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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

April 7, 2006

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

531ST MEETING

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FRIDAY,

APRIL 7, 2006

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The meeting was convened in Room O-1G16 of One White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Dr. Graham B. Wallis, Chairman, presiding.

MEMBERS PRESENT:

GRAHAM B. WALLIS	Chairman
WILLIAM J. SHACK	Vice-Chairman
J. SAM ARMIJO	ACRS Member
RICHARD S. DENNING	ACRS Member
THOMAS S. KRESS	ACRS Member
DANA A. POWERS	ACRS Member
OTTO L. MAYNARD	ACRS Member
JOHN D. SIEBER	ACRS Member-at-Large

ACRS STAFF PRESENT:

SAM DURAISWAMY	ACRS Staff, Designated Federal Official
JOHN T. LARKINS	Executive Director, ACRS/ACNW
CAYETANO G. SANTOS, JR.	ACRS Staff

NRC STAFF PRESENT:

JOHN FAIR	NRR
GENE IMBRO	NRR

ASME STAFF PRESENT:

KEN BALKEY

RICHARD BARNES

KEVIN ENNIS

I-N-D-E-X

M-O-R-N-I-N-G S-E-S-S-I-O-N

8:33 a.m.

CHAIR WALLIS: On the record. The meeting will now come to order. This is the third day of the 531st meeting of the Advisory Committee on Reactor Safeguards. During today's meeting, the Committee will consider the following: Review of the 1994 Addenda for Class 1, 2 and 3 Piping systems to the ASME Code Section III and the Resolutions of the Differences Between the Staff and ASME. We will then take a break and we will move to Room T2B1 which is the Subcommittee Room of the ACRS up on the second floor in the other building.

Then we will discuss subcommittee reports, future ACRS Activities/Report of the Planning and Procedures Subcommittee, reconciliation of ACRS comments and recommendations, selection of and assignments for the quality assessment of NRC research projects and the preparation of ACRS Reports. This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Sam Duraiswamy is the Designated Federal Official for the initial portion of the meeting.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's session. A transcript of the portion of the meeting is being kept and it is requested that that speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

I now turn to Sam Armijo to lead us through the first items the ASME Code for Class 1, 2 and 3 piping.

MEMBER ARMIJO: Thank you, Mr. Chairman. During this session, we will hear presentations from representatives of the staff and ASME to discuss the resolution of differences between the NRC and SME regarding the 1994 Addenda to Section III of the ASME Boiler and Pressure Vessel Code for Class 1, 2 and 3 piping systems. The seismic design criteria described in 1994 Addenda to the Code permitted higher allowable stresses than in previous versions and the staff did not endorse these revisions because of concerns with the technical bases used to establish these criteria. The Materials and Metallurgy Subcommittee reviewed the status of the resolution of these issues in June of 1998 and March of 1999.

Today's presentations will describe the 1994 Addenda to the Code, the staff's concerns with these revisions and efforts and I should say also progress by the staff and ASME to resolve their differences. I would like to turn it over to Mr. Gene Imbro of NRR to begin.

MR. IMBRO: My name is Gene Imbro. I'm the Deputy Director of the Division of Engineering and I also participate in ASME Code activities as does John. I just wanted to give a quick overview of our Agency's participation in ASME and a description of ASME and I know some of you have been members of ASME for years. So this may be information that you already know. Please bear with me.

Just to start, the ASME Board on Pressure Vessel Code is compromised of, I think, it's 12 sections, it might be 13. and it covers things like how power boilers, unfired pressure vessels, NDE, a whole host of things. It's a consensus code and it's based on the expert opinions of the participants.

But today we're going to focus on Section III, "Rules for Construction of Nuclear Facility Components." Section III of the ASME Boiler and Pressure Vessel Code focuses on the design of pressure vessels and piping for nuclear applications. The ASME Code is written by volunteers and the volunteers represent utility organizations, design organizations, consultants and the NRC, the regulator. The NRC participates in many code committees with ASME and we have approximately 20 staffers that participate on ASME Code Committees. ASME Boiler and Pressure Vessel Code plays an important part of NRC's regulations of NPPs. It has been incorporated by reference in the Code of Federal Regulations.

(Tape recording issues.)

CHAIR WALLIS: Can we just come off the record?

(Whereupon, the foregoing matter went off the record at 8:37 a.m. and went back on the record at 8:38 a.m.)

CHAIR WALLIS: We're back on the record.

MR. IMBRO: Thank you. The ASME Boiler and Pressure Vessel Code is compromised of 12 sections covering power boilers, unfired pressure vessels, NDE, in-service testing and a host of other things. It's a consensus code that's based on the expert opinions of the participants.

Today we want to focus on Section III, "Rules for Construction of Nuclear Facility Components." Section III of the ASME Code on Pressure Vessel Code focuses on the design of pressure vessels and piping for nuclear applications. The ASME Code is written by volunteers representing utilities, design organizations, consulting organizations and NRC, the regulator. We have approximately 20 staffers that participate on various ASME Code committees. So we have quite a large presence on ASME.

The ASME Board on Pressure Vessel Code plays an important part in NRC's regulation of nuclear power plants. It has been incorporated by reference in the Federal Code of Regulations since, I believe, 1971. What that means "incorporation by reference" is verbatim compliance with the ASME Boiler and Pressure Vessel Code as required by NRC regulations. So it basically takes on the status of law. The Boiler and Pressure Vessel Code and only a few other codes have really incorporated in CFR. So the status of the ASME Section 3 is somewhat unique. The other -- incorporated in 10 CFR 5055(a) and ASME Section -- which is the in-service -- in-service inspection, Operation of Maintenance Code IEEE 279 and IEEE 603.

(Tape recording issues.)

CHAIR WALLIS: Off the record.

(Whereupon, the foregoing matter went off the record at 8:40 a.m. and went back on the record at 8:43 a.m.)

CHAIR WALLIS: Okay. We're off again.

MR. IMBRO: As I said before, verbatim compliance with the ASME Boiler and Pressure Vessel Code is required by NRC regulation. Section 3 has a special status in that it and only a few other codes are incorporated into the 10 CFR. Management Directive 6.5 has NRC participation in the development and use of consensus standards specializes staff responsibilities for participation in the development of consensus standards and part of what that says is the NRC staff are directed to represent the Agency opinion and not necessarily their own personal views. Most of the time, they coincide.

Occasionally, the Staff's technical position does not agree with the requirements of the Code and this results in limitations and modifications which the Agency places in CFR when we endorse a later addition and addenda of the Code and the Regulation. Overall, the NRC and ASME have a professional and constructive working relationship and however as I said, the NRC and ASME don't always agree on technical things which I will discuss today is one area where the staff has taken exception to ASME Section 3 Seismic Design Rules and the resolution of most of these issues.

MR. FAIR: Yes, I'm John Fair with NRR and

I'll discuss the issue with the piping seismic rules. The concern was in 1994. ASME Code Section 3 adopted revised criteria for the Piping Seismic Design and these criteria allowed for significantly higher allowable stresses than were specified in the previous ASME Code.

The staff did not endorse the revised criteria because of concerns with the technical basis used to establish the criteria and the staff still has not endorsed these criteria up to this state.

CHAIR WALLIS: It's been around for 12 years.

MR. FAIR: It's been around for even longer than 12 years. What I'll do is go over --

CHAIR WALLIS: We're supposed to snap our fingers and solve it.

MR. FAIR: Yes. I thought that's what was going to happen. We were waiting for ACRS. This issue has been around for quite a while. Back in the mid '80s, there was a concern that the piping design criteria had become overly conservative and that too much supports were being used and so a number of initiatives were taken at that time to try to revise the criteria and make the criteria more realistic. One of the initiatives happened to be dynamic tests of piping components and these tests were used as the bases for establishing the new allowable criteria.

In 1991, ASME established a special task group to assess the margins in the piping design rules and the staff participated as members in this group. As a result of the effort of this group, the ASME published the revised rules in the 1994 Addenda and the revised rules established these higher allowable stress values. The NRC representatives on the committee voted negative on the proposed change to the rules because of the technical concerns we had the time. The NRC actually informed ASME via letter that we would not endorse the new rules and in a second letter we sent to them, we specified the reasons why we wouldn't endorse these rules.

In the response to the NRC letter, the ASME established a special working group on seismic rules to evaluate the technical concerns raised by the NRC and there had been some technical concerns raised by other people, too. In parallel with this effort, the NRC established the contract under research with the Engineering Technology Research Center to review the technical basis for the '94 rules and the NRC staff and the research contractors participated in the ASME group meetings as observers and not representatives. The research effort was culminated in a NUREG 5361 which contained the assessment of the 1994 Piping Seismic Rules. The staff had twice briefed the ASME subcommittee in June Of '98 and March of '99.

In order to understanding some of the technical issues, I'm just going to have a very brief overview of the piping design criteria. This is at a very high level. There's a lot of detail to the criteria that I really won't go into. But the ASME contains criteria for Class 1, 2 and 3 piping. The Class 1 piping was the reactor coolant pressure boundary. The difference between Class 1 and Class 2 and Class 3 is that Class 1 requires a detailed fatigue analysis, whereas Class 2 and Class 3 don't and Class 2 and Class 3 are essentially the same design criteria.

Piping is typically evaluated using design rules in ASME Code Sections NB,/NC,/ND-3600 and these are really simplified formulas for evaluating the stresses. Occasionally, the rules in NB-3200 are used for Class 1 piping and the rules in 3200 are basically allowable stress limits and generally what is done in 3200 analysis is a finite element analysis of the component and the stresses are compared to the allowable stresses.

Now the Code contains allowable stress limits for four levels of load combinations, A, B, C and D. Level A is generally your operating loads like dead weight and pressure. Level B are plant transients and generally include an operating basis earthquake load combination. Level C is designed pipe rates other than LOCA and main steam and feed water. Usually this criteria is not used at often. You don't see too many load combinations under Level C. And Level D contains LOCA loads and SSE loads.

I'll just go over the more significant changes in the 1994 Code revisions. Strain limits were added to NB-3200 which are the detailed design rules and these strain limits were specifically for piping. The rest of the bullets on this slide pertain to the 3600 Rules. The Level D allowable strain limit was raised by 50 percent.

