

Official Transcript of Proceedings ACRST-3247

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards
Subcommittee on Future Plant Designs

Docket Number: (not applicable)

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

Location: Monroeville, Pennsylvania

Date: Thursday, July 17, 2003

Work Order No.: NRC-1011

Pages 1-216

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1323 Rhode Island Avenue, N.W.
Washington, D.C. 20005
(202) 234-4433

TROY

**ACRS Office Copy - Retain
for the Life of the Committee**

ORIGINAL

1 UNITED STATES OF AMERICA
2 NUCLEAR REGULATORY COMMISSION

3 + + + + +

4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

5 SUBCOMMITTEE ON FUTURE PLANT DESIGNS

6 + + + + +

7 THURSDAY, JULY 17, 2003

8 + + + + +

9 MONROEVILLE, PENNSYLVANIA

10 The Subcommittee met at the Westinghouse Energy
11 Center, 4350 Northern Pike, Monroeville, PA, at 1:00
12 p.m., Thomas Kress, Chairman, presiding.

13 SUBCOMMITTEE MEMBERS:

14 THOMAS KRESS - CHAIRMAN

15 GRAHAM WALLIS - MEMBER

16 JOHN SIEBER - MEMBER

17 GRAHAM LEITCH - MEMBER

18 VICTOR RANSOM - MEMBER

19 F. PETER FORD - MEMBER

20

21

22

23

24

25

NEAL R. GROSS
COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 ALSO PRESENT:
2 MEDHAT EL-ZEFTAWY
3 MIKE CORLETTI
4 TERRY SCHULZ
5 ED CUMMINS
6 TOM HAYES
7 DAN FREDERICK
8 RALPH CARUSO
9 JIM SCOBEL
10 SELIM SANCAKTAR
11 JUN LI
12 JIM GRESHAM
13 M. KHATIB-RAHBAR
14 MIKE ZAVISCA
15 SUD BASU
16 H ESMAILI
17 JOELLE STARFOS
18 RICHARD ORR
19
20
21
22
23
24
25

1	C-O-N-T-E-N-T-S	
2	INTRODUCTION	
3	Thomas Kress, Chairman	4
4	ADS 4 SQUIB VALVE RELIABILITY	
5	System design -Terry Schulz	7
6	ADS 4 Controls - Tom Hayes	30
7	Valve Design -- Dan Frederick	45
8	Modeling in AP1000 PRA - Selim Sancaktar	80
9	Post LOCA Aerosol Deposition on Containment	
10	Jun Li	92
11	Thermal Hydraulic Conditions for AP1000 Lambda	
12	Calculation - Jim Scobel	130
13	MELCOR Analysis - M. Zavisca	137
14	In-Vessel Retention and Ex-Vessel Fuel Coolant	
15	Interactions with AP1000 - H. Esmaili	155
16	AP1000 Seismic and Structural Design	
17	Richard Orr	194

18
19
20
21
22
23
24
25

P-R-O-C-E-E-D-I-N-G-S

1:00 p.m.

CHAIRMAN KRESS: Let's get started if we can, please. The meeting will now please come to order. This is a meeting of the ACRS Subcommittee on Future Plant Design.

I'm Thomas Kress, Chairman of this Subcommittee. The other ACRS members in attendance are Peter Ford, Graham Leitch, Victor Ransom, Graham Wallis, and I presume Jack Sieber will be here shortly.

For today's meeting the Subcommittee will review and discuss the AP1000 instrumentation and control design concept, the manned machine interface design acceptance criteria, human factors issues, and the open items regarding the design reviews.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate, for deliberation for the full Committee.

Mr. Medhat El-Zeftawy is the cognizant ACRS staff member, staff engineer, for this meeting. The rules for participation in today's meeting have been announced, as part of the notice of this meeting, previously published in the Federal Register, on July

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 8th, 2003.

2 The transcript of this meeting is being
3 kept, and the transcript will be made available as
4 stated in the Federal Register Notice. It is
5 requested that speakers identify themselves, and speak
6 with sufficient clarity and volume, so that they can
7 be readily heard.

8 We have received no written comments, or
9 requests for time to make oral statements from any
10 members of the public. I don't have any particular
11 introductory comments, so with that I will turn it
12 over to Mike, to get it started.

13 MR. CORLETTI: Thanks, Tom. The
14 presentations that we are going to have for the next
15 day and a half are geared to providing you information
16 that has either been -- the Committee has expressed an
17 interest in seeing, a more detailed presentation, or
18 related to the Draft Safety Evaluation Report.

19 And we've got our first presentation
20 today, it is on the ADS Squib valve reliability, which
21 was an issue that was raised at the PRA Subcommittee
22 meeting.

23 The first presentation is with Terry
24 Schulz.

25 MR. SCHULZ: Good afternoon. I'm going to

1 start this off, we will be talking a little bit about
2 the system design and concentrating on the
3 requirements for the stage 4 ADS squib valves. Then
4 Tom Hayes will talk about the instrumentation control
5 of the ADS 4 squib valves.

