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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON CONTAINMENT DEGRADATION

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PUBLIC MEETING

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Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, Maryland

Wednesday, October 16, 1996

The Commission met in open session, pursuant to notice, at 9:10 a.m., the Honorable SHIRLEY A. JACKSON, Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

SHIRLEY A. JACKSON, Chairman of the Commission
KENNETH C. ROGERS, Member of the Commission
GRETA J. DICUS, Member of the Commission
NILS J. DIAZ, Member of the Commission
EDWARD McGAFFIGAN, JR., Member of the Commission

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

KAREN CYR, GENERAL COUNSEL

JAMES TAYLOR, EDO

ASHOK THADANI, Associate Director for Inspection and Technical Assessment, NRR

JOSEPH MURPHY, Special Assistant, RES

ANDREW MURPHY, Chief Structural and Geological Engineering Branch, RES

GOUTAM BAGCHI, Chief Civil Engineering & Geosciences Branch, NRR

P R O C E E D I N G S

[9:10 a.m.]

CHAIRMAN JACKSON: Good morning, ladies and gentlemen. The purpose of this meeting is for the NRC Staff to brief the Commission on degradation of containment structures.

The containment is a fission product boundary, and it is a cornerstone of the defense in depth strategy applied at all power reactors in this country. Containment degradation, particularly if it involves a challenge to the capability of a containment to perform its safety function is of concern.

Additionally, our recent implementation of a performance-based 10 CFR Appendix J rule further underscores the importance of keeping abreast of this issue.

The Commission recognizes that a great deal of effort has been expended over the last several years in better understanding the material condition of containment structures.

Following the identification of examples of degraded containments and varying degrees of licensee containment inspection programs, a new inspection rule endorsing the applicable sections of the ACME Code, Section 11, was made effective in September of this year.

During today's briefing, the Staff will inform the

Commission of the nature of the degradation observed to date and long-term staff efforts in this area. We are also interested in how the new inspection rule addresses these degradation mechanisms.

I understand that copies of the presentation are available at the entrance to the room. Do any of my fellow Commissioners have any additional comments?

[No response.]

CHAIRMAN JACKSON: Mr. Taylor, please proceed.

MR. TAYLOR: Good morning. Chairman, you have already outlined the important safety function of containments.

I would note in starting that containments are typically very robust structures designed to withstand the loading of external events such as tornadoes and hurricanes and earthquakes in addition to the internal pressures in elevated temperatures associated with design basis accident.

With me at the table to continue the briefing are Ashok Thadani, Goutam Bagchi from the Office of NRR, and from the Office of Research, Joe Murphy and Andy Murphy.

CHAIRMAN JACKSON: Are you brothers?

[Laughter.]

MR. TAYLOR: Chairman, they formally disclaim that.

Ashok has some additional opening comments.

MR. THADANI: Good morning.

CHAIRMAN JACKSON: Good morning.

MR. THADANI: Thank you, Jim.

This morning, the briefing will be given by members of NRR as well as members from the Office of Research.

Goutam Bagchi, sitting to my right from NRR, and Andy Murphy from Research will outline the containment degradation mechanisms and problems that have been detected in the operating reactors, discuss the kind of responses that the NRC has undertaken as a result of these identified problems, and in particular, will focus on the recently issued inspection requirements and to go on and talk about type of research activities that are underway now, recognizing that we are seeing a variety of degradation mechanisms in structural containment.

The key point is that the number of incidents of degradation is increasing. That is an important point to note.

Some of these problems have actually been identified by the NRC. Many of them, of course, have been identified by the licensees themselves.

Mr. Bagchi will describe the mechanisms involved, as well as the degradation rates, and this is clearly a time-dependent phenomenon, and that is another important

element to where we are going.

While the degree of degradation that has been observed to date has not been significant, but it is critical that early attention be given because, as I said, it is a time-dependent phenomenon and there could be a problem over the long term in terms of maintaining the types of margins we believe that exist with robust containment.

You have indicated, Chairman Jackson, that Appendix J does, in fact, call for inspections, particularly when you do integrated leak rate testing prior to and afterwards, but there is no specific guidance provided either in Appendix J or elsewhere as to what does that really mean, what do we mean by inspections, and that is where the need for this rule became evident. There is a need for specific guidance, and it is captured as part of the ASME 1993 addendum codes.

So what we have proposed here -- in fact, not proposed -- the final rule actually calls for adoption of this 1992 addendum, 250.55(a) requirement of the regulations.

Now, the other issue that is important is to make sure that what we do is properly integrated in terms of our activities. The maintenance rule scope includes structural systems and components, in particular. That means the containment structure is certainly part of the maintenance

rule requirements. It is within the scope of the requirements.

The role of containment is going to be obviously critical for reactors as they continue to operate. Therefore, it becomes an important issue as part of the license renewal activities, and whatever we do in terms of our inspections or monitoring licensees' performance needs to recognize that. There is no need to have separate programs to deal with these issues. So what we are looking at is one -- at least from our side -- one inspection approach that would be good enough in terms of maintenance rule considerations, would be good enough in terms of license renewal considerations. That is an important element that work is currently ongoing.

I will go to Mr. Bagchi to give you some of the details of what we are seeing and the actions that we have taken.

MR. BAGCHI: Thank you, Mr. Thadani.

Good morning, Chairman Jackson and Commissioners.

Containment structures, as was pointed out, are designed to withstand the effects of conservative loads and combinations of extreme loads while remaining essentially within elastic limits.

For example, the design basis internal pressure caused by loss of coolant accidents and the large seismic

loads are applied simultaneously. These structures are built with high-quality materials and construction techniques. However, as good as the structures are, they are showing signs of degradation, but the integrity of containment structures is being maintained through timely repairs.

Next slide, please.

This is the outline of our presentation. I am going to cover the problems encountered so far, the safety significance, NRC response, and the summary, and Dr. Murphy will speak about the inspection rule and the research programs.

Next one, please.

