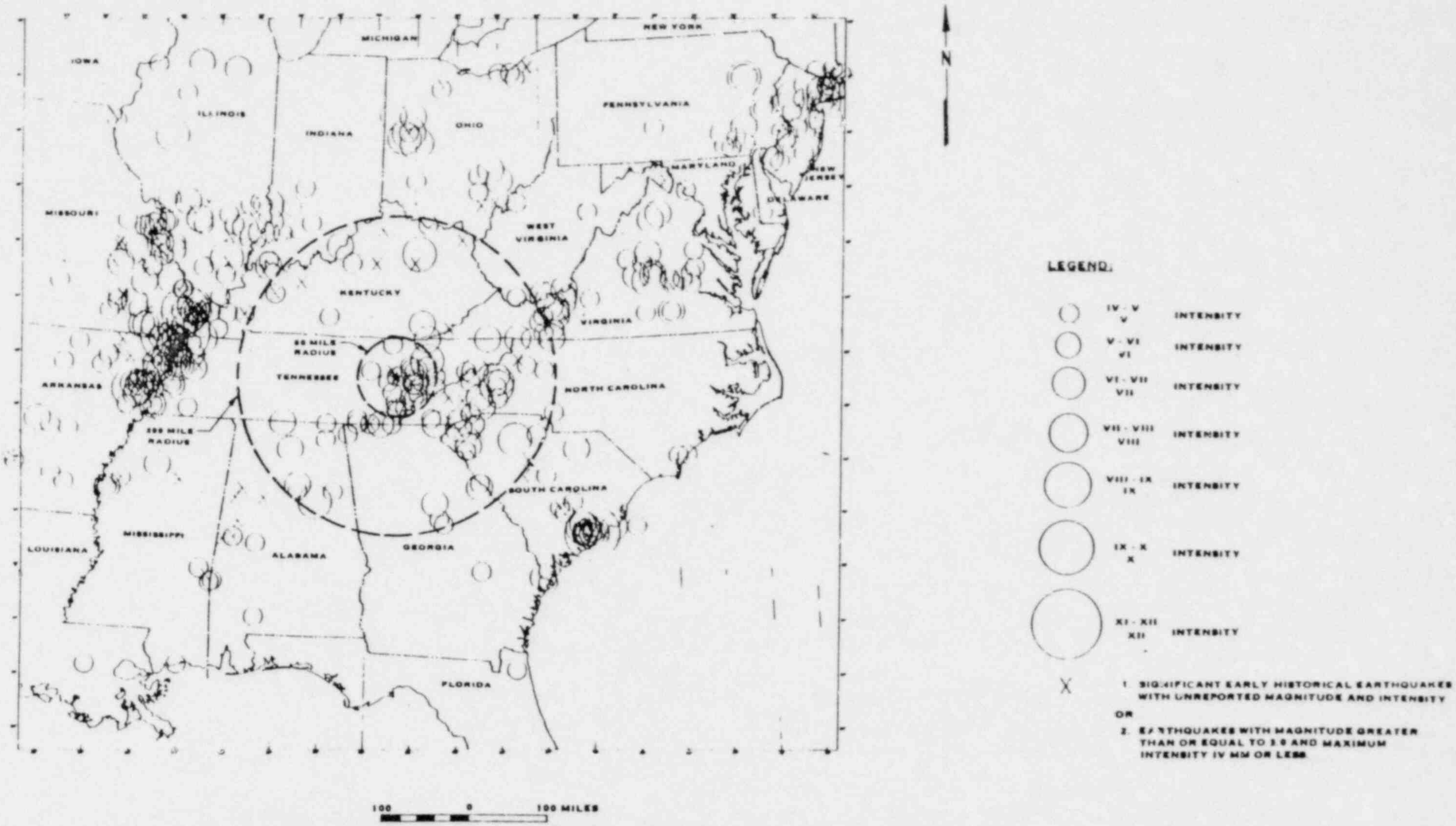
- GEOPHYSICAL INVESTIGATIONS
- IN SITU VELOCITY MEASUREMENTS
- SELECTED DESIGN VALUES

DEVELOPMENT OF FOUNDATION DESIGN PARAMETERS

(A) STATIC

(B) DYNAMIC

FIGURE 12



REGIONAL EARTHQUAKES WITH MAXIMUM INTENSITY EXCEEDING IV MM

FIGURE 13

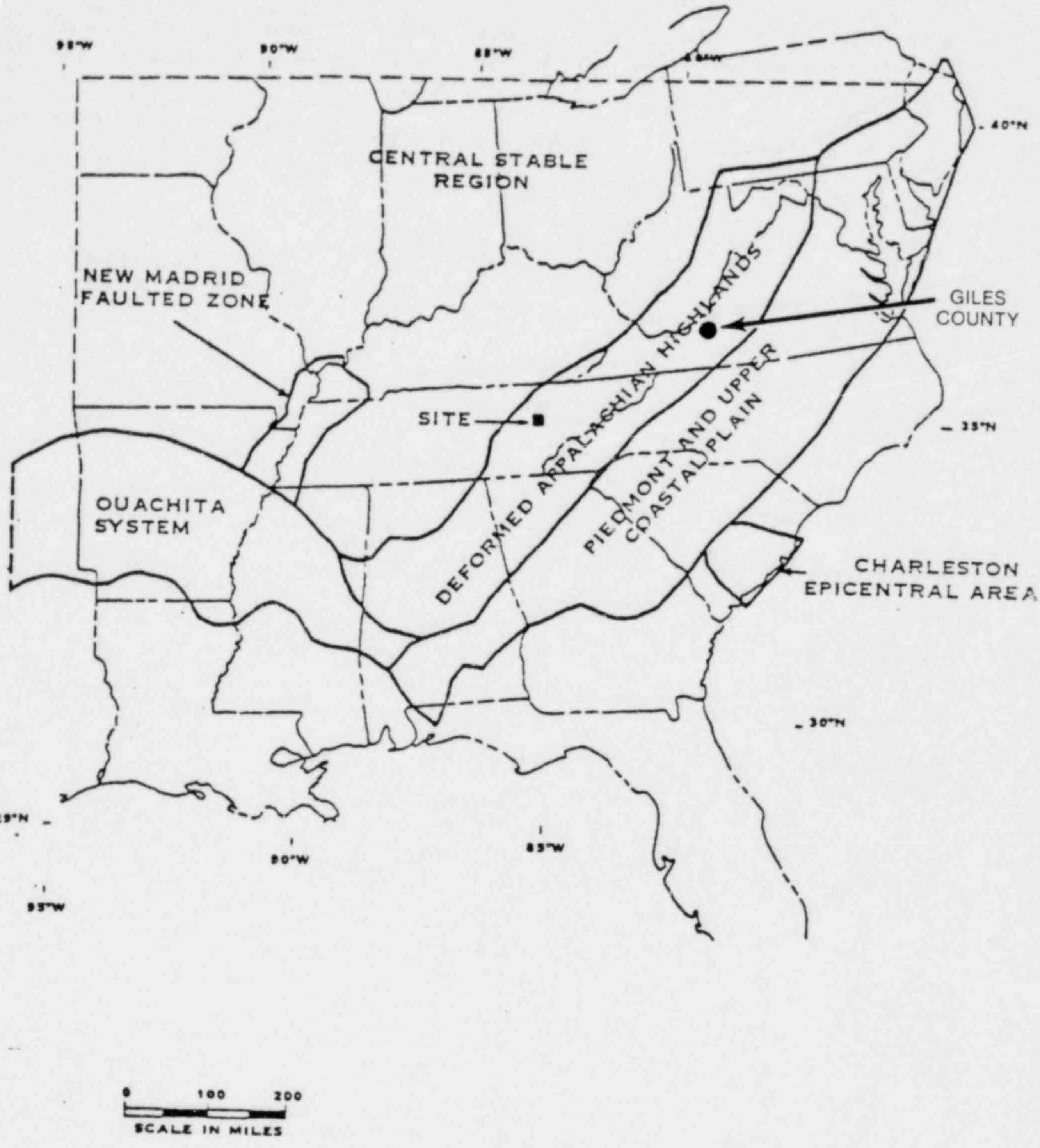
IMPACT OF REGIONAL EARTHQUAKES ON CRBRP SITE

- NEW MADRID AND CHARLESTON — ATTENUATION WILL NOT IMPACT SITE GREATER THAN MAXIMUM HISTORICAL EARTHQUAKE
- NEW MADRID — INTENSITY VI — VII AT SITE
- CHARLESTON — INTENSITY VI AT SITE
- GILES COUNTY EARTHQUAKE

EARTHQUAKE HISTORY

TECTONIC PROVINCE APPROACH TO DEFINING SSE

- SELECTED PROVINCIAL BOUNDARIES
- DEFINE INTENSITY OF MAXIMUM HISTORICAL EARTHQUAKE
- MAXIMUM HISTORICAL EARTHQUAKE MOVED WITHIN PROVINCE
- SELECT S.S.E.
- DEFINE INTENSITY/ACCELERATION CORRELATION

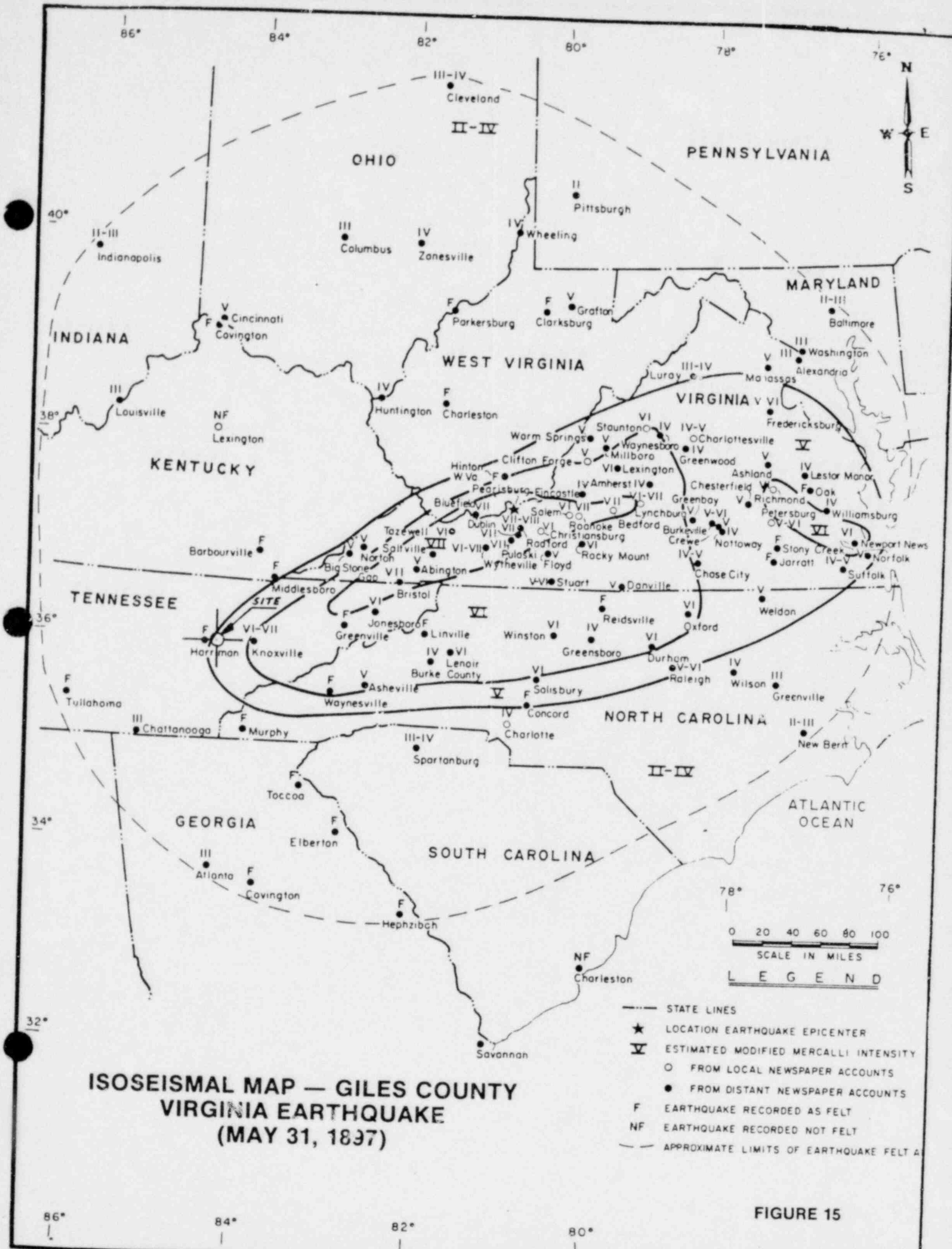


TECTONIC PROVINCE MAP

FIGURE 14

INDEPENDENT ASSESSMENT OF GILES COUNTY EARTHQUAKE

- ISOSEISMAL MAP DEVELOPED BASED ON MODIFIED MERCALLI INTENSITY EFFECTS
- CONSULTATION WITH RECOGNIZED AUTHORITIES ON SOUTHEASTERN U.S. SEISMICITY
- CONSENSUS OF GEOLOGICAL OPINION THAT GILES COUNTY EARTHQUAKE SHOULD BE CLASSIFIED AS INTENSITY VII-VIII

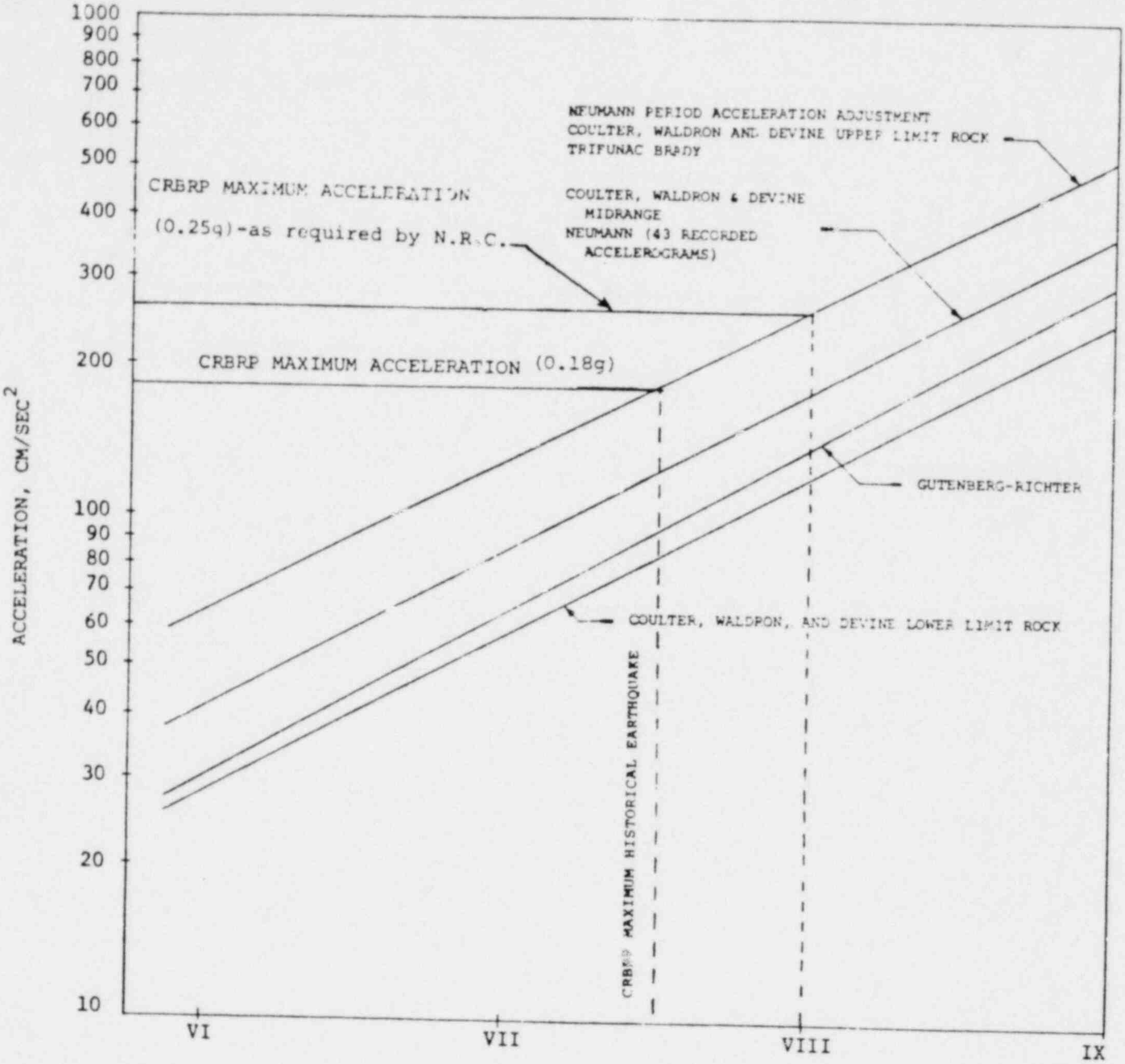


ISOSEISMAL MAP — GILES COUNTY VIRGINIA EARTHQUAKE (MAY 31, 1897)

FIGURE 15

SELECTION OF SSE AND OBE

- GILES COUNTY EQ. CLASSIFIED AS INTENSITY VIII BY NRC FOR THE SITE
- SELECTION OF ACCELERATION/INTENSITY RELATIONSHIP
- MAXIMUM GROUND ACCELERATION — 0.25_g USED IN DESIGN FOR S.S.E.
- MAXIMUM GROUND ACCELERATION — 0.125_g USED IN DESIGN FOR O.B.E.



MODIFIED MERCALLI INTENSITY

ACCELERATION — INTENSITY RELATIONSHIP
SELECTION OF SSE

FIGURE 16

SUMMARY

INHERENT CONSERVATISM IN DESIGN

- EXTENSIVE GEOLOGIC, GEOTECHNICAL, AND SEISMOLOGIC INVESTIGATIONS
- INTENSITY VIII EARTHQUAKE USED INSTEAD OF VII-VIII
- CONSERVATIVE INTENSITY/ACCELERATION RELATIONSHIP USED
- O.B.E. SELECTED AT 1/2 (S.S.E.)

BRIEFING FOR
ADVISORY COMMITTEE ON
REACTOR SAFEGUARDS (ACRS)

SEISMIC DESIGN

Presented by

A.T. DAJANI

Assistant Project Manager
Engineering and Design
CRBRP Project

BURNS AND ROE, INC.

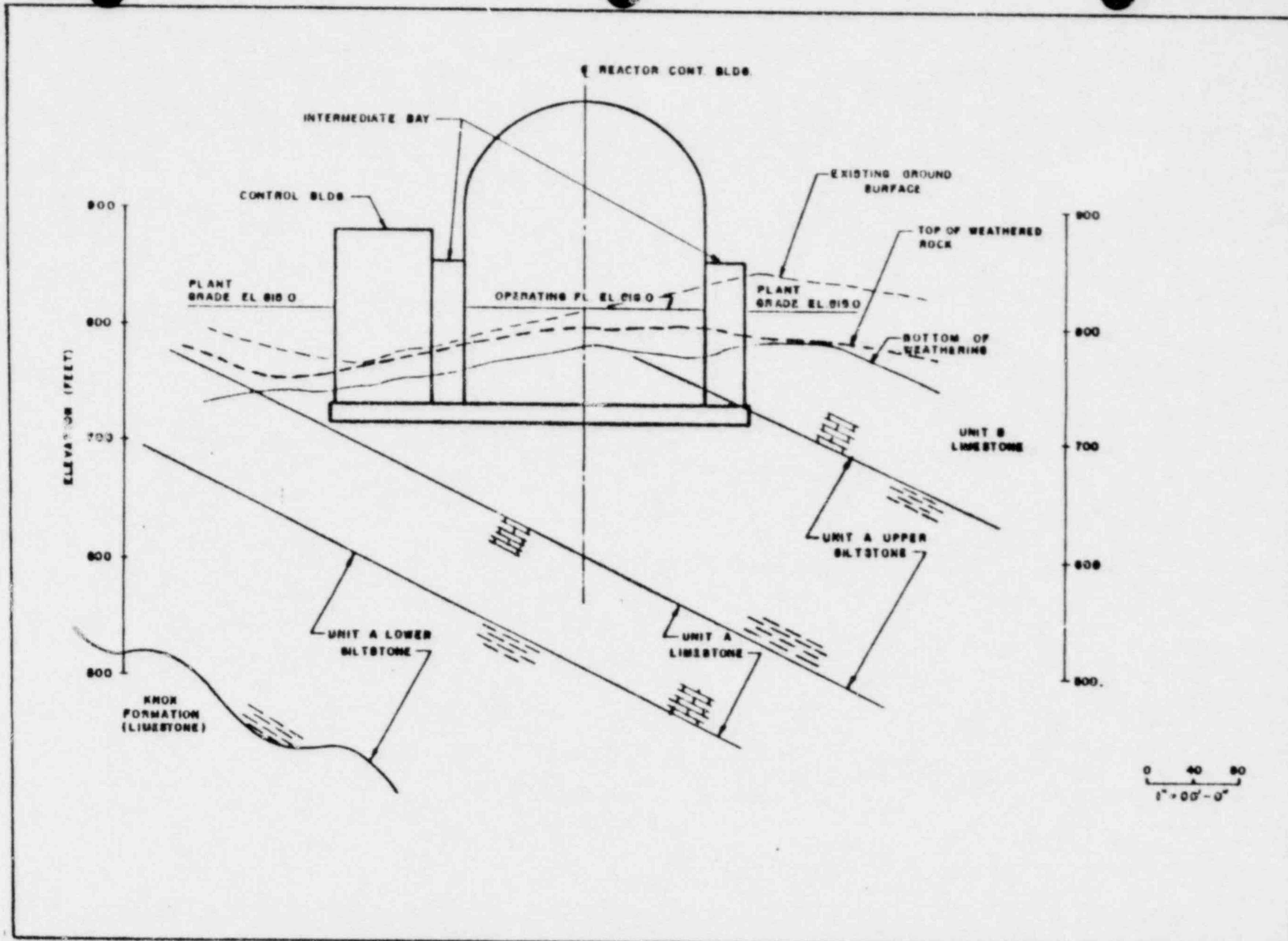
T3.T5

OUTLINE

- SITE CHARACTERISTICS
- APPLICABLE CODES AND STANDARDS
- SEISMIC CLASSIFICATION
- NUCLEAR ISLAND
- OTHER MAJOR CATEGORY I STRUCTURES
- CATEGORY III STRUCTURES
- SUMMARY

SITE CHARACTERISTICS

- INCLINED LAYERS OF SILTSTONE AND LIMESTONE
- FINISHED GRADE ELEVATION 815 FEET
- TOP OF SOUND ROCK APPROXIMATELY 80 FEET BELOW GRADE
- NUCLEAR ISLAND FOUNDATION MAT BOTTOM AT ELEVATION 715
- SSE, ZERO PERIOD ACCELERATION: 0.25G
- OBE, ZERO PERIOD ACCELERATION: 0.125G



CROSS SECTION - NUCLEAR ISLAND

SEISMIC DESIGN
APPLICABLE CODES AND STANDARDS

REGULATORY GUIDE 1.60

- DESIGN RESPONSE SPECTRA FOR SEISMIC DESIGN OF NUCLEAR POWER PLANTS

REGULATORY GUIDE 1.61

- DAMPING VALUE FOR SEISMIC DESIGN OF NUCLEAR POWER PLANTS

REGULATORY GUIDE 1.92

- COMBINATION OF MODES AND SPATIAL COMPONENTS IN SEISMIC RESPONSE ANALYSIS

REGULATORY GUIDE 1.122

- DEVELOPMENT OF FLOOR DESIGN RESPONSE SPECTRA FOR SEISMIC DESIGN OF FLOOR SUPPORTED EQUIPMENT OR COMPONENTS

SRP NUREG-75/087 SECTIONS 3.7.1 AND 3.7.2

PSAR APPENDIX 3.7A — CRBRP — SEISMIC DESIGN CRITERIA

SEISMIC CLASSIFICATION OF STRUCTURES SYSTEMS AND COMPONENTS

- SEISMIC CATEGORY I
  - REQUIRED TO PERFORM THEIR SAFETY FUNCTION FOR SSE MOTIONS
    - DESIGNED FOR OBE AND SSE
- SEISMIC CATEGORY II
  - REQUIRED TO PERMIT CONTINUED REACTOR OPERATION
  - TO PROTECT INVESTMENT AND ASSURE CONTINUANCE OF PRIORITY PROGRAMS
    - DESIGNED FOR OBE
- SEISMIC CATEGORY III
  - STANDARD BUILDING CODE, ZONE 2
  - TO PREVENT DAMAGE TO CATEGORY I STRUCTURES, THE ADJACENT TURBINE GENERATOR & RADWASTE BUILDINGS ANALYZED AND DESIGNED FOR SSE

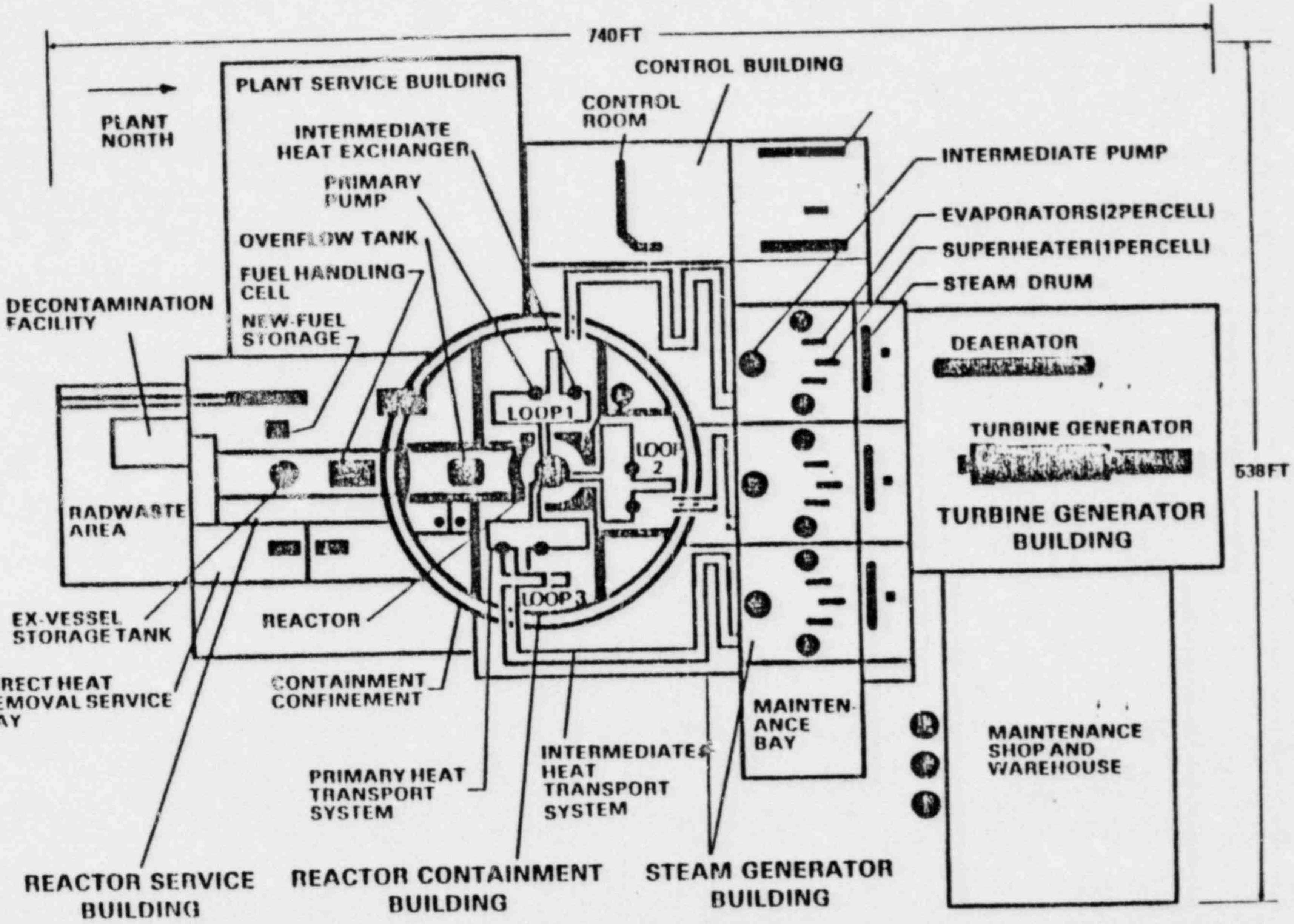
MAIN STRUCTURES

STRUCTURE	SEISMIC CATEGORY	FOUNDATION CONDITIONS
NUCLEAR ISLAND	I	ROCK
EMERGENCY COOLING TOWER	I	ROCK
DIESEL GENERATOR BUILDING	I	SOIL
TURBINE-GENERATOR BUILDING	III — ADJACENT TO CATEGORY I	SOIL
RADWASTE BUILDING	III — ADJACENT TO CATEGORY I	SOIL — ROCK