6 And then Dan Frederick is here from the
7 valve vendor that makes these kinds of valves, and is
8 our expert witness on how these valves are being
9 designed, what has been their experience in the past.

10 And then, to wrap it up, we will have
11 Selim Sancaktar talk about the PRA modeling, and in
12 particular some -- considering some newer information
13 on valve reliabilities, and what means to the PRA.

14 You've seen this picture before, I don't
15 want to really belabor it, but the four valves that we
16 are talking about are the four squib valves connected
17 to the hot legs, which we have been talking about,
18 from a thermal-hydraulic performance, extensively.

19 These valves are normally closed. There
20 is an upstream, normally opened, motor operated valve.
21 That valve provides isolation capability, in case
22 there is any leakage through the squib valve, which is
23 an extremely unlikely situation to happen.

24 They also provide an ability to isolate
25 the valve, if it had opened in an accident, and you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 are in a recovery mode.

2 CHAIRMAN KRESS: Do those things ever fire
3 off accidentally, and open up?

4 MR. SCHULZ: We will --

5 CHAIRMAN KRESS: That is part of the
6 reliability questions.

7 MR. SCHULZ: Yes. Tom Hayes, in
8 particular, will be talking about the details of the
9 INC, I will talk a little bit about the logic, and the
10 interlocks, and permissives that we have in the design
11 from a logic point of view, and Tom will talk, very
12 much, about the potential, or how the valve is
13 controlled.

14 And, in fact, he will go into fire hazards
15 issues and how we will prevent that from inadvertently
16 opening the valve.

17 MR. CUMMINS: Just to review the open
18 item. Was the ACRS comment that the AP1000 PRA relied
19 significantly on the performance of the 4 stage ADS
20 valves, and could we please present why they will open
21 when we want them to open, and why they won't open
22 when we don't want them to open, and that is the title
23 of this presentation, really.

24 CHAIRMAN KRESS: The question was, where
25 did you get the reliability number that goes in the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 PRA.

2 MR. SCHULZ: Yes, and why is that a good
3 number to have. If you step back a little bit, I was
4 not involved with the certification of the AP600.

5 MEMBER LEITCH: But as I understand it, it
6 did not have a valve such as this?

7 MR. SCHULZ: No, it did.

8 MEMBER LEITCH: It did?

9 MR. SCHULZ: The configuration, as you see
10 on this picture, was both for AP600 and AP1000.

11 MEMBER LEITCH: Okay.

12 MR. SCHULZ: There were two of the four
13 squib valves are shown here, AP600 had four squib
14 valves. The only difference is these are bigger than
15 AP600. These are 14 inch pipe, the AP600 were in a
16 ten inch pipe.

17 Now, that doesn't really connect them to
18 the IDS, but they are bigger for AP1000. There also
19 are squib valves in the injection lines, and the
20 recirc lines. We are not specifically going to talk
21 about those today.

22 But most of what we are talking about, or
23 will talk about, is applicable to those valves, also,
24 in terms of their reliability and the simplicity of
25 their design and operation.

1 MEMBER LEITCH: Okay, thank you.

2 MR. SCHULZ: The ADS 4 valves are -- their
3 function is to work in a loss of coolant accident,
4 because they are not needed, or intended to be used in
5 non-LOCA accidents.

6 They are -- they play a role in getting
7 the plant down to the low pressures required for the
8 gravity drain from the IRWST, as was talked about in
9 the last day and a half in the Therma-Hydraulic
10 Subcommittee meetings.

11 That is a very important function of these
12 valves. The whole ADS system, as we -- as you see
13 here, actually involves four separate stages. Three
14 of them are connected to the pressurizer, discharge
15 into the IRWST from a sparger. Those are motor
16 operated valves.

17 I show three stages here, there is
18 actually two groups of those, there is a total of six
19 flow paths. There is four stage 4 valves, they are
20 actually kind of in a sequence. This valve opens, and
21 then about a minute later the second stage 4 opens in
22 both pairs, too.

23 And the whole purpose of the staging of
24 the ADS is to control and smooth out the transient
25 that the reactor cooling system goes through, in going

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 from high pressures down to very close to atmospheric
2 pressure.

3 The ADS valves are controlled by their
4 core make up tanks level. That is what actuates them.
5 The core make up tank level was a good indication, in
6 our plant, of how much high pressure inventory, safety
7 injection inventory is still available.

8 So as the inventory gets depleted, then in
9 a kind of a LOCA sequence, then, we actuate ADS. And
10 stage 1 is actuated on what we call a low 1 core make
11 up tank level. That is about two-thirds volume set
12 point.

13 That is sent by four level sensors in each
14 core make up tank.

15 CHAIRMAN KRESS: What are those level
16 sensors?

17 MR. SCHULZ: What kind of sensors?

18 CHAIRMAN KRESS: Yes. Are they weight --

19 MR. SCHULZ: They are DP switch, actually.
20 They are very simple. We've actually used the
21 switches because to keep them somewhat different from
22 some of the other DP sensors that we have in the plant
23 from a PRA point of view.