CHAIR WALLIS: Do you remember the numbers? What was the stress limit before and what was it afterwards?

MR. FAIR: I'm going to show you on the next one.

CHAIR WALLIS: You're going to show us.

MR. FAIR: Yes. A frequency limitation

was established and the reason this occurred is when they did the testing at ANCO on these components, the way they tested is they drove them at their natural frequencies and the reason you drive at the natural frequency is it's easy to drive the response to high level. When we were discussing the evaluation of this criteria, it turns out that you get your maximum margin if you compare it to the Code analysis criteria at the resonance of the component because the elastic analysis shows a very high amplification and if you get any inelastic response of the piping you won't get that much of an amplification.

So part of the evaluation, the complexity of the evaluation, was to have to look at off-resonance conditions and if you look at, say, a very slowly applied force to a component you find it acts more like a static load. That's why this frequency limitation was put into the '94 Code rules.

Another thing that was added in 1994 was a Level D limit for seismic anchor motions. Now the ASME Code divides stresses into two categories, primary and secondary. Primary loads are for loads like dead weight that can cause a failure of the component by collapse. Secondary loads are generally used for femoral type stresses where you're worried about progressive distortions and fatigue and not collapse. So in coding evaluation space for Level B limits which are one time loads, you generally don't evaluate secondary type stresses, but because there was a concern that the seismic anchor motions had caused failures at the fossil plants during plant surveys, they added a Level D limit in the rules for seismic.

They also based on the testing that was done --

VICE CHAIR SHACK: How was that limit put in, John?

MR. FAIR: It's just an equation. What it is --

VICE CHAIR SHACK: So it's a stress limit.

MR. FAIR: It's a stress limit and actually at the time they put it in, I didn't consider it very meaningful because usually you evaluate secondary loads to what's known as $3S_m$ stress limit. What they did when they put this in, secondary loads include OBE loads in Level B under a $3S_m$ limit. What they did when they put this Level D in is they put a $6S_m$ limit for seismic anchor motions which if you would have met the $3S_m$ limit with OBE you're obviously going to meet the $6S_m$ limit with SSE. It is now irrelevant since the rules changed for seismic where the new rules for seismic say you don't have to evaluate OBE if you meet certain criteria. So it is now a relevant limit and it's one of the issues that came up later in the review process.

The last major thing that was done was new Level B and Level C limits were established in parallel with the Level D limit. The one I talk about is the '94 Level D stress limit which is the one that was of most concern and most of the evaluation effort was geared towards reviewing.

What I've shown here is the basic code designed by rule formula for Level D and it's a fairly simple formula. What it is is the first term is simply longitudinal pressure stress. The second term is your bending stress and it has to be less than equal to the allowable limit.

CHAIR WALLIS: Four times 4.5 times --

MR. FAIR: S_m and I'll go over that in a minute what that means. First, the B indices are a function of the type of components you're evaluating and they're simple adjustments to go from a straight pipe to a component like a elbow or a T.

CHAIR WALLIS: This is all thin-walled pipe theory.

MR. FAIR: It's -- Yeah, it is thin-walled pipe theory, but if you look at the B indices for straight pipe, the B-1 index would be a one-half. So this would just be the longitudinal pressure stress in the first term and again for straight pipes, the B-2 index would be one. So you just have MC/I type of stress.

Now the S_m is a function of the material that you're evaluating and the basic allowable S_m is established by a couple of criteria, either two-thirds of the minimum yield stress at temperature or one-third of the ultimate stress. So if you look at this equation, it's quite obvious that the $4.5S_m$ would allow you to go over the ultimate strength of the material.

CHAIR WALLIS: Seems like a good criterion to me.

MR. FAIR: So that's why we were very concerned with it.

CHAIR WALLIS: -- to break it.

MR. FAIR: The next slide I'll go over the basis.

VICE CHAIR SHACK: That's the last that we calculated.

MR. FAIR: Exactly.

CHAIR WALLIS: Right.

MR. FAIR: The justification for this new limit was that the component test data demonstrated that piping collapse cannot occur during a seismic event so that the possible failure modes during a seismic event are fatigue, fatigue ratchet and progressive ratchet. What I mean by these are fatigue is a fairly simply concept. If you keep cycling --

CHAIR WALLIS: It's a fairly funny statement. Piping collapse cannot occur. I mean obviously if a seismic event is big enough you can collapse a pipe. It's just that it --

(Several speaking at once.)

CHAIR WALLIS: It's a very strange thing.

MR. FAIR: I'll go into that in the next slide, but I just want to explain these three terms. Fatigue is regular fatigue/slightly fatigue. Fatigue ratchet really means that if you're cycling the piping, a pressurized pipe under high strains, the pipe tends to budge and this budging can affect the fatigue endurance of the pipe. And the third concern was progressive ratchet which is essentially a progressive displacement of the system under the cyclic loads.

MEMBER SIEBER: That is plastic

deformation.

MR. FAIR: Plastic deformation. So the bottom line was that the ASME considered their evaluation that the component test data demonstrated that the new rule did provide adequate margin against the possible failure of modes discussed above and they also believe that their evaluation of the piping system, their tests, confirm the new seismic rules.

CHAIR WALLIS: Now what do they mean by adequate margin? Does that mean that they're within 50 percent of failure or one percent or what?

MR. FAIR: Yes. At the time that these rules were established, the adequate margin was defined as a factor of safety of two on the lowest bound value from the tests and we did have some concerns with that and I'll get into that in the next slide.

The first bullet is there were insufficient test data to demonstrate, to support, the conclusion that a piping system collapse will not occur. As a matter of fact, in our opinion, one of the tests was exhibiting collapse before they stopped and they stopped prior to the end of the seismic input before it did fall down and collapse.

MEMBER SIEBER: Test 38.

MR. FAIR: Test 37.

MEMBER SIEBER: Test 37.

MR. FAIR: Yes. Our second concern was that there were inadequate evaluation of the existing test data and what I mean by that is when these components were tested some of them took more than one seismic input before they failed. So in order to normalize the data, the failure load was adjusted by the number of cycles of fatigue type loading because the issue was that it was more of a fatigue loading than anything else.

The way they adjusted it was to adjust it by the same criteria that's in the fatigue curve. For instances, at very low cycle fatigue if you were to double the amount of cycles, you would have about a 40 percent change in the fatigue life of the component. So this adjustment was done on the data and then the adjusted data was used to establish the margin.

The problem we had with that was when you look at the adjusted data, the scatter was greater than the unadjusted data which told us there's something wrong with your adjustment and the reason there's something wrong with the adjustment in this situation was there was some funny ways they did the adjustment on some of the data. But when you look at trying to use the fatigue curve, the fatigue curve is for strain based on an elastic basis. When you're testing these components, you have a combination of fatigue and ratchet occurring simultaneously. So you wouldn't expect the adjustment to be the same as you would with a specimen under a fixed displacement condition.

The third issue was there was really insufficient basis for establishing the minimum design margin. The margin of two sounds good, but again given the adjusted data had a greater data scatter, we felt there needed to be some consideration of the data scatter in the development of margin.

And finally, they had a couple of system tests to confirm the conservatism of the criteria, but there was no way to adjust the system test data in similar fashion to the component test data. So we didn't think that they had enough basis to extrapolate the margins from the component test to the system test.

Now I'll go over the results of the NRC Research Program. It was established with ETEC in 1993. It includes an independent evaluation of the test data, independent from the ASME evaluation and the independent analytical studies of test margins extrapolations were performed. These extrapolations were done by CalTech researchers and also the program included peer review group of experts and the results were published in the NUREG 5361. The review concluded that the basis published for the '94 rules were incomplete and this data was provided to the ASME working group.

I'll go over it really briefly. There was a lot of effort on this special working group on seismic rules, but I'll just briefly go over the key elements. The special working group relied heavily on the ETEC evaluation of the data because they didn't have resources to contract out additional evaluations. They did vote to accept the margin definition that was proposed by Bob Kennedy which he was one of the peer reviewers and he had proposed a margin that was based on the existing seismic margin studies, derived from that. That was essentially a factor of two on the one percent capacity failure probability and when you translated this into the actual component test data, some credit was given for system redundancy in the piping system going from a component to a piping system. So the actual evaluation of the component test data was looking at the one percent capacity factor of 1.5 giving some credit for system redundancy.

And the reason that we don't have a problem with that is when they finally did the evaluations of the capacities they went away from the margin extrapolations analytically to an actual evaluation of measured margins during the test and these were called "ultimate dynamic moments" that were measured actually during the test. So we have the real capacity of the component and not a calculated value. On the basis of this evaluation, this special working group proposed modifications of the rules and revisions were incorporated in the 2001 and 2002 Addenda of the Code.

After this effort was performed, the staff decided it was time to try to endorse the current code rules since they had made some changes to address our concerns. Let me go over briefly what the changes in 2002 Addenda were. The Level D stress limit was revised back to what it was previously, $3S_m$. New seismic stress indices were added for elbows, Ts and thickness transitions.

Now the reason that happened was the original proposal raised the allowable stress limits across the board for all components. However, the component test data only had certain components tested and the evaluation of the data also showed that some cases that the Code criteria really wasn't that conservative. I'll get into that later on the revised criteria.

CHAIR WALLIS: Did they make adjustments for welds in all of this?

MR. FAIR: Yes, and I'll get into that. Yes sir. So anyway, they made these revisions. What happened when they --

VICE CHAIR SHACK: Just a question, Chairman. This $3S_m$ limit, how is that related to the Kennedy margin? You go through, you get the ultimate bending moment, you make some estimate of the nonlinear dynamic effect, some less than the redundancy effect, and then you end up with these stresses as roughly equivalent to that.

MR. FAIR: The way it works is you take from the test data you measure the ultimate dynamic moment. This is a measured moment. It's actually not measured at the point. You're measuring the translated moment down to the point of the component failure. You have that measured moment and you have the moment computed by the Code equation with $3S_m$ in it and you take that measured moment divided by the $3S_m$ limit, calculating moment with $3S_m$ and make sure that that margin in there has a factor of safety of 1.5 really. That's the way that thing was evaluated.