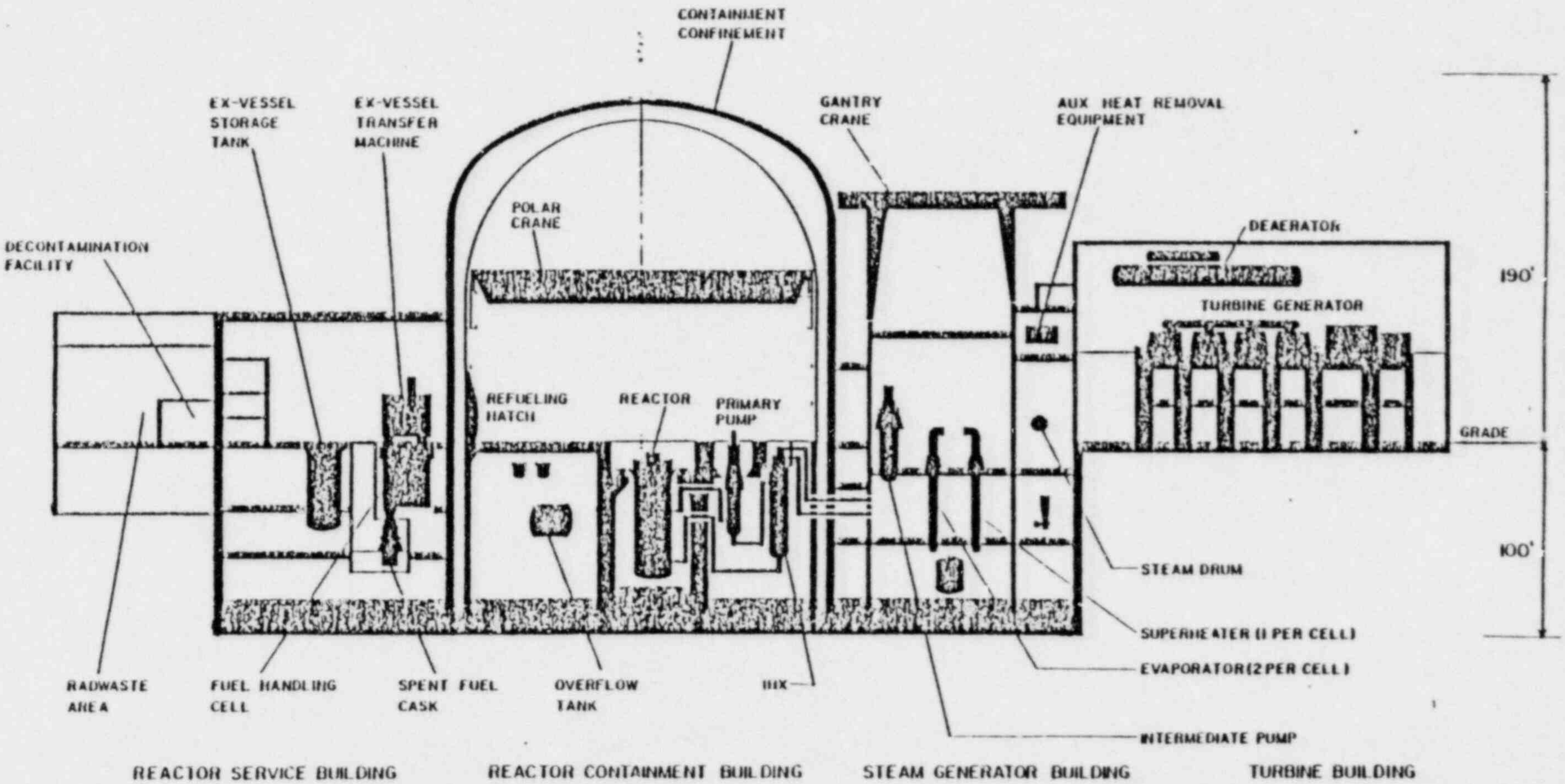
NUCLEAR ISLAND

- INTERCONNECTED STRUCTURES
- COMMON FOUNDATION MAT
- BUILDINGS IN NUCLEAR ISLAND
  - REACTOR CONTAINMENT
  - CONFINEMENT
  - STEAM GENERATOR
  - CONTROL
  - ELECTRICAL EQUIPMENT BUILDING
  - REACTOR SERVICE
- FOUNDATION MAT
  - LENGTH (MAXIMUM): 475 FEET
  - WIDTH (MAXIMUM): 360 FEET
  - THICKNESS: 15 FEET

CRBRP OVERALL LAYOUT
(PLAN VIEW)

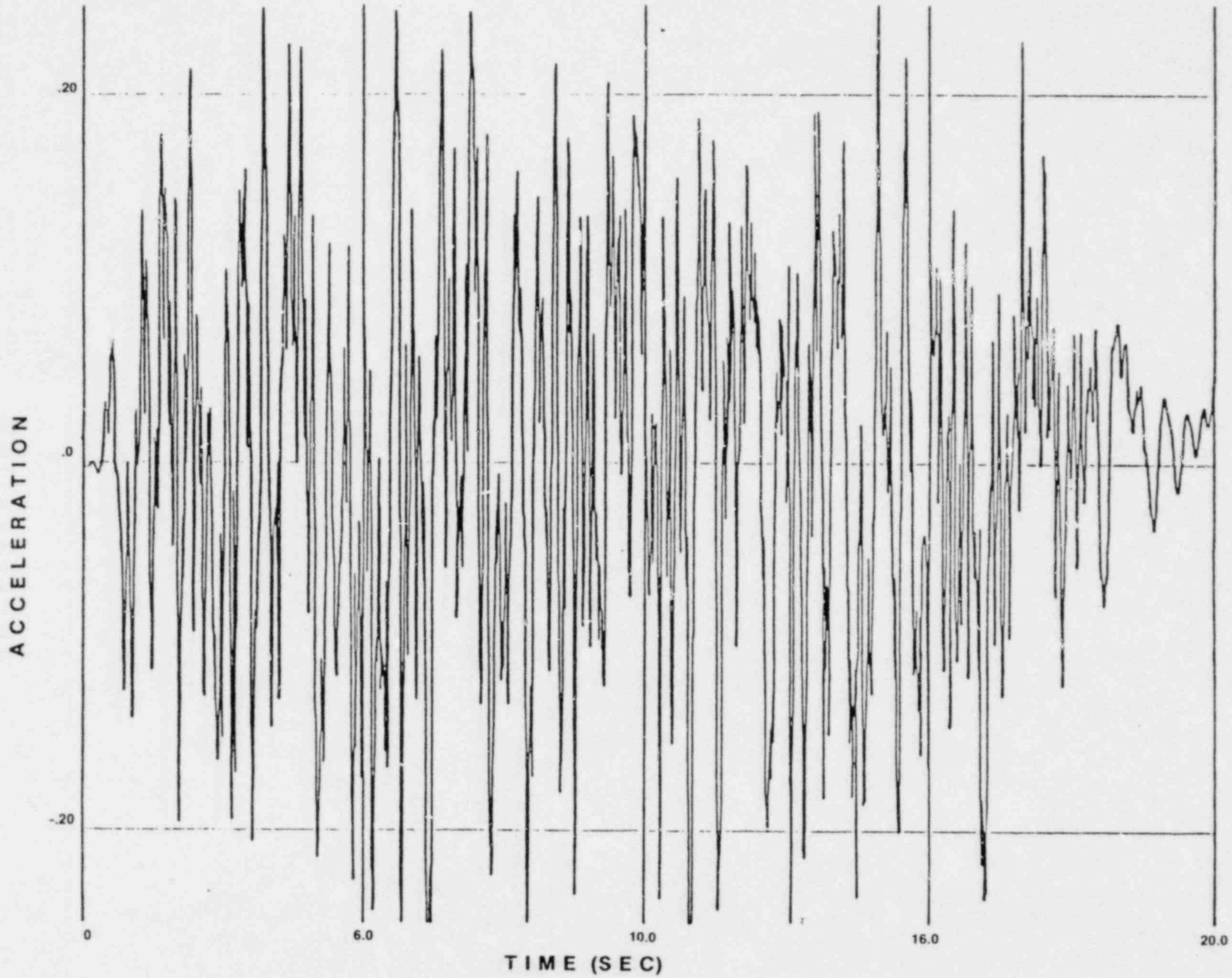


CLINCH RIVER BREEDER REACTOR PLANT
(Overall Plant Layout — Section)



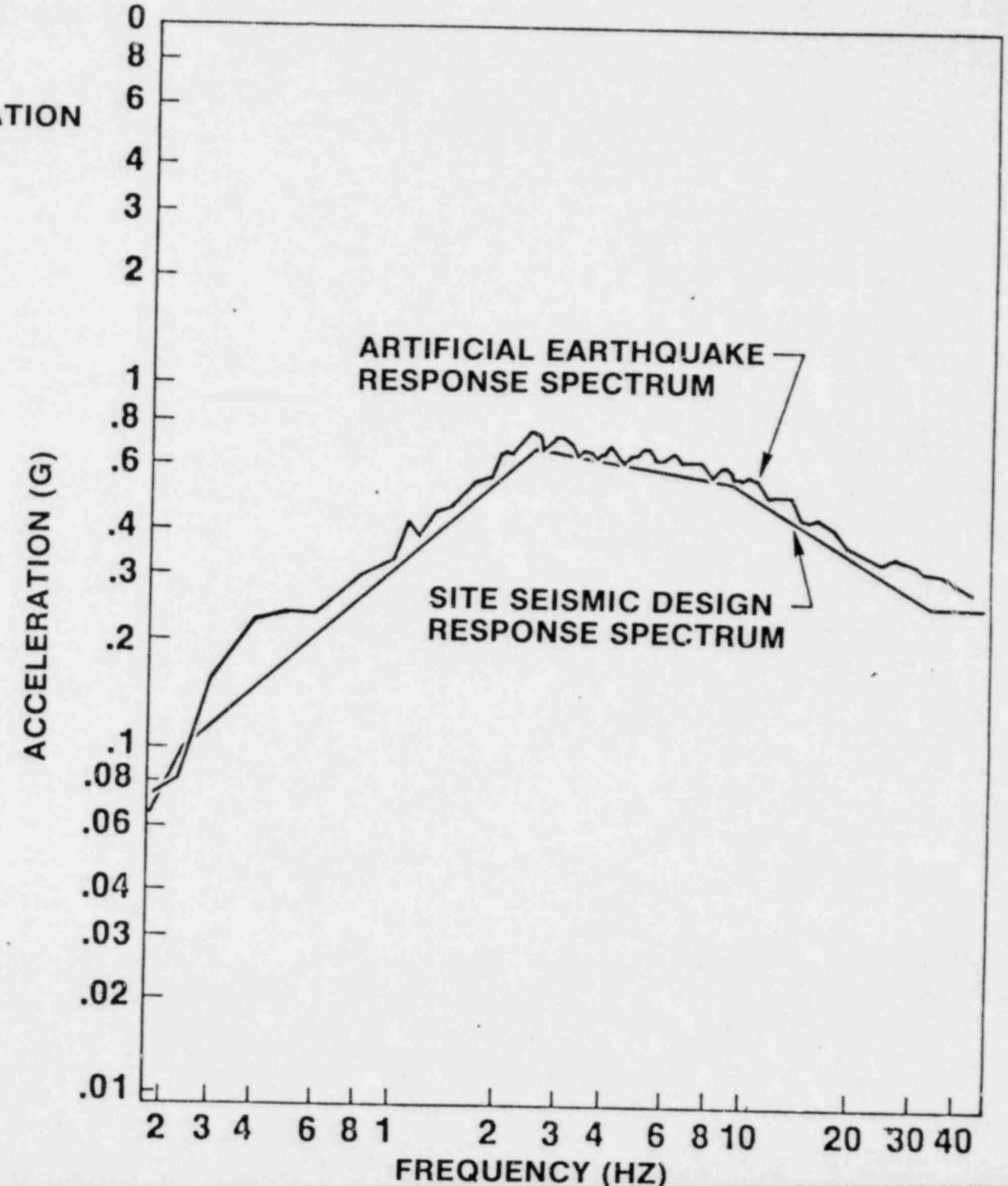
INPUT MOTIONS

- THREE STATISTICALLY INDEPENDENT ARTIFICIAL ACCELERATION TIME-HISTORIES: NORTH-SOUTH, EAST-WEST AND VERTICAL
- ARTIFICIAL ACCELERATION TIME-HISTORY SPECTRA ENVELOPE REGULATORY GUIDE 1.60 SPECTRA NORMALIZED TO A ZERO PERIOD ACCELERATION OF 0.25G FOR THE SSE
- DURATION OF TIME HISTORIES: 20 SECONDS, DIGITIZED AT 0.01 SECOND INTERVALS
- ONE SECOND BUILD-UP OF STRONG MOTION, THREE SECONDS DECAY



HORIZONTAL MOTION A SSE GROUND ACCELERATION TIME-HISTORY

GROUND ACCELERATION
DEVELOPMENT



NUCLEAR ISLAND
METHOD OF ANALYSIS

- LUMPED MASS WITH DIRECT INTEGRATION OF COUPLED EQUATIONS OF MOTION
- FOUNDATION SPRINGS AND DAMPERS CALCULATED BY A STATIC FINITE ELEMENT ANALYSIS USING THE COMPUTER PROGRAM STARDYNE AND BY HALF-SPACE THEORY
- MAXIMUM DIRECTIONAL EFFECTS COMBINED BY SQUARE ROOT OF THE SUM OF THE SQUARES
- DEGREES OF FREEDOM INCLUDE TRANSLATIONS AND ROTATIONS IN THREE DIRECTIONS

T5

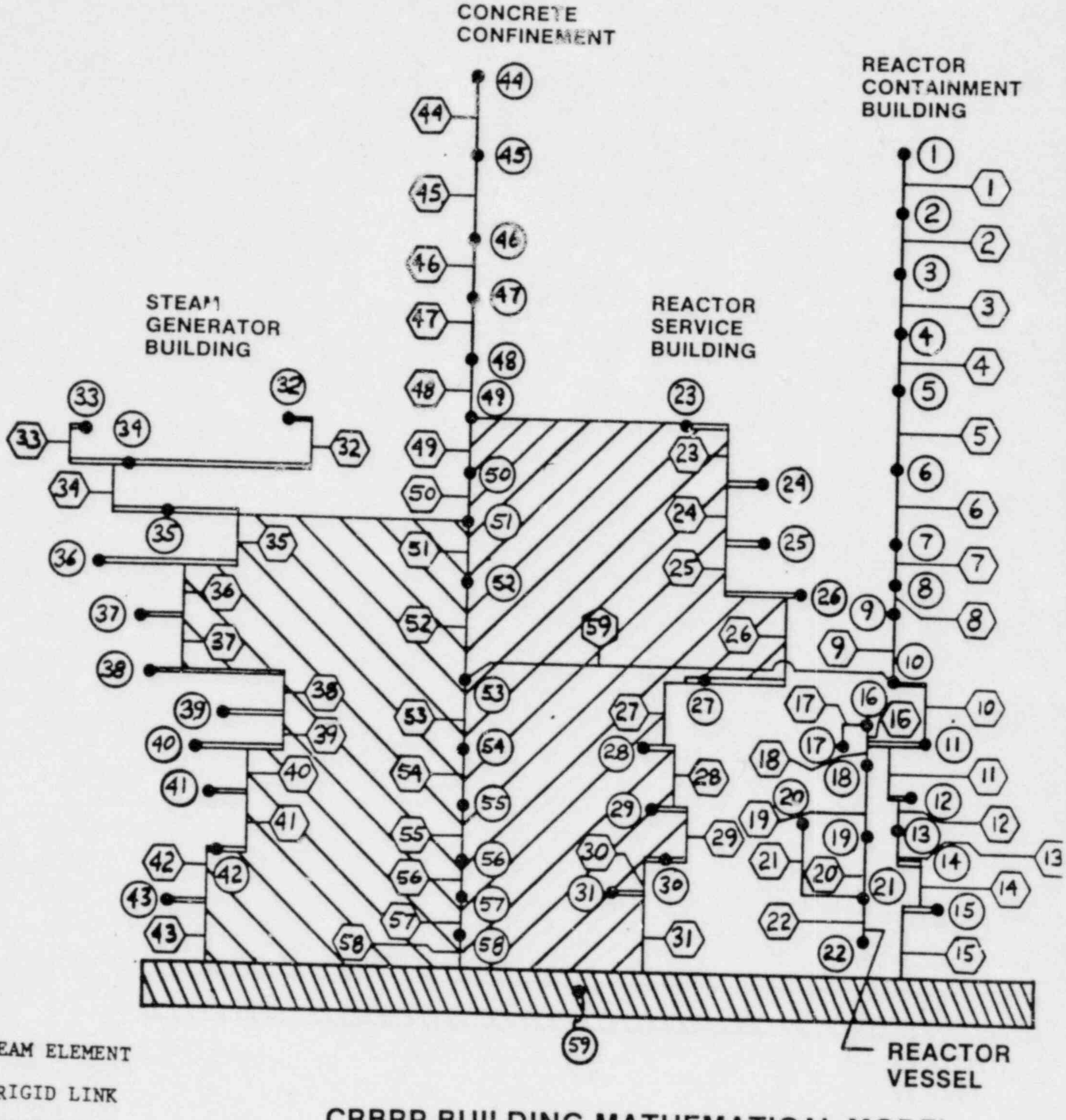
NUCLEAR ISLAND SEISMIC MATHEMATICAL MODEL

- INDEPENDENT ANALYSIS FOR EACH OF THE THREE ORTHOGONAL DIRECTIONS
- FOUR MAIN STICKS: CONTAINMENT BUILDING, CONFINEMENT, REACTOR SERVICE BUILDING AND STEAM GENERATOR BUILDINGS
- POLAR CRANE AND REACTOR VESSEL REPRESENTED IN MODEL
- FLEXIBLE TIES BETWEEN THE CONFINEMENT, REACTOR SERVICE AND STEAM GENERATOR BUILDING CANTILEVERS AT ALL ELEVATIONS, CALCULATED BY FINITE ELEMENT ANALYSIS WITH STARDYNE. REACTOR CONTAINMENT BUILDING TIED AT FOUNDATION AND OPERATING FLOOR LEVELS ONLY.
- MASS POINTS LOCATED AT CENTERS OF MASS

TS

NUCLEAR ISLAND
SEISMIC MATHEMATICAL MODEL (Cont'd.)

- MASSLESS MEMBERS LOCATED AT CENTER OF RIGIDITY
- ANALYSES FOR UPPER BOUND AND LOWER BOUND OF ROCK PROPERTIES. RESULTS OF BOTH WERE ENVELOPED.
- RESPONSE SPECTRA AND ACCELERATION AND DISPLACEMENT TIME-HISTORIES PRODUCED AT MASS POINTS
- DESIGN RESPONSE SPECTRA PRODUCED BY ENVELOPING AND SMOOTHENING UPPER AND LOWER BOUND SPECTRA, WITH PEAKS WIDENED BY ± 10%
- TRANSLATIONAL AND ROTATIONAL SPECTRA COMBINED TO CALCULATE RESPONSE SPECTRA AT POINTS AWAY FROM MASS POINTS



BEAM ELEMENT

RIGID LINK

MASS POINT

BEAM ELEMENT

FLEXIBLE TIES BETWEEN NODAL POINTS INCLUDING CROSS-COUPLING

* FOUNDATION SPRINGS NOT SHOWN

CRBRP BUILDING MATHEMATICAL MODEL FOR THE N-S EARTHQUAKE

EVALUATION OF NUCLEAR ISLAND STRUCTURES FOR SEISMIC LOADS

- LOAD COMBINATIONS IN ACCORDANCE WITH CODES AND GUIDELINES
- AISC AND ACI-349 CODES USED FOR STEEL AND CONCRETE STRUCTURES RESPECTIVELY
- IN GENERAL ALL STRUCTURES CONTROLLED BY OBE
- MANY STRUCTURAL COMPONENTS ARE CONTROLLED BY CONDITIONS OTHER THAN SEISMIC SUCH AS DBA's, SHIELDING, AND TMBDB (REACTOR CAVITY, CONFINEMENT)

SEISMIC ANALYSIS
OTHER MAJOR CATEGORY I STRUCTURES

- EMERGENCY COOLING TOWER
  - SUPPORTED ON ROCK
  - LUMPED MASS ANALYSIS
  - RANGE OF ROCK/SOIL PROPERTIES
  - FLUID STRUCTURE INTERACTION IN ACCORDANCE WITH HAUSNER'S THEORY

- DIESEL GENERATOR BUILDING
  - SUPPORTED ON SOIL
  - SOIL STRUCTURE INTERACTION BY FINITE ELEMENT (FLUSH)
  - DETAILED IN-STRUCTURE RESPONSES BY THREE DIMENSIONAL LUMPED MASS ANALYSIS
  - RANGE OF SOIL PROPERTIES

SEISMIC ANALYSIS
CATEGORY III STRUCTURES ADJACENT TO CATEGORY I

- TO PROTECT ADJACENT CATEGORY I, STRUCTURES WERE ANALYZED AND DESIGNED FOR SSE
- TURBINE GENERATOR BUILDING
  - SUPPORTED ON SOIL
  - SOIL STRUCTURE INTERACTION BY FINITE ELEMENT (FLUSH)
  - FORCES IN STRUCTURE BY THREE DIMENSIONAL ANALYSIS
- RADWASTE BUILDING
  - SUPPORTED PART ON SOIL AND PART ON ROCK
  - SOIL/ROCK STRUCTURE INTERACTION BY FINITE ELEMENT (FLUSH)
  - FORCES IN STRUCTURE BY THREE DIMENSIONAL ANALYSIS

SUMMARY
CONSERVATISMS IN STRUCTURES

- LARGEST HISTORICAL EARTHQUAKE IN TECTONIC PROVINCE ASSUMED TO OCCUR AT CRBRP SITE
- SSE INCREASED FROM 0.18G TO 0.25G
- DESIGN RESPONSE SPECTRA CONSISTS OF SMOOTH WIDE BAND ENVELOPE SPECTRA BASED ON STATISTICAL STUDIES OF MANY PAST EARTHQUAKE RECORDS
- ARTIFICIAL ACCELERATION TIME-HISTORIES USED IN ANALYSIS ENVELOPED AND FOR MOST FREQUENCIES ARE ABOVE THE DESIGN RESPONSE SPECTRA
- LINEAR SEISMIC ANALYSIS USED DOES NOT CONSIDER SUBSTANTIAL RESERVE STRENGTH IN THE INELASTIC RANGE
- APPLICATION OF SAFETY FACTORS REQUIRED BY CODES
- USE OF MINIMUM TEST VALUES IN STRENGTH OF STRUCTURAL MATERIALS
  - ACTUAL YIELD STRENGTH VALUES FOR STRUCTURAL AND REINFORCING STEEL ARE, IN GENERAL, HIGHER
  - COMPRESSION STRENGTH OF CONCRETE AT 28 DAYS DISREGARDING SUBSTANTIAL INCREASE OF STRENGTH WITH AGE

SUMMARY
CONSERVATISMS IN STRUCTURES (Cont'd.)

- USE OF STATIC STRENGTH OF STRUCTURAL MATERIALS IN LIEU OF THE GREATER DYNAMIC STRENGTH, WHEN ACTUAL SEISMIC LOAD IS DYNAMIC

- TO SIMPLIFY CONSTRUCTION, STRUCTURAL MEMBER SIZES ARE DUPLICATED RESULTING IN STRONGER THAN REQUIRED STRUCTURAL SHAPES OR REINFORCED CONCRETE SECTIONS IN MANY AREAS

- STRUCTURAL SECTIONS IN GENERAL CONTROLLED BY OBE PROVIDING ADDITIONAL MARGIN FOR THE SSE

- MANY STRUCTURAL ELEMENTS ARE CONTROLLED BY REQUIREMENTS OTHER THAN SEISMIC

  - SHIELDING, STIFFNESS, TMBDB, DBA

  - EXAMPLE, REACTOR CAVITY CONTROLLED BY SHIELDING AND TMBDB, CONFINEMENT BY SHIELDING, ETC.

- INTERCONNECTED STRUCTURES ON COMMON FOUNDATION MAT AND MULTIPLE INTERCONNECTED CELLS IN BUILDINGS TEND TO INCREASE OVERALL SEISMIC CAPACITY

  - REDUNDANT LOAD PATHS ARE PROVIDED

SEISMIC DESIGN OF SYSTEMS AND COMPONENTS

Systems And Components
Seismic Design Criteria

- Seismic classification and qualification
- Seismic input development
- Damping
- Load combinations
- Seismic test requirements and procedures

7230-9

T8, T9

Morrone
T8

SEISMIC CLASSIFICATION

Seismic Category I:

Designed to perform safety functions for the SSE and remain functional for the OBE

- Assure integrity of reactor coolant pressure boundary
- Provide capability for reactor shutdown
- Provide capability to prevent or mitigate accident consequences

Seismic Category II*:

Designed to remain functional for the OBE

- Permit continued reactor operation
- Protect plant investment

Seismic Category III*:

Local design criteria

- Maintain support of normal operations

* Must be designed for no gross structural failure under SSE loads for protection of Seismic Category I components when applicable

SEISMIC QUALIFICATION

Analysis

Seismic Category I and II

Detailed Dynamic Analyses

- Response spectrum method
- Time history method

Conservative simplified methods

Seismic Category III

Static Analysis

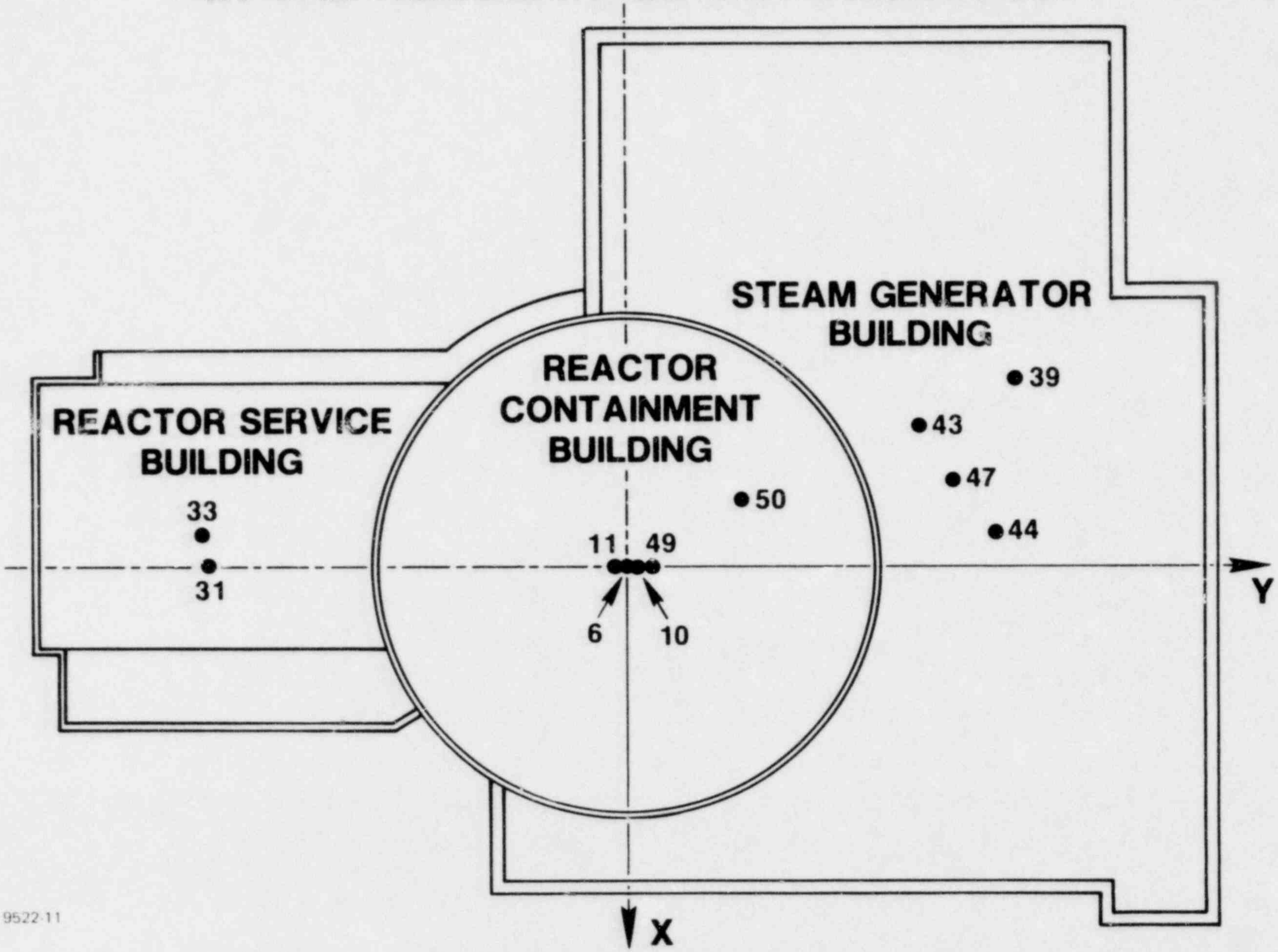
- Standard building code, zone 2
- Local codes

Testing

Seismic Category I

- Multiple frequency tests
- Single frequency tests at resonance
- Envelop required response spectrum with test response spectrum

LOCATION OF HORIZONTAL NODES IN THE NUCLEAR ISLAND BUILDINGS



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SEISMIC INPUT FOR SYSTEMS AND COMPONENTS

- Responses obtained from building analysis in three independent directions
- Seven spectra and time histories for each node (3 translation, 2 torsion, 2 rotation)
- 28 spectra and time histories for OBE, SSE and upper and lower bounds of soil moduli
- Input applied individually in each direction for combining responses by SRSS