Prior to the issuance of the containment inspection rule, the Commission was informed about the need for the rule to ensure that degraded condition are detected in a timely manner using uniform and technically sound methods, such as those incorporated in the ASME criteria, but today's presentation is intended to provide the details of degradation and the status of containment structures at operating plants.

The next picture, please.

I would like to go over very quickly with some sketches and pictures, so that I can set the context of our --

CHAIRMAN JACKSON: Could we have the next slide, lease? I think there is a list of the problems detected. It is the previous slide.

MR. BAGCHI: Let me go over this one. This is a Mark I, BWR metal containment structure. It is light bulb-shaped, and it is the bottom of the light bulb where vent lights come out and go into the torroidal shape wet wells. Corrosion has been found in the sand cushion area which transitions from the embedded concrete just below the vent pipes. That is on the outside surface of the steel shell.

MR. THADANI: If I may make a comment, those areas are being pointed on the screen as Mr. Bagchi is describing them.

MR. BAGCHI: Also, inside the wet well, near the free surface of the water, that is where the water is in contact with the steel shell. That is where corrosion has been found.

They are coded primarily, except for one plant, but they are regularly, generally inspected frequently, and they are being monitored with respect to their condition, measuring thicknesses by non-destructive techniques and so forth.

The next picture, please.

Programs, of course, have been implemented to

maintain the integrity of the containment. There have been some repairs, but in other cases, they are being monitored through surveillance to make sure that the thickness required is maintained.

This is a picture looking at the dry well shell from the outside, putting a camera inside the sand cushion area. It is a very small opening, and it does show extensive area of rusting.

Next one, please.

This picture shows the steel shell area which is in contact with the sand cushion. The lower portion of the picture, you see the sand cushion, and in the upper right-hand corner, the interface goes right through the middle of the picture. You can see the steel shell.

In some cases, corrosion has been extensive, but as I pointed out earlier, rust has been scaled off and it has been repainted.

Next picture, please.

I am trying to give you instances of what the containment structures look like, what their specialties are. This is a distressed, as they call it, post-tension reinforced concrete containment structure.

The thing to point out is that this is such a large volume. The entire inside surface of this prestressed concrete containment structure is lined with steel liner.

That provides the barrier against radionuclides coming outside. Even on the top of the base mat, the liner goes underneath a little bit of cover of concrete, and those areas were being pointed out as we were looking at the picture.

The next picture, please.

Now, this is instructive. People think that structures are built forever, especially those made out of concrete. One is built to last forever, but this one clearly didn't. It is on the top of a dome somewhere on the containment structure, and that is the extent of spalling of concrete that was observed.

Now, this has, of course, been repaired and resurfaced.

Next picture, please.

This picture shows grease coming out of the outside surface of the containment structure. This is in a prestressed concrete containment structure. Grease is used to protect the tendons that go through the sheaths embedded inside the concrete, and the grease itself is supposed to prevent chemical contaminants that might attach and corrode the free-stressing tendons.

Please note here that the streaks line up with the locations of the tendon ducts.

CHAIRMAN JACKSON: Is it that this leaching of the

grease out -- is it evidence of corrosion or is it partly a corrosive mechanism itself?

MR. BAGCHI: It is neither, and this is an intriguing thing. The grease comes out of the concrete, and therefore, the presence of grease, whether or not it changes mechanical properties of the concrete itself so that it might affect the compressive behavior of the sheer transfer behavior -- it is something that is being studied, and Dr. Murphy is going to talk about that in his research program.

We are not sure how this affects the safety of the containment, but to some extent, the mechanical properties of concrete could be affected.

Next picture, please.

This is an ice condenser containment. It has a steel shell inside an outside concrete shield building. Corrosion has been observed on the outside surface of the steel shell near the bottom where the pointer is being pointed, and then, also, on the inside near the upper floor, that is where there is a piece of core that is going around it, the containment shell, which attracted water and, therefore, had local corrosion, but this has since been repaired, and they are being monitored and so forth.

Next picture, please.

This is probably trying to go into a little more detail than necessary, but it would show how free-stress

concrete containments look.

This is a cross-section between the wall and the base mat, and if you notice right through the inside core of the concrete, there is some hollow ducts that are going on and the tendons go through those ducts and anchor on the underside of the concrete so that the concrete is compressed, and when the inside pressure pressurizes inside the containment, the pressure would be released somewhat, but the concrete would still essentially remain in compression.

In French practice, pre-stress concrete containments are used without any liners, but here, we do use liners.

Next picture, please.

This is a cross-section through the vertical wall of a prestressed concrete containment, the upper one, and again, please note the tendon duct going through the concrete, right through there.

Then, the lower portion is a cross-section through the buttress, and the buttress is an area of tensions that go horizontally around the containment structure. These are very large, 130-feet-diameter structures, and usually, they use three of them. This is one buttress where the tendon steel is anchored on the concrete.

Next slide, please.

Well, this is another cross-section through a reinforced concrete containment wall. In the picture, you don't see the effective scale, but in the reinforced concrete, the wall thickness is bigger. It is 4 feet 6 as opposed to 3 feet 6 in a prestressed concrete containment because concrete is being compressed, and it is used in a different manner, but this is a typical cross-section.

Next slide, please.

I pointed out earlier incidents of local corrosion of scale through the pictures in the Mark I containment. That is the typical degradation.

Degradation of bellows. Now, bellows are typical devices that are connected to penetrations, usually processed piping and things like that. For example, the vent pipe that you saw is connected through bellows to the wet well portion. The purpose of the bellows is to allow the containment to grow and breathe when the accident-induced load is going to pressurize the containment from inside.

Now, these bellows are an integrate part of the containment boundary, and during some integrated leak rate testing, there have been instances of bellows leaking, and they have eventually been replaced and then the integrity has been restored, but nevertheless, those have been observed.

Also, in concrete area, cracking of anchors for post-tensioning tendons, corrosion and relaxation of tendons, tendon wires and wire anchor head failures have been encountered.

Something to remember with respect to prestressed concrete containments is that the tendon itself is a collection of a large number of wires, individual wires that ended up in the head, and the head is anchored through an anchoring plate, and then it deposits its compressive load on the concrete through that plate.