VICE CHAIR SHACK: But Kennedy's thing has a nonlinear dynamic adjustment. So the 1.5 is the redundancy adjustment.

MR. FAIR: No, let me start -- I probably should have brought a slide on that. Their proposal was a capacity factor of 2.0. What he proposed was the fact that there are some nonlinear factors and a redundancy factor which could give you additional margin. He took a fixed number of 1.33 as being a lower bound conservative number and divided two by 1.33 to come up with a fixed value of 1.5 as the criteria using to evaluate to the one percent level. So you took all the test data, calculated the margin based on the Code $3S_m$ limit, did a statistical evaluation of the data to determine that the one percent limit met that 1.5 factor.

MEMBER SIEBER: What constitutes a test failure? We've established that collapse is not one of those. I take it that plastic deformation is a failure.

MR. FAIR: In many of the cases and in the majority of the cases, it was through-wall crack through the system which then leaked. In a couple of the cases, there was excessive deformation. As I said one of the cases, Test 37, was about to collapse and they stopped the run. So most of the cases it was through-wall fatigue failures. In a couple of the cases, it was excessive deformation failures.

MEMBER SIEBER: Right.

CHAIR WALLIS: It is an interesting culmination of things. You're doing a lot reasonably sophisticated statistics to get one percent.

MR. FAIR: Yes.

CHAIR WALLIS: And presumably you need some competence attached to that and then you slapped on these numbers which are very crude like 1.52 of three. There's an incompatibility here in the levels of sophistication applied.

MR. FAIR: There are, but if you go back to the bases for deriving the capacity factors, the one percent capacity factors, there are some judgmental numbers that go into that evaluation. So if you try to take it out to two or three decimal points, it's meaningless.

Again, when they translated this into the Code revisions, actually what happened was that the stress indices for ASME Class 1 and Class 2 components came out different than the ones for the Class 3 components. Now the reason this occurred and again this comes at the end as one of the remaining issues was there was a staff proposal on what these indices should be made at the special working group level and that staff proposal was working its way up through the Code and when it got to the main committee, there were some objections at the main committee and so they revised the criteria to another criteria.

When they translated it into the Code, apparently they left some of it the way it was proposed by the staff and other areas, it was what the ASME wanted. That's why the dual criteria. I'll discuss that. And they corrected that via a RATA later on.

The other thing that was done was a D/t limitation was put in and this was to address the one case where you had the collapse, the Test 37, which was a thin-walled piping system that had a very low margin and it's probably due to a local buckling of unpressurized --

CHAIR WALLIS: What's going through my mind is you hold the theory you present is extraordinarily crude. Doesn't it count for certain modes of theory like buckling?

MR. FAIR: Yes.

CHAIR WALLIS: Which is what happens. You take a beer can and twist it. It buckles.

MR. FAIR: Yes, and that's why they put D/t on that.

MEMBER SIEBER: Yes, the original assumption was though that that was impossible. Right?

MR. FAIR: Yes.

CHAIR WALLIS: Buckling your paper.

MEMBER SIEBER: Yes.

MR. FAIR: Just a comment on that now, it's not as bad as it sounds because the original criteria for the use of a B indices has a D/t criteria of 50 which is not that thin a wall but it is thin and again, that wasn't good enough if you're going to go to these higher limits. So we cut it back to a D/t of 40 and since we had gotten rid of all this extrapolation evaluation of trying to calculate and extrapolate in margin and went with the actual measure margins from the test, we were able to eliminate, the frequency limitation was eliminated and this frequency limitation would have been very hard to implement in a practical sense when you're doing piping analyses.

The next slide shows the revised 2002 primary stress limit. You can see the criteria went back to $3S_m$. You have instead of the B2s you have B2 primes for specific components. Now if you look at the second B2 prime which is the one that the ASME wanted and you put that into the equation above and flip it around, you essentially get close to the $4.5S_m$ that they originally wanted. But this is just for elbows and Ts. It's not for all the components, straight pipes, etc.

If you go down to the next bullet, it was actually going more conservative for places where you have thickness transitions. What happened in the evaluation of the data is these tests were canti-levers driven by sleds at the base and the component was done near the bottom of the canti-level with a small transition piece to attach to the sled base. In order that the prosticity (PH) occurred in the component, the little transition piece to the sled had to be much thicker.

So when we went back and looked at the actual failure, a lot of times the failures were occurring not in the component themselves, but on the other side of wall that the transition feeds and when you evaluated the margins which would have a B of 1 at that location, you found that maybe you didn't have adequate margins. So since the proposal was to make all the margins more or less compatible with each other, you really needed to put a B prime of 1.33 at these thickness transitions. So it's actually more conservative than the original Code criteria at these particular locations.

Now the staff concerns with --

CHAIR WALLIS: This is very strange to me. Shouldn't all this be related somehow to your probability of failure in a nuclear context and what you're aiming for in terms of that probability of failure in a nuclear context rather than just arbitrarily having these threes and 4.5s?

MR. FAIR: It's not that arbitrary because the basis for the --

CHAIR WALLIS: If you want your pipe not to break in a seismic event with a probability of 10^{-6} or something, then this may tell you something about what you need to do. You don't seem to put it in any kind of a nuclear context.

MR. FAIR: Well, let me try again.

CHAIR WALLIS: Risk context.

MR. FAIR: I thought I did. The basis for establishing the required margin was started out with the margins that are in existing seismic margin studies in PRAs and the concept was we didn't want piping to become a dominant factor in there. So the starting point of the evaluation was the margin in existing seismic margin studies and derived from that was the capacity factor needed for the piping.

CHAIR WALLIS: But if you get 10^{-6} or that sort of order, you're way out on the tail of some distribution. You have to be very careful about how you make predictions, don't you?

MR. FAIR: I agree with you. It's --

VICE CHAIR SHACK: But it's not 10^{-6} given the occurrence of the earthquake.

MR. FAIR: Right.

CHAIR WALLIS: What is the -- occurrence?

MR. FAIR: Zero.

CHAIR WALLIS: What's the conditional? Is it one percent? That's the Kennedy thing?

MR. FAIR: That's the Kennedy thing. That's exactly right. Yes.

CHAIR WALLIS: Okay. That's where it came from.

MR. FAIR: Yes.

MEMBER SIEBER: Now all these seismic loads are added to the stress that's caused by dead weight and pressure.

MR. FAIR: The equation for the seismic

load contains dead weight and pressure.

MEMBER SIEBER: Okay.

MR. FAIR: And the terminology used in the Code is reversing bionic load. So what you have is dead weight and pressure with whatever the reversing dynamic loads are associated with that. If you have, say, a large, what they call, nonreversing load in concert with these, you can't use that criteria.

MEMBER SIEBER: Like if you were standing on the --

MR. FAIR: Yes.

CHAIR WALLIS: Do you have some kind of residual stress for welds or something in all this as well?

MR. FAIR: Those are usually not evaluated in ASME Code criteria.

CHAIR WALLIS: It's a separate criterion of some sort.

MEMBER SIEBER: Yes, it's like they don't exist because they're supposed to be stronger than the base material.

MR. FAIR: Yes, the way residual stress works into the Code evaluation is really when you do fatigue analysis in the fatigue curve which is adjusted for residuals.

So we have a change in the piping rules in 2002 and the staff went to endorse it in 5055(a) and went back and reviewed the rules carefully. Now again, we had spend a lot of time on this Level D allowable limit of 4.5. When we went back for the endorsement, we looked at the whole set of rules that had been changed way back in 1994 and said, "Well we've probably overlooked a few things in the Code deliberations."

One of the issues the way the Code rules were written is that these rules would apply to anything called a reversing dynamic load and these reversing dynamic loads would have included flow transient type loads that you have a water hammer or a valve opening. The problem was all the data reduction was done on components that were loaded by the base sled motions and not by internal pressure loads. So there was no basis to use this criteria for flow transient loads.

A second concern --

CHAIR WALLIS: This is where you do have real incidents in plants where -- dead breakers are a result of water harm.

MEMBER SIEBER: You certainly do.

MR. FAIR: Yes.

CHAIR WALLIS: So presumably they weren't designed to take that kind of load or the load was underestimated or something.

MEMBER SIEBER: They're pretty severe.

MR. FAIR: Yes.

CHAIR WALLIS: Yes, they were severe, but it might still --

MR. FAIR: What happens on some of those is you've supposedly designed the system so that you don't have those.

CHAIR WALLIS: That's right.

MEMBER SIEBER: Right. Then you don't have to figure out how big they are.

MR. FAIR: Yes, very difficult to design something to take the worst case water hammer type load.

So the second concern we had was back in the original slides that they had added some strain criteria to NB-3200. This was complex criteria which was looked at ratchet strains and peak strains and we didn't think the technical basis had been established for those rules.

The third item we had was when they went back and modified the Level D limit they didn't go back and look at the impact on the Level B limits and thought that they needed to be brought into consistency with the change in the Level D limits.

Another item was in the definition of the moment load and this goes back, way back, to the original development of the margins. The moments specified the method of analysis to obtain the moment which was damping and inspector input. That's really licensing basis criteria. So we couldn't have the Code superseding licensing basis criteria and that was the reason we had a concern with that.

And the next item was the inconsistency in the B indices. The three quarters we liked. The two-thirds we didn't like.

The other one was with the new allowables for seismic anchor motions. We had a concern that at $6S_m$ there's a concern that if you have a strain concentration that you could cause a problem even though they were a secondary type load. So we felt the need to have some restriction in on that.

To go over the recent activities in that, the staff proposed an amendment to 5055(a) to incorporate the new rules with limitations. The ASME submitted comments on the rules and essentially asked us to keep our non-endorsement of the rules until we worked out our differences. Then the ASME formed a special project team to resolve the remaining issues and the project team resolved five of the six issues.

CHAIR WALLIS: So you're very close to closure.

MR. FAIR: Very close.

CHAIR WALLIS: I was hoping you would be because the last thing we need is to have ACRS doing all these calculations and things for you.

MR. FAIR: I'll take whatever help we can get.

MEMBER SIEBER: It's more like the revolver though. You keep pulling the trigger until you find the cylinder that's not empty.

MR. FAIR: Yes.

VICE CHAIR SHACK: You don't want that.