SIMPLIFIED SPECTRA PROCEDURE

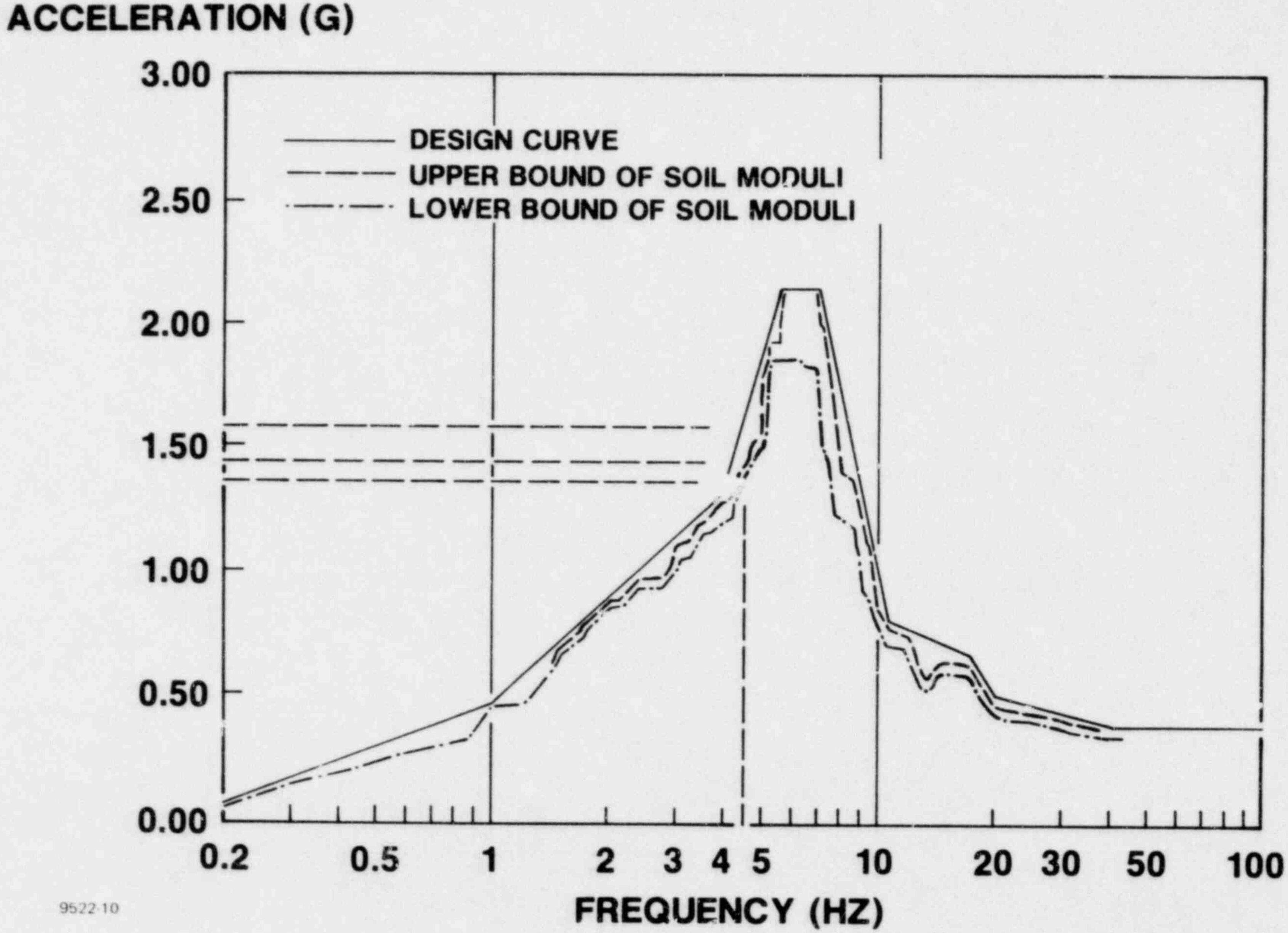
- Seven spectra reduced to three spectra
- Combine translational, torsional and rotational spectra by SRSS
- Combine resulting responses by absolute sum
- Always conservative
- Results in combining directional effects absolutely instead of by SRSS when cross coupling terms are small

DESIGN SPECTRA

- Envelop upper and lower bounds of soil moduli
- Peaks widened for uncertainties
- Spectra smoothed to eliminate valleys and spectral fluctuations
- Results in conservative design spectra

Text
T9

RESPONSE SPECTRA ENVELOPING PROCEDURE



9522-10

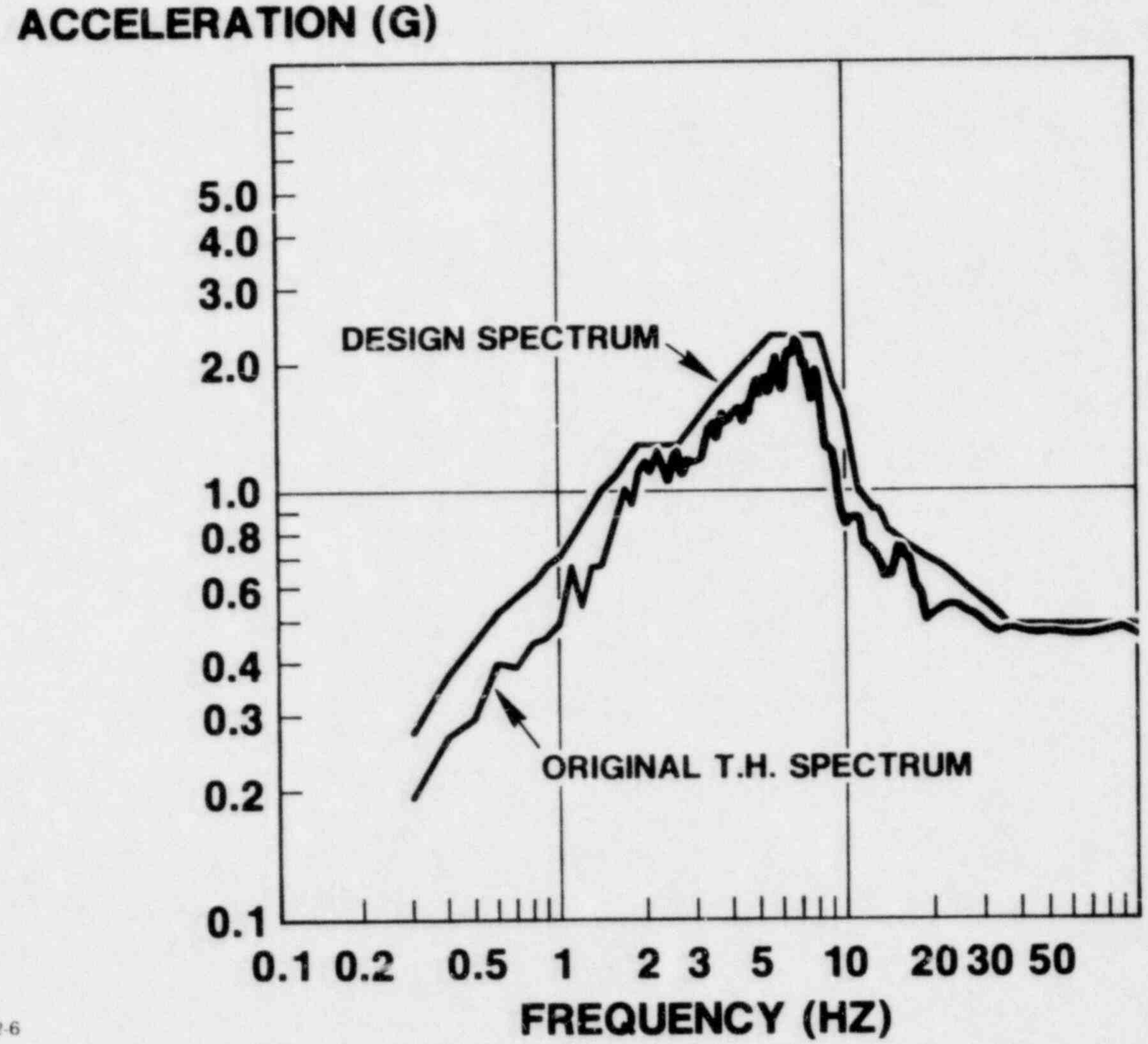
DESIGN HISTORIES

- Possible frequency variations of building
- Vary Δt, compress and expand history
- Develop spectra-consistent synthetic histories
- Results in conservative design histories

7230-14

SSE E-W HORIZONTAL + TORSIONAL COMBINED—DESIGN AND ORIGINAL T.H. RESPONSE SPECTRA AT R.V. SUPPORTS, EL. 800 FT.

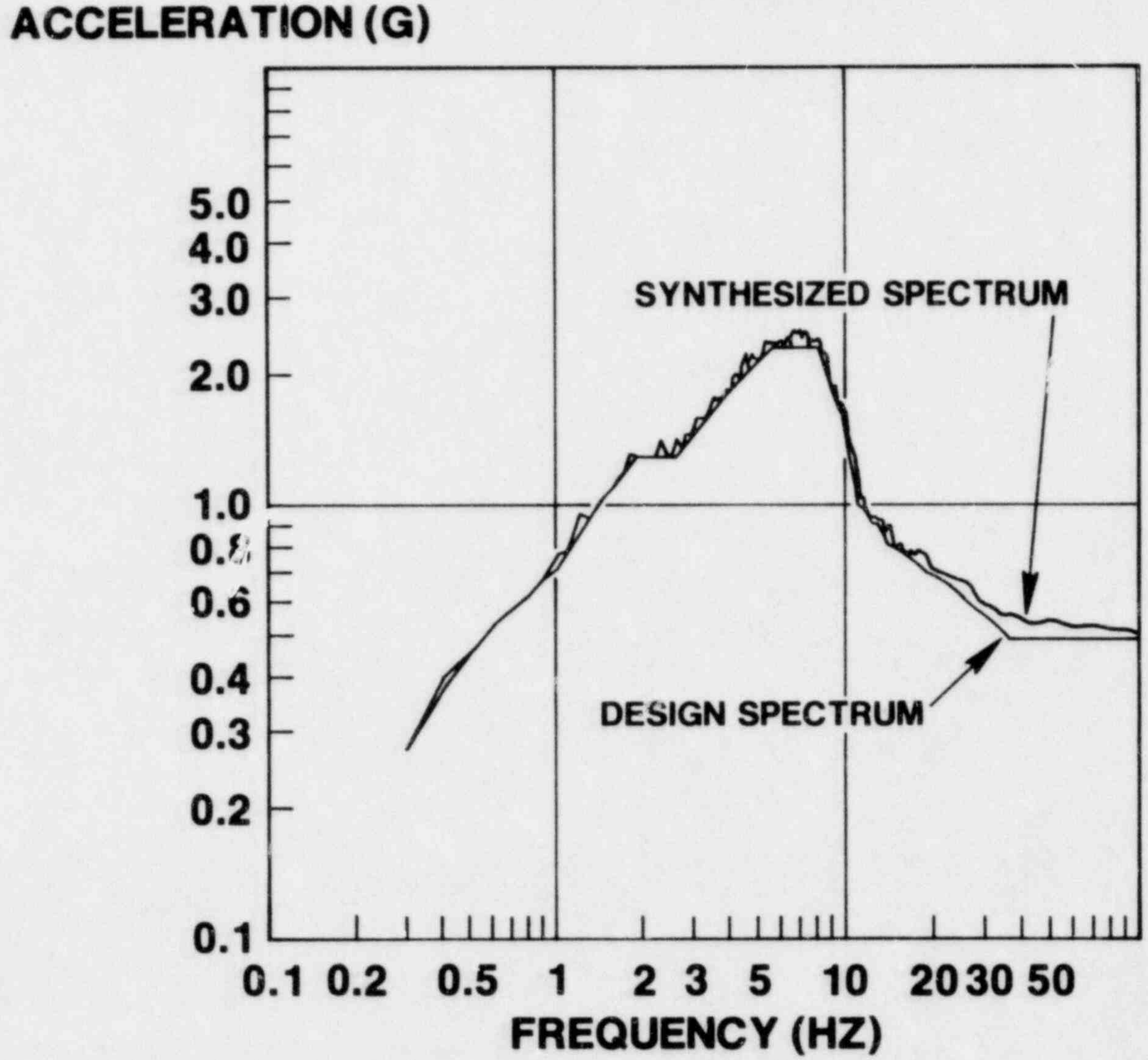
(3% CRITICAL DAMPING)



9522-6

SSE EW COMBINED HORIZONTAL AND TORSION-DESIGN AND SYNTHESIZED RESPONSE SPECTRA

(3% CRITICAL DAMPING)



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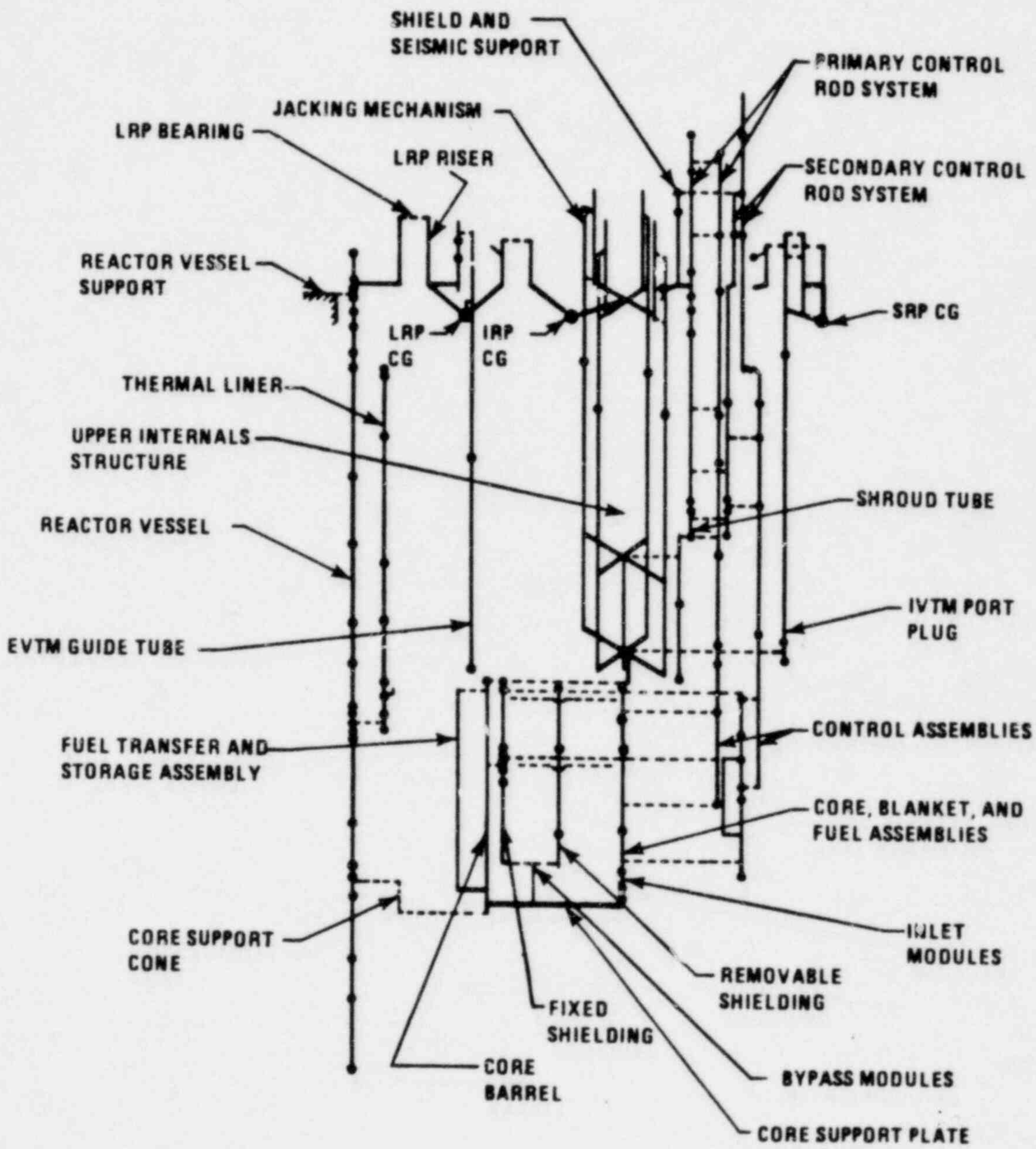
COMPONENTS SEISMIC INPUT

- Model and analysis of system
- Input design histories
- Output response histories and response spectra for dynamic analysis of components
- Again widen and smooth components spectra
- Input design spectra
- Output loads for components design

7230-18

LEGEND:

SRP = SMALL ROTATING PLUG		CG = CENTER OF GRAVITY	
IRP = INTERMEDIATE ROTATING PLUG		IVTM = IN-VESSEL TRANSFER MACHINE	
LRP = LARGE ROTATING PLUG		EVTM = EX-VESSEL TRANSFER MACHINE	



SCHEMATIC OF REACTOR SYSTEM SEISMIC MODEL

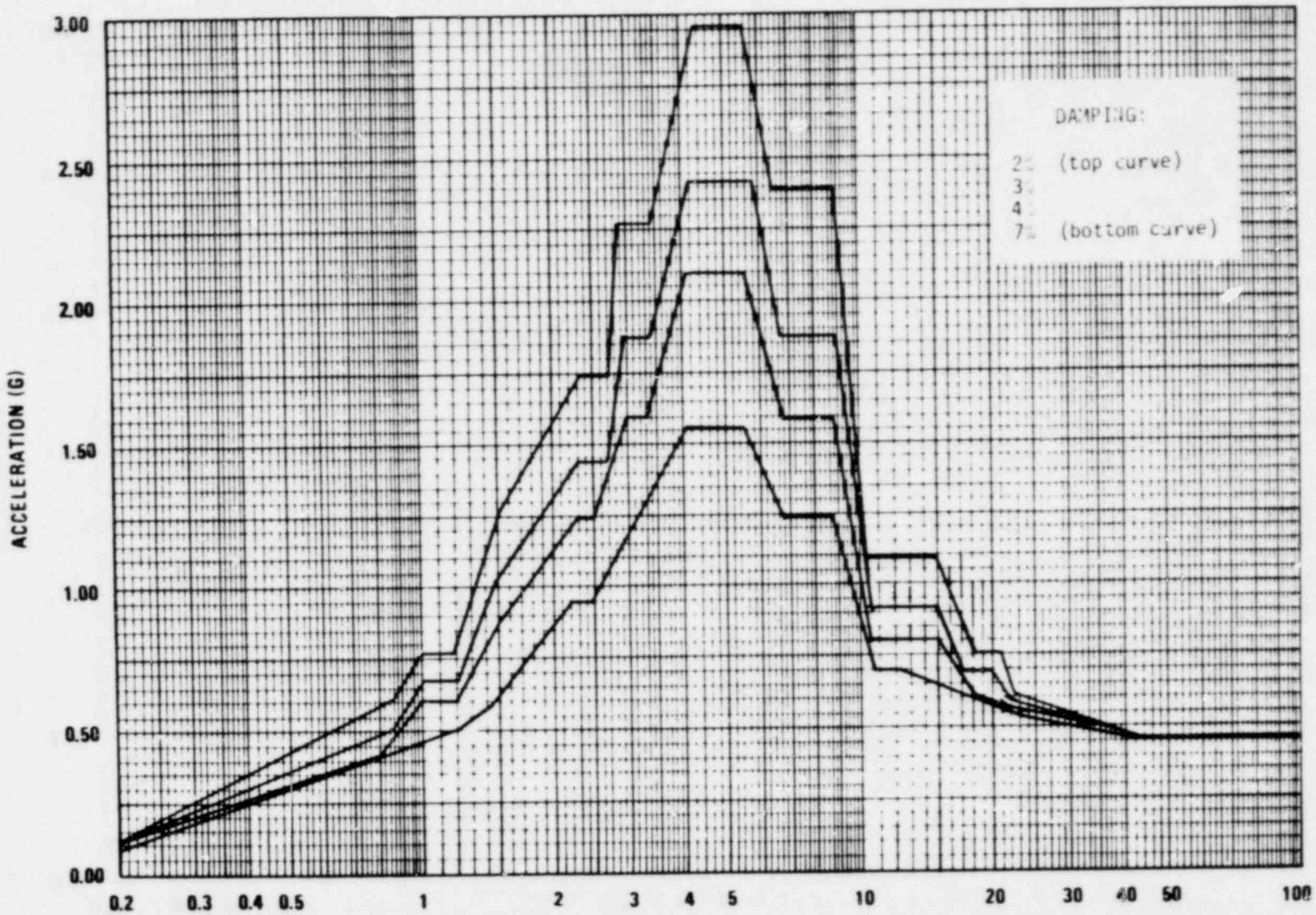
DAMPING VALUES

Structural System	Damping Values (1) (Percent Of Critical)	
	Operating Basis Earthquake	Safe Shutdown Earthquake
Equipment and large diameter piping systems ($>$ 12 in. nominal diameter)	2.0	3.0
Small diameter piping system ($\leq$ 12 in. nominal diameter)	1.0	2.0
Welded steel structures	2.0	4.0
Bolted or riveted steel structures	4.0	7.0
Prestressed concrete structures	2.0	5.0
Reinforced concrete structures	4.0	7.0

(1) Reduced damping values should be used when combined stresses are considerably below 1/2 yield for the OBE and yield for the SSE.

7230-8

CRBRP SSE HORIZONTAL E-W DESIGN RESPONSE SPECTRA FOR REACTOR CONTAINMENT BUILDING AT EL. 816'



BASIC SEISMIC LOAD COMBINATIONS
(Seismic Category I Vessels, Piping And Non-Active Pumps And Valves)

Upset (Level B) Condition:

D + L + Operating + Thermal + Transients + OBE

Faulted (Level D) Condition

D + L + Operating + Thermal + Transients + SSE + DSL*

- For active pumps and valves all loadings are upset condition

*Dynamic system loadings associated with pipe leak/rupture loads

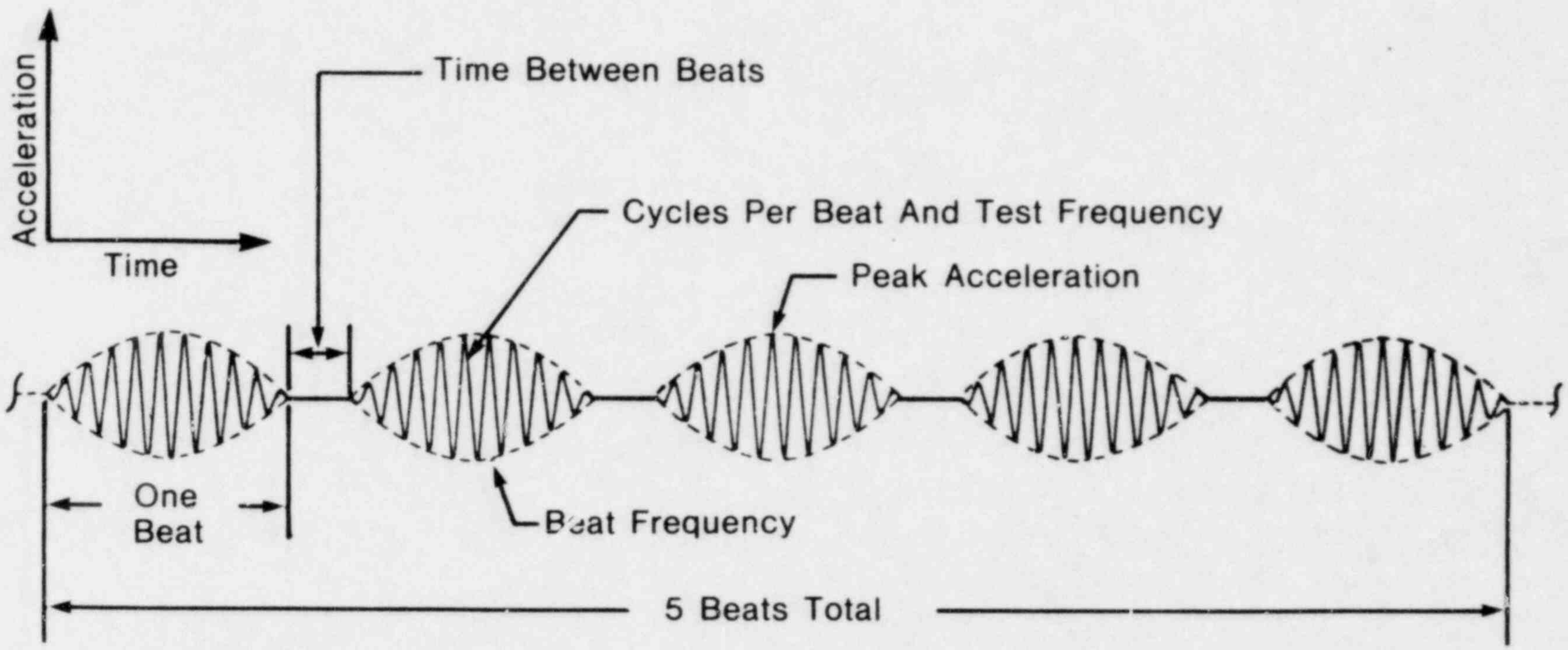
7230-7

SEISMIC TESTING FOR CLASS 1E EQUIPMENT

- Qualify to IEEE std. 344-1975
- Single frequency tests
- Multiple frequency tests
- Single frequency plus multiple frequency
- Multiple frequency and recommended single frequency

7230-6

SINE BEAT INPUT FOR TESTING



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BASIC SEISMIC TEST PROCEDURE

Single Frequency Sine Beat Tests

- Frequency search from 1-33 Hz
- SSE sine beat tests at natural frequencies and 1/2 octave intervals
- Five beats motion with 10 cycles/beat
- Shake table motion maximum acceleration equal to ZPA of RRS
- TRS maximum response acceleration greater than RRS
- One OBE test preceding SSE test at each frequency
- Independent direction input

Multiple Frequency Tests

- IEEE std. 344-1975
- Five OBE and one SSE
- Random motion
- Biaxial direction input
- Envelop RRS with TRS

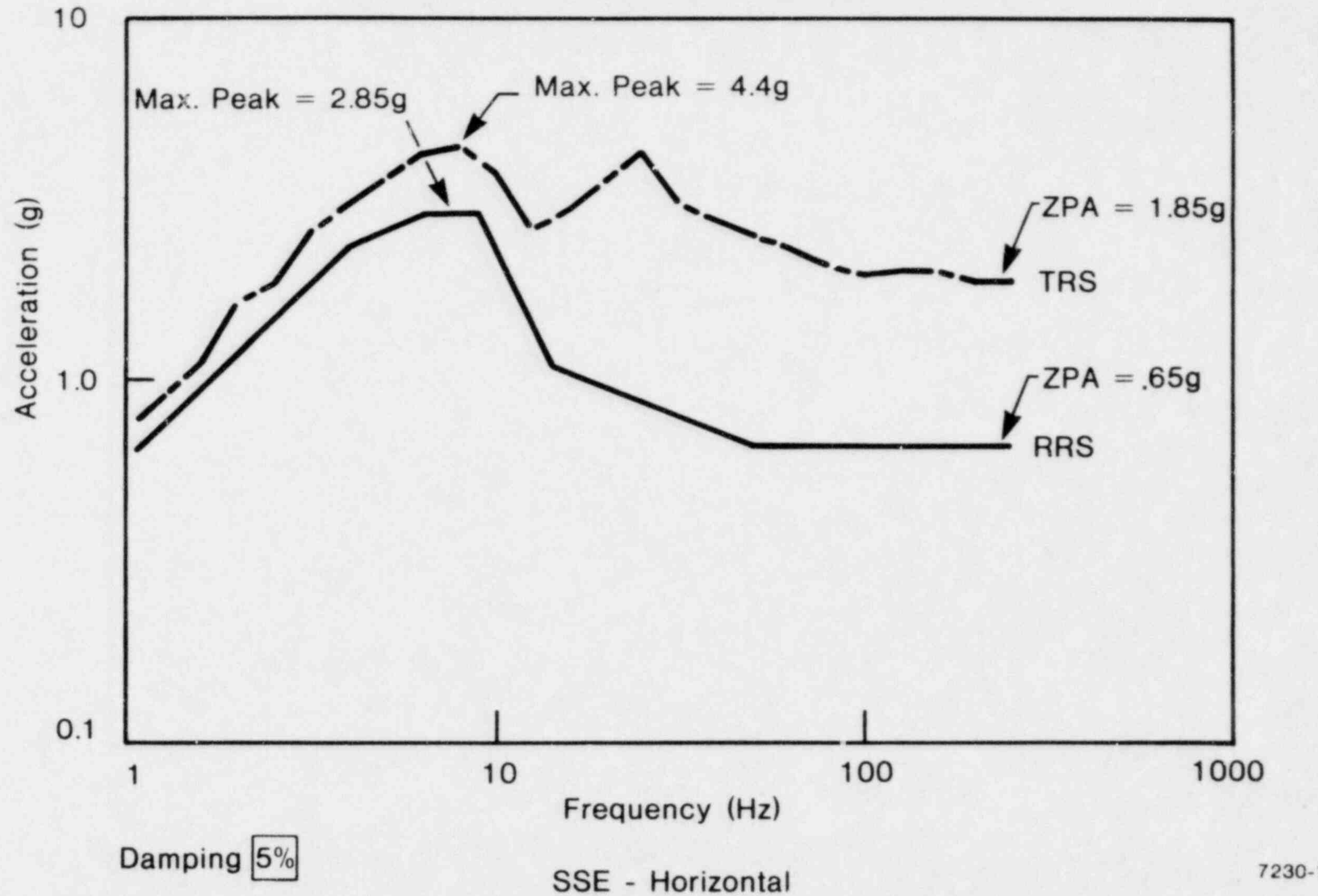
EXAMPLE OF COMPARISON OF TRS/RRS FOR TESTED EQUIPMENT

- Reactor shutdown and isolation equipment
- Housed in cabinets and whole cabinet shake table tested
- Both sine beat unidirectional and multiple frequency biaxial motion
- Cabinet rotated 90°
- Functioned properly during and after testing
- TRS conservatively enveloped RRS
- Additional conservatism by enveloping horizontal RRS, 10% IEEE-323 margin and use of design spectra