Those anchor heads or buttons, those are the ones that have been found to be cracked, but because they are so numerous one or two crackings is not a problem.

Next slide, please.

For steel, the degradation mechanism are generally an accelerated corrosion in normal and corrosive environments. Corrosive environments are encountered when the steel is in contact with perhaps spilled or borated water or some other kind of water that contains contaminants.

In cases of stainless steel bellows, they are subjected to transgranular stress corrosion cracking, and this is a very common degradation mechanism in stainless steel.

Next slide, please.

Degradation of concrete is perhaps best understood in case of environment specifics. There is some crack that develops and moisture gets in, and in the case of very cold weather, when it freezes, it expands in volume, and the crack is aggravated, and then the cycle goes on and the degradation takes place.

The other mechanisms are creeping of the concrete when subjected to large compressive force as it is in case of a prestressed concrete containment. The deformation of the concrete in response to the load applied to it remains proportional to some extent, but after a while, it begins to creep, even without an increase in load. So that is the phenomenon that causes loss of pre-stressing force.

Shrinkage cracks are very common on concrete. Any time you build a structure out of concrete, your shrinks and cracks develop, very minute cracks. These are not structural.

Spalling of concrete and anchorage cracking, I talked about those before.

Next slide, please.

These are degradation rates. I wanted to put it in perspective by saying the steel shells vary in thickness from half an inch to 1-3/4 inch or, in other words, 500 to 1,750 mils, and the liner plate itself varies in thickness from a quarter inch to half an inch or 250 to 500 mils.

So the general degradation rate of 1 mil per year does not really pose a safety concern. However, the accelerated degradation rates that have been observed require an effective inspection program to be put in place, and the need for the inspection rule and the fact that we do have a rule in place has been spoken to before.

Next slide, please.

The load-bearing capacity of the containment can be reduced as a result of degradation, but it is a time-dependent phenomenon, a Mr. Thadani pointed out and Mr. Taylor. In steel shells, localized corrosion and pitting do not significantly affect the strength of the containment. For instance, one could have a pin hole in the containment and not necessarily reduce the capacity of the containment, but we don't want any compromise of the pressure boundary of the containment. That is why inspection and monitoring is necessary.

In case of concrete structure, spalling and cracking of concrete has been observed, and the effect is to generally expose the reinforcing bars which can then corrode in a typical reinforced concrete containment, the reinforcing bars, the main reinforcing bars, the No. 18's. These are 2-1/4-inch-, 2-1/2-inch-diameter bars. They are huge, and to date, we have not had any instance of corrosion of the reinforcements inside the containment, but it is the

reinforcing bar that takes the load. The major loading is inside pressure, and it is subjected to tension, and the entire tension load is taken by the reenforcing bars.

Concrete does not take or carry any tensile load. In post-tension containments, premature loss of pre-stressing force is an area of concern, but as we have wisely incorporated the design feature that our containments are mostly designed with non-grouted tendons. That means we can later on go in and re-tension those steel wires and reintroduce the force that might have been lost.

COMMISSIONER ROGERS: Is that being done?

MR. BAGCHI: That has been done in one plant. The entire tendons in the vertical direction were re-tensioned, all of the tendons.

COMMISSIONER ROGERS: Does everybody agree that that is a good thing to do?

MR. BAGCHI: That is a good thing to do when th loss has been predicted to be beyond a certain rate. We used to have technical specification which required that the stressing force be monitored and trended.

When the design was initially conducted, there was an expectation that creep and shrinkage would bring down the pre-stressing force below a certain point after 40 years, and that is being monitored, and if the degradation rate seems to be accelerated, then the best thing to do is to re-

tension them.

COMMISSIONER ROGERS: My understanding is that in the Russian containments, where the tendons are helical rather than just simply circular, that the studies that have been done there seem to indicate that it's not a good idea to re-tension.

MR. BAGCHI: The designs are different. The helical design requires that the wires go in a tortuous way, in a very narrow, restricted path. It is very difficult to rethread the wires if substantial numbers get broken, but here, we have mostly buttresses that I indicated, and the ability to go and tension the wires is very simple.

COMMISSIONER ROGERS: It doesn't introduce any new problems?

MR. BAGCHI: It does not introduce any new problems. Even if large amounts of wires break, we can introduce new tendons and re-tension them. It is important to ensure that the pre-stressing force remains in place and the design condition is maintained and the margins are maintained.

Next slide, please.

These are the NRC responses. I won't go over the details of every one of those, but I will touch upon the important aspects, so that I save your time and everybody's time.

The information notices, the first two were related to Mark I dry well and wet well steel containments, and the last one, the third one, is with respect to corrosion and steel shell for ice condenser containments. I introduced the picture and showed where these corrosions occurred.

The Generic Letter that was prepared was to gather information from licensees with respect to corrosion and conditions that existed at their plant. This was for Mark I containments. Once this information was received, the staff evaluated the responses and determined that Mark I and Mark II steel containments should be under some kind of an inspection program, required inspection program, and that led to the proposed Generic Letter.

However, around this time, the work was continuing on a rule for inspection of containment structures of all types rather than just the Mark I and II. They were already underway.

So the proposed inspection of Mark I and II steel containments through the Generic Letter was canceled, and the whole effort was subsumed in the new rule that endorsed the semicode criteria for all containment types.

Next slide, please.

From 1991 to 1992, the Staff conducted audits of six older plant sites to assess conditions of structures.

The results of these audits are discussed in NUREG 1522. It is pointed out here in this NUREG that surveillance and maintenance of structures is essential to maintain their functional performance.

This document was influential in the development of structural maintenance guidelines prepared by the industry.

NUREG 1540 provides a history of BWR steel containment corrosion and endorses the need to adopt the ASME Section 11 inspection criteria.

The new rule on containment inspection endorsing IWE for steel shell and steel liners and IWL for reinforced concrete containment structures became effective as of September 9, 1996.

Now Dr. Murphy is going to go over the rule itself and the research program that is in place and will address some of the complex issues.