MR. FAIR: I'll go quickly over the resolved issues. ASME initiated Code changes to eliminate the operability of the seismic rules to flow transient loads. ASME initiated changes to eliminate 3200 strain criteria. They had initiated this prior to our comments because of the practicality of applying it.

ASME initiated Code changes to modify the Class 2 and Class 3 level B limits to be consistent with the Level D using the B prime criteria, initiated

Code changes to eliminate the discussion of the method to generate the loads from the definition of the moment and they initiated changes to add provisions to the criteria to address strain concentration and these are just precautionary limits put in there. It says look out for cases where you could have possible strain concentrations such as smaller pipes in series with larger pipes and things like that. We think that's good enough to at least give a precaution to the designer that he doesn't do anything bad in the design.

The remaining open item was that there's testing at Battelle showing that certain carbon steel materials are subject to dynamic strain aging at temperatures greater than 300 degrees F. The concern here was all the pipe testing was done at room temperature. So you have to either assume that these same margins will apply at temperature or you needed some data to show that they were good at the higher temperatures.

The actual testing that was done, the specimen testing, showed a fairly significant reduction in ultimate tensile capacity at higher strain rates. There was also some testing of loops with large flaws that showed a reduction at temperature versus at room temperature at higher strain rates and we concluded that the seismic strain rates can be in a range of concern of dynamic strain aging.

The next slide is just to show some of the data from Battelle. This is just one set of specimen data. If you look at the bottom it's elongation. At the top is showing ultimate tensile strength and yield. On the left side, the data points are equivalent to what you get on a quasi-static type of strain, a fairly slow strain rate, and these would be the basis that you would establish the ASME Code allowable limits. If you go over to where they test it at, at one inch per inch per second and ten inches per inch per second you get a fairly significant drop.

The other thing between us and the ASME on that is how high the seismic strain rates can possibly get. Their evaluations, we estimated they could be at the one inch per inch per second level and they estimate that they're somewhat less than that and their feeling is it was not enough difference to revise the Code rules for the little bit of difference in capacities at their estimated strain rates.

Now I will say I don't want to drag on too long. But I will say that a lot of the arguments that we had was we believe that you had to evaluate these capacities at the failure point and we have to look at the strains that you would get if the component were failing. Some of the ASME evaluations were looking at it at pseudo-Code limits and things like that where you didn't go up to the failure point. So you would calculate a much lower strain and consequently a much lower strain rate.

And we don't agree with that methodology. We think that if you're trying to evaluate these capacities for margins studies where the loads could be above what you're designing to then you have to look at the failure capacity of the component at its limit, not at the Code allowable limit.

So our proposed resolution of the final issue is to take exception in 5055(a) endorsement that the B2 prime, B3 quarters, B2 for carbon steel elbows and Ts at temperatures greater than 300 degrees F and again the ASME has it at two-thirds. So the difference is not that great. We're taking about a 12 percent reduction for this concern with dynamic straining aging.

MEMBER SIEBER: Other than that, you agree that the rest of the Code's requirements are adequate.

MR. FAIR: With the changes that they've

proposed, yes.

MEMBER SIEBER: Okay.

VICE CHAIR SHACK: Now that only affects the Class 3 components.

MR. FAIR: No, did I say that? Oh, gosh, I hope I didn't.

MEMBER SIEBER: You didn't say that.

VICE CHAIR SHACK: No, I'm just going back looking at the Level D limits. They're already three-quarters for 1 and 2.

MR. FAIR: Yes, but they fixed that via a RADA to make it two-thirds. They didn't intend to do that. That was a mistake.

MEMBER SIEBER: Less than Code. So what's the plan now? Revise 5055(a)?

MR. FAIR: Yes, when the new Code changes, get it into the Code. Then the plan is the next endorsement in 5055(a) after those changes get in, we will endorse with this one exception.

MEMBER SIEBER: What do you want from us?

MR. FAIR: I really wasn't --

(Several speaking at once.)

MEMBER SIEBER: Just information.

MEMBER ARMIJO: John, when do you think that's going to get resolved, the final issue in the new Addenda?

MR. FAIR: I think the ASME representative is probably better posed to give you the schedule.

MEMBER ARMIJO: Okay.

MR. FAIR: But once the Code gets changed, then in our cycle of updates we'll pick it up.

MEMBER ARMIJO: Okay. Mr. Chairman, I think the next speaker will be ASME and Mr. Balkey. We're running a little bit late. So we'll try not to interrupt if you'll just move right along.

MR. BALKEY: Good morning. I'm Ken Balkey. I'm Vice President of ASME, Nuclear Codes and Standards. I'm joined here today with my colleagues, Richard Barnes who is the Chairman of ASME Section 3 and also with Kevin Ennis who's the Director of ASME's Nuclear Codes and Standards from the ASME's staff. Thank you for the opportunity to meet with you here on a subject that has gotten an enormous amount of work over the many years addressing these seismic concerns. Could we go to the next slide please?

What we'd like to do is Kevin and I would like to give a little bit of an overview of our Codes and Standards process and some of the questions you just raised about using more of a risk-informed approach to dealing with these issues. I'm going to discuss about that in terms of addressing the issues we have here, of today's topic, but where we're trying to go in the future. I'll just take a few minutes to do that and then we'll turn it over to Richard Barnes to do the technology discussion that will compliment the remarks the staff has just provided to you and then Richard will provide a summary. Next slide please.

Today's a special day for our society. It was founded exactly 126 years ago today at the first meeting of the society and our Boiler and Pressure Vessel Code was founded in 1911. So the main committee of the Boiler and Pressure Vessel Code is in its 95th year of operation.

MEMBER SIEBER: You don't look that old.

MR. BALKEY: None of us were there. Our colleagues from Westinghouse in the early days were there back, not 1915, but back of that very long period and the Boiler and Pressure Vessel Code of course addresses a very serious issue that was occurring 100 years ago with we had a boiler explosion every day that was killing people and the strength of the process is actually bringing representatives from the people who built the equipment, the people who owned the equipment, those who insure it, those who manufacture it and come in as engineers, as individuals engineers, to come to agreement on what are the appropriate standards we all need to work to in order to assure safety in our operation.

So in our codes and standards while we are representing the nuclear codes and standards, we also have three other boards that deal with standards dealing with standardization and testing, dealing for instance like screw threads and safety codes and standards such as like for elevators and escalators. In our Board on Pressure Technology is where the Boiler and Pressure Vessel Committee resides and as Gene Imbro indicated in his remarks, there are 12 sections reporting to the Boiler and Pressure Vessel Committee, two of them being nuclear, Section 3 and Section 11, Section 3 with the design rules and Section 11 with the in-service inspection.

But the way that we are organized, our Board on Nuclear Code and Standards, we have technical oversight of Sections 3 and 11. But any technical procedures that come forward out of those groups come before the main committee that has very broad representation from a number of industries who are of course addressing the same issues and I think you heard John Fair indicate that even though the nuclear representatives can bring an action forward John mentioned a case where other representatives from other industries say that they may disagree before they were allowed to move forward.

The other connection we're trying to make, I won't go through our entire organizations, but our newest group is on the left side there with this Committee on Nuclear Risk Management. So we have been working for the last at least ten years, maybe even 12 years bringing experts on to our standards committees who have background in risk analysis and in probabilistic methods. The issue is how we organize it and I'll discuss it in terms of some of our strategic initiatives that build off the discussion on the issue of concern. Next slide.

The next slide just gives verbally the listing of the committees in order to go along with the abbreviations. So we have the committees reporting to the Boiler and Pressure Vessel Committee including our subcommittee on Nuclear Accreditation and on the direct nuclear ones dealing with the in-service testing, quality assurance, risk management and we even have a committee on cranes. Next slide please.

I'd like to ask Kevin Ennis to take a few minutes to walk through how we put our roles together and I know the question came up, this has been going on for 12 years and one thing that ASME has done is we have greatly expanded the international organization.

We have Mr. Barnes who will discuss we have enormous contributions coming from Japan in particular dealing on this issue in addition to our colleagues here in the United States with the Electric Power Research Institute along with many others. In fact, Mr. Barnes is from Canada and chairs our group. So we are trying and as all of you are well aware, our nuclear industry is becoming more global as each day moves forward, just not that the plants operate globally, but in terms of how other countries look to us for standards and seek our standard or another standards and we're always trying to seek the input, the worldwide input, on what we do.

At this point, I would like to turn it to my colleague, Kevin Ennis, here to just go through the process we go through to get this input.

MR. ENNIS: Thank you, Ken. As noted earlier, I'm Kevin Ennis. I'm Director of Nuclear Codes and Standards. I'm the person, I guess, responsible for finally getting all these documents actually in print and out the door which means I get blamed for most everything. But that's the nature of what I do.

We sum up our process saying that we try to bring together two things to equal a product. We try to get the best people we can. We have a good process that we understand and we actually follow. And we try to deliver a product that everyone can use. Our people are good technically, some of the best in the world and as Ken noted, internationally we have people from all over the world that do participate in our process.

Just in nuclear, there is approximately 800 engineers that do participate in the process. Now most of them are in Sections 3 and 11. Those are the two really big groups that we have and these participants are supported by their employers. They're not paid by ASME. The NRC, thank you, strongly supports our process and sends their people.

Our process is formal. We do have requirements and we do maintain it for balance of interest so no one can predominant. We have the regulatory authorities. We have the suppliers, the vendors. We have the utilities. We have inspection agencies and we actually have state authorities represented at both 3 and 11, so that there is a broad group that goes on. While it was mentioned a number of times especially in the Boiler Code, something unusual happens in that after we get through discussing all the issues and we come to consensus on the solution, we have to bring it to the Boiler and Pressure Vessel main committee. We really have an extremely broad view of all the items because now you bring in petrochemical, you bring in fossil fired utilities and others, even pharmaceutical companies that use our equipment. So there is a broad range of knowledge and experience, a lot of it very sophisticated, but has a different point of view.

CHAIR WALLIS: So while this was going on with these numbers changing from three to 4.5 or whatever they were doing, was this consistent with what's done in the chemical industry or was it much more conservative or what was it?

MR. ENNIS: A personal opinion if I could put it there is this is more conservative than what's done in the petrochemical industry.