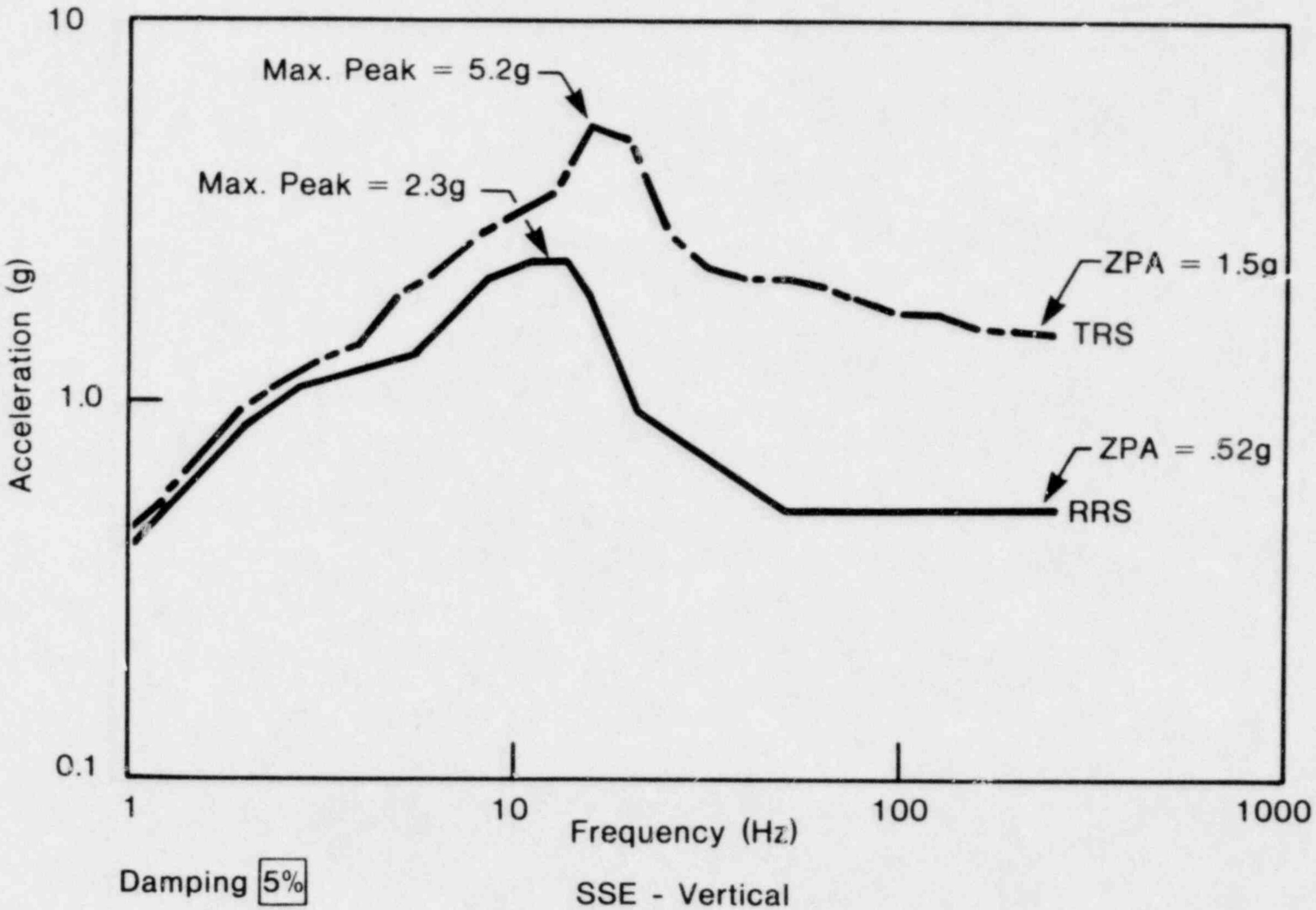
Start
T10

7230-19

PRIMARY REACTOR SHUTDOWN SYSTEM COMPARATOR/BUFFER CABINET AND LOGIC CABINET ASSEMBLIES



PRIMARY REACTOR SHUTDOWN SYSTEM COMPARATOR/BUFFER CABINET AND LOGIC CABINET ASSEMBLIES



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SUMMARY OF CONSERVATISM IN SEISMIC CRITERIA

Simplified Spectra
- Conservatism approaches absolute sum versus SRSS of directional effects
- 1.5 peak for static analysis

Design Spectra
- Upper and lower bounds enveloped
- Valleys eliminated
- Spectra widened and smoothed

Design Histories
- Design spectra-consistent histories
- Conservatively envelop design spectra
- Combine translational and torsional design spectra

7230-20

SUMMARY OF CONSERVATISM IN SEISMIC CRITERIA (Continued)

Components Spectra

- Spectra additionally widened and smoothed with conservative input
- Envelop three operating conditions

Damping

- Damping values of systems and components
- 3% versus 4% of critical

Seismic Testing

- Both single frequency and multiple frequency testing
- Both unidirectional and biaxial
- ZPA and peak responses of TRS higher than RRS
- Design spectra RSS
- Envelop N-S and E-W RRS
- 10% IEEE-323 margin

SEISMIC REQUIREMENTS

IEEE 344

Demonstrate an equipment's ability to perform its required safety function during and after an SSE

EQUIPMENT SPECIFICATION

A. Testing
   1. Sine Beats and
   2. Random Multi Frequency
B. Analysis/Testing
C. Analysis

T10

TYPICAL PPS INSTRUMENTATION

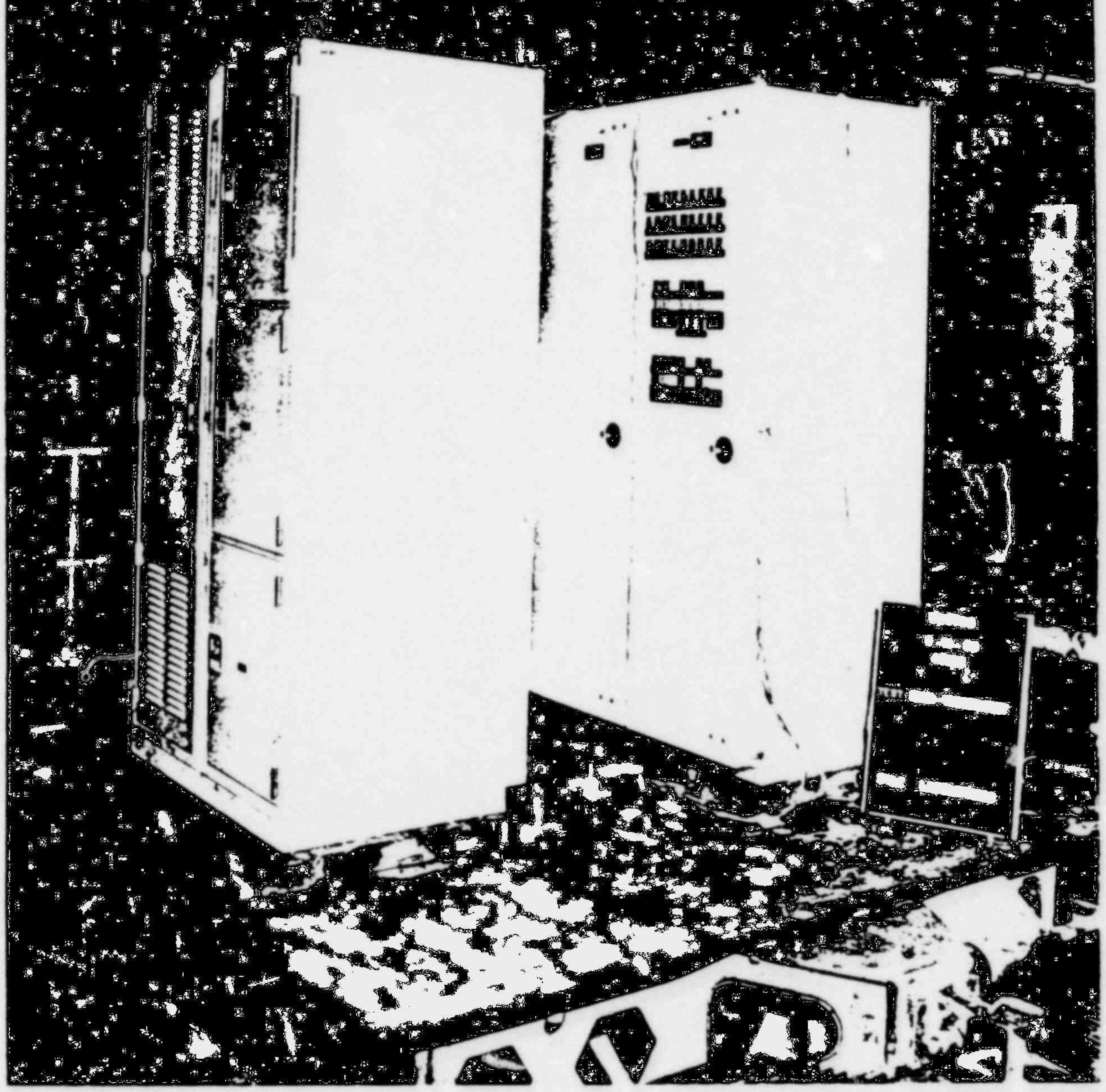
Sensors	Signal Conditioners	Logic Components	Actuators
Compensated Ion Chamber	Flux Drawer	Isolators	Scram Breakers
Fission Counter	Flux Drawer	2/3 Logic	Scram Solenoid Valves
Pressure Detector	Pressure Transmitter	1/4 Logic	CIS Breakers
PM Flowmeter	MV/I Transmitter	Latch Logic	
Thermocouple	MV/I Transmitter		
Inductive Level Probe	Level Drawer		
Tachometers	D/A Converter		

SEISMICALLY QUALIFIED

(To Date)

EQUIPMENT	QUALIFICATION METHOD
Primary Reactor Shutdown System	Type Testing
Secondary Reactor Shutdown System	Type Testing
Primary Linear Flux Drawers	Type Testing
Secondary Linear Flux Drawers	Type Testing
Primary Scram Breakers	Type Testing

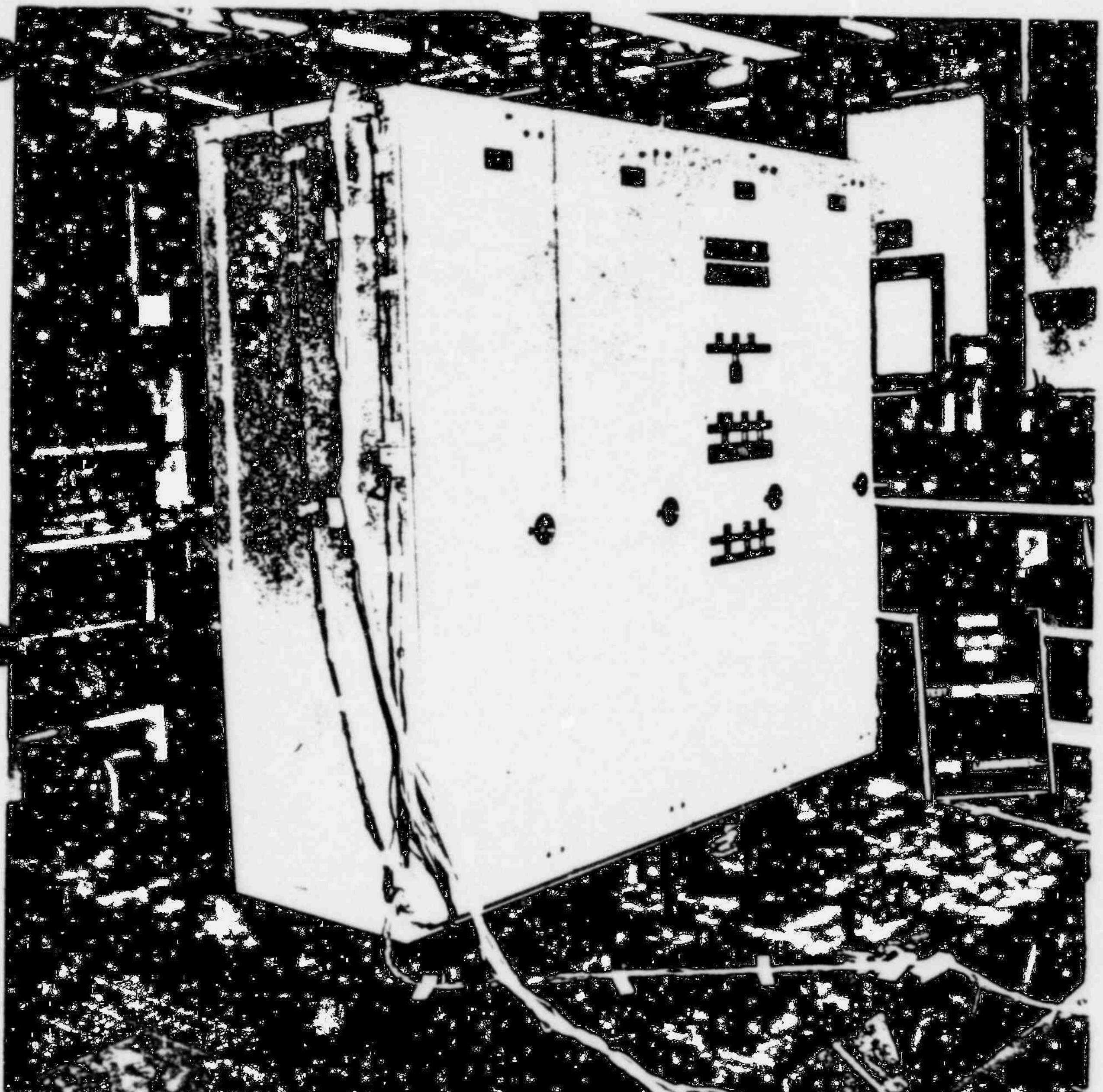
Top



PRIMARY REACTOR SHUTDOWN SYSTEMS
COMPARATOR/BUFFER CABINET AND
LOGIC CABINET ASSEMBLIES

7193-2

Top



SECONDARY REACTOR SHUTDOWN SYSTEM
COMPARATOR/BUFFER CABINET ASSEMBLY

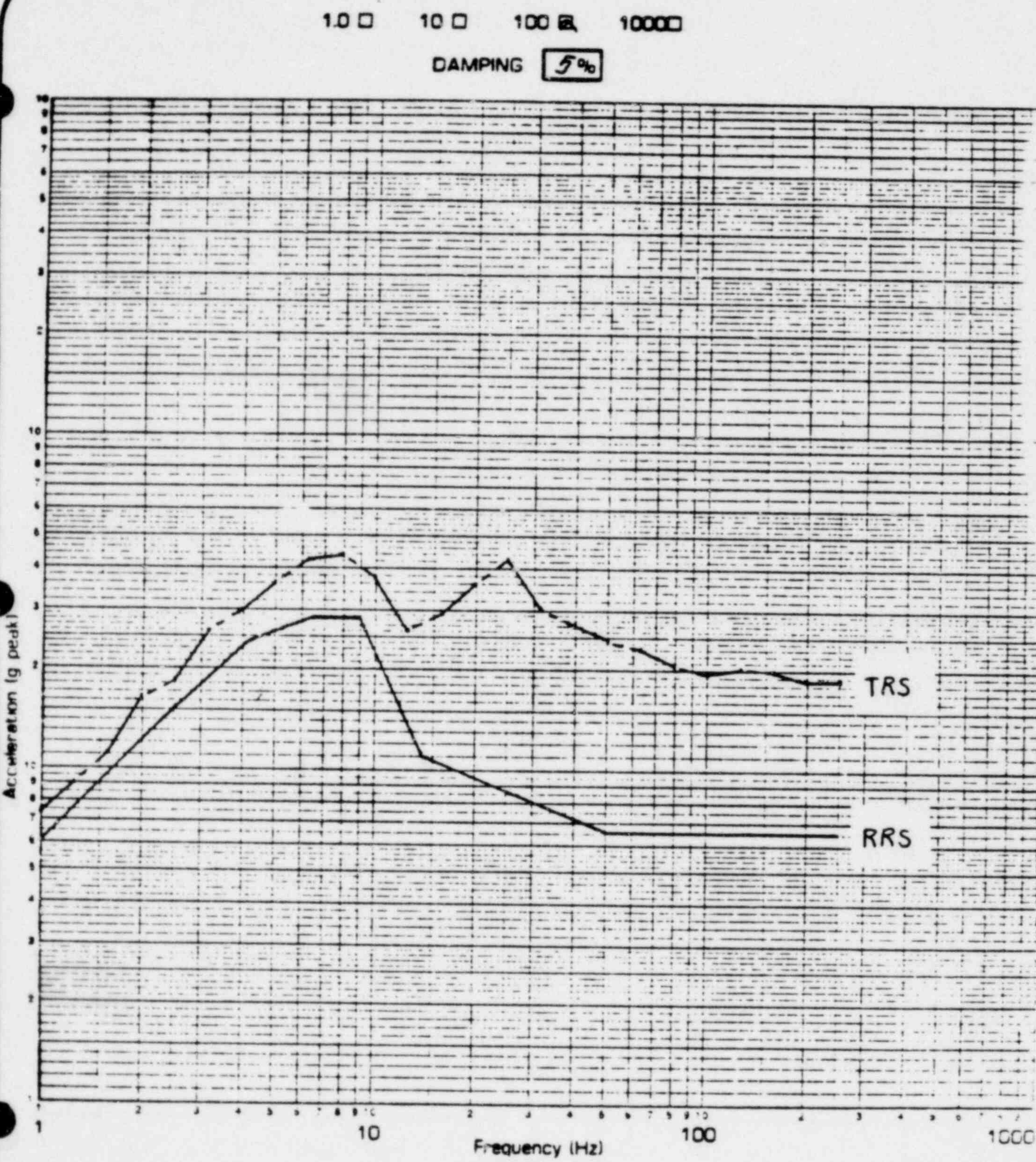
7193-3

Top

CONTAINMENT ISOLATION SYSTEM COMPARATORS, LOGIC AND BREAKER CABINET ASSEMBLIES

7193-1

TOP



PRIMARY REACTOR SHUTDOWN SYSTEM COMPARATOR/BUFFER CABINET AND LOGIC CABINET ASSEMBLIES

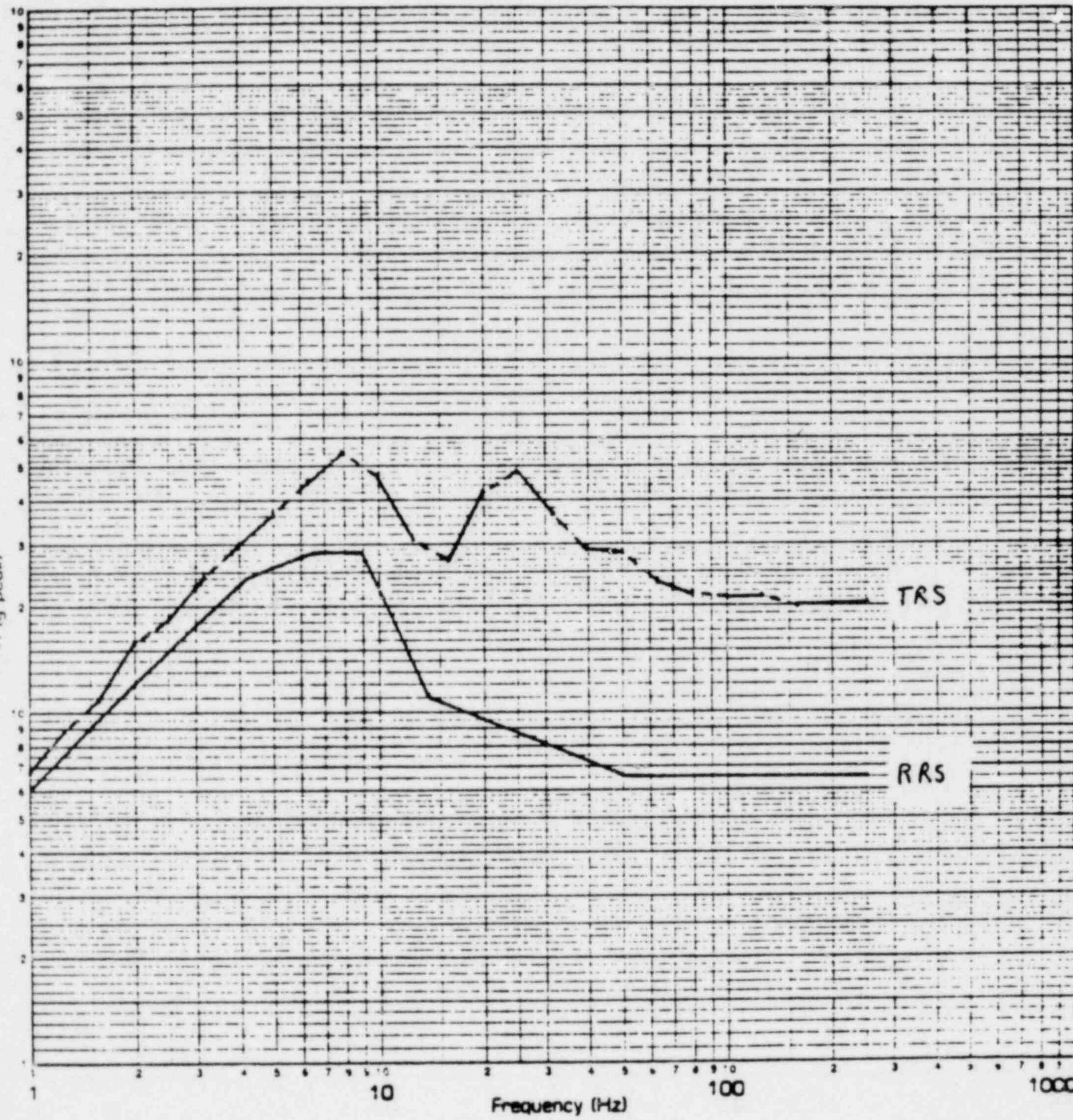
SSE-SIDE TO SIDE-HORIZONTAL

TOP

FULL SCALE SHOCK SPECTRUM (g Peak)

1.0 ☐ 10 ☐ 100 ☒ 1000 ☐

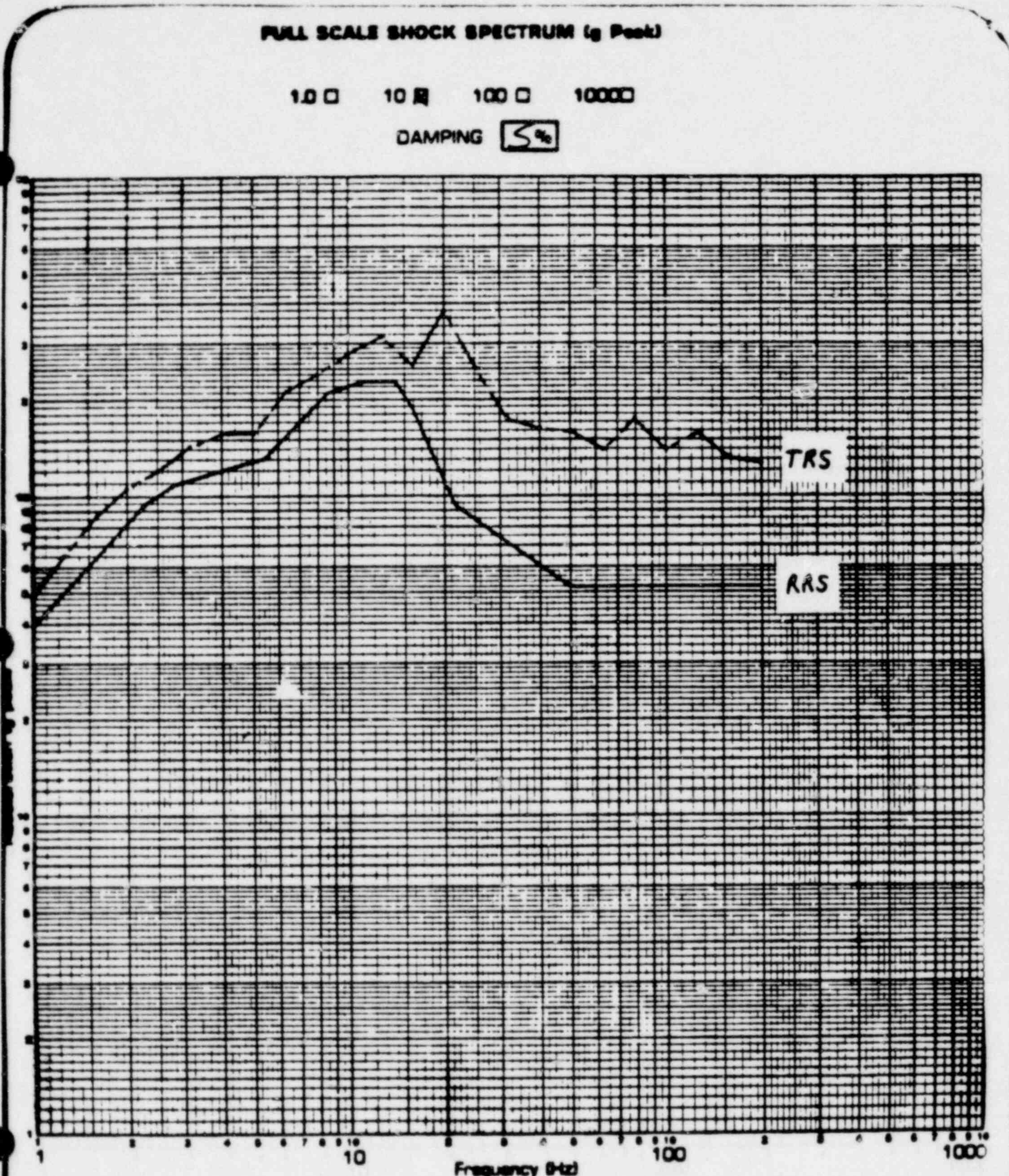
DAMPING $\boxed{5\%}$



SECONDARY REACTOR SHUTDOWN SYSTEM
COMPARATOR/BUFFER CABINET ASSY

SSE-FRONT TO BACK-HORIZONTAL

TOP



CONTAINMENT ISOLATION SYSTEM COMPARATORS,
LOGIC AND BREAKER CABINET ASSEMBLIES

SSE-SIDE TO SIDE-VERTICAL

SEISMIC TEST RESULTS

ALL OF THE EQUIPMENT TESTED PERFORMED ITS REQUIRED SAFETY FUNCTION DURING AND AFTER THE MULTIPLE SEISMIC TESTS AND RETAINED ITS STRUCTURAL INTEGRITY

MECHANICAL CONTROL ROD SYSTEMS
DYNAMIC/SEISMIC TESTS

Dynamic Friction

- Determine "Effective Coefficient of Friction" for seismic scram analysis
- Simple rod in bushings, sinusoidal input
- Test media - air, Argon, H_2O, Na
- Material couples - 304/718, 718/316, 718/718
- Cylindrical and hex test rods
- Coefficient of friction for design at 2σ level = 0.45 for all materials
  - design requirement is 1.0 except as supported by data
- Develop test experience for more complex seismic test

PCRS Seismic Test

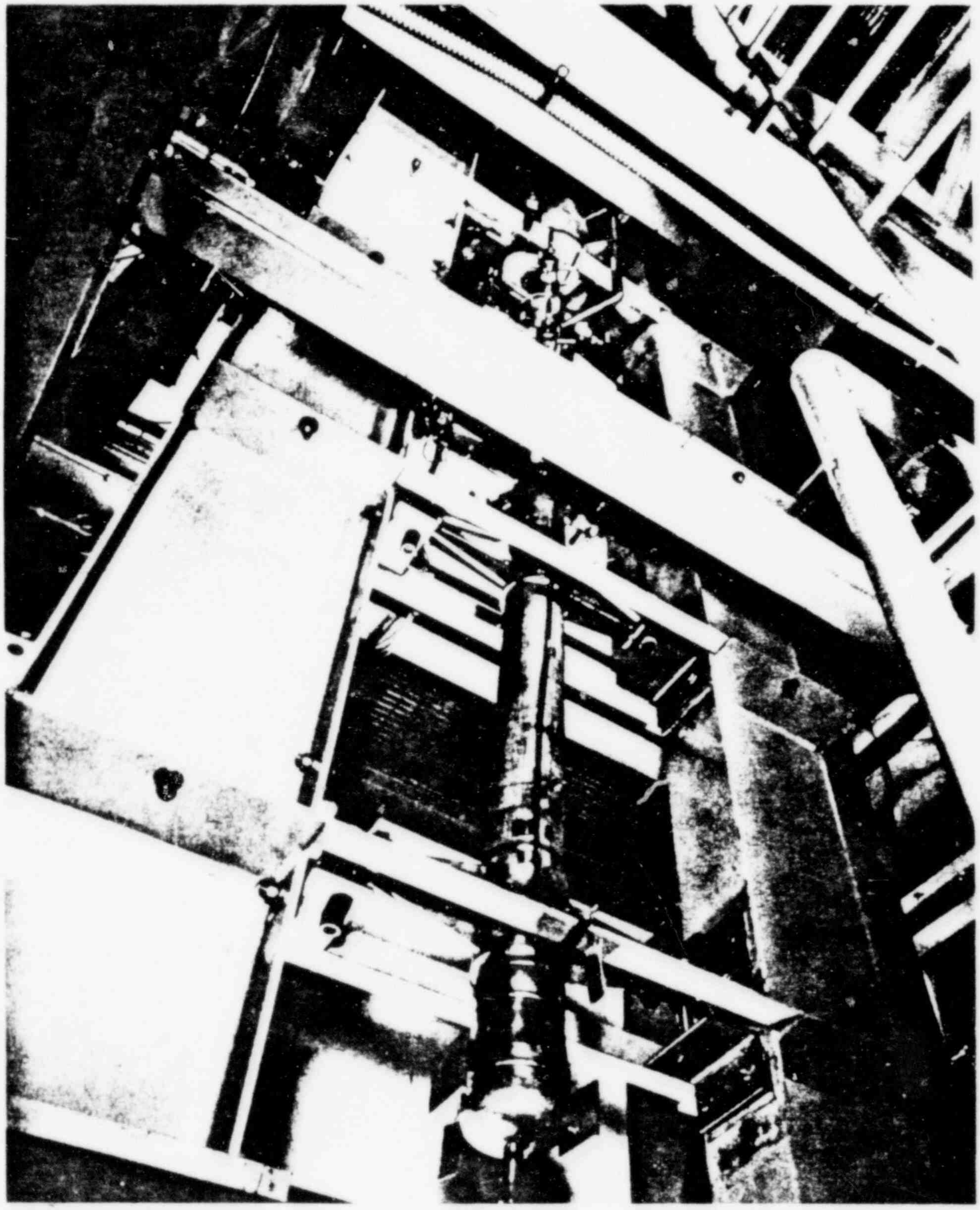
- Scram performance under dynamic input conditions
- Validate seismic scram analysis methods
- Prototype test hardware
- Water test medium
- Scram testing to start by early CY83