DR. ANDREW MURPHY: Good morning. Thank you, Goutam.

This morning, I will describe the content of the two ASME subsections on containment inspection that were recently incorporated by reference into 10 CFR Part 100.

The two subsections that I will be talking about are Subsection IWE which covers metal containments and the steel liners of concrete containments and Subsection IWL

which covers concrete containments, both reinforced concrete and prestressed concrete containments and the post-tensioning systems that are used for the prestressed concrete containments.

This rule became effective, as Goutam noted, on September 9, 1996. With an expedited implementation period, the inspections are to be completed by all utilities by September of 2001. Those inspections require 100-percent inspection of all accessible metal areas. There is also a requirement for inspection, an augment inspection of areas of special interest.

Two examples of these would be areas with no codings or areas that have suffered repeated loss of coding, leading to substantial corrosion or pitting.

A second example would be areas subjected to excessive wear or erosion that would cause, again, the loss of the coding and corrosion degradation.

These augmented inspections are required until the areas examined have remained substantially unchanged, no further corrosion, for at least three inspection periods. At that time, they would fall back into an unaugmented inspection, a simple visual inspection.

There is also a requirement for a visual inspection of seals, bolts, and gaskets that are integral to the containment system.

For IWL, the inspection of the concrete containments and the post-tensioning systems, they are required to be inspected twice in 10 years. Again, it is 100-percent visual inspection of all accessible concrete areas. There is also a requirement for an inspection of the post-tensioning system. This includes tendon monitoring, monitoring of the forces on the tendons, sampling and removal of tendon wires for further laboratory testing, and for the re-tensioning of tendons as they have become exposed to creep.

We will go to the next viewgraph No. 12.

Here, we will talk for a few moments about three research projects that we have ongoing at the moment. The first at Oak Ridge National Laboratory and the second at Sandia Laboratory are coupled, one being the first phase and the other being a second phase, of a general degradation of containment research effort.

The program at Oak Ridge is intended to identify corrosion mechanisms to assess the available techniques, both destructive and nondestructive, for evaluating the corrosion or detecting the corrosion, for the establishment of the effectiveness and/or the limitations associated with techniques to prevent or mitigate damage.

Looking at the viewgraph itself, the contractors involved in the analysis and evaluation of these

nondestructive and destructive techniques, at this time, particular emphasis is being given to areas that are called inaccessible. These would be areas of the containment shells that are below concrete floors or, in the case of the steel liners, behind the liner itself.

CHAIRMAN JACKSON: What kinds of techniques are used to do that?

DR. ANDREW MURPHY: At this stage, they fall under the general category of ultrasonics and associated techniques. The sophistication isn't so much in the technique or the transducers that are involved, but in my opinion, in the analysis that is able to be done with that.

Another part of the program, another task that is ongoing is a subcontract from Oak Ridge to Johns Hopkins University to enlarge or expand upon a program and technique that we had developed under our structural aging program, which was a concrete aging program, again at Oak Ridge, to assess the residual strength and service life of a containment, given its past history and the current condition of degradation.

Looking at the next program, the next phase in this program, I will return to Sandia National Laboratory and their efforts. They are working to provide for the NRC reviewers as means to assess the current structural capacity of a containment or the margins associated with that

capacity and to estimate the residual capacity of a degraded containment. This would be as a service tool for the NRR.

We will drop down to the fourth bullet for a moment. We participate in a program at CNSI. This is the principal working group, three subgroups on concrete structures. That is a newly formed subgroup, and it is becoming very active. It has already scheduled a specialist meeting on NDE techniques for inaccessible areas that will be held in March of next year, and it's in the fairly well-developed program stages, planning stages for a specialist meeting in July, probably on the tendon issues that we spoke about earlier.

We also have been making overtures and contacts with the folks in Germany at GRS, NUPEC in Japan, INER in Taiwan, and the KIND's folks in Korea to develop cooperative exchange programs on containment degradation and the general aging of the structures.

Dropping back to the third bullet, which is a topic that we have already touched on a little bit, this is the grease intrusion into the concrete on the prestressed containments.

As Goutam noted and showed you in the photograph, we are seeing grease, the protective grease in the tendons leaking through to the concrete surface. Our concern is for the degradation of the concrete. We have a program ongoing

at Oak Ridge where they are in the process of collecting approximately 60 core samples from the Trojan containment. These will be tested to failure using, I'll say, standard structural techniques, materials testing techniques, to tell us whether or not we have got a problem here and whether there is an issue that needs to be addressed.

CHAIRMAN JACKSON: So it is too early to say whether there is a direct linkage?

DR. ANDREW MURPHY: Yes, there is. We have done a lot of, I'll say, background studies, industry in general, that makes use of concrete structures, including the oil industry where leakage and the presence of grease has been found on concrete structures. A number of studies in that area have been done, and at this moment, it would probably be best to call those equivocal as to whether or not there is a significance to our problems.

Like I say, I expect that we will have preliminary results from this Oak Ridge study probably by the beginning of next summer.

With those comments, I will turn it back to Goutam.

COMMISSIONER DICUS: I would like to ask a question on the time frame for these research projects. You have mentioned the one that you hope to have your results next summer.

The other ones are ongoing. Do they have finite limitations on the time limits to complete them?

DR. ANDREW MURPHY: We expect to have the results from the other two programs, the other two phases of the program within two to three years.

COMMISSIONER DICUS: I have raised the question because of the aging nature of our plants. These research projects do not need to be too long term. They may outlive the plant.

DR. ANDREW MURPHY: I understand the point, and the projects are intended to provide results in a timely fashion.

CHAIRMAN JACKSON: Let us put the question another way.

DR. ANDREW MURPHY: Okay.

CHAIRMAN JACKSON: Given the general and accelerated rates that you talked about, how long would it take for there to be corrosion below some acceptable wall thickness level or strength level?

MR. BAGCHI: We can discover one tomorrow.

CHAIRMAN JACKSON: I see.

MR. BAGCHI: That is not to say that we don't have a process in place to take care of it. The repairs will take care of it.