MEMBER POWERS: A lot of the chemical industry differences are associated with the anticipated link to lifetime of equipment.

MR. ENNIS: Right, and they also use risk technology in the petrochemical industry also and their use of risk technology is also quite sophisticated, but it is different from ours.

MEMBER POWERS: Yes.

MR. ENNIS: So they do bring something to the table. All our meetings are open to all and, of course, we do provide for procedural due process. Anybody who is adversely affected by a rule change can appeal to a higher authority at the ASME. It happens, fortunately, rarely, but it does happen.

And here's where we talk specific about now. We want a technologically-superior product at the end of the day and we are willing, as you note, 12 years to sacrifice our schedule to achieve it. Sometimes in good humor and sometimes not, we refer to some time frames as ASME years and I think if we usually use the one to seven ratio we're only two years into this process. Hopefully, we can speed it up. Next slide.

Our participation as I said earlier is voluntary participation. For those in my position, the term of art is herding cats. We know we want certain things to happen, but the priorities are really set by the volunteers themselves. We rely on industry experts and so the expertise that comes to the table is what develops the code. My staff, we provide the structure and administrative support and we do check to make sure all the procedural processes are followed before any item will ever get to my board for final approval.

CHAIR WALLIS: You don't say anything about academia. There are many members of ASME in academia.

MR. ENNIS: Yes, there are.

CHAIR WALLIS: There is not just industry that you're referring. Industry includes academia.

MR. ENNIS: Industry in my term includes everybody.

CHAIR WALLIS: Okay.

MR. ENNIS: We include at ASME the NRC as part of our industry that we support. The regulatory authority isn't separate from that industry and actually we had a joint meeting yesterday where one of the individuals who's the Chairman of ANS committee, we have a joint committee going, who is a professor. So, yes, we do have academia in our structure. Actually, on that particular group yesterday, we had two professors. One is from the University of Mexico.

MEMBER POWERS: That's way too much.

MR. ENNIS: So we have Texas and Mexico represented on our committees. With that, I'll turn it over back to Ken.

MR. BALKEY: Next slide please. In looking at the issues that were discussed here with the seismic design rules, our board has been looking out to the future, where we need to go, and we have gone through a very intense strategic planning effort and we have four areas that we're trying to address and it gets right at the heart of the technical issue which is the subject here today.

We have, as you well know, been in front of the ACRS on risk-informed in-service inspection and testing, our policy risk informed standard. But now under Mr. Barnes' leadership, we have set up a working group on probabilistic methods and design. And the reason for that is that in the piping design you're always competing against, if you add too much conservatism in the seismic, it then can cause actual challenges and making systems stiffer that can cause higher stresses during normal operations, just heating up and cooling down the plant.

And you're trading off how do you deal with this event. It occurs with the likelihood hopefully much less than one with events that do occur at one and trying to balance that and it depends on the system. If I have a system with many different operating states where I get a lot of changes, I need to have more flexibility to deal with the thermal expansion and if I make that system stiff, it will work against me in my normal operation.

The Code in its present form, the deterministic rules, don't allow for that. You have to use the same stress indices and allowables for each system and what we're trying to move to is a reliability-based method using this load resistance factor design method that would allow the designer to move those margins as appropriate depending on the case and you would be working to a probability of failure and acceptance criteria rather than saying I have a factor of two.

I think as most would know I could say I have a factor of two and in one system it may translate to a very low probability. But in another system because of all the scatter, the probability may not be as low as you may think it would be. So we are trying to get to that, but to get to that point we're bringing the expertise into standards groups and in fact, we have an effort underway how we organize in developing rules. Do we bring the experts all into Section 3 or do we let our committee on Nuclear Risk Management build on their expertise and have a relationship? So we are right now evaluating how to organize to be able to move forward with that initiative and we actually have a research project underway with support from an NRC grant and a Japanese grant looking at this approach.

The other need as you're all very well aware is the filing here for early site permits and combined construction and operating licenses and, of course, developments in China and over in Europe and Eastern Europe and we are very interested in getting this issue today done, endorsed and Mr. Barnes will talk to it because of the developments around the world. We can't take that long in the future if we're going to support new construction.

So we're trying to make our codes and standards easier to use not just in the United States, but in the international community and we have actually set a team up under our board and so has the Nuclear Regulatory Commission. As we get our standards done, they get endorsed in a more timely manner, both together. As Kevin indicated, we need to get things through our process and likewise if we keep the staff informed of what our priorities are that will help things move along as well. We have that in place as well.

But we just thought you may interested instead of just talking this issue about what we're trying to do in a broader context as well. With that, I'm going to turn it over to Mr. Barnes and let him now get into the technical discussion.

MR. BARNES: Thanks, Kevin. Kevin was the Chairman, gentlemen. I think I've met a couple of you previously. The face is familiar but I think you were in one of the presentations we made.

I would just like to turn to the slide where the background review is and I'm not going to take long on this. Obviously, it's been hit a couple of times. There are effectively three studies the way I viewed it and the first one was the one where we looked at the results of the experiments. An actual fact: Industry provided $1 million to set up a separate group of people to try and develop rules from that and they picked out the experts that they felt could do that.

These rules were provided back to the Code committees and this occurred just at the time I took on the chair of Subgroup Design. So I've been around as long. I also must admit to you that I still didn't have hair when I started on. I didn't lose the hair because of this work, however. What happened there was we had extensive discussions and we came up with a set of rules.

The second study occurred. We got the letter from -- We set up a committee immediately afterwards because that was my role and I realized that when the new rules came out, we had unresolved issues. We got the letter from NRC and that was the basis of some of the discussion, but we also got letters from Japan and we got letters from individual members. We had whole slew of issues that a couple of meetings were spent just breaking them out into lots to know how to handle it. This resulted in some small changes in the Code that were set out in 1994. It's small in our opinion, but obviously significant from the U.S. NRC.

The Study No. 3, 2003-2005, I refer to the recent cooperative effort between U.S. NRC staff and ASME people, experts, and I'll address those. I think I've handled this next slide.

CHAIR WALLIS: Can I ask you something?

MR. BARNES: Sure. Go ahead.

CHAIR WALLIS: We saw very crude numbers formulated this morning.

MR. BARNES: Yes.

CHAIR WALLIS: Threes and fours and so on.

MR. BARNES: Right.

CHAIR WALLIS: This must depend on the materials. I mean the stainless piping isn't the same as carbon steel piping and it isn't the same at different temperatures and so on. You can't just have a magic number it seems to me that covers all materials.

MR. BARNES: Let me explain my understanding of this. One of the problems, I'd just like to preface this by saying unfortunately we're an organization as you see we meet four times a year and our ability to get ready for something like this that came up after the last meeting and before the next one, it's impossible to get people organized. I'm going to ask that we have a chance to make a presentation at a later date to at least get our position on there.

I don't usually talk about frivolity but I believe we've spent so many millions and millions of dollars and man hours on this job. It's extensive that's going on and I believe it deserves at least to have our side also put into it even though we have reached agreement on things.

It's just Study No. Two I would like to just address the issues, Mr. Chairman. The two, the factor of two, as I understood it, was based on the fact that if we maintain the factor of two, the capacity factor of two I think it is, for one percent probability that the piping would then no longer be considered as part of the meltdown of the reactor. So if we kept two, that factor, then we are kept out of that hornet's nest. Now I may be wrong, but that was my understanding.

We then put a factor of 1.5, they were three factors that Robert Kennedy, and just to preface this, the three factors, the 1.5 was on the stresses. Then there was the factor for redundancy and the factor for -- What was the other one?

VICE CHAIR SHACK: Dynamic effect.

MR. BARNES: Dynamic effects, yes.

VICE CHAIR SHACK: Nonlinear dynamic effects.

MR. BARNES: And Kennedy came up with the point, the 1.33, was there. Then the rest was in the redundancy. So the term of it is all we have a set of experiments which we tried to get some understanding. What we did discover was that the experiment showed which everybody I think sort of knew that the failure mechanism was not collapse but fatigue when you got -- Now that's pretty obvious, but however we had tried to handle it with plastic collapse. It resulted in very conservative results and you have to excuse me. I am not an expert in this field, but I've been around long enough that I have some of the language together. It resulted in this excessive conservatism at the time.

Furthermore, the thing that worried me as chairman of Subgroup Design, it did not address the failure mechanism and I don't care how strong you make things if you don't understand why things fail. So what happened was they took all the results and there was a lot of discussion. John was part of the first area of it very much so.

They developed these equations. They had a problem. They had these equations in programs, hundreds, probably thousands of programs around the world and they said if we change the equation which it should have been a fatigue-based equation, they're going to impact all these programs. So what they decided to do was effectively change the factors in the equations and make it an empirical equation. And what always astounds me is people go into this empirical equation and start to adjust the numbers as if it were a true descriptor of the --

CHAIR WALLIS: But it's supposed to describe it. It says it describes a brand new pipe and a 60 years old pipe as the same.

MR. BARNES: What it does is basically the way you use, the way I interpret this, is if you put the numbers into this equation what it effectively gives you is a system that's supple enough to withstand the earthquake. See, the concept is is to keep away from the forcing function of the frequency, the forcing function that is the same as the natural frequency of the system. That's where the worse situation is.

What this does if you meet these equations, you effectively get a system that's more flexible. Now the difference is how you take all these experiments and translate it into this empirical equation and that's one of the difficulties we did have in ASME because our people are interestingly type people, not on the experimental side and we brought in Robert Kennedy and Bill Iwan from CalTech to assist us and they had been part of the U.S. NRC effort in this area as well.

Effectively the rules we have, the concept, we had this 4.5 which wasn't a true descriptor of the stresses, but the trouble of it is is it looks like it and it created a lot of problems. And Kennedy said let's adjust it. Let's go to three and adjust the figures on the front end and the optics are correct. But basically, if you would, you get into the detail of it, Kennedy shows you that effectively the components remain elastic although some local plastic activity in it. But effectively, the overall system is elastic.

Now I'm starting to get into really deep water here.

CHAIR WALLIS: Good swimming.

MR. BARNES: There's a good chance that I could quite easily become very tired if somebody questions all these details. But the point is that was the sort of concept and we have a very lot of intelligent people as U.S. NRC has too and they aren't just playing numbers for the sake of it.