SCRS Seismic Test

- Scram valve/cylinder assembly
- Seismic response spectra test per IEEE-344

7237-2

T11



PRELIMINARY CHECK OF SCRAM ANALYSIS METHODS
(Dynamic Friction Test Data)

Methods For Scram Retarding Normal Forces

- ANSYS finite element analysis with interface gaps (type 5-2D)
- Three rod withdrawal elevations—6, 18, 36 inch
- Impact stiffnesses—hertzian contact method
- Impact damping—ignored as shown negligible effect by sensitivity analysis
- Structural damping—.3% for test
- Fluid coupling—concentric cylinder model (ANSYS element S11F38)

Application To Dynamic Friction Tests

- Analytically calculate normal forces
- Analytical correction for hydraulic forces normalized by Og test data
- Obtain μ by adjustment to test drop time
  - Compare with μ from measured normal forces
- Compare average normal force between analysis and test

7237-1

PRELIMINARY CHECK OF SCRAM ANALYSIS METHODS
(Dynamic Friction Test Data)

Analysis vs Test	Friction Coefficient		Average Normal Force	
	Analysis	Test	Analysis	Test
Air, I-718, 228 Hz, 1.5G	0.32	0.30±.04 (0.32±.02)	84.7	82.7
Air, I-718, 228 Hz, 0.5G	Insensitive	0.28±.07	20.2	37.0
Water, I-718, 228 Hz, 1.5G	0.32	0.31±.02 (0.36±.04)	~81	86.2

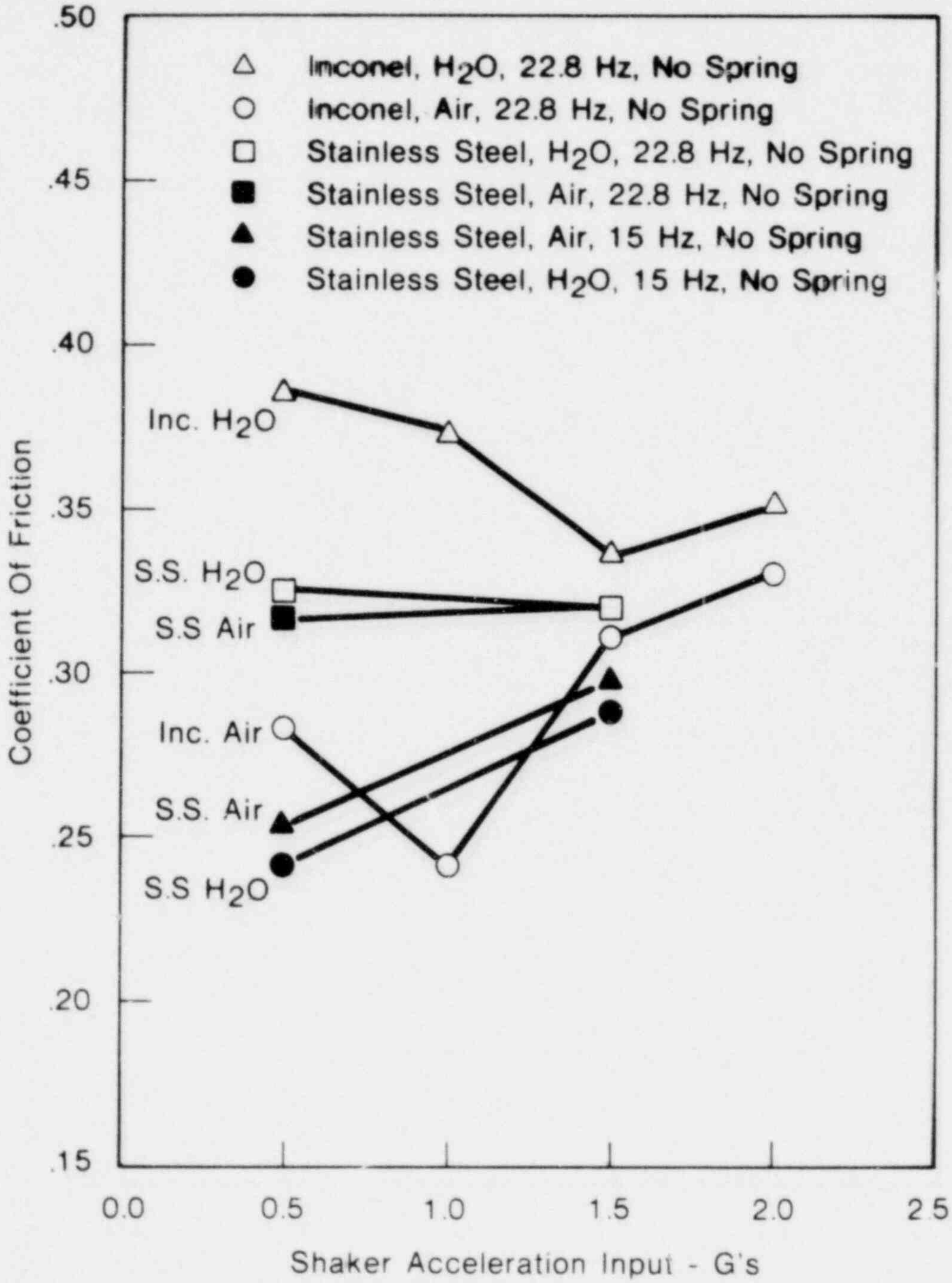
Note: Test values are average of 10 drops. values in parenthesis are repeat tests

7237-3

PRELIMINARY CHECK OF SCRAM ANALYSIS METHODS
(Dynamic Friction Test Data)
General Conclusions - Test vs Analysis

- Good agreement on analytical and test μ or drop times using test μ in analysis
- Good agreement on average normal forces
  - Force and impact frequency dependence on rod position also generally predicted
  - Supports general methods and 3 elevation model assumptions
- Test and analysis do not show significant fluid coupling effect
- Analysis not strongly sensitive to impact stiffness
  - Factor of 10 reduction in stiffness increases test drop time by 8%
- Recommend design values of μ = 0.45 for fluid and μ = 0.41 for gas

DYNAMIC FRICTION TEST COEFFICIENT OF FRICTION EFFECTS OF BUSHING MATERIAL AND FREQUENCY



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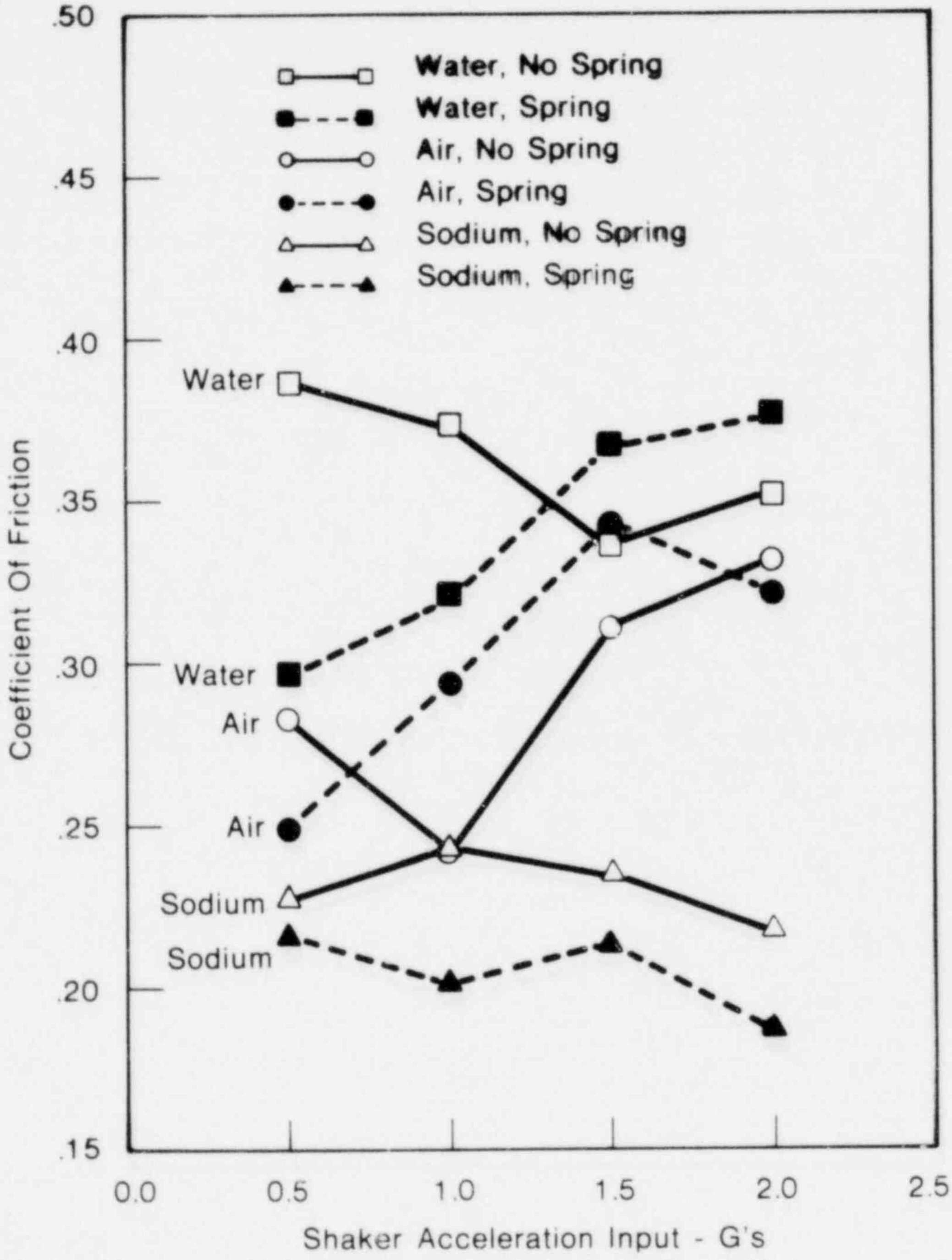
DYNAMIC FRICTION TEST COEFFICIENT OF FRICTION EFFECTS OF ENVIRONMENT AND ROD VELOCITY FOR ALLOY 718 ROD & BUSHINGS (22.8 Hz)



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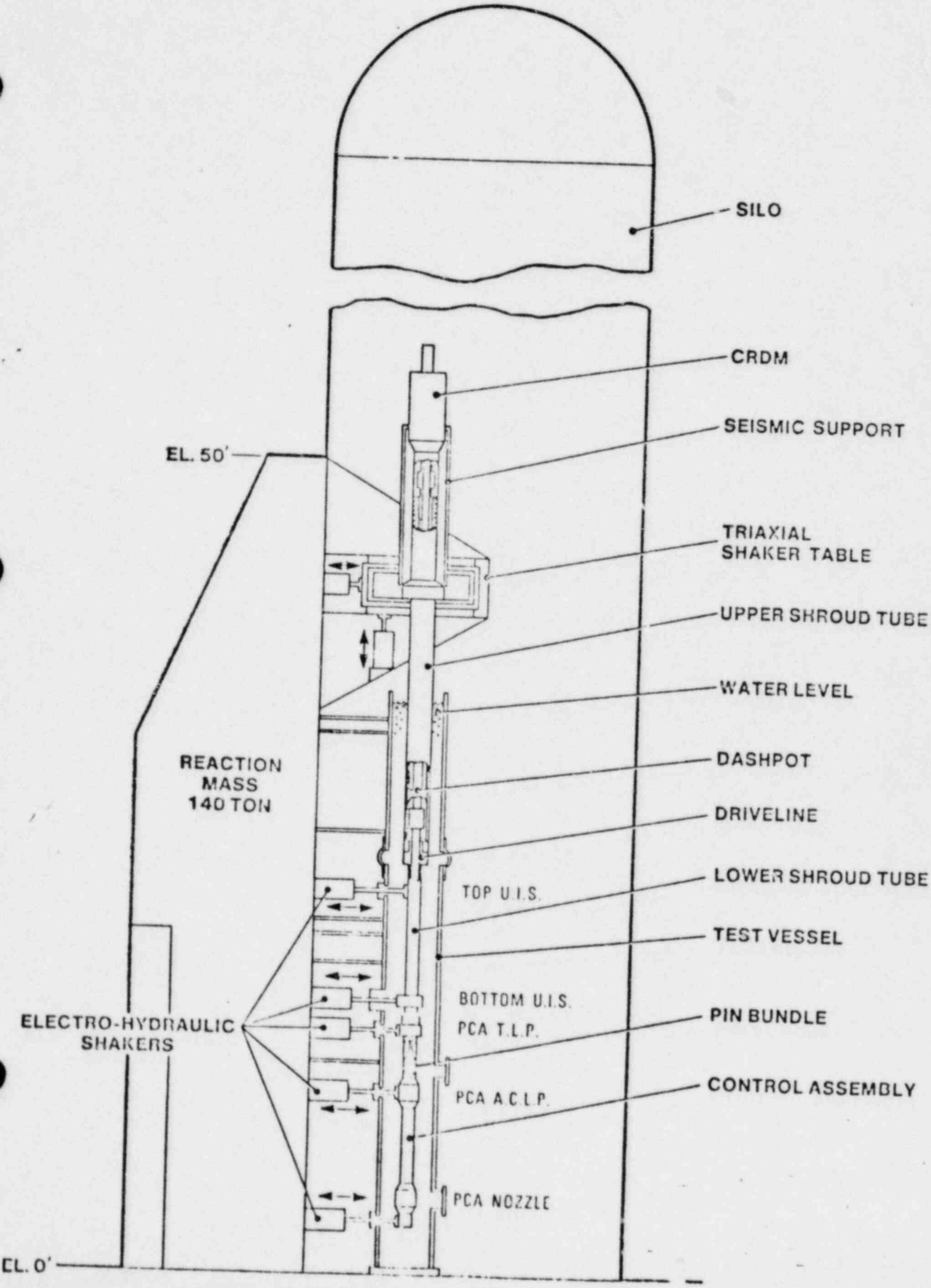
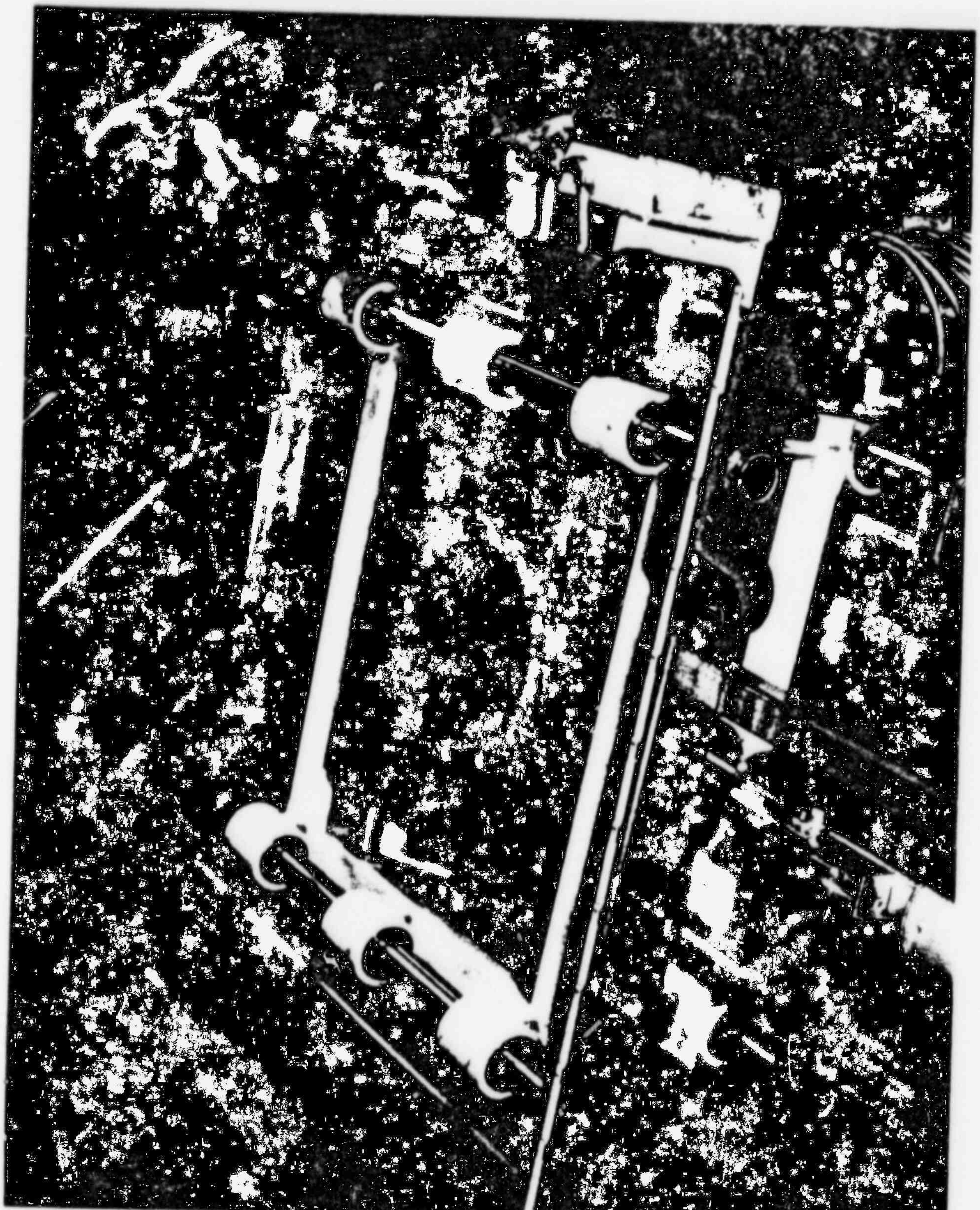
DYNAMIC AND SEISMIC TEST FACILITY





SCRS SCRAM VALVE SEISMIC TEST

Requirements

- Scram valve (pilot valve portion) is part of the plant protection system and falls within IEEE class 1E definition
- Reg. Guide 1.89 and IEEE-323 require seismic qualification of class 1E components
- Reg. Guide 1.100 and IEEE-344 specify seismic qualification requirements
- Reactor system seismic analysis results provide required response spectra

7237-5

SCRS SCRAM VALVE SEISMIC TEST
(Continued)

Seismic Test Description

- Complete valve/cylinder assembly tested
- Subjected to 5 OBE and 1 SSE simulations (multi-axis excitation)
- Functional test during each simulation and after OBE and SSE simulations

Test Results To Date

- Completed seismic test of prototype valve/cylinder assembly
- Met all requirements

7237-6

SCRS SCRAM VALVE/CYLINDER SEISMIC TEST

Method

- IEEE-344
- Response spectra based on 1% damping and for location within SCRDM
- Bi-axial, verticle and horizontal
- 90° equipment rotation for each OBE and the SSE
- 30 second minimum duration at each position
- Axial load applied to tension rod
- Tenson rod movement instrumented
- Each scram performed during seismic vibration with a single valve logic train (2 of 3) non-operational
- Room temperature in air

Sequence

- Pre-seismic test
- 5 OBE, with 90° equipment rotation
  - Two at reference position, three at 90°
- Scram after each OBE
- Three SSE, with 90° equipment rotation
  - One SSE for each logic train
  - Duration: 30 sec., 5 sec., 5 sec.
- Post-seismic test
  - Two SSE's at reference position, 1 at 90° rotation

SCRS SCRAM VALVE/CYLINDER SEISMIC TEST
(Continued)

Criteria

- Scram time (tension rod movement) occurs within control rod release delay time (.1 sec.)
- No visable or functional damage

Prototype Test Results

- No damage
- Tension rod movement time limit
  - Criteria: $\leq$ .1 sec.
  - Test values: .062 sec. max.
.050 sec. min.

7237-12

CONTROL ROD SYSTEMS
DYNAMIC/SEISMIC TESTS

Application Of Seismic Test Results To Design Support

- Dynamic friction test
  - Friction coefficients used in PCRS and SCRS seismic scram analysis
  - Preliminary verification of scram insertion analysis methods
- PCRS seismic test
  - Confirmation of PCRDM unlatch design basis
  - Validate methods used for PCRS and SCRS seismic scram insertion analyses
- SCRS scram valve test
  - Verification of scram actuator performance under seismic conditions

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CONTROL ROD SYSTEMS
DYNAMIC/SEISMIC TESTS
(Continued)

Conclusions

- Completed tests show satisfaction of design requirements
  - Dynamic friction test
    - Seismic scram speed requirements met using test friction coefficients in scram analyses
  - SCRS prototype scram valve test
    - Functional requirements satisfied
- Tests plans defined for confirmation of PCRS and SCRS seismic scram capability

7237-8

SEISMIC DESIGN OF HTS COMPONENTS

QUESTIONS ADDRESSED

- WHAT IS THE ARRANGEMENT OF HTS COMPONENTS?
- DO THE CRBRP SEISMIC METHODS AND CRITERIA INCLUDE THE CONVENTIONAL CONSERVATISMS?
- DO THE MAJOR COMPONENTS HAVE INHERENT SEISMIC MARGIN CAPABILITY?
- WHAT ARE SOME OF THE SPECIAL ATTRIBUTES CONSIDERED IN DESIGN OF CRBRP COMPONENTS?
- WHAT SPECIAL ACTIONS HAVE BEEN TAKEN IN VIEW OF THE LIMITED PRIOR LMFBR EXPERIENCE?

CONCLUSION

- SEISMIC SAFETY LEVELS FOR CRBRP AND LWR COMPONENTS ARE COMPARABLE.