CHAIRMAN JACKSON: So, if it does go below, it can

be mitigated. That is what you are telling us?

MR. BAGCHI: That is correct.

CHAIRMAN JACKSON: Okay.

MR. BAGCHI: The last slide, please.

We have talked about the importance of the containment structure, what kinds of degradations we will observe, and all of the NRC responses. I would like to really emphasize the point that we have an integrated approach.

We are attacking this problem from several fronts. One was the performance-based Appendix J rule which looks at the containment leak rate and integrity from the tightness standpoint. Also, visual examinations are required as a result of that rule.

We have containment inspection rules specifically endorsing the ASME Section 11, the Subsections IWE and IWL. This would provide a uniform and technically sound method of performing these inspections.

We also have the maintenance rule, which is an overall rule requiring not only the pressure boundary portions of the containment structure, but also things like foundation and other pertinence that might have impact on the safety significance or safety performance of these containment structures.

We also have a license renewal rule, license

renewal activity that is in process to think about what kinds of things the Commission needs to take care of in terms of aging management.

But in summary, then, the integrity of containment structures is being maintained, and their conditions are generally good. Where degradations were observed, they have been repaired to restore their integrity. Our monitoring and surveillance programs have been implemented to ensure that degraded conditions are detected in time.

With the implementation of the new rule, containments will be inspected routinely, and degradation will be detected and appropriate corrective actions will be taken. Thus, inspection and maintenance are essential to ensuring the current licensing basis or margins that these structures have been designed with, and research programs, of course, are going to give us insights with respect to what kind of overall margin we can get, what is the behavior of degraded conditions given that certain local degraded conditions could be simulated and assessed in analytical models and tests, as necessary.

We are also exchanging information with international entities, and these will address other long-term issues.

CHAIRMAN JACKSON: Thank you.

Commissioner Rogers?

COMMISSIONER ROGERS: Have any of the lessons learned from our experience here with existing reactors been translated into any design feature requirements for the advanced reactor?

MR. BAGCHI: Primarily, the access to inspection, but this structural engineering aspect is old, if I may say so, and they have bene utilizing the traditional methods, use of good materials, good construction practice, and the ability to inspect the containments. That is one area where I have personally put emphasis on.

The engineering aspects of advanced reactor application review is being conducted in my branch, and I am quite familiar with that area, but that is an area where we have put some emphasis.

COMMISSIONER ROGERS: Good.

MR. BAGCHI: And also, related to fracture toughness of the material, that is required by the general design criteria. That is nothing new.

CHAIRMAN JACKSON: Do ice condenser containments present any particular inspection challenges?

MR. BAGCHI: They are smaller in size. They are smaller pressure; for example, 15 pounds per square inch accident pressure, design basis pressure, as opposed to 45 to 55, 67 PSI and prestressed dry concrete containments.

They do provide a challenge in the sense that the

accessibility is restricted.

When we went out to look at the corrosion at the bottom of the shell, this was about 12 to 18 inches above the base mat. So it was hard to inspect, but folks who had the plan really did a very good job.

CHAIRMAN JACKSON: Commissioner?

COMMISSIONER DICUS: Yes. How well do you feel that -- I just need to get a feel for this. How well do you feel that you think we understand the effects of degradation, particularly with concrete, and how well we are really able to quantify the effects of what we are seeing?

MR. BAGCHI: With concrete, degradation for containments, it is not a problem that I can see.

COMMISSIONER DICUS: What about with steel?

MR. BAGCHI: With steel containments, the emphasis would have to be on local corrosion, and areas of extended corrosion, areas where aggressive environmental conditions exist, it is a concern that we have to keep our eyes open and look for areas of degradation and do a thorough inspection.

CHAIRMAN JACKSON: Commissioner McGaffigan?

COMMISSIONER McGAFFIGAN: Could I just ask on the research programs, what is the total amount of money in FY '97 going to these four projects? Do you know?

DR. ANDREW MURPHY: Let me start with the easy

one. The tendon, grease tendon work at Oak Ridge, we have got about $120,000 set aside for fiscal '97. If there are additional problems identified, we hope that the basic work will be paid for with fiscal '96 money. The two programs, one at Oak Ridge and Sandia, are funded at about the 250- to $300,000-a-year level.

MR. BAGCHI: May I take that question back to Commissioner Dicus? You are probably aware that we had, again, through a research program, conducted ultimate strength test of the reinforced concrete containment scaled one-sixth or scaled one-eighth --

MR. THADANI: One-eighth.

MR. BAGCHI: One-eighth scale. Fairly large, and it retained pressure three and a half times more than it was designed for. We have substantial margin in concrete containments.

MR. THADANI: Since this issue is up, I might note that is really important, and a lot of the studies that are done to really understand risks from severe accidents, that margin to be able to handle certain loads is quite important in terms of the risk to public health and safety, and that is an important element that I think the containments here provide. That may not be the case in some other places.

MR. TAYLOR: I think that structure is still standing out at Sandia. We haven't been able to rent it to

anybody.

COMMISSIONER ROGERS: It's got a crack in it.

MR. TAYLOR: Right. If you go out there, it's worth a short ride out to look at it. You can actually see it was, I believe, at some type of penetration into the containment that the first damage occurred, and it was at quite a high pressure. So it is an interesting model.

COMMISSIONER DICUS: The important issue here is that we are able to identify in a timely fashion when we have lost our margin of safety.

MR. THADANI: Thank you.

CHAIRMAN JACKSON: So, in fact, that anticipates a comment. Is it fair to say that what you are trying to tell us is that an appropriate focus has to be on detection because if there is detection, there can be mitigation?

MR. BAGCHI: Absolutely.

CHAIRMAN JACKSON: With respect to looking at degradation mechanisms, we are particularly interested in the effect of degradation on the strength to withstand the pressures under accident conditions. Is that a fair statement?

MR. BAGCHI: Yes.

CHAIRMAN JACKSON: Okay. Well, let me thank you. I thank the Staff very much for a very informative briefing. You have presented a great deal of information today on the

mechanisms, the significance, and the impact of containment degradation and the research that is being done to assess all of these issues.