What we ended up coming down to because the practicality of life also rules, what you end up doing is you make decisions and say "What the heck? That doesn't mean anything. We can argue about this. We can disagree, but if we change it to that, nothing has changed. We still have to save systems." So that's the way standards are developed. Nothing is perfect, but we know that we have at least a safe area.

MEMBER KRESS: Sounds like to me ACRS

knew.

MR. BARNES: Yes. Well, I'm sure you tell an operator the same given all the background that you have.

CHAIR WALLIS: Well, you're really scaring me because you're making me feel like I'd better find out more about what you're doing.

MR. BARNES: And we'd be happy.

CHAIR WALLIS: I don't really want to get involved.

MR. BARNES: We have the same feeling. Believe me. We would love the opportunity to go into it in more depth if you would like to.

VICE CHAIR SHACK: Just out of curiosity, do you think that the piping systems for new plants, will they still be designed by rule or will they be designed by analysis now? We can do so much more.

MR. BARNES: Piping, I think it's too complex to decide.

VICE CHAIR SHACK: Still --

MR. BARNES: Yes. Furthermore, piping is so forgiving. It's hard to believe. You look at the effort that's going in and you wonder about it. You look at the unknowns that are in the seismic event and all of that and you come up with these rules. The way

I look at it is as long as if you address the failure mechanism and you've given as much bounding as you can, then you've done about what you can do I think. I think we need much more complex analytical techniques eventually to actually truly analyze.

VICE CHAIR SHACK: Of course, the conservatism has turned out to be quite useful that you can live with cracking. It's amazing how flaw tolerant these systems have turned out to be.

MR. BARNES: Yes.

VICE CHAIR SHACK: And no one designed them to be that way.

MR. BARNES: No, except in actual fact, it's the materials.

VICE CHAIR SHACK: Yes.

MR. BARNES: They went to a great effort and ASME goes to extreme effort to make materials good and in the Class 1 particularly, it's limited to very, very forgiving material. Do you know what I mean? So in the end, that's probably the clue to the whole thing.

MR. ENNIS: Yes, and if you look at the other sections of the Code, sometimes in Nuclear, we forget that the rest of the world exists. There is ASME stamped equipment that has been operating for 80 years and when I worked at my previous employer at the National Board, we would answer questions on riveted vehicles. So the limitations while many times they seem to be 1.5, 3, three-quarters, the basis of the Code is not only to design it new but to assure that there is a good useful life so that equipment, yes, has imperfections and it over time cracks, leaks, what have you, but it prevents it from catastrophic failure and that comes back into when these things come up to the main committee, there is experience with this. Some of these people are running utilities that are much older than the nuclear plants on the fossil side. So they do have lots of experience with this type of problem.

MR. BARNES: Okay. I just want to make a couple more points on this second study. One thing that John forgot to mention was that there was a very extensive Japanese effort that went into this as well and Kennedy was able to take the Japanese experimental results and use those to validate what had happened previously and to validate the approach that he had given ASME in that direction.

The Japanese did some fantastic work. They took that Test 37 that went over. They were able to actually reproduce that analytically and explain it. So we had a much better understanding of all this. In fact, we had some pretty interesting tools that could come out of it. We didn't have to end up doing this very complex analysis. They were able to take the work that they did and the work that Iwan did, although this is not in the Code as such, but predict this with much simpler analytical techniques.

Generally speaking, those two people agreed with what we had come up with, although NRC had disagreed with it, some aspects of it. But effectively, Study 2, the rules we came up with then, we had really good analytical and really good expert background from all areas as a basis for the concepts we came up with. And we believe we had more than enough adequate conservatism in them.

Moving on, I'd just like to go to Study 3. Gene Imbro and I got together and I really appreciate it. To be honest, I must compliment to Gene. He's a very accessible person who is looking for solutions and as the Chairman of 3, I found that very useful and ended in a very collaborative effort, of which we came up with and we finally came down, we got a group of experts together again, and we came up with and resolved five of the issues.

So I would like quickly to just go through to the sixth issue which is on page 16. And our 12 percent, I look at that 12 percent and I think what's 12 percent. With all the uncertainties around this, it's a joke. Well, I don't want to be recorded as saying that, but the point about it is --

CHAIR WALLIS: But you have been here.

MR. BARNES: But I didn't finish if you notice. I just said joke. Anyhow the point I'm trying to make is that why we have a difficulty with it I guess is because when the Code committees looked at it they thought that it is just not that significant. We believe that the strain rates achieved during the seismic event is insignificant in its impact on dynamic strain aging. We agree it's there, but for the reactors, we just don't believe it's significant.

Although there are no experimental tests to demonstrate this, an analytical evaluation was done to show that the safety margin did not reduce below 1.5 at the higher temperatures.

VICE CHAIR SHACK: Haven't we done enough dynamic analyses of these systems to have a pretty good feel for what the strain rates are?

MR. BARNES: Well, we think so, but there are disagreements. There are opinions. The Code committee decided that the margins available are more than enough to cover the seismic loadings and so no change was made to the Code requirements from that.

CHAIR WALLIS: So what you're saying is the seismic event is nothing like getting hit with a hammer. It's something that builds up.

MR. BARNES: Yes, and it's a fatigue. That's why we address that part of it as fatigue.

MEMBER POWERS: When you think about a seismic event and you think about failure by fatigue, do you think about a seismic event or do you recognize that all significant seismic events will be accompanied by certainly aftershocks and often preshocks? Do you think of them as the set of seismic events or do you just think of a single event?

MR. BARNES: You're hitting me in deep water here at this particular point, but we effectively have, the way the Code evaluates it, it takes 20 cycles of this criteria. It was based on 20 of the cycles. I don't know whether John can answer that question.

CHAIR WALLIS: So it's only 20 cycles or some seismic events last longer than that or come back instead.

MR. BARNES: Yes. I think what happens is when we get past the 20 cycles, then we --

MEMBER SIEBER: It appears longer.

MR. BARNES: Yes, I don't know whether --

MR. FAIR: I have to get up near the mike. If I go there, it's the wrong place. The current criteria you evaluate fatigue under OBE and you assume five OBEs. In the new criteria that's eliminating OBE, the previous design certifications have thrown in two SSEs for the fatigue evaluation. We haven't really developed an official staff position right now for going forward, but, say, for the older plants, the staff position was 5 OBEs which were intended to account for the build-up of cycles to aftershocks and things like that.

CHAIR WALLIS: What's an OBE?

VICE CHAIR SHACK: Operating basis equation. Your plant keeps on ticking after that.

MR. BARNES: That's right.

CHAIR WALLIS: I thought an OBE was an Order of the British Empire.

MR. BARNES: That's my time to exit. I'm starting to get in deep water here.

MR. ENNIS: Yes. When we said he was Canadian, we didn't tell you the whole truth. He's really Australian, then Canadian.

MR. BARNES: I'm really very confused.

MEMBER POWERS: That's all very interesting because we think about sites and spend a lot of time worrying about the intense earthquake, but we don't characterize sites by if you had an earthquake how many preshocks do you have, how many postshocks do you have.

MR. BARNES: Yes.

MEMBER POWERS: And clearly the challenge that we face is is it hard enough to find the paleoseismic data for having an earthquake. We have no paleo-data from preshocks and aftershocks and if you don't have good models of seismic events on the east coast, how do you have a database that substantiates whether 5 OBEs or 2 SSEs are inadequate for failure that you assume is occurring by fatigue?

VICE CHAIR SHACK: Of course, it is the big ones that kill you. You can take a lot of elastic cycles, the number of plastic cycles that you can take goes down real fast.

MEMBER POWERS: Understand that an aftershock can be pretty indistinguishable from the main shock. Seismologists have an understanding on what constitutes an aftershock, but the magnitude of the earthquake can come very close to what the main shock is. Now five is a pretty good number for large. I mean it's a conservative estimate of large aftershocks, but it's not completely wild by any means. There's nothing. It's not completely unimaginable for California earthquakes that I have absolutely no experience nor does anybody here though maybe your founders in 1880 did with large east coast earthquakes and how many aftershocks and preshocks. But I would suspect they have more.

MR. BARNES: The summary, the industry cooperation with ASME and U.S. NRC have spent millions. NRC has funded very extensively and we appreciate that input. We have reached major agreement and there really is only one issue separating us and the Code committee believes that the impact of dynamic strain aging for the reactors is insignificant. As you have seen in our presentation, the Code process is consensual. We really require meetings to discuss and approve the Code position.

We didn't have an opportunity to develop a consensus presentation for the Code position in time for this meeting. The next set of meetings is in May and a presentation will be developed at that time and we respectfully request the opportunity to --

CHAIR WALLIS: By that time, you will have resolved your differences.

MR. ENNIS: Maybe.

CHAIR WALLIS: I think that would be a good time to tell us when you've resolved your differences which I hope will be soon.

MR. BARNES: Okay. Yes, that's mine. Thank you very much.

CHAIR WALLIS: Mr. Barnes, gentlemen, thank you for the opportunity.

MEMBER ARMIJO: We're right on schedule. A little bit over. I think we can wrap this up. Although we don't have a date for closure which would be nice to have, maybe May or so, and I think the issue of dynamic strain aging has to take some negotiation. It seems like a small issue but apparently not so small to the NRC staff. So we'll have to just wait and see how they can resolve that.

Does anyone else have any comments? I'll just tell you from myself this is an issues that's surprisingly long term and it is pretty much resolved and I frankly don't understand why we're reviewing it.

CHAIR WALLIS: I think the question is do we write anything about this or do we just wait until we hear resolutions?

MEMBER ARMIJO: Right. I think other than a short note to whomever you care to write that we've reviewed it and it's well on its --

CHAIR WALLIS: We don't necessarily have to write anything. We don't necessarily need to.

MEMBER ARMIJO: We don't have to. That's fine. I don't know if anybody else on the Committee.

MR. SANTOS: The way it was explained to me, Cayetano Santos, NRC staff, by Sandra Osami is that the Commission ordinarily asks the ACRS to review and once the Addenda came out and the staff raised all the concerns with it, that's why it's before the Committee in this format as opposed to when the staff typically updates this 10 CFR 55(a). That's the way it was explained to me and why the Committee was asked to review it and maybe write a letter to the Commission.