Mallett

T14

ACRS CRBRP SUBCOMMITTEE MEETING

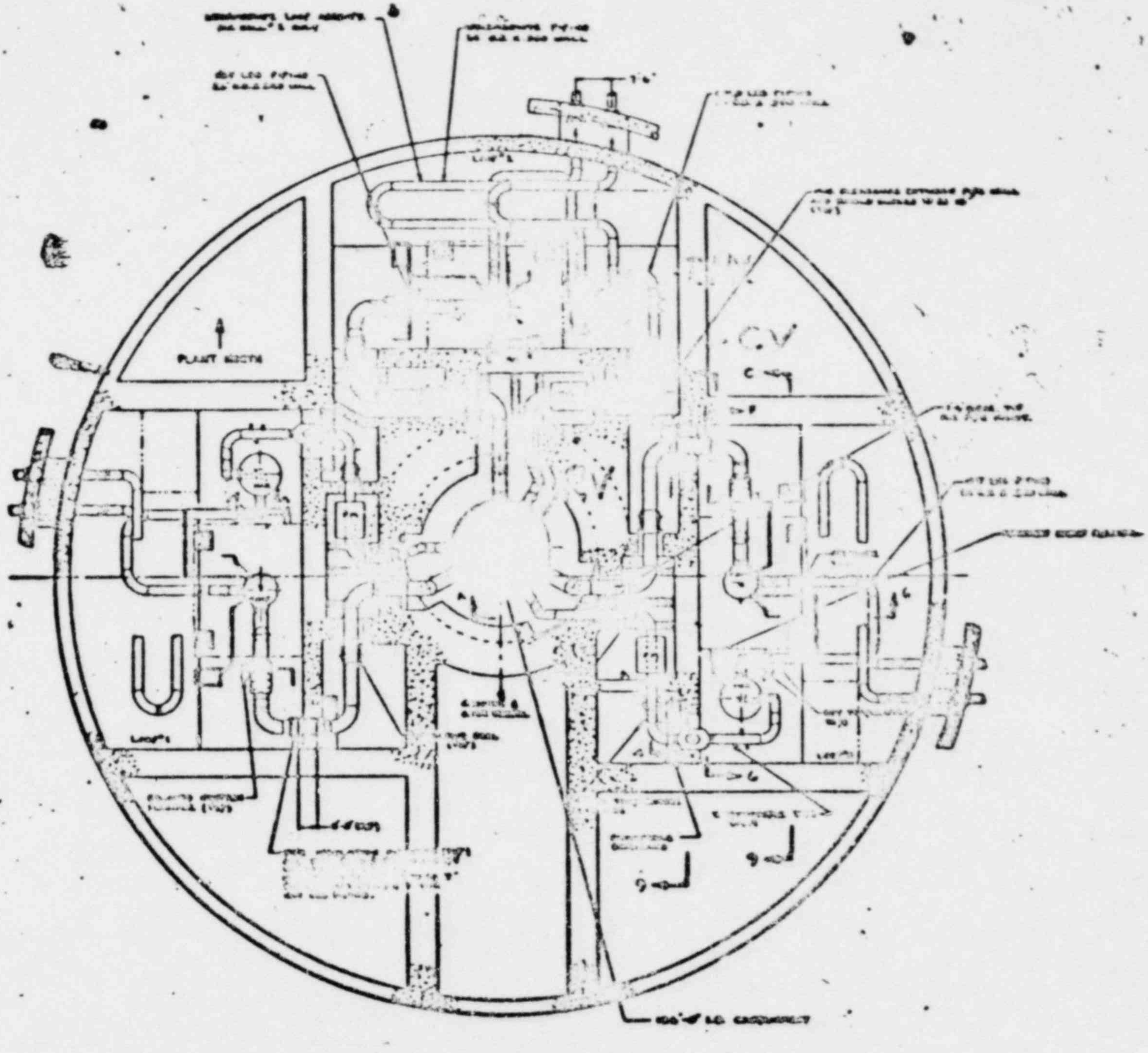
ON

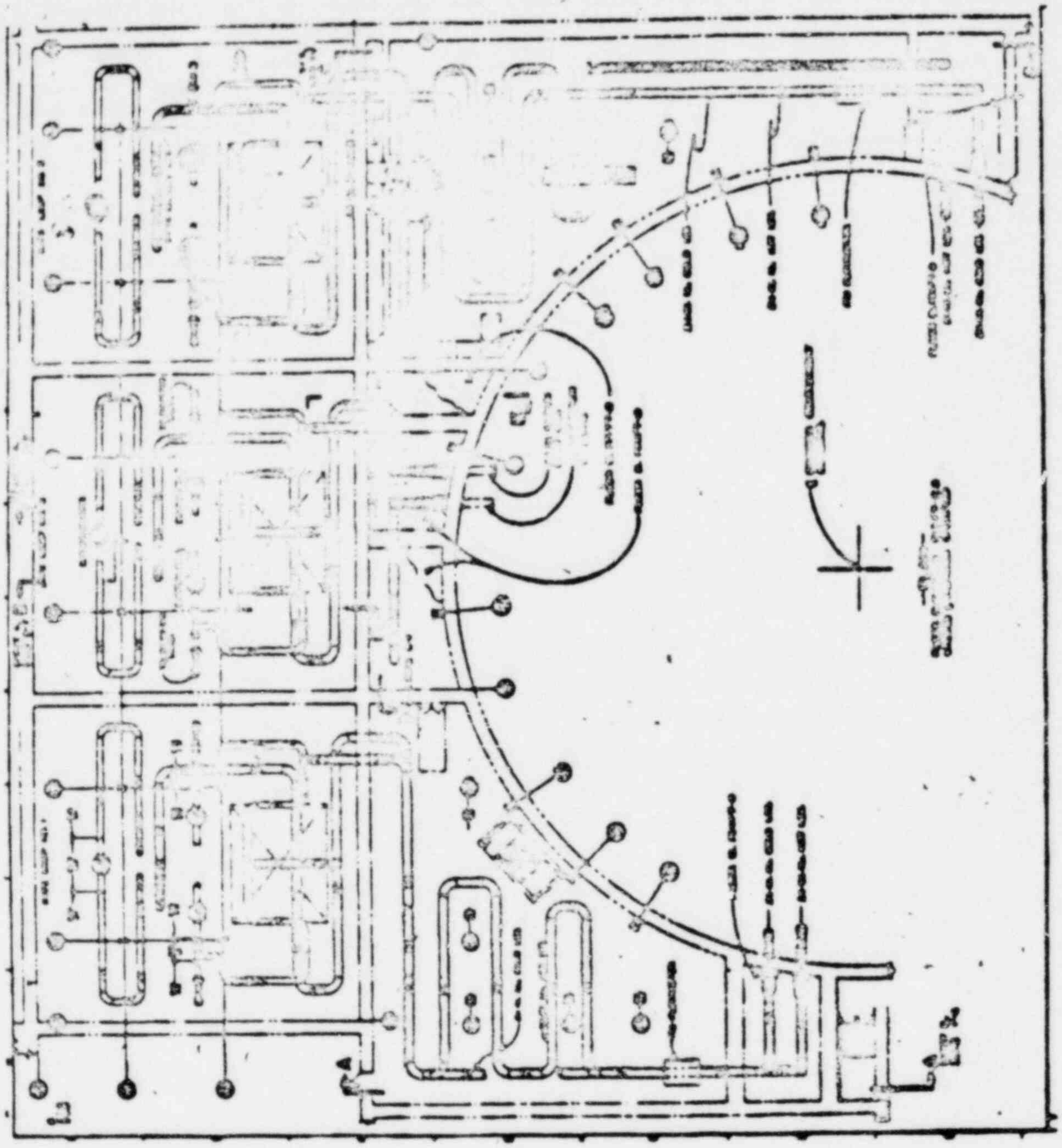
SEISMIC DESIGN

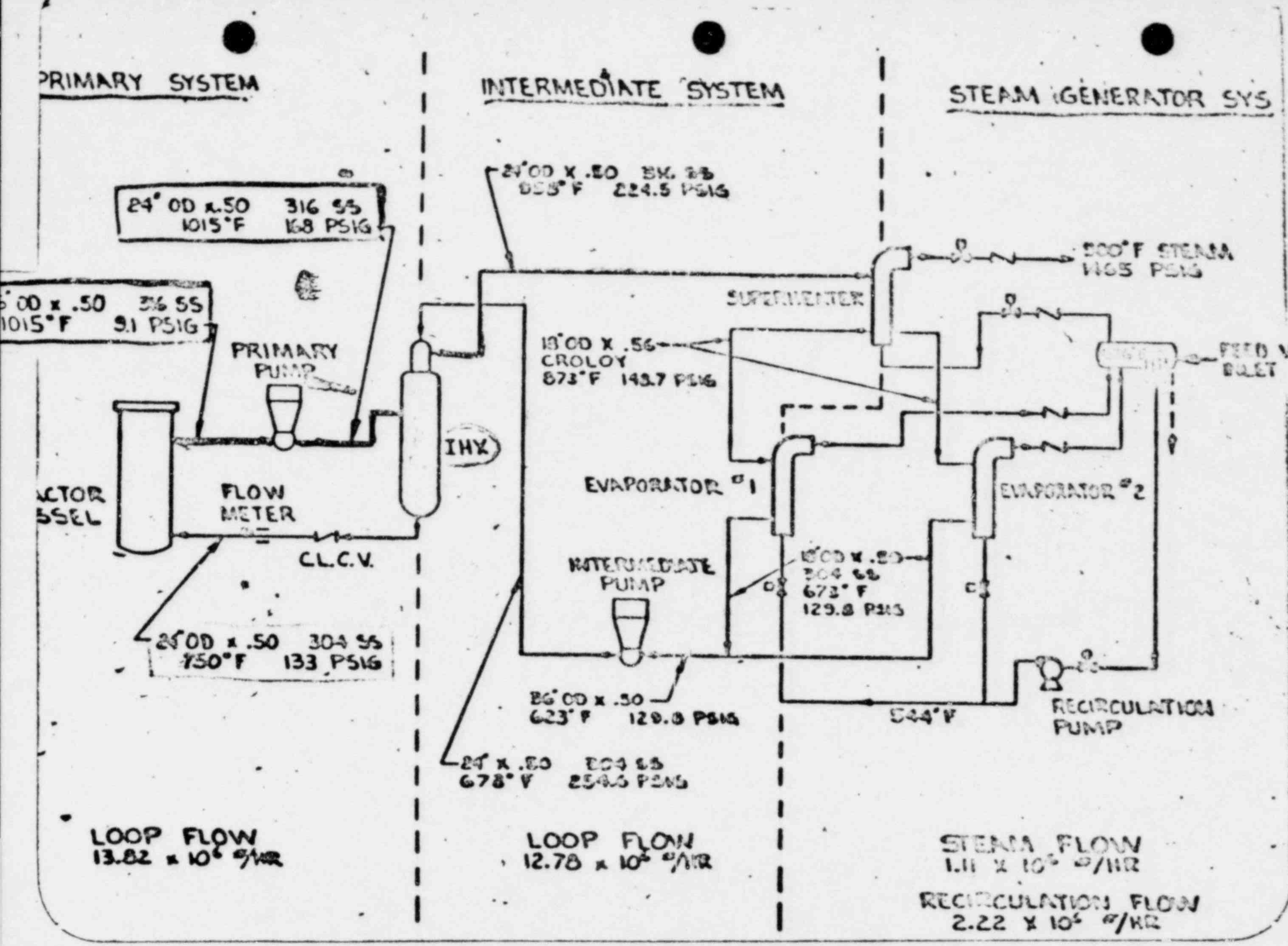
JUNE 1 & 2, 1982

AGENDA ITEM	TOPIC
IV.B	SEISMIC DESIGN OF HEAT TRANSPORT SYSTEM COMPONENTS

ROBERT H. MALLETT
MECHANICAL EQUIPMENT &
PIPING DESIGN
WESTINGHOUSE
ADVANCED REACTORS DIVISION

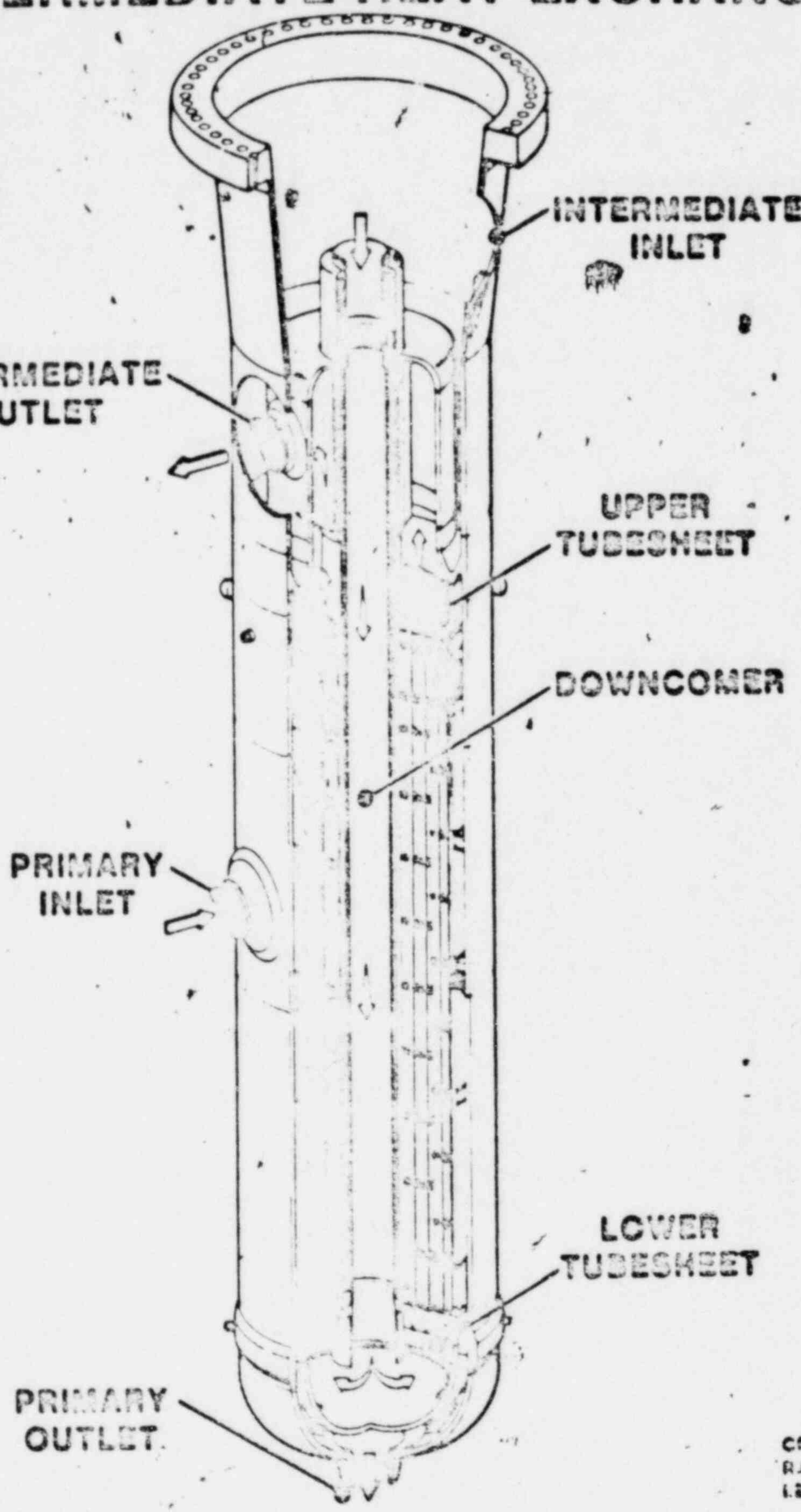




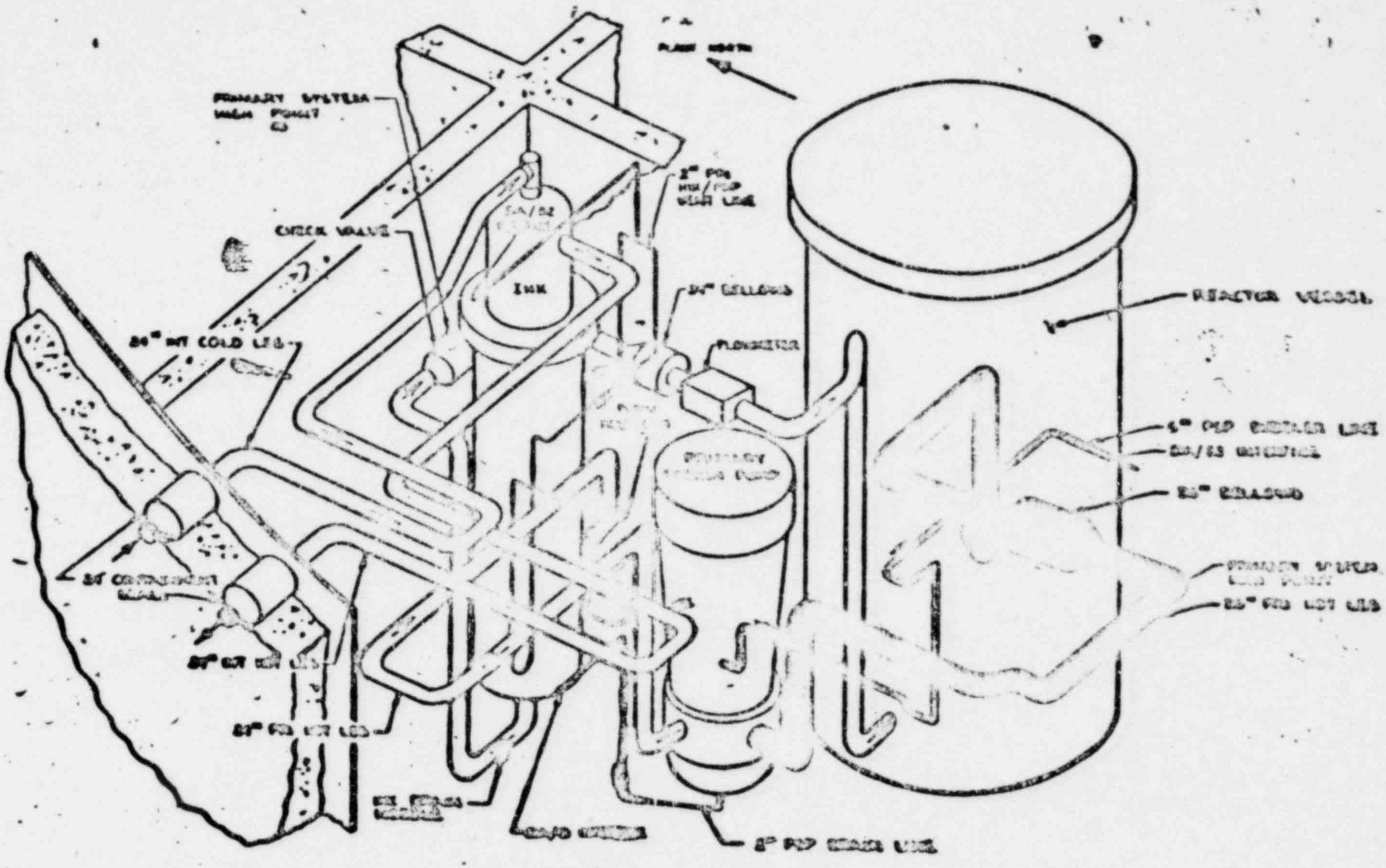

PRIMARY SYSTEM
INTERMEDIATE SYSTEM
STEAM GENERATOR SYS
24" OD x .50 316 SS
1015°F 168 PSIG
OD x .50 316 SS
1015°F 9.1 PSIG
PRIMARY PUMP
IHX
ACTOR
SSEL
FLOW METER
CL.C.V.
25" OD x .50 304 SS
750°F 133 PSIG
LOOP FLOW
13.82 x 10⁶ #/HR
18" OD x .56
CROLOY
873°F 143.7 PSIG
SUPERHEATER
EVAPORATOR #1
EVAPORATOR #2
INTERMEDIATE PUMP
304 SS
673°F
129.8 PSIG
623°F 129.8 PSIG
24" x .50 304 SS
678°F
544°F
RECIRCULATION PUMP
LOOP FLOW
12.78 x 10⁶ #/HR
STEAM FLOW
1.11 x 10⁶ #/HR
RECIRCULATION FLOW
2.22 x 10⁶ #/HR

③ Support for STIFFNESS - High strength m

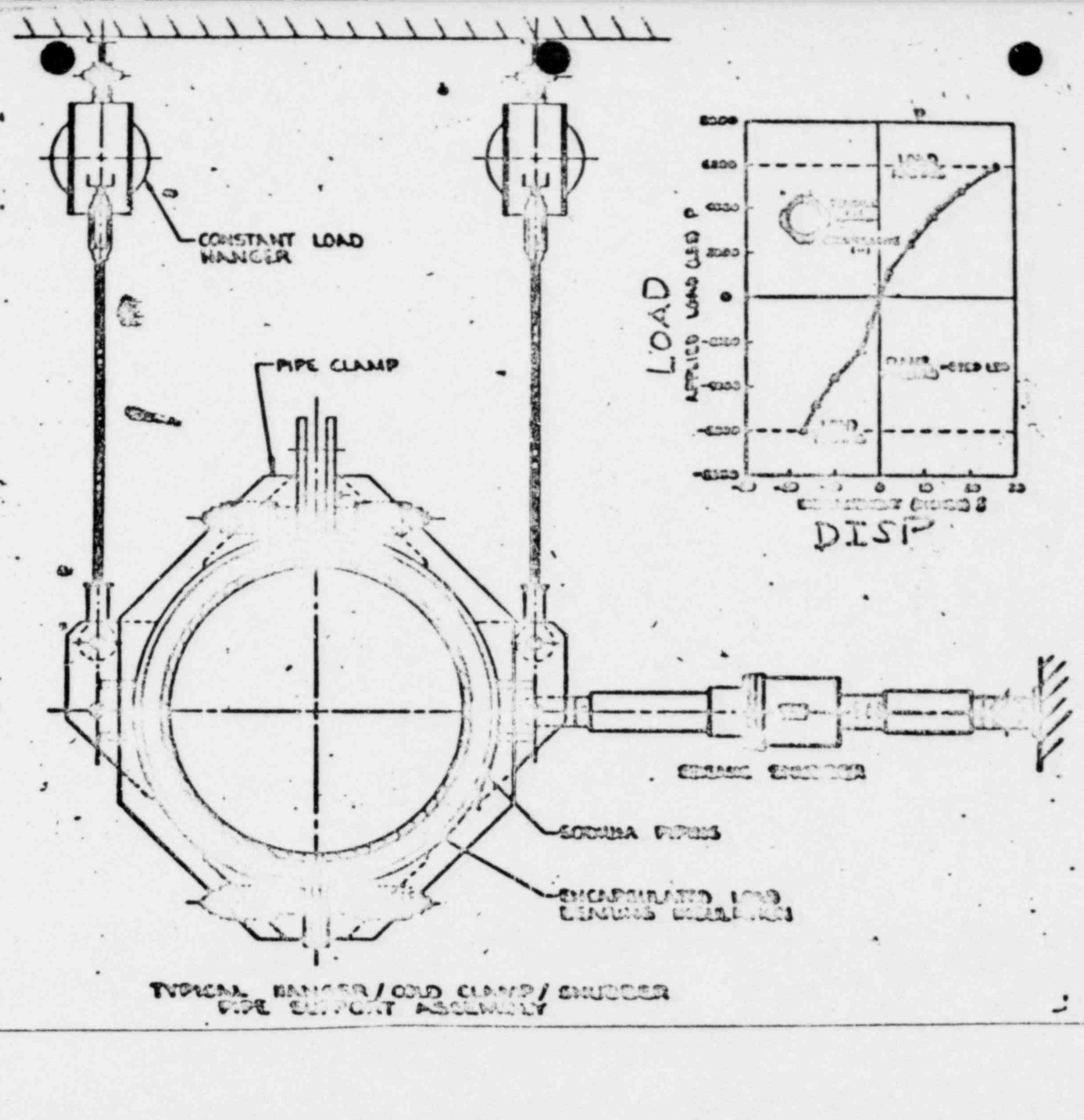
INTERMEDIATE HEAT EXCHANGER



④ Under Seismic → WAG → Cone buckling
→ No ~~axle~~ motion



IN CONTAINMENT HTS PIPING
LOOP #1



TYPICAL HANGER/COLD CLAMP/SNUBBER PIPE SUPPORT ASSEMBLY

9

SEISMIC DESIGN OF HTS COMPONENTS

CONCLUSION

THE SEISMIC DESIGN PROBLEM IS ESSENTIALLY THE SAME EXCEPT FOR DIFFERENCES DUE TO HIGHER TEMPERATURE AND LOWER PRESSURE.

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SEISMIC DESIGN OF HTS COMPONENTS

QUESTION

- DO THE CRBRP SEISMIC METHODS AND CRITERIA INCLUDE THE CONVENTIONAL CONSERVATISMS?
  - MODELS
  - METHODS
  - CRITERIA

WECAN

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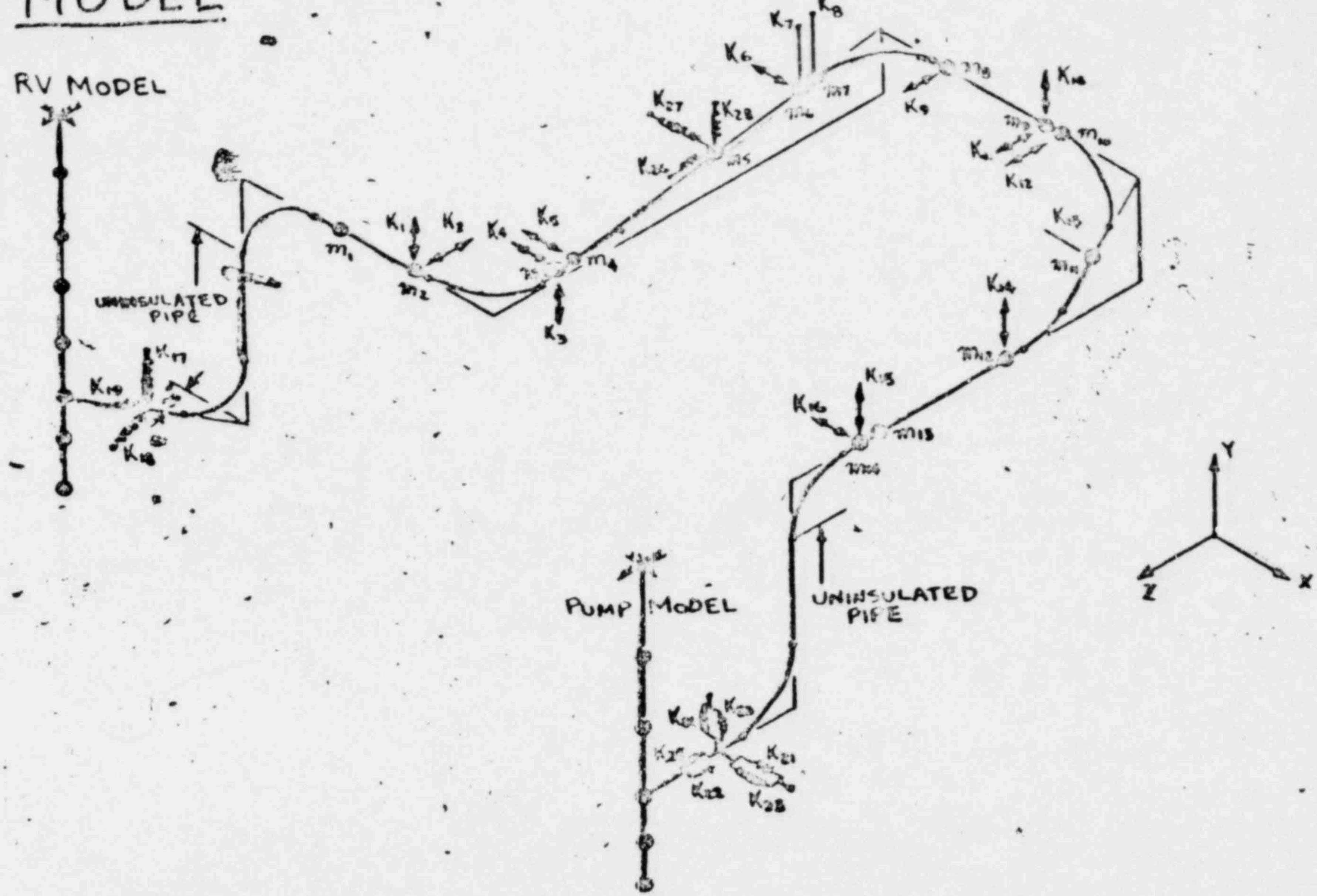
MODEL



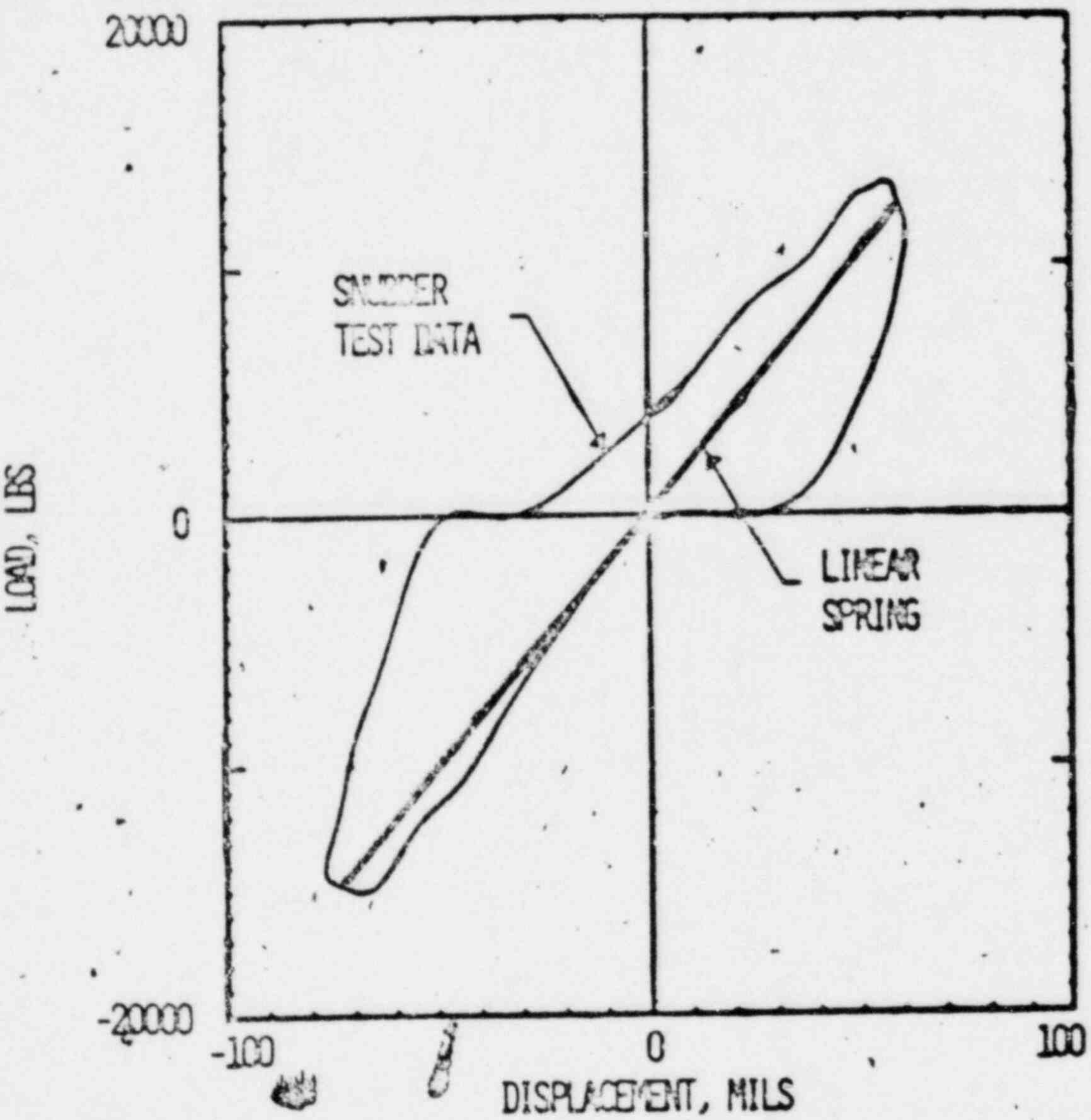
Difference is: — number of ELBOWs

① Example of conventional conservatism

12 ⑤ Somewhat greater for LMFBR

SEISMIC DESIGN OF HTS COMPONENTS

SNUBBER MODEL CONSERVATISM



COMPARISON OF LINEAR SPRING MODEL RESPONSE AND SNUBBER TEST DATA

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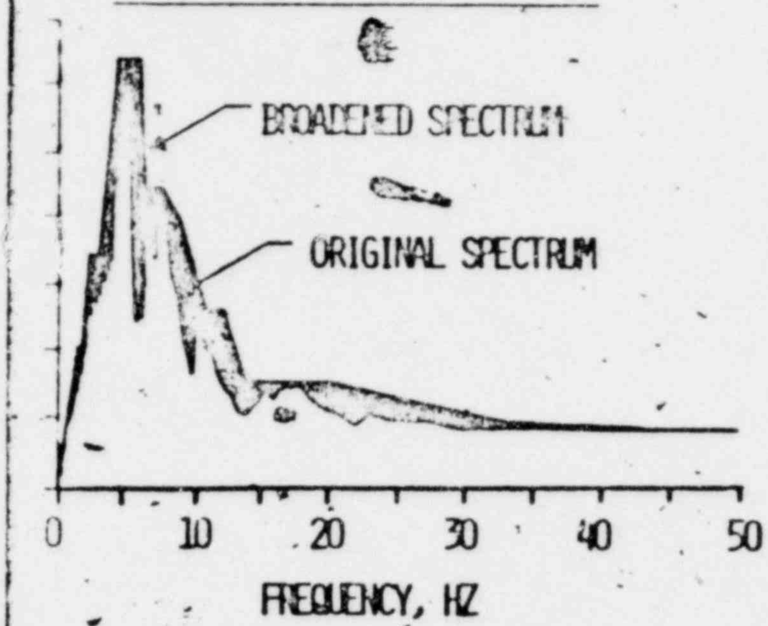
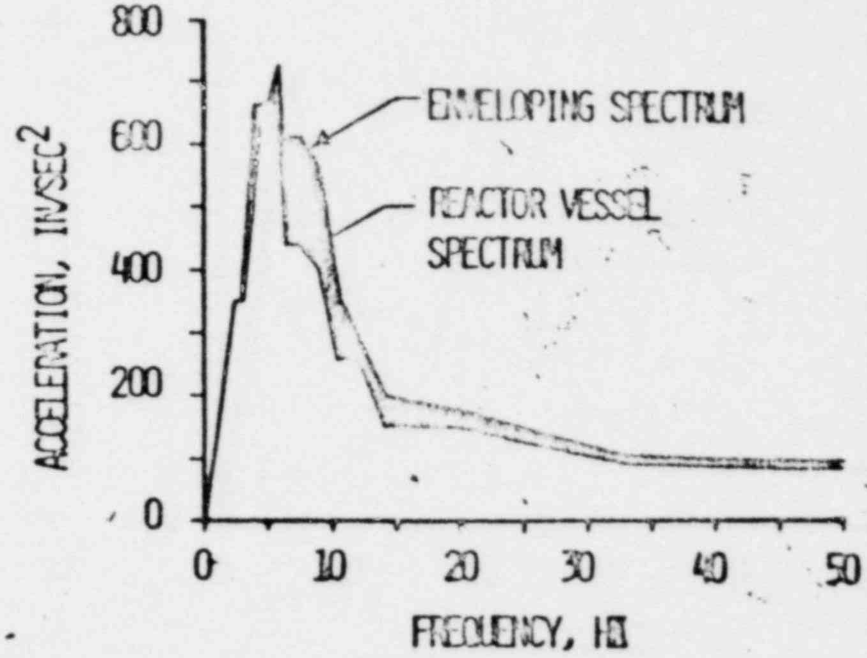
SEISMIC DESIGN OF HTS COMPONENTS

RESPONSE SPECTRA CONSERVATISM



SPECTRUM BROADENING FOR FREQUENCY UNCERTAINTY



SPECTRUM ENVELOPING FOR UNIFORM BASE MOTION

SEISMIC DESIGN OF [illegible] COMPONENTS

CRITERIA:

SEISMIC ANALYSIS RESULTS

	OBE CONDITION		SSE CONDITION	
EL. NO.	MAXIMUM STRESS	ALLOWABLE STRESS	MAXIMUM STRESS	ALLOWABLE STRESS
1	18.41 — 57% —	19.44	31.94 — 75% —	45.93
2	15.67	19.44	27.33	45.93
3	10.14	19.44	17.78	45.93
4	9.56	19.44	16.26	45.93
5	6.85	19.44	11.48	45.93
6	8.42	19.44	14.51	45.93
7	7.11	19.44	12.04	45.93
8	7.21	19.44	12.12	45.93

$(P_L + P_B)$ 36" HOT LEG

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SEISMIC DESIGN OF HTS COMPONENTS

CONCLUSION

- CRBRP SEISMIC DESIGN METHODS AND CRITERIA INCLUDE THE CONVENTIONAL CONSERVATISMS.

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SEISMIC DESIGN OF HTS COMPONENTS

QUESTION

- DO THE MAJOR COMPONENTS HAVE INHERENT SEISMIC MARGIN CAPABILITY?