I believe the challenge now is how best we are going to review and understand, if there is further understanding needed, the licensee's containment inspection programs. That is what we all seem to be saying or understanding; that that is where the focus has to be. So it is critical in that sense that our initial reviews of licensee and inspection programs be timely and provide feedback to other licensees, as well as to our inspection programs.

So, unless my fellow Commissioners have any closing comments, we stand adjourned. Thank you.

[Whereupon, at 9:59 a.m., the briefing concluded.]

CERTIFICATE

This is to certify that the attached description of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON CONTAINMENT DEGRADATION - PUBLIC MEETING

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Wednesday, October 16, 1996

was held as herein appears, is a true and accurate record of the meeting, and that this is the original transcript thereof taken stenographically by me, thereafter reduced to typewriting by me or under the direction of the court reporting company

Transcriber: Jennie Malloy

Reporter: Mark Mahoney

United States Nuclear Regulatory Commission

DEGRADATION OF CONTAINMENT STRUCTURES

COMMISSION BRIEFING

October 16, 1996

Presented By:

Goutam Bagchi, Chief ECGB

Division of Engineering, NRR

Andrew Murphy, Chief SGEB

Division of Engineering Technology, RES

OUTLINE OF PRESENTATION

- **Problems Detected**
  - Degradation Mechanisms
  - Degradation Rate
- **Significance**
- **NRC Response**
- **Inspection Rule and Research Programs**
- **Summary**

PURPOSE

- Provide an Information Briefing on Containment Degradation Following the Approval of New Inspection Rule Endorsing ASME Code Criteria in Section XI

PROBLEMS DETECTED

- **Steel**
  - Local Corrosion of Structural Steel
  - Degradation of Stainless Steel Bellows
  - Corrosion of Liner
- **Concrete**
  - Degradation of Dome Concrete
  - Anchorage Cracking
- **Tendons**
  - Reduction in Prestressing Force
  - Failed or Corroded Tendons
  - Anchor Head Failure

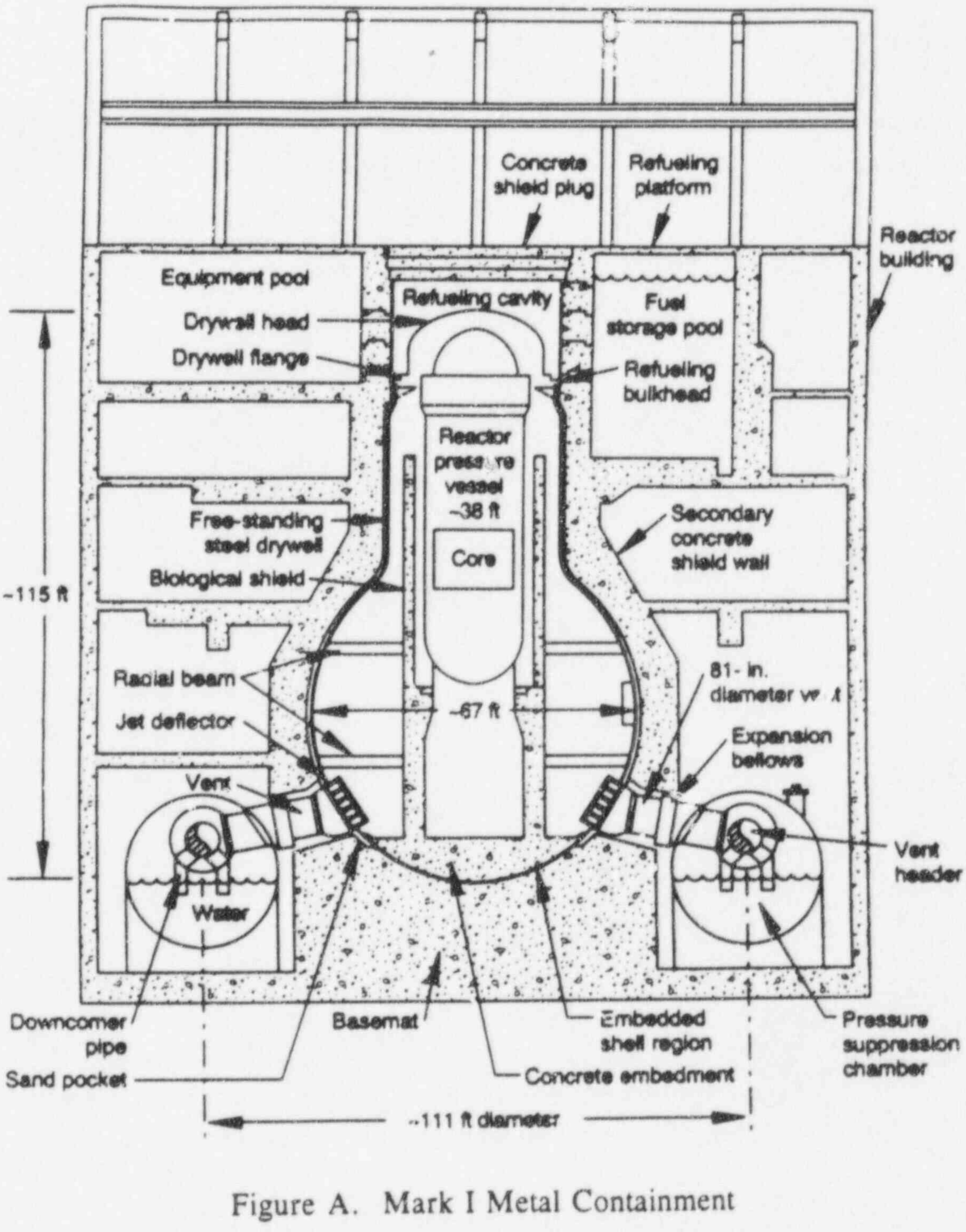
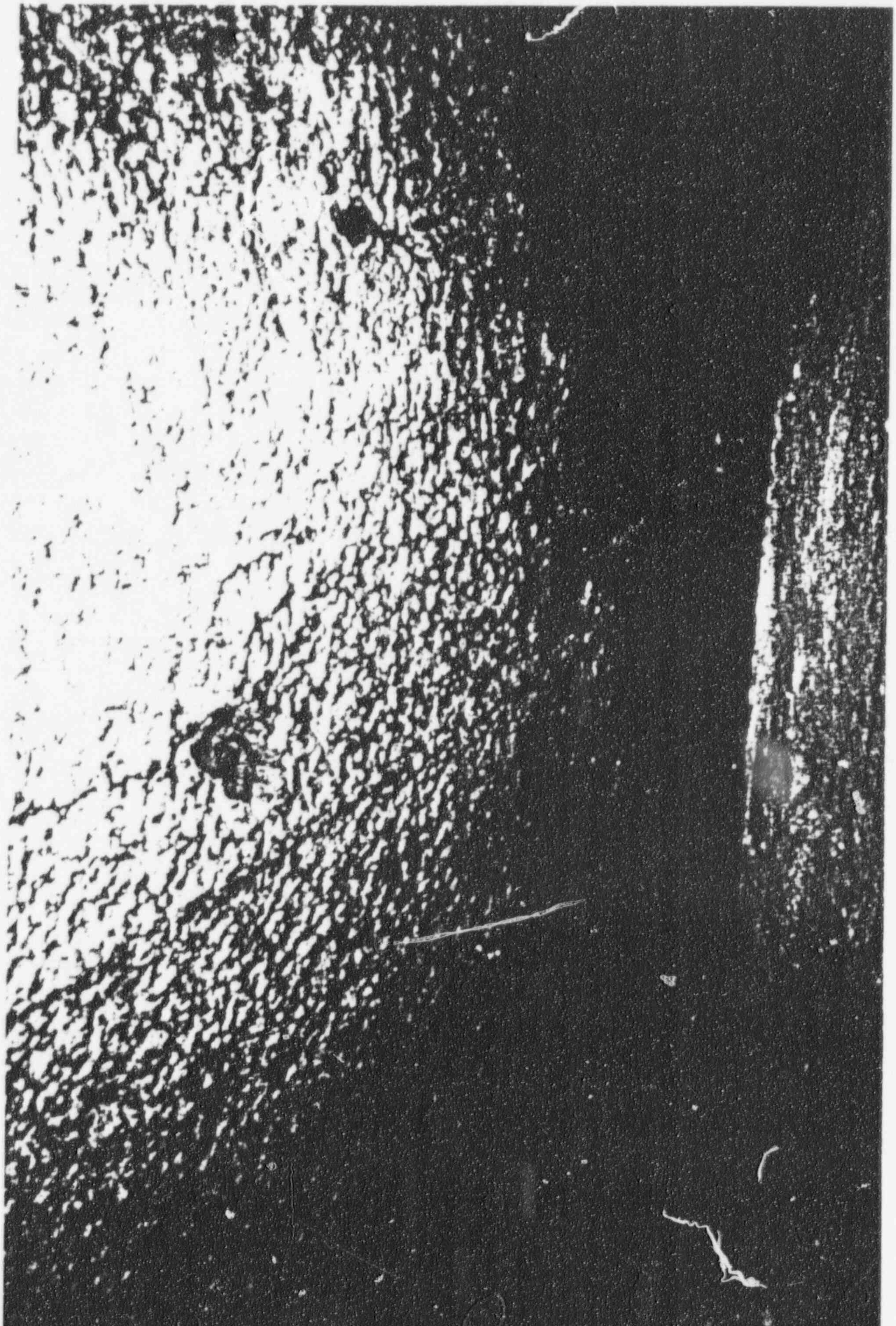