CHAIR WALLIS: They want us to make a technical review of the issues. That's quite an undertaking.

MEMBER ARMIJO: I can't imagine that. I think if it's a status report, I don't know whether that's our function. We reviewed it. It seems on its way to resolution.

MEMBER MAYNARD: I don't think we necessarily need to send a letter. I do think we should encourage both the staff and the ASME to come to agreement on this. I don't see that there's that big a difference and I'm wondering if we're kind of getting into egos here or whatever when really you just need to decide on one of the two numbers. I don't see that it's that big a difference.

VICE CHAIR SHACK: Yes, without reviewing a number of dynamic analyses of plants, I have no real good feel for what these strain rates are. But it seems to me a technically resolvable thing. I just believe there are enough calculations that have been done that they can be reviewed and the decision made. But I certainly can't do it.

MEMBER ARMIJO: Even if there is no resolution, there's resolution on five of six items and the other one can just be NRC staff takes exception to that and continues on.

CHAIR WALLIS: So if we get involved in this, we might decide the number should be 2.95 instead of something else and then we'll really get in trouble.

MEMBER ARMIJO: I don't think --

MEMBER MAYNARD: I would like to encourage the staff though and the ASME to try to come to resolution even on this one so that it doesn't have to be endorsed with an exception. Again, I'm struggling with whether there's a big enough difference to constitute an exception or not.

MEMBER ARMIJO: Okay. Thank you, Mr. Chairman.

MEMBER POWERS: It seems to me that there's a couple of issues that one needs to think about a little bit not in connection specifically with this but in the future. I think Dr. Shack raised the question of design by rule design by analysis and what will happen there and that seems like an interesting issue for the Committee to pursue a little bit. In the thinking about what we're going to face in 2008, this question of fatigue and earthquakes seems to be one that we need to chase down a little bit farther.

CHAIR WALLIS: So we have some take-aways from this too. Anyone else? Are you ready for me to declare a break? We will take a break until 10:30 a.m. We will reassemble in the Subcommittee Room up on the second floor in the other building. We won't need the transcript anymore. Thank you very much and thank you for your patience with the mike problem. Off the record.

(Whereupon, at 10:11 a.m., the above-entitled matter was concluded.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards 531ST Meeting

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Lindsey Barnes

LINDSEY BARNES
Official Reporter
Neal R. Gross & Co., Inc.

PIPING SEISMIC DESIGN CRITERIA

Presented to
Advisory Committee on Reactor Safeguards

April 7, 2006

John R. Fair
Engineering Mechanics Branch
Division of Engineering
Office of Nuclear Reactor Regulation
Telephone: 415-2759

Statement of Issue

1994 Addenda to the ASME Code, Section III adopted revised criteria for piping seismic design. These criteria specify significantly higher allowable stresses than those specified in the previous ASME Code version. The NRC staff did not endorse the revised criteria because of concerns with the technical basis used to establish these criteria.

Background

- Dynamic tests of piping components (EPRI, ANCO) performed during mid to late eighties.
- ASME Code Special Task Group established 1991 to assess margins in current piping rules. NRC staff participated as members.
- ASME revised the Code piping rules in the 1994 Addenda. The revised rules established higher allowable stress limits for seismic loads.
- NRC representatives on ASME committees voted negative on the proposed change to the rules.
- NRC informed ASME that it would not endorse the new piping criteria in a December 14, 1994 letter.
- NRC staff documented its technical concerns with the new rules in a May 24, 1995, letter to ASME.

Background (Continued)

- ASME established the Special Working Group - Seismic Rules (SWG-SR) in September 1995 to evaluate technical concerns raised by NRC and others.
- Energy Technology Research Center (ETEC) reviewed the technical basis 1994 for the piping seismic criteria under contract with RES.
- NRC staff and RES contractors participated in SWG-SR meetings as observers.
- NUREG/CR-5361 published June 1998 documented ETEC assessment of the 1994 piping seismic criteria.
- NRC Staff Briefed ACRS Subcommittee on Materials and Metallurgy June 1, 1998 and March 25, 1999.

Piping Design Criteria

- The ASME Code contains design criteria for Class 1, 2 and 3 piping.
- ASME Class 1 piping includes the reactor coolant pressure boundary.
- The design requirements for ASME Class 1 piping include a detailed fatigue evaluation whereas the design requirements for Class 2 and 3 piping do not.
- Piping is typically evaluated using the design rules in ASME Code Sections NB/NC/ND-3600.
- Class 1 piping is sometimes evaluated using the design by analysis criteria in Section NB-3200.
- The Code contains allowable stress limits for Level A, B, C and D load combinations.

Significant 1994 Code Revisions

- Strain limits were added to NB-3200.
- The Level D allowable stress limit was raised by 50%.
- A frequency limitation was established.
- Level D allowable limits for seismic anchor motions were established.
- A Level D allowable weight limit was established.
- New Level B and C allowable limits were established.

1994 ASME Code Level D Primary Stress Limit

$$B_1 \frac{P_D D_O}{2t} + B_2 \frac{D_O}{2I} M_E \leq 4.5 S_m$$

B_1, B_2 = stress indices

P_D = pressure

D_O = pipe diameter

t = pipe wall thickness

I = pipe moment of inertia

M_E = moment amplitude

S_m = material allowable stress

ASME Basis For Piping Criteria Changes

- Piping component test data demonstrates that piping collapse cannot occur during a seismic event.
- Piping component test data demonstrates that the possible failure modes during a seismic event are fatigue, fatigue/ratchet and progressive ratchet.
- Evaluation of the piping component test data demonstrates that the new seismic rules provide adequate margin against the possible failure modes.
- Evaluation of piping system tests confirms that the new seismic rules provide adequate margin against the possible failure modes.

Major NRC Staff Technical Concerns (May 24, 1995 letter)

- Insufficient test data to support the conclusion that piping system collapse will not occur.

- Inadequate evaluation of the existing test data.

- Insufficient technical basis for establishing minimum design margin.

- Inadequate technical justification for extrapolating margins obtained from component test results to actual piping systems.

NRC Research Program

- NRC established a program with ETEC in 1993.
- The program included an independent evaluation of EPRI/ANCO test data.
- Independent analytical studies of test margin extrapolations were performed.
- The program included a peer review group of experts.
- The program was completed and the results of this effort were published in NUREG/CR-5361.
- The review concluded that the technical basis for the rules published in the 1994 Addenda was incomplete.
- ETEC provided the technical information to the SWG-SR.

SWG-SR Effort

- The SWG-SR relied on the ETEC evaluation of the EPRI test data.
- The SWG-SR voted to adopt the margin definition proposed by R. Kennedy (i.e., 1% probability of failure capacity of 2).
- The SWG-SR proposed modifications to the rules based on evaluation of the test data using the Kennedy margin definition.
- Revisions to the piping rules were incorporated to address NRC technical concerns in the 2001 and 2002 Addenda to the Code.

Piping Seismic Design Criteria in 2002 Code Addenda

- The Level D allowable stress limit was revised back to 3Sm.
- New seismic stress indices were added for elbows, tees and thickness transitions.
- The stress indices for elbows and tees are different for ASME Class 1/2 components from those for Class 3 components.
- A D/t limitation was added to the criteria.
- The frequency limitation was deleted.

2002 ASME Code Level D Primary Stress Limit

$$B_1 \frac{P_D D_O}{2t} + B_2' \frac{D_O}{2I} M_E \leq 3 S_m$$

$B_2' = 3/4 B_2$ *for Class 1/2 elbows and tees, but not less than* 1.0

$B_2' = 2/3 B_2$ *for Class 3 elbows and tees, but not less than* 1.0

$B_2' = 1.33$ *for thickness transitions*

$D_O / t \leq 40$

Staff Concerns With 2002 Piping Rules

- The new criteria should not be used with flow transient loads.
- The technical basis for the detailed rules in NB-3200 has not been established.
- The Class 2 and 3 Level B rules should be consistent with the Level D criteria.
- The rules should not supercede licensing basis criteria for generating seismic loads.
- The stress indices published in the 2002 Addenda for Class 3 tees and elbows were not acceptable.
- The use of the allowable stress for anchor motions should be restricted.

Recent Activities

- The staff issued a proposed rule amending 10 CFR 50.55a to incorporate by reference the 2001 Edition up to and including the 2003 Addenda.

- The proposed rule contained limitations to address the remaining staff concerns with the piping seismic design criteria.

- The ASME submitted comments on the rule limitations and requested that NRC continue its prohibition on using the seismic rules until the remaining issues were resolved (March 22, 2004 letter).

- The ASME formed a Seismic Project Team to resolve the remaining issues.

- The Seismic Project Team resolved 5 of the 6 issues.

Resolved Issues

- ASME initiated Code changes to eliminate applicability of the seismic rules to flow transient loads.
- ASME initiated Code changes to eliminate the NB-3200 strain criteria. This change was initiated by ASME prior to NRC comments.
- ASME initiated Code changes to modify the Class 2 and 3 Level B limits to be consistent with the Level D criteria.
- ASME initiated Code changes to eliminate specifying the methods to generate the seismic loads in the definition of M_E.
- ASME initiated Code changes to add provisions to the piping seismic criteria to address potential strain concentrations.

Remaining Open Issue

- Testing at Battelle has shown that certain carbon steel materials are subject to dynamic strain aging at temperatures greater than 300 °F.
- The dynamic strain aging results in a significant reduction in ultimate tensile capacity of the material (NUREG/CR-6226).
- Battelle testing of actual piping loops with large flaws under simulated seismic loads have shown a significant reduction in dynamic capacity at high temperature for certain materials (NUREG/CR-6233).
- Seismic strain rates can be in the range of concern (NUREG/CR-6226).