    - REFERENCE LETTER

      PSL:L:77-286, APRIL 21, 1977

X

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SEISMIC DESIGN OF HTS COMPONENTS

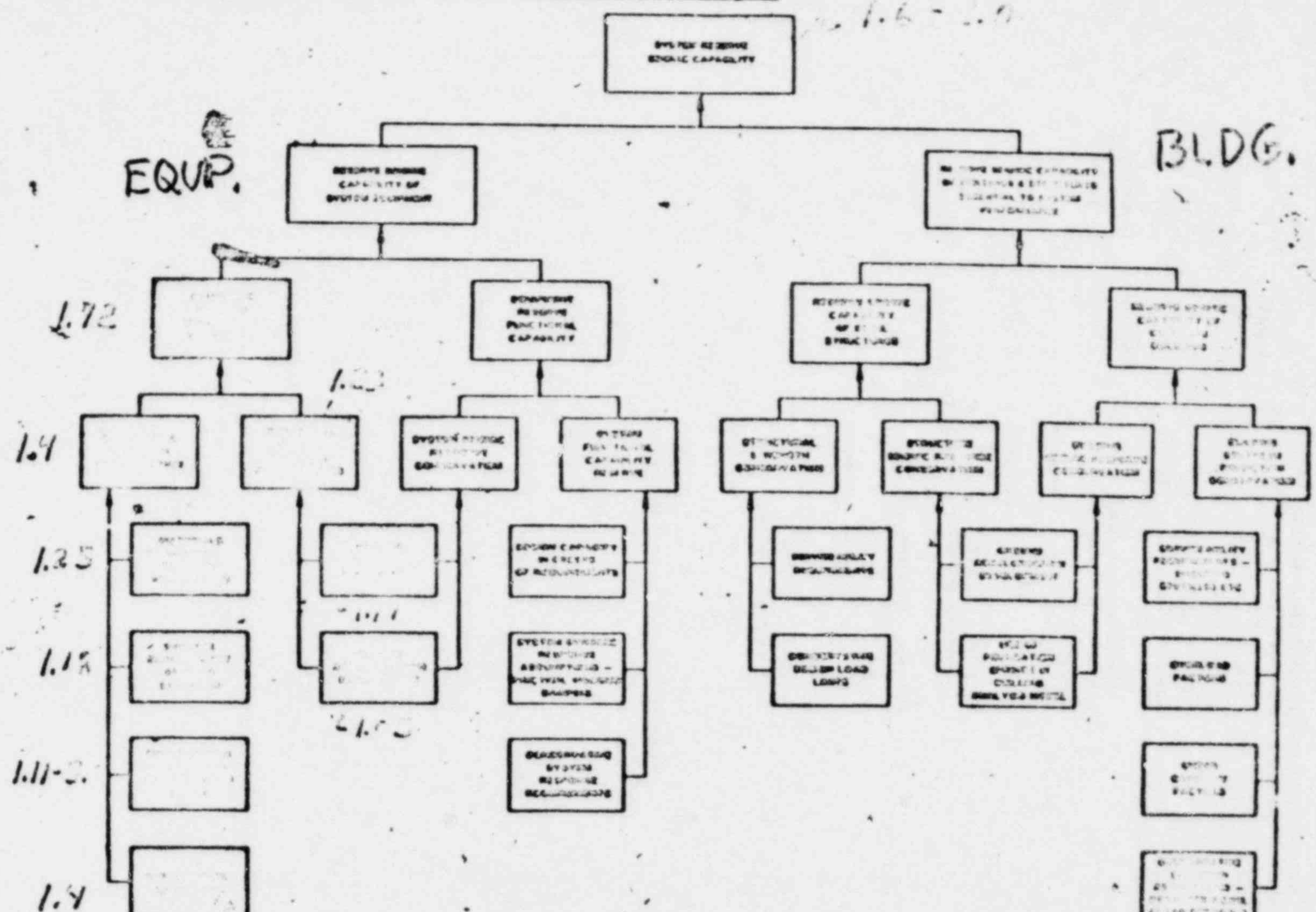
SOURCES OF MARGIN

- CONSERVATIVE PREDICTIONS OF RESPONSE.
- CONSERVATIVE DEFINITIONS OF STRUCTURAL AND PERFORMANCE LIMITS.
- CONSERVATISM INCORPORATED BY DESIGNER.

SEISMIC DESIGN OF HTS COMPONENTS

(Nominal Allowable / Design Limit)

SYSTEM EVALUATION PROCEDURE FOR SEISMIC MARGIN



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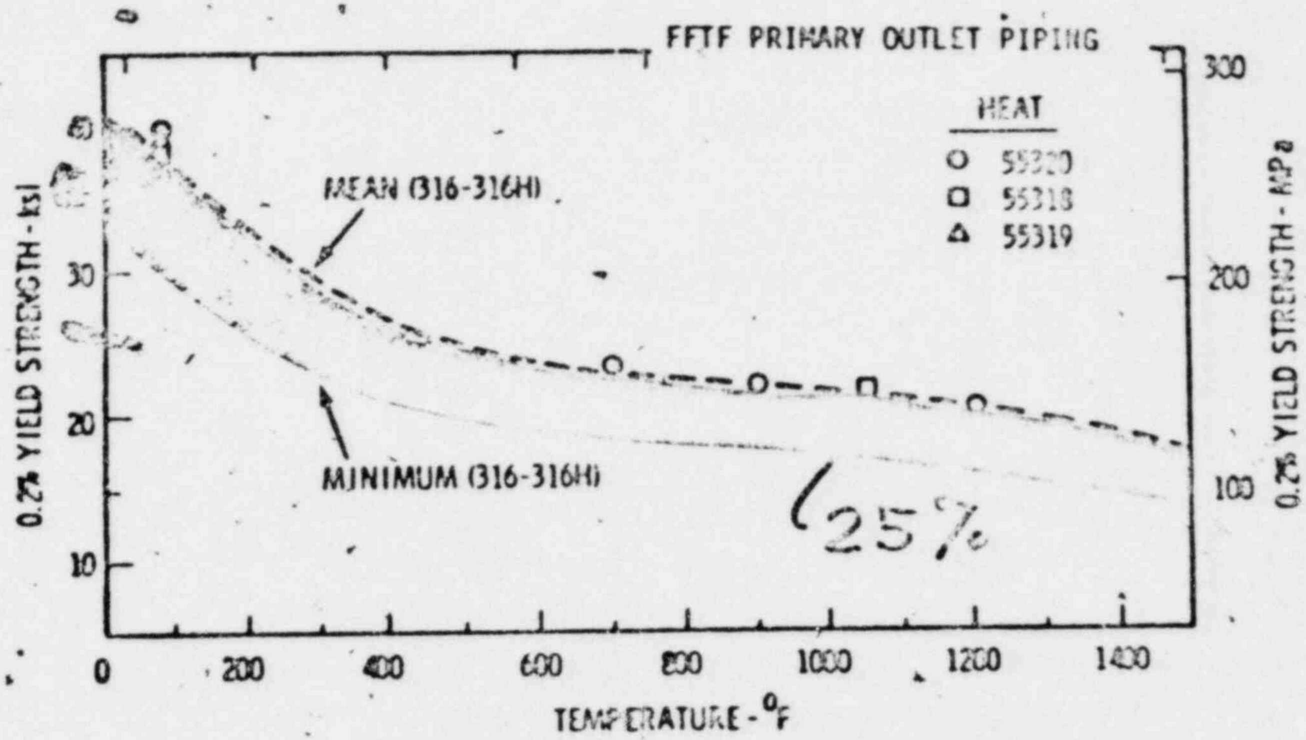
SEISMIC DESIGN OF HTS COMPONENTS

LIMIT MARGIN SOURCE	STRENGTH MARGIN
• ASSUMPTION OF MINIMUM STRENGTH MATERIALS PROPERTIES	25%
• DYNAMIC ENHANCEMENT OF MATERIALS YIELD STRENGTH	18%
• CONSERVATIVE SAFETY FACTORS BUILT INTO THE DESIGN LOAD & STRESS LIMITS	11% - 300%

EQUIPMENT STRENGTH MARGIN $\simeq 1.4$

$$\frac{\text{Nominal Allowable}}{\text{Design Limit}}$$



Temperature Dependence of Strength of Type 316H Stainless Steel Piping Material.

SEISMIC DESIGN OF HTS COMPONENTS

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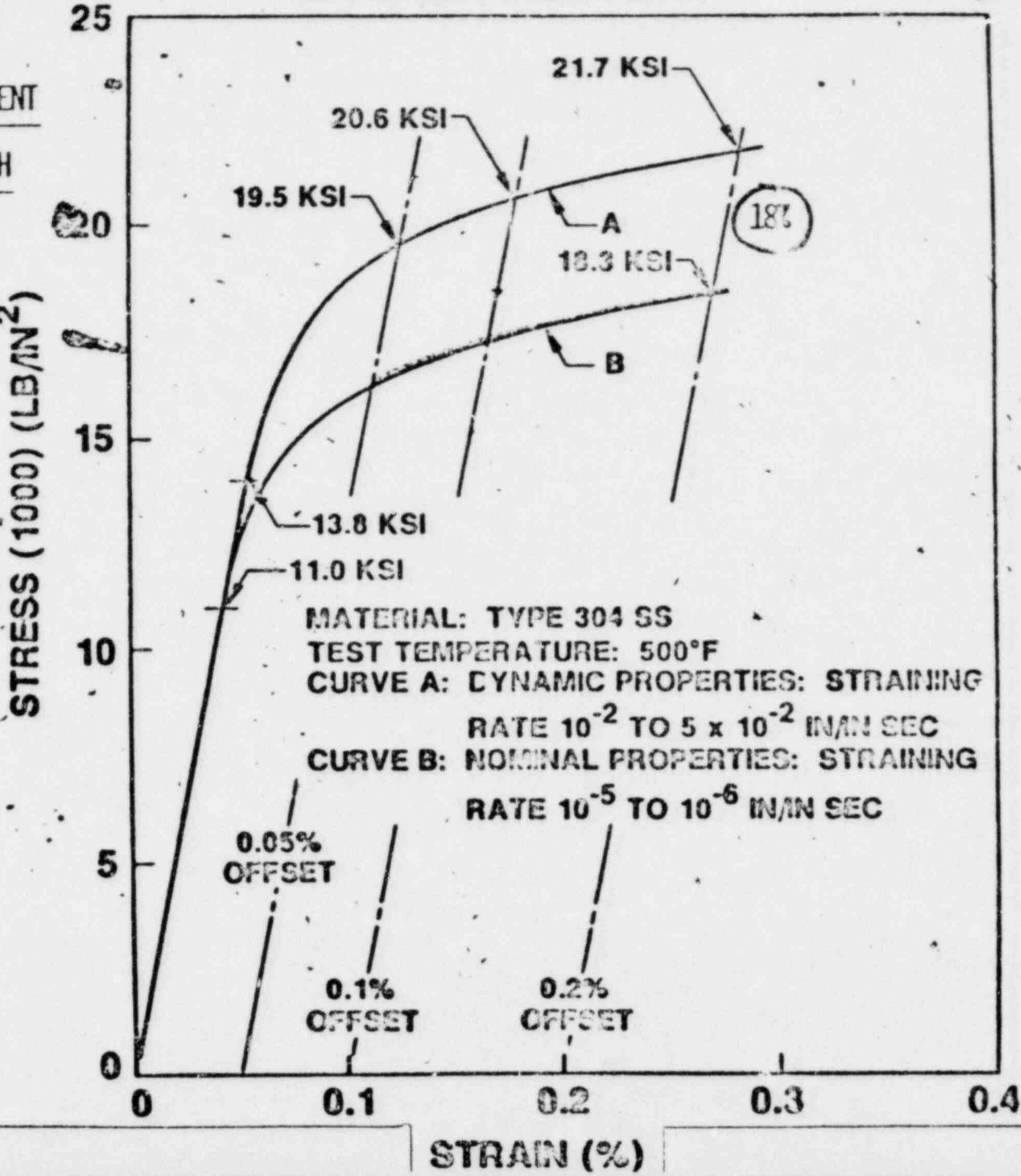
DYNAMIC ENHANCEMENT OF YIELD STRENGTH



SEISMIC DESIGN OF [illegible] COMPONENTS

RESPONSE MARGIN SOURCE	RESPONSE MARGIN
• DEVELOPMENT OF GROUND ACCELEROGRAM	5%
• USE OF CONSERVATIVE SYSTEM DAMPING COEFFICIENTS	17%

EQUIPMENT CONSERVATISM = 1.05 x 1.17 = 1.23

2

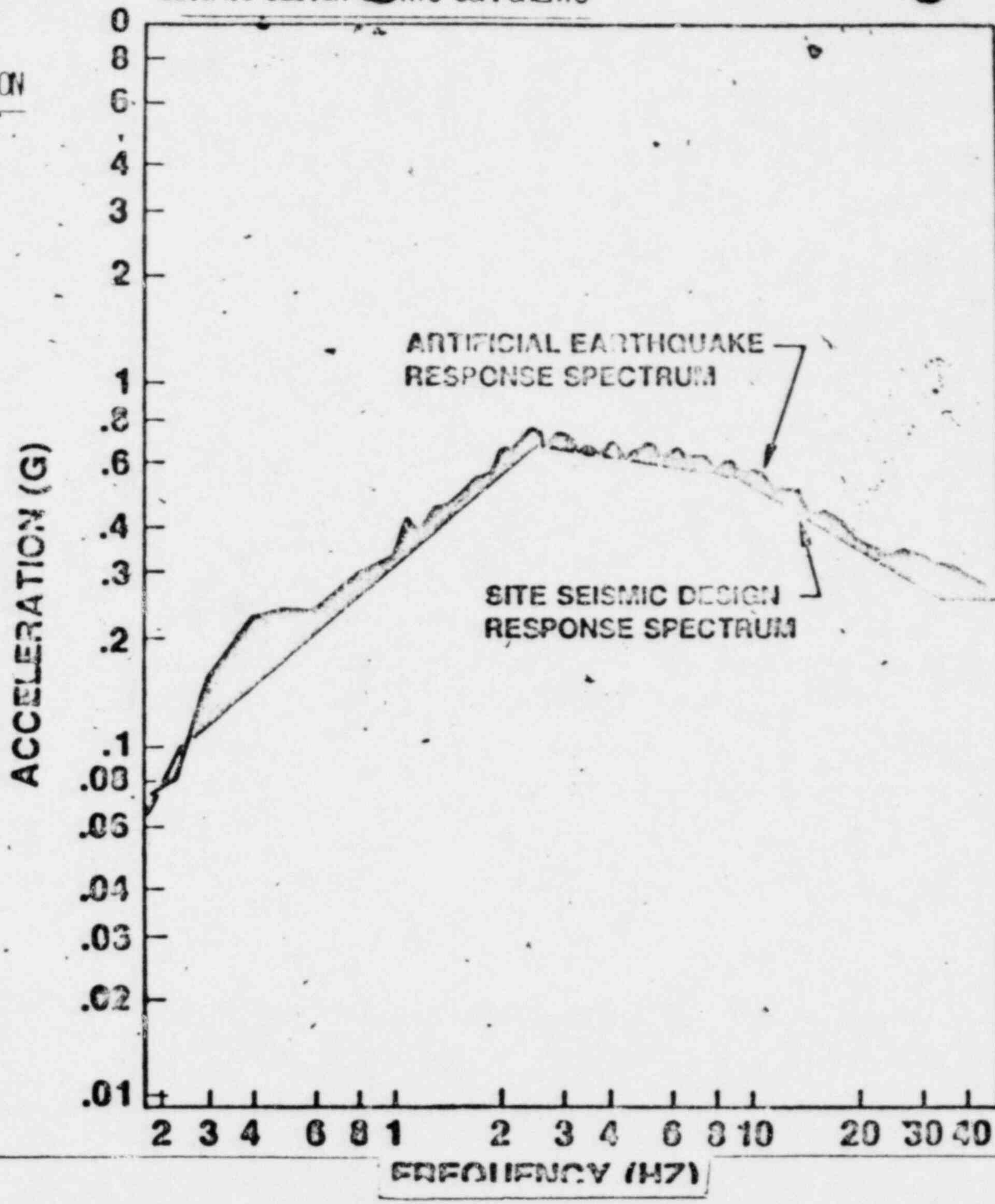
SEISMIC DESIGN [illegible]HTS COMPONENTS

GROUND ACCELERATION

DEVELOPMENT

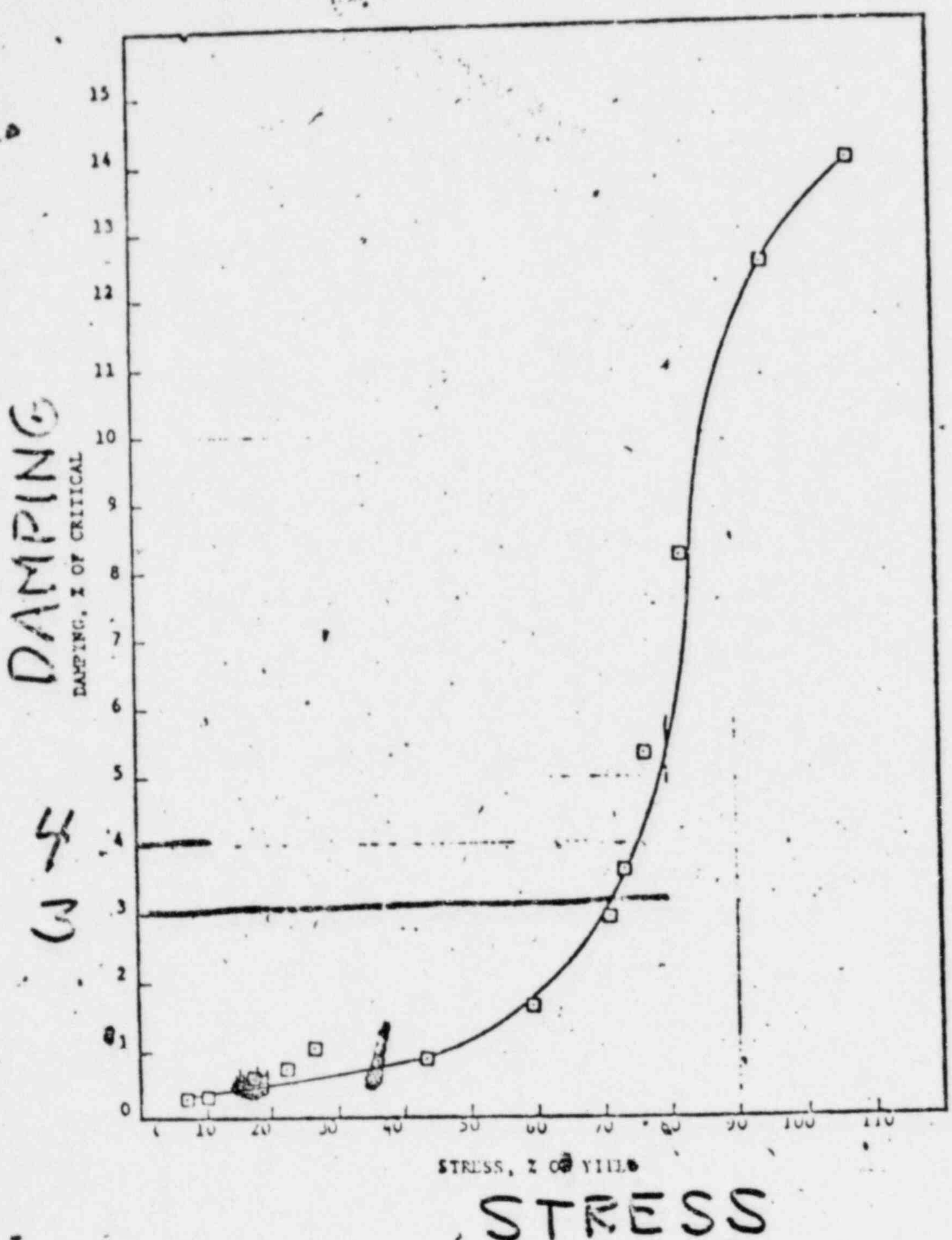
23

X



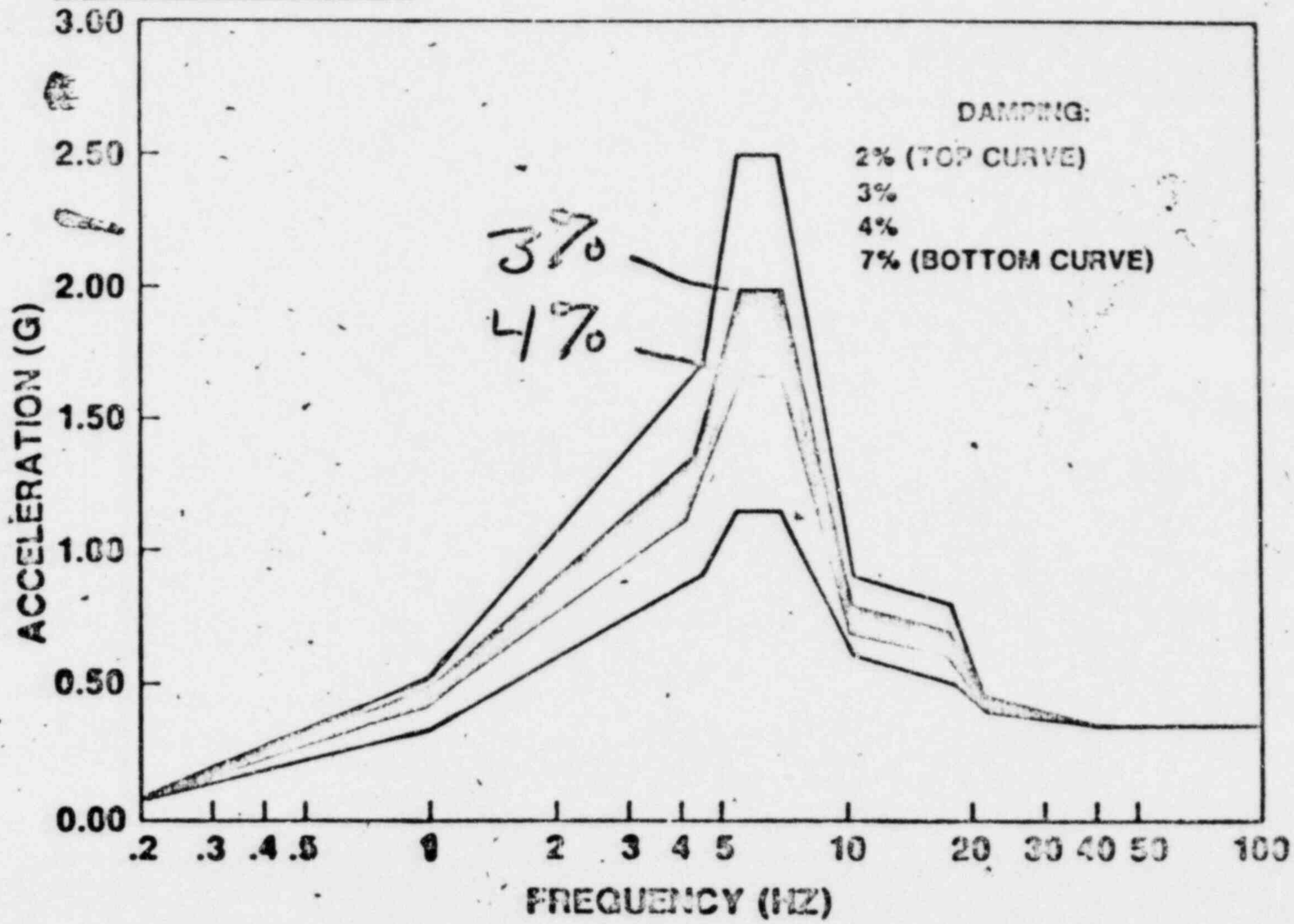
FESULTS OF FIXED-END 1/2" O.D.

PIPE DAMPING TESTS



SEISMIC DESIGN OF HTS COMPONENTS

SYSTEM DAMPING ASSUMPTION



SEISMIC DESIGN OF HTS COMPONENTS

RESERVE STRUCTURAL STRENGTH	
• CODE AVERAGE TO MINIMUM YIELD STRENGTH	1.25
• STRAIN RATE EFFECT ON YIELD STRENGTH	1.18
• CODE SAFETY FACTORS	1.50
• COMBINED EFFECT OF ITEMS 1, 2, AND 3	1.40
SEISMIC RESPONSE CONSERVATISM	
• MARGIN BETWEEN THE CRBRP ARTIFICIAL RESPONSE SPECTRUM AND CRITERIA RESPONSE SPECTRUM	1.05
• SYSTEM DAMPING INCREASES FOR SEISMIC RESPONSES IN EXCESS OF SSE LEVELS	1.17
• COMBINED EFFECT OF ITEMS 1 AND 2	1.23
COMBINED EFFECT	1.72

SEISMIC DESIGN OF HTS COMPONENTS

CONCLUSIONS

INHERENT SEISMIC MARGIN IS AVAILABLE AND COULD BE USED WITHOUT COMPROMISING PLANT SAFETY.

SEISMIC DESIGN OF HTS COMPONENTS

QUESTION

- WHAT ARE SOME OF THE SPECIAL ATTRIBUTES CONSIDERED IN DESIGN OF CRBRP COMPONENTS?
  - LOADINGS
  - FLEXIBILITY
  - CONSEQUENCES

COMPARISON OF SWR/SSE RESTRAINT LOADS

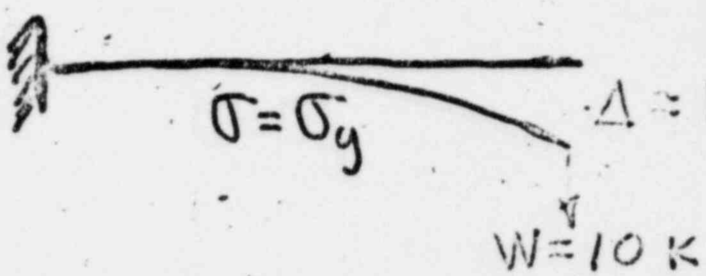
LOADING

- IHTS Hot Leg Piping Designed for Seismic Events.

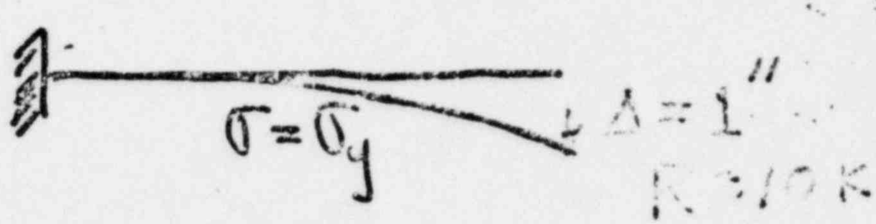
SNUBBER NUMBER	SSE LOAD KIPS	SWR LOAD, KIPS
S-201	21	60
S-202	20	55
S-204	17	18
S-206	30	45
S-207	12	22
S-211	5	12
S-208	4	19
S-210	15	22

STRESS CATEGORIZATION

Name	Characteristic	Symbol
Primary	Can fail in one load application	P
Secondary	No single application can cause failure. Can cause minor distortion	Q
Peak	No distortion. Fatigue failure possible	F



PRIMARY



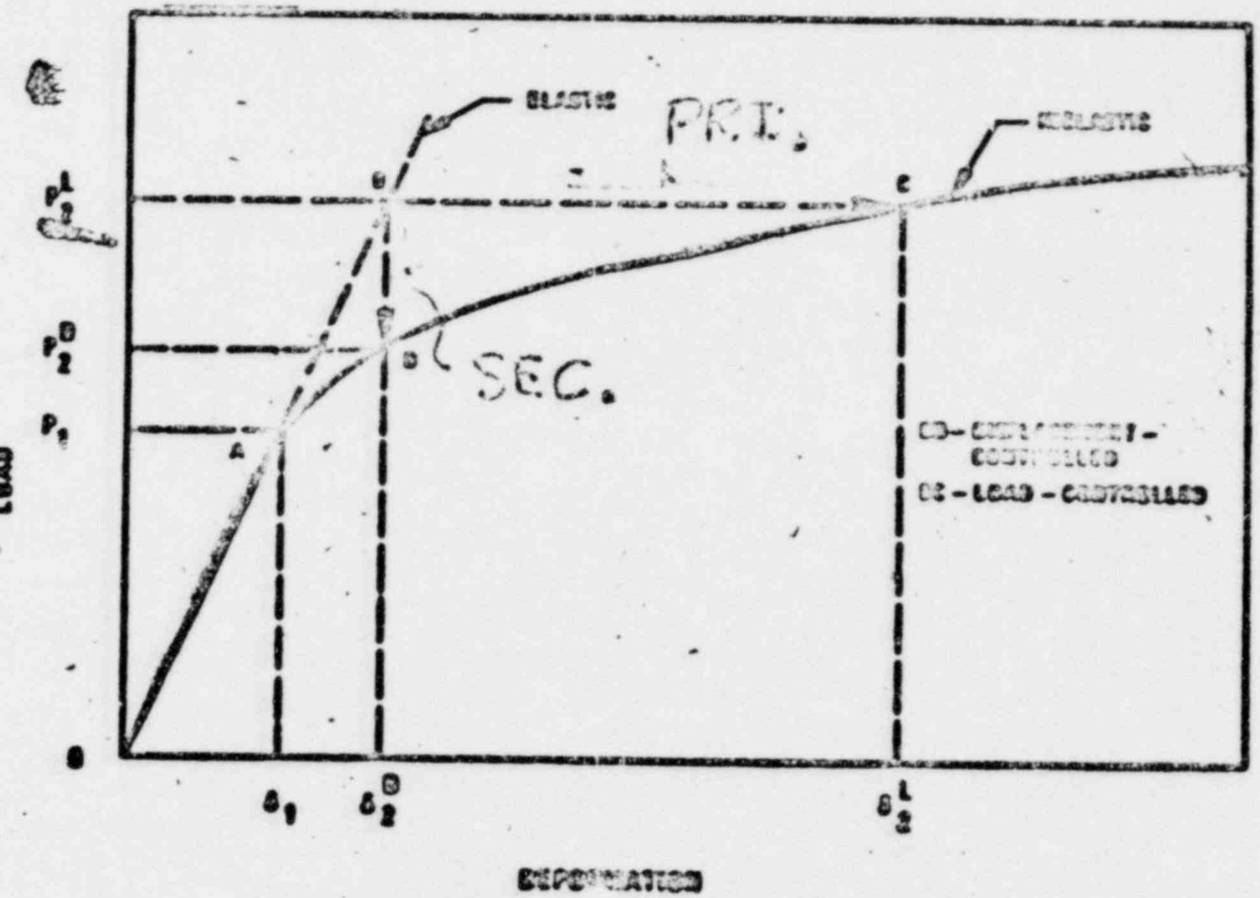
SECONDARY

8226-3

Seismic stress limits are defined assuming seismic stresses are pri.