Figure A. Mark I Metal Containment



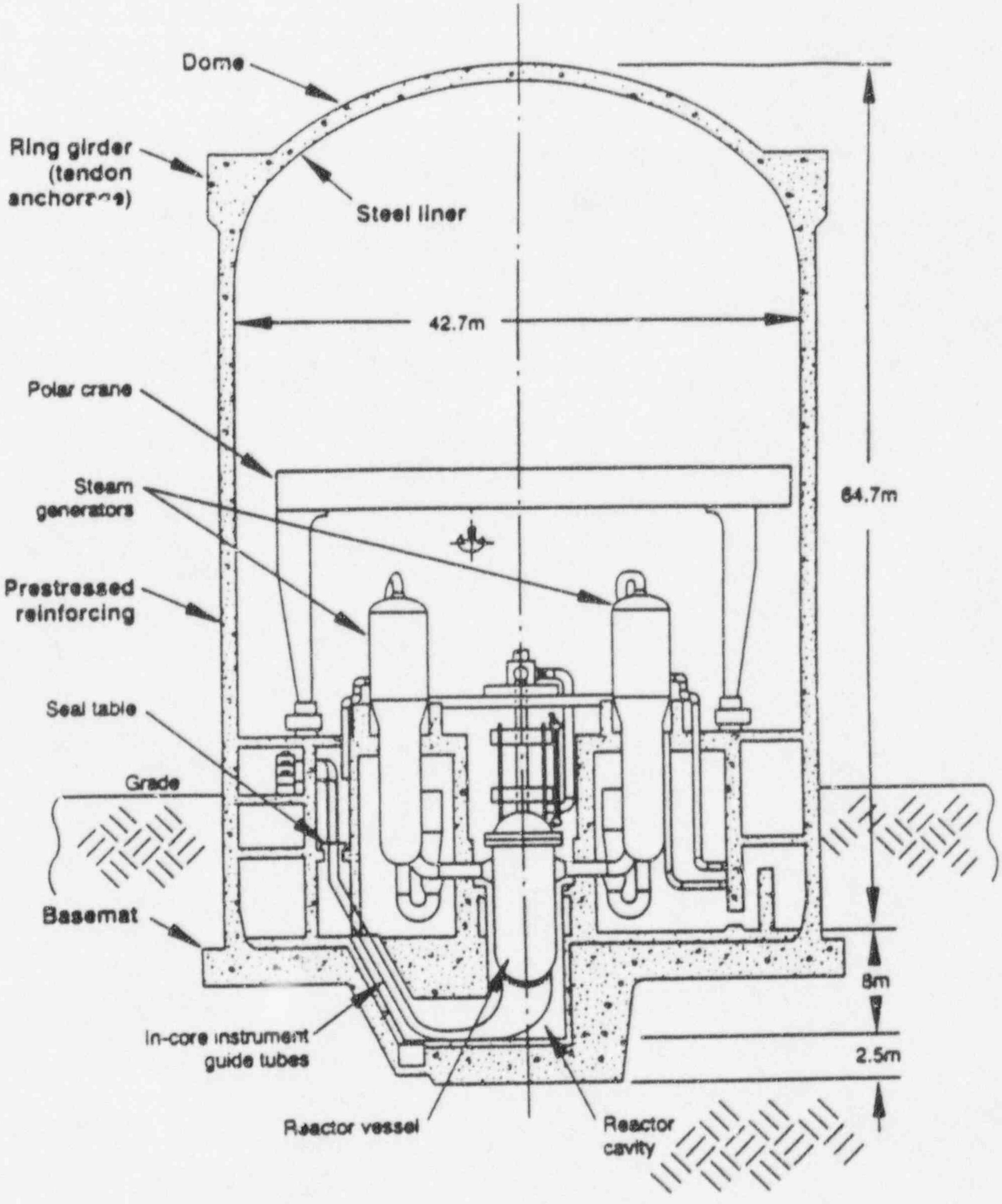


Figure B. PWR Large Dry Containment (Prestressed Concrete)

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DEGRADATION MECHANISMS

Steel

- **General Corrosion**
  - Areas of Water Accumulation and High Humidity
- **Chemical Attack**
  - Borated Water Spills and Contaminants Leaching Out of Insulation Material
- **Trans Granular Stress Corrosion Cracking**
  - Stainless Steel Bellows

DEGRADATION MECHANISMS

Concrete

- **Creep, Relaxation, and Shrinkage**
  - Minute Cracks Develop that Eventually Lead to Degradation Loss of Prestressing Force
- **Environmental Conditions**
  - Freeze-Thaw, Alkali-Carbonate Aggregate Reactions
  - Failed/Corroded Tendons
- **Other Causes**
  - Splitting, Spalling, and Leaching of Concrete
  - Anchorage Cracking
  - Grease Intrusion from Tendon Ducts

DEGRADATION RATES

Steel Containment Shells and Liners

- **General Corrosion Rate**
  - 1 mil (0.001 inch) Per Year
- **Accelerated Corrosion Rate**
  - 9.5 to 10 mils Per Year in the Presence of Contaminants
  - 20 to 38 mils Per Year in the Presence of Aggressive Chemicals

SIGNIFICANCE

Degradation May Reduce Load-Bearing Capacity; Time Dependent Phenomena

- Steel (Net Loss of Section)
- Concrete (Strength Reduction)
- Tendons (Loss of Prestressing Force)

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NRC RESPONSES

- **Information Notices on Containment Corrosion**
  - IN 86-99 "Degradation of Stee' Containments" & Supplement
  - IN 88-82 "Torus Shells with Corrosion and Degraded Coatings in BWR Containments" & Supp
  - IN 89-79 "Degraded Coatings and Corrosion of Steel Containment Vessels" & Supp
- **Generic Letters**
  - GL 87-05 "Request for Additional Information - Assessment of Licensee Measures to Mitigate and /or Identify Potential Degradation of Mark I Drywells "
  - Proposed GL "Augmented Inservice Inspection Requirements for Mark I and Mark II Steel Containments, Refueling Cavities, and Associated Drainage Systems" November 20, 1992 (57 FR 54860)

NRC RESPONSES

- **Other NRC Documents**
  - NUREG-1522 "Assessment of Inservice Conditions of Safety-Related Nuclear Plant Structures" Dated June 1995
  - NUREG-1540 "BWR Steel Containment Corrosion Dated April 1996

- **Regulation Endorsing ASME Section XI Subsections IWE and IWL (August 8, 1996 - 61 FR 41303)**
  - Inservice Inspection, Repair, and Replacement Per ASME Code Requirements - All Containment Structures

INSPECTION RULE

Subsections IWE & IWL

- **Subsection IWE - Metal Containments and the Liners of Concrete Containments**
  - Inspection Frequency - 3 Times in 10 Years
    - Visual of 100% of Metal Surfaces
    - Augmented Inspections of Special Areas
    - Visual of Seals, Bolts, and Gaskets

- **Subsection IWL- Concrete Containments and Their Post-Tensioning Systems**
  - Inspection Frequency - 2 Times in 10 Years
    - Visual of 100% of Concrete Surfaces
    - Post-Tensioning System Examination

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RESEARCH PROGRAMS

- **Oak Ridge National Laboratory - Inspection/Mitigation/Reliability**
  - State-of-the-Art Destructive and Nondestructive Examination Techniques (With Emphasis on Inaccessible Areas)
  - Root Cause Analysis and Mitigation Techniques
  - Time-Dependent Reliability; Residual Strength and Service Life Given Past History and Present Containment Conditions
- **Sandia National Laboratory - Containment Load-Bearing Capacity**
  - Evaluate Effects of Corrosion on the Capability of Containment to Withstand Accident Pressures
- **Oak Ridge National Laboratory - Grease Intrusion into Concrete**
  - Evaluate Effects of Grease on Concrete Strength
- **CSNI - PWG3 Subgroup on Concrete Structures (includes containments)**
  - Specialists Meetings on NDE for Inaccessible Areas and Tendon Issues
- **International Interest on NRC Research Programs**

SUMMARY

- Current State of Containments Is Generally Good
- To Date, Units with Degradation Have Repaired, Instituted Mitigation Measures, or Are Monitoring on a Frequent Basis
- With Implementation of New Rule, Degradation Is Expected To Be Discovered on a Timely Basis
- Inspection and Maintenance Are Key to Maintaining Licensing Basis/Margins
- Research Programs Addressing Long-Term Issues