High Temperature Strain Rate Test Data (NUREG/CR-6226)

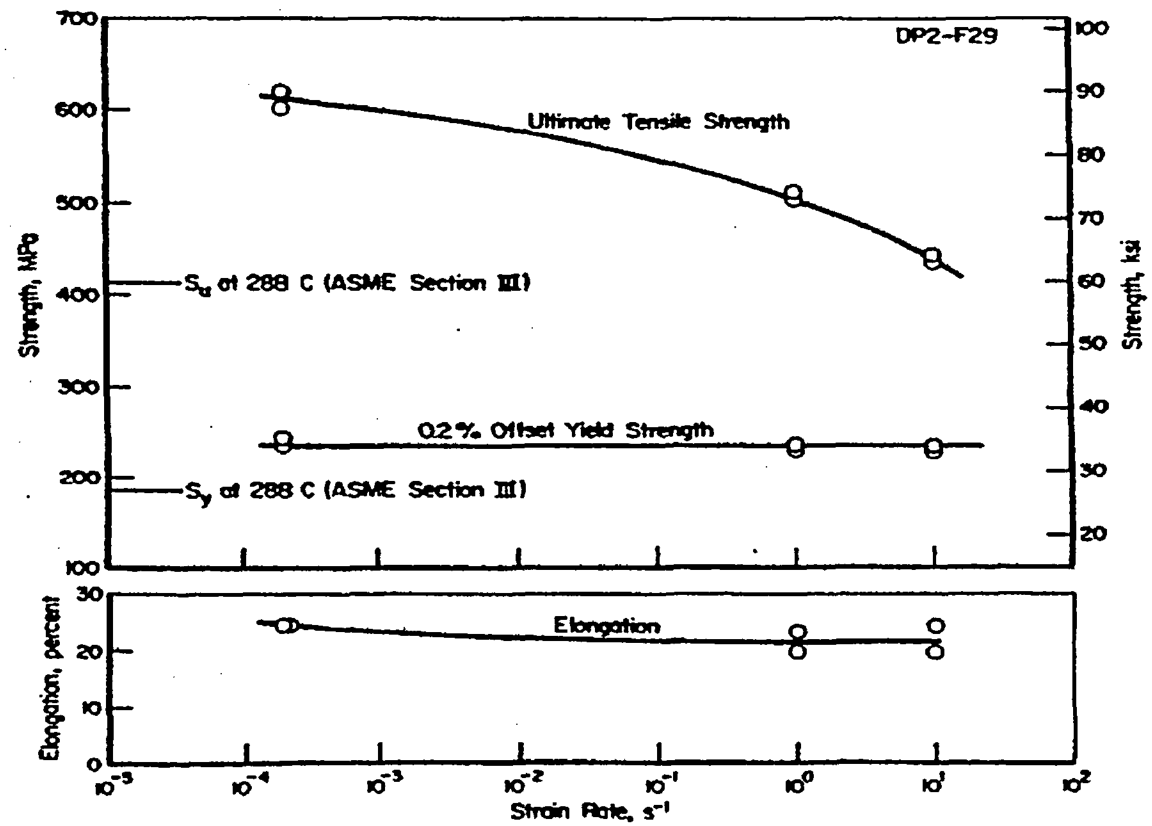

Figure 2.15 Tensile properties at 288 C (550 F) versus strain rate for Pipe DP2-F29 (A106 Grade B carbon steel pipe)

Proposed Resolution of the Issue

- Place restriction in the 10 CFR 50.55a endorsement of the ASME Code piping rules that $B_2' = 3/4 B_2$ for carbon steel elbows and tees at temperatures greater than 300 °F.

ASME

SETTING THE STANDARD

1880 — 2005

ASME Nuclear Codes and Standards
ASME Code Section III – 1994 Addenda for Class 1, 2, and 3 Piping Systems

Advisory Committee on Reactor Safeguards
April 7, 2006
Rockville, Maryland

Ken Balkey, Vice President, ASME Nuclear Codes & Standards
Richard Barnes, Chair, ASME B&PV Subcommittee III
Kevin Ennis, ASME Director, Nuclear Codes & Standards

Topics

- ASME Nuclear Codes and Standards Overview and Initiatives
- Technical Discussion on Section III 1994 Addenda for Class 1, 2, and 3 Piping Systems
- Summary

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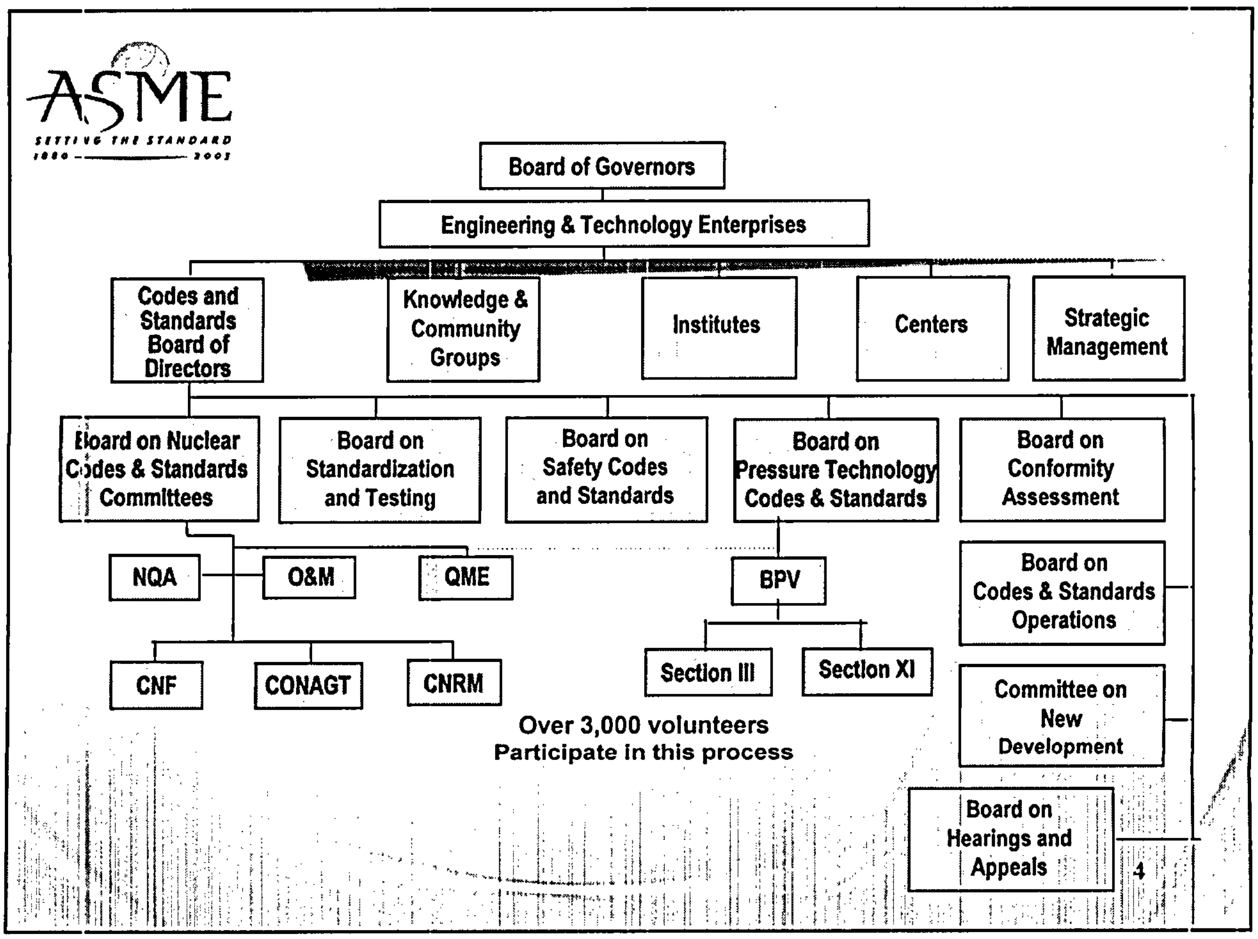
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ASME SETTING THE STANDARD

Board on Nuclear Codes & Standards

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  - Qualification of Mechanical Equipment
  - Nuclear Air & Gas Treatment
  - Nuclear Quality Assurance
  - Nuclear Risk Management
  - Nuclear Cranes
- 3 Subcommittees of BPV Committee
  - III – Nuclear Power
  - XI Inservice Inspection
  - Nuclear Accreditation

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Nuclear Codes and Standards Consensus Process

- People
  - good technical people
  - approximately 800 engineers participate
  - participants are supported by their employers
- Process
  - formal procedures
  - balance of interest
  - open to all
  - Procedural due process
- Product
  - technically superior product
  - willing to sacrifice schedule to achieve it

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ASME
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Nuclear Codes and Standards Consensus Process

Participation

- Voluntary participation.
- ASME Codes and Standards relies on industry supporting participation by knowledgeable experts.
- ASME provides the structure and and administrative support.

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ASME
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Board on Nuclear Codes and Standards Initiatives

- Apply risk technology to Nuclear Codes and Standards
- Evaluate technical needs for new reactor technology
- Make Nuclear Codes and Standards easier to use for the international community
- Facilitate regulatory endorsement of Nuclear Codes and Standards

Seismic Rules for Piping

Status Report

ASME
SETTING THE STANDARD

Background Review

- Three separate studies were done under the guidance of Section III
  - Study No: 1 1990-1994
    - Resulted in the publishing of new requirements in the BPV Code
  - Study No: 2 1995-2003
    - Resulted in some relatively small changes to the Code requirements set out in 1994
  - Study No: 3 2003-2005
    - Resulted in the further changes to the Section III Code

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ASME
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Study No: 1 1990-1994

- The rules developed were based on a set of experiments that were funded by industry and government.
- Industry funded the development of a set of requirements that were presented to SWG that included USNRC membership, which reviewed and modified the proposed requirements.
- The USNRC had concerns and wrote to the Chair of BNCS.
  - These concerns were addressed in Study No: 2.

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Study No: 2 1995-2003

- This Special Working Group (SWP) of the code attempted to address all the concerns expressed by various stakeholders of the Code, including the USNRC
- It consisted of various experts
  - Code members, external consultants, international representation particularly from Japan
  - Various external experts were also invited to make presentations on appropriate aspects of the work
  - Results of new experiments run in Japan were introduced to SWG, and
  - Results of a USNRC funded review of the original experiments were also provided
  - The USNRC did not participate as members in this activity but maintained a watching brief on the committee activity

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