SEISMIC DESIGN OF HTS COMPONENTS

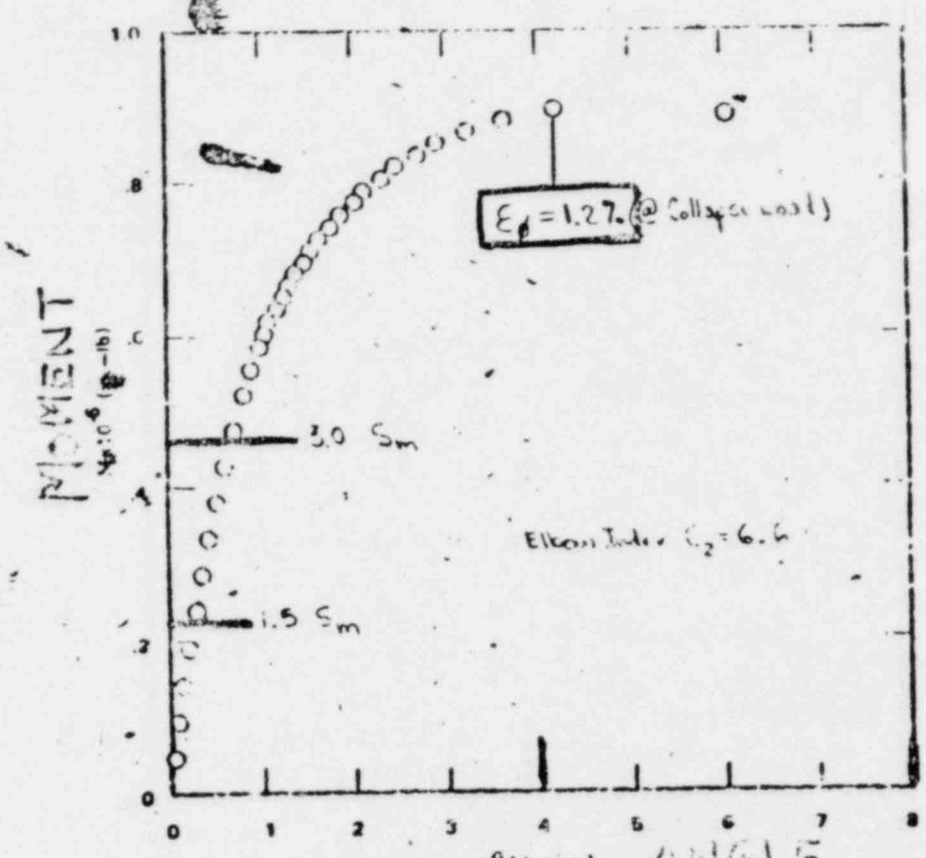
FLEXIBILITY



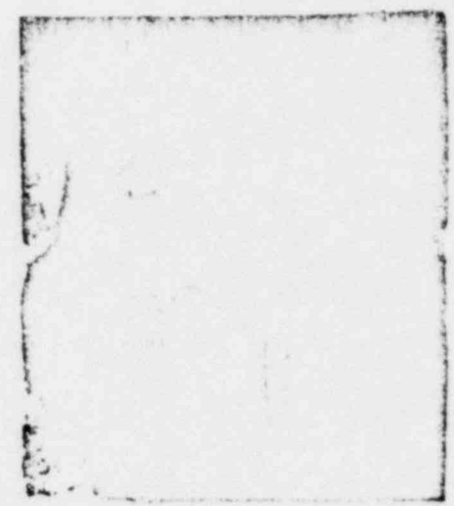
3

SPECIAL ATTRIBUTES

Moment vs Rotation for 16. Inch Elbow With In-Plane Bending Moment



304SS @ 1100°F = 20.37.



Can not reach Failure strain

SIN

[illegible] HOLES LARGE PIPE LOCATIONS

37

CONSEQUENCES

Dwg 6376A38

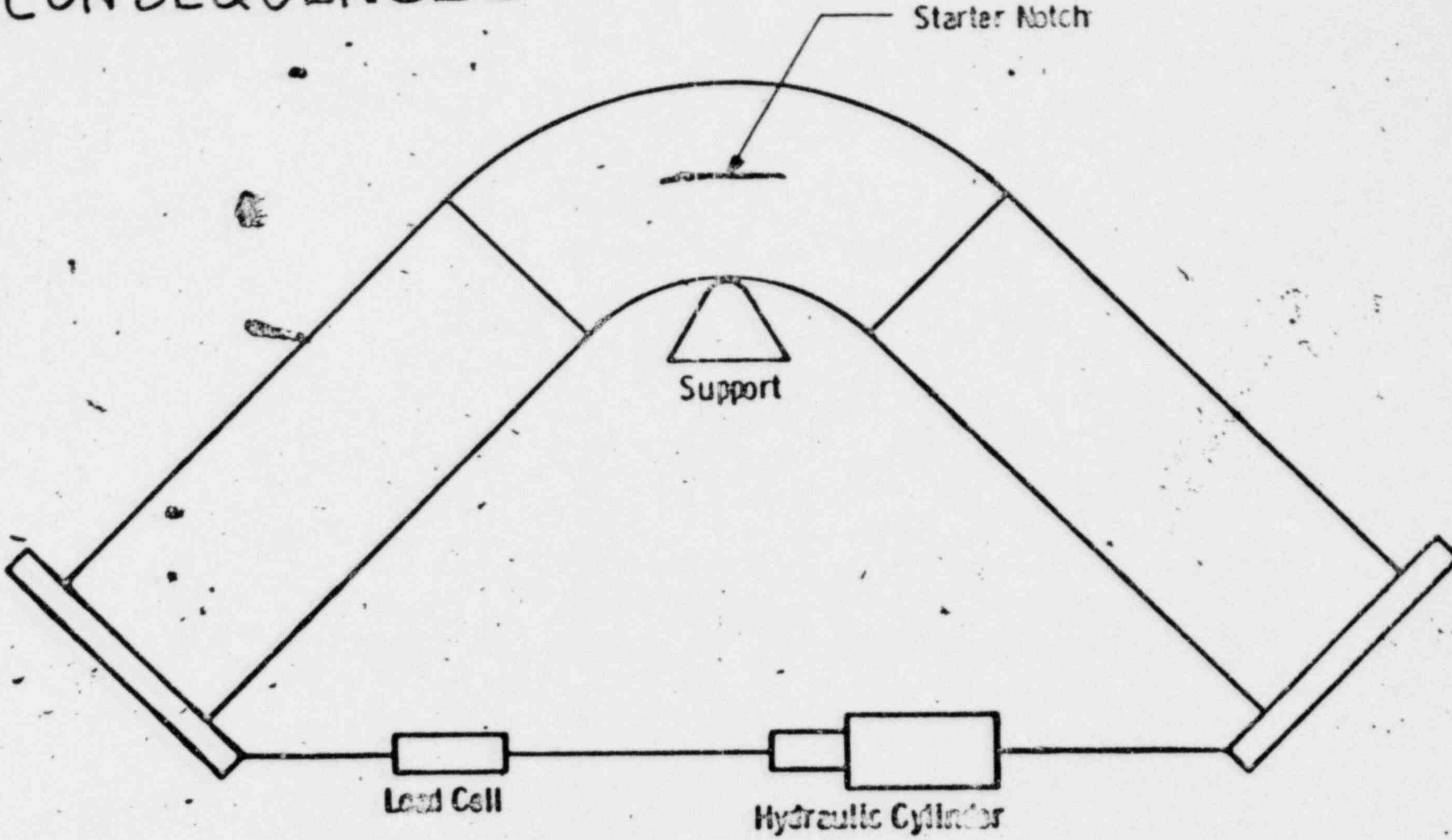


Fig. 24 – Schematic diagram of loading assembly for in-plane bending fatigue test of full-scale elbow

FULL SCALE ELBOW AT END OF
PRESSURIZATION TEST

SEISMIC DESIGN OF RCS COMPONENTS

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CONSEQUENCES

EVALUATION OF PIPING INTEGRITY

- BASIC
  - BASED UPON DESIGN SPECIFICATION
- SPECIAL
  - BASED UPON POSTULATED DEFECT
- EXTENDED
  - BASED UPON FORCING CRACK GROWTH

CONCLUSION

- ABRUPT GROSS LEAKAGE IS NOT CREDIBLE

4C

SEISMIC DESIGN OF HTS COMPONENTS

CONCLUSION

- CRBRP EXHIBITS SPECIAL ATTRIBUTES THAT REDUCE THE RISK ASSOCIATED WITH HIGH SEISMIC LOADS.

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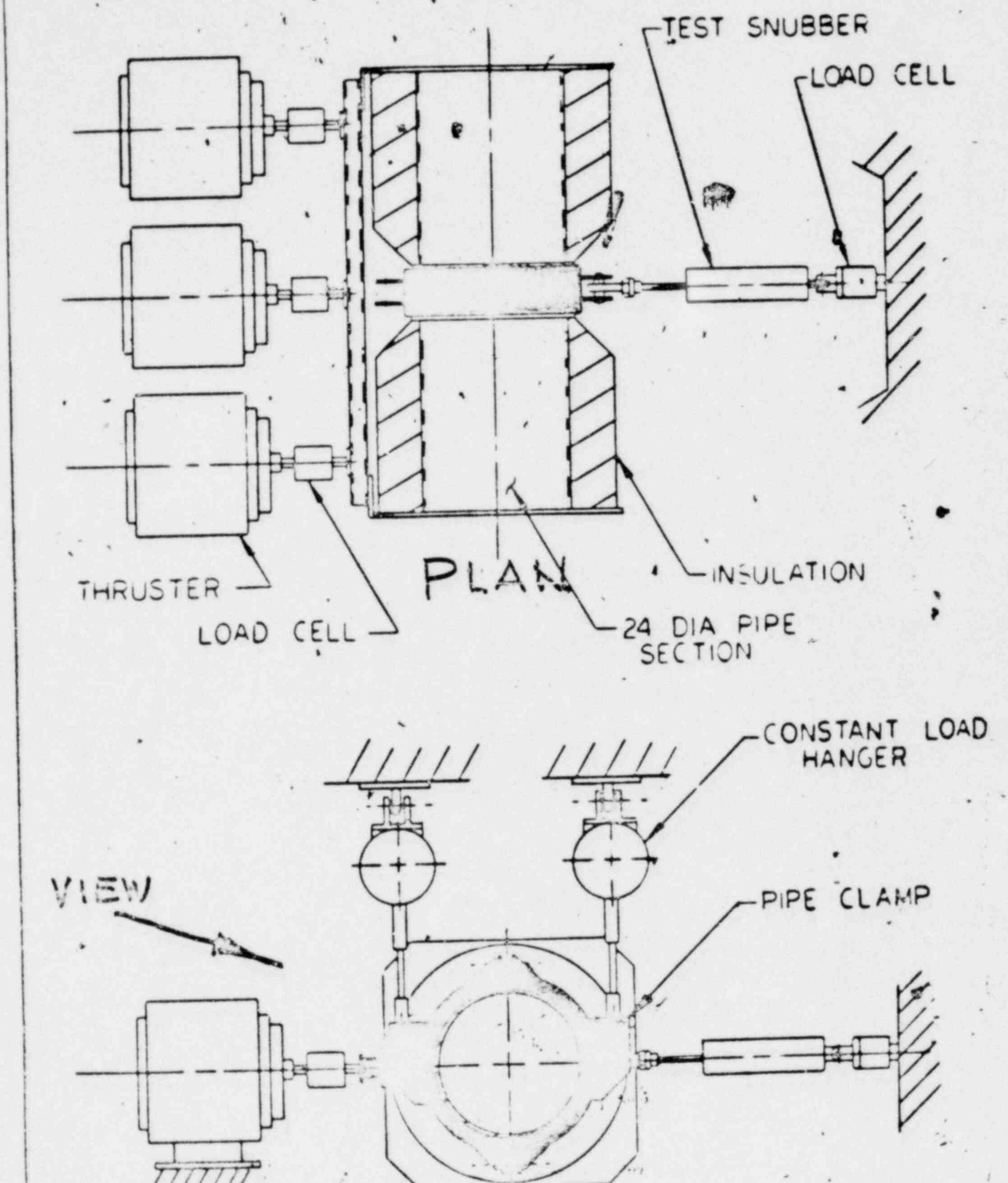
SEISMIC DESIGN OF HTS COMPONENTS

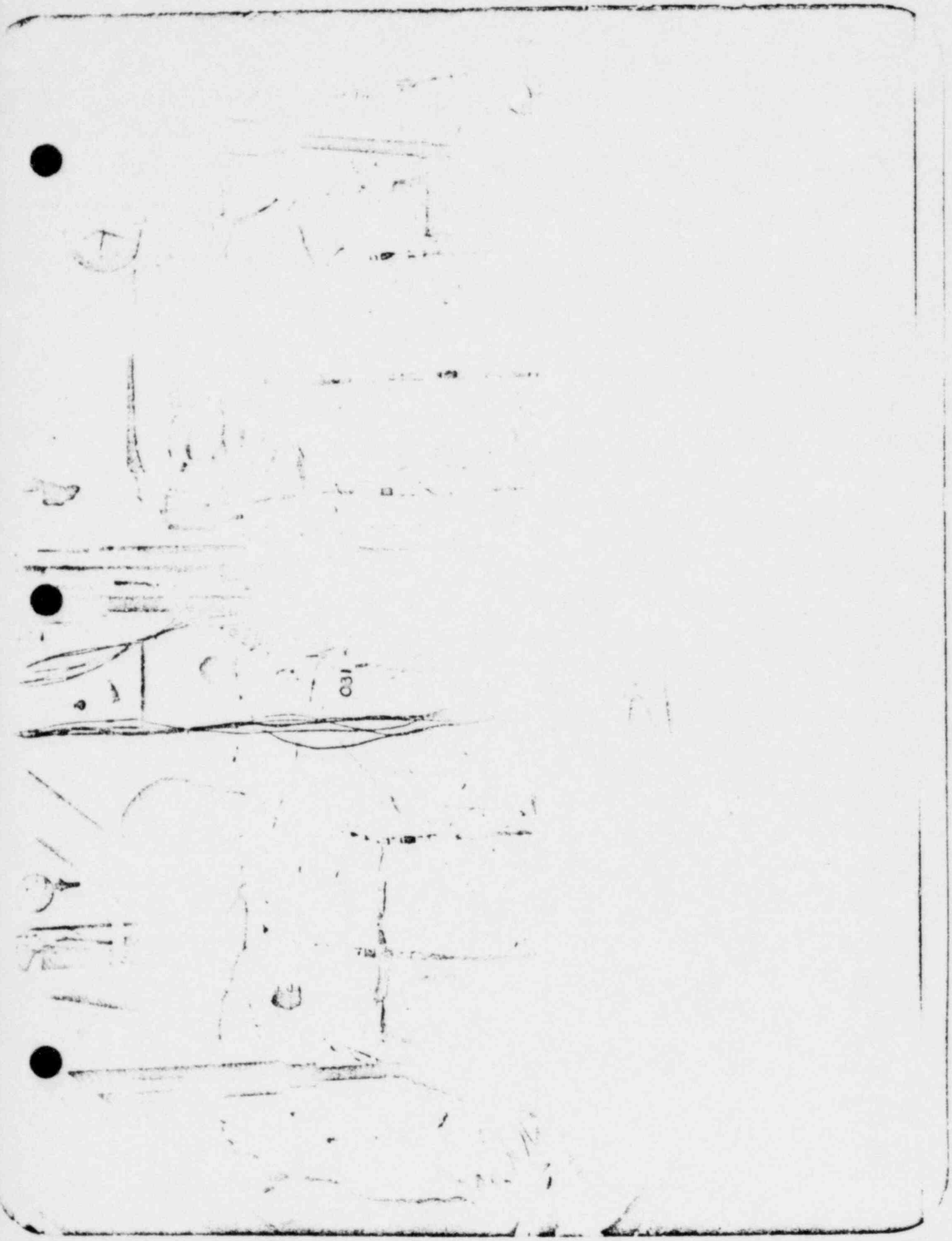
QUESTION

- WHAT SPECIAL ACTIONS HAVE BEEN TAKEN IN VIEW OF LIMITED PRIOR LMFBR EXPERIENCE?

  - DEVELOPMENT
  - VERIFICATION
  - COORDINATION

CLAMP TEST SETUP





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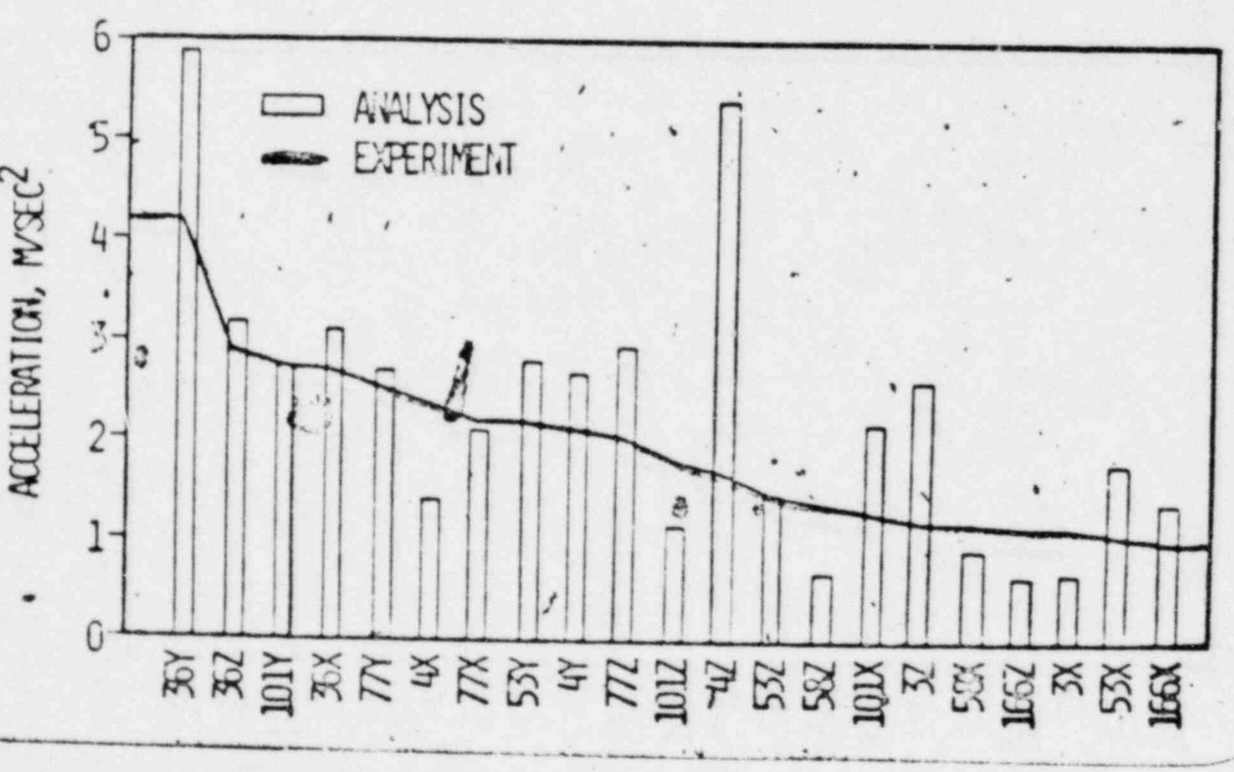
HDR SEISMIC STUDY (EG&G/[illegible])

VERIFICATION

- PIPING NATURAL FREQUENCIES

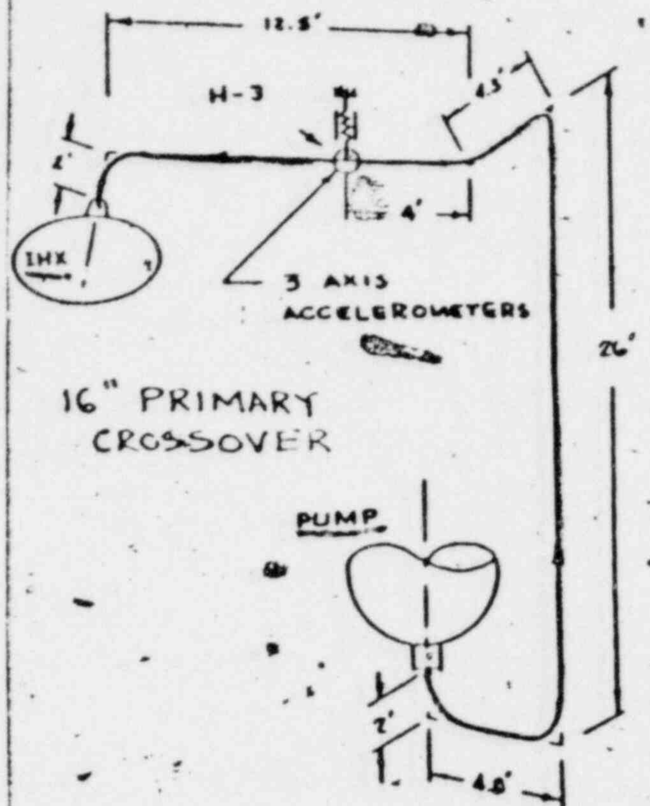
EXPERIMENTAL FREQUENCY, HZ	ANALYTICAL FREQUENCY, HZ
2.40	1.82
2.75 - 2.95	2.84
3.72 - 3.95	3.62

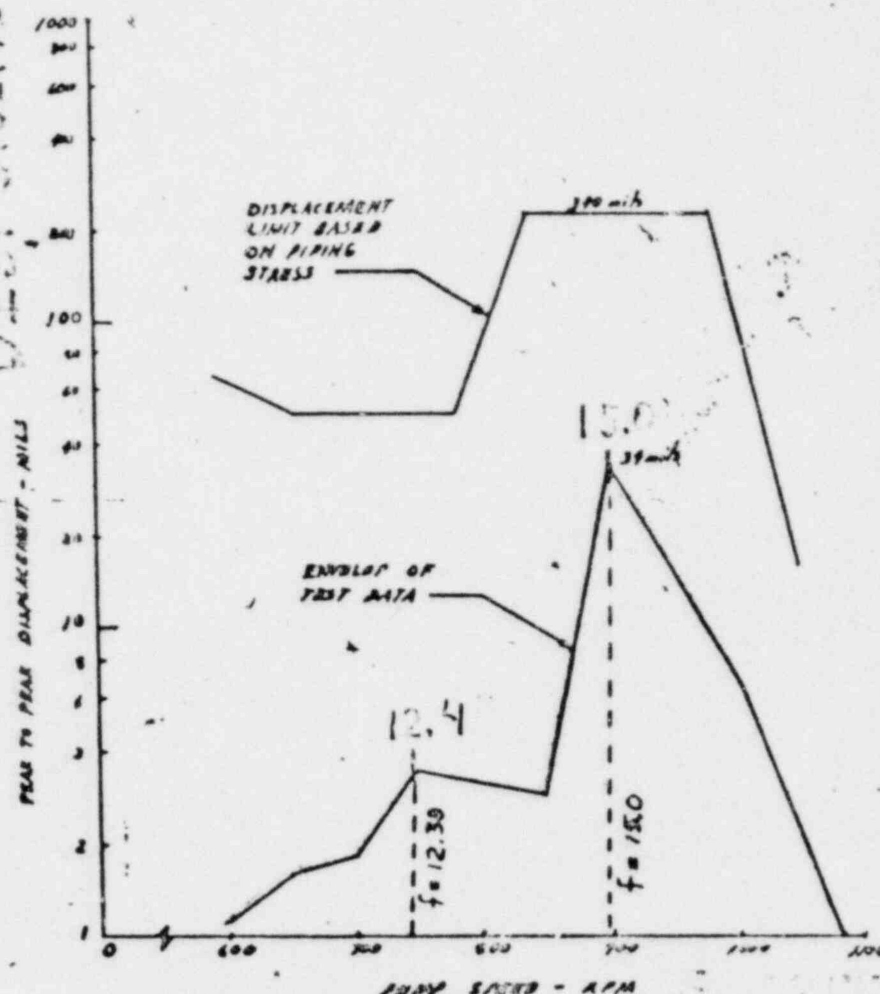
- PIPING ACCELERATION RESPONSE



FFTF XOVER PIPING - SURVEY OF PUMP INDUCED VIBRATIONS

VERIFICATION





NATURAL FREQUENCIES

f_1 = 7.522 Hz (451 rpm)
f_2 = 8.590 (515)
f_3 = 12.129 (728)
f_4 = 15.108 (906)
f_5 = 18.922 (1135)

VIBRATION DISPLS. VS. PUMP SPEED

4

4

SEISMIC DESIGN OF HTS COMPONENTS

IN-SITU VERIFICATION OF JOYO PIPING DYNAMICS

COORDINATION

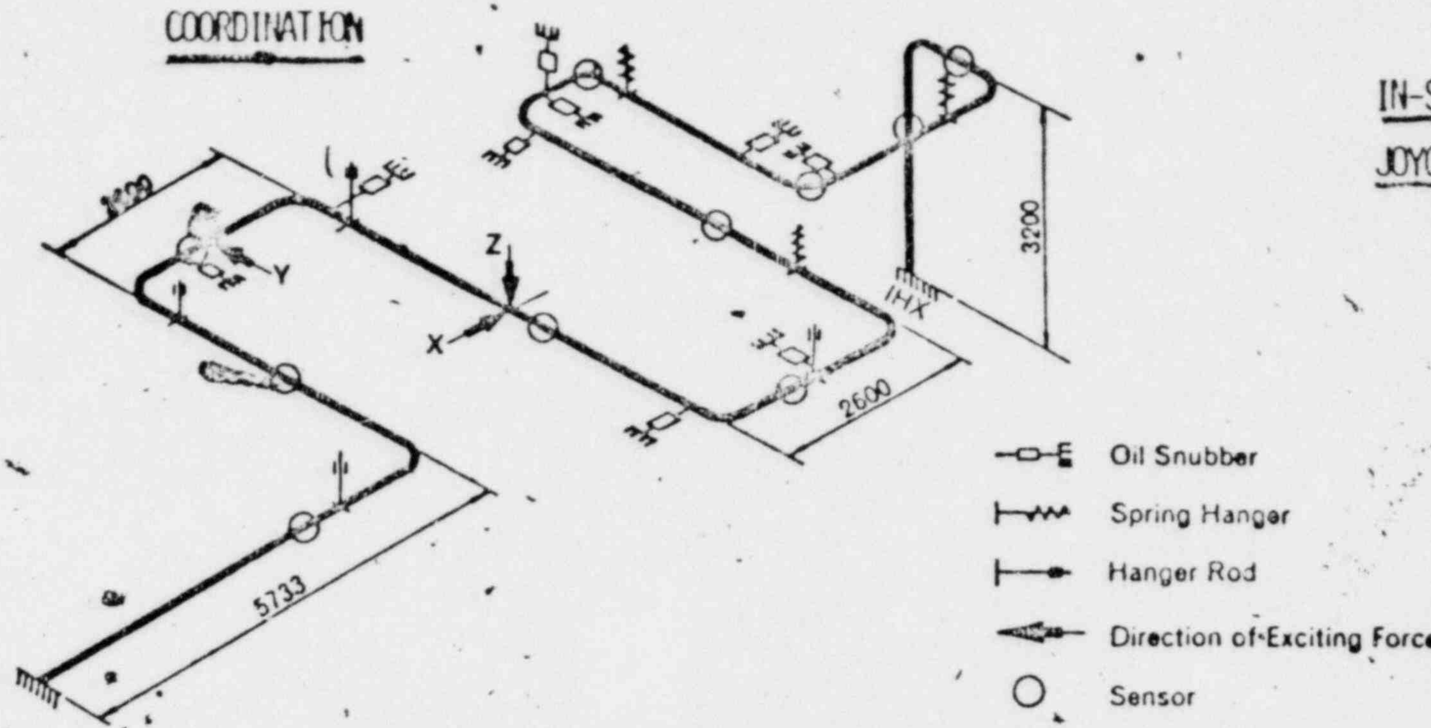


Fig. 4 Piping Tested on the Secondary Loop(12 inch)

MODE	FREQUENCY (HZ) TEST	ANALYSIS RIGID	ANALYSIS SPRING	TEST DAMPING
1	5.3	5.9	5.6	17.5 - 18.2
2	7.2	7.5	7.2	14.8 - 22.4
3	8.3	11.1	7.8	---
4	8.8	12.3	10.1	3.7 - 5.3

SEISMIC DESIGN OF HTS COMPONENTS

CONCLUSIONS

- CRBRP SEISMIC DESIGN METHODS AND CRITERIA INCLUDE THE CONVENTIONAL CONSERVATISMS.
- CRBRP COMPONENTS HAVE INHERENT MARGIN THAT COULD BE USED WITHOUT COMPROMISING THE SAFETY OF THE PLANT.
- CRBRP EXHIBITS SPECIAL ATTRIBUTES THAT REDUCE THE RISK ASSOCIATED WITH HIGH SEISMIC EVENTS.
- CRBRP DESIGN PROGRAMS INCLUDE A WIDE RANGE OF ACTIVITIES TO VERIFY THE DESIGNS AND AVOID OVERSIGHTS.

OVERALL - SEISMIC SAFETY LEVELS FOR CRBRP AND LWR COMPONENTS ARE COMPARABLE.