24 So there is a narrow range set of four DP
25 sensors for the low 1. There is a separate set of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 narrow range DP sensors for the level 2. And one of
2 the reasons why we use that level narrow range, is
3 because we can run into significant density
4 differences in the safety water, depending on whether
5 it is recircd or not.

6 Initially it is cold, high density water.
7 We could have gone through, in a very small LOCA,
8 substantial recirculation period, the water could heat
9 up. And because of that the density could be reduced.

10 And to minimize the impact on the set
11 point we came up with a very narrow range sensors.
12 These sensors, of course, go into the protection
13 system to actuate the valves.

14 The second and third stage are controlled
15 by the low 1 set point plus timers. So that the stage
16 2 will always go off a minute or so after stage 1; and
17 stage 3 will go off three minutes after stage one,
18 kind of sequencing.

19 Stage 4 the CMT level is --

20 MEMBER LEITCH: Restored? Will that stop
21 the action of ADS 2 and 3?

22 MR. SCHULZ: No.

23 MEMBER LEITCH: So once the sequence is
24 started you are going to get 1, 2, and 3?

25 MR. SCHULZ: That is right. Now, you

1 won't necessarily get 4.

2 MEMBER LEITCH: I understand.

3 MR. SCHULZ: It is a separate set point.
4 And that set point is low, more like 20 percent volume
5 of the core make up tank. And the fact that the
6 operators take the recommended emergency procedure
7 actions, which is to turn the normal RHR system, which
8 can act like a low head safety injection pump.

9 If they take that action, and that system
10 works, and it is not a safety system, so we can't
11 guarantee that it will work. But if it does work then
12 what it does is it slows down the core make up tank
13 injection and stops it, because of a favorable
14 interaction in the wake of RNS pump flow comes in, it
15 comes in here, goes through this orifice.

16 Which then, if these pumps are running,
17 and replacing the core makeup tank flow, the back
18 pressure stops the core makeup tank injection, the
19 water stays in the core makeup tank, so it is
20 available should the RNS system quit, or be shut off
21 inadvertently later on.

22 But if the RNS does get started, and keeps
23 running, then the CMT level will not drop down to
24 actuate stage 4. Because you don't really need it
25 with RNS pumps running, because they provide enough

1 pressure, with ADS 1-3 to adequately cool the core.

2 There are, of course, manual controls both
3 through the projection system, and the diverse
4 actuation system. Either one of those systems, there
5 are separate controls, in the control room, to control
6 the ADS valves.

7 In both cases it requires two switches to
8 be actuated, to minimize the chance of inadvertent
9 actuation. The power supplies, each stage 4 has three
10 separate sets of wires coming to it, coming to three
11 separate igniters that are located in the valve. Two
12 of those sensor wires are coming from the protection
13 system. So any one of the four squib valve either has
14 a train A and train C wire coming through it, or a
15 train B and D.

16 This minimized, improves the reliability,
17 minimizes the consequences of a single failure. So in
18 that whole ADS system, the worse single failure is a
19 single stage 4 valve. You cannot have a single
20 failure that will affect stage 1, 2, and 3, and stage
21 4, for example.

22 In addition each stage 4 valve has a third
23 set of wires coming to it, coming from the diverse
24 actuation system. This is a diverse INC system, the
25 DAS control of the ADS is only manual, there is no

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 automatic.

2 And we did that, partly, to minimize the
3 chance of inadvertent actuation, and partly because it
4 wasn't needed to be automatic, based on our PRA
5 insights.

6 Now, I will talk a little bit about the
7 logic that controls the automatic signals. In order
8 to get an automated protection system actuation of
9 stage 4, we first need to actuate the core makeup
10 tanks, this is basically an S-signal, like low
11 pressurizer pressure.

12 You will also need the core makeup tank
13 level to drop, to this low 1 set point, and then you
14 need timers to go through to give a permissive for the
15 low 2 level, and then you need the low 2 level to have
16 occurred.

17 And you will also need to be below a
18 specified RCS pressure. This is about 1,300, 1,200
19 psi. This is where you would go to in a small LOCA,
20 and it is a little bit below the set point. Excuse
21 me, the set point is a little bit above the steam
22 generator safety valve set point.

23 So in a case where passive RHR is going to
24 be moving all the decay heat, which can happen shortly
25 after an accident, that is where the plant will tend

1 to go with the leak.

2 But it also gives us an additional
3 interlock to prevent inadvertent actuation at high
4 pressure. So you need all these things to take place,
5 from a logic point of view, and in order for the stage
6 4 valve to be automatically actuated.

7 MEMBER LEITCH: Are the instrument lines
8 connected to these level switches, are they
9 independent all the way into the CMT? In other words,
10 or do you have multiple instruments hanging off the
11 same set of instrument lines? Maybe that is a detail
12 that hasn't been worked out.

13 MR. SCHULZ: You are talking about the
14 tubing sensors going into the tank?

15 MEMBER LEITCH: Yes. In other words you
16 talked about four different level switches.

17 MR. SCHULZ: Yes.

18 MEMBER LEITCH: But are they independent
19 all the way to the penetrations into the tank?

20 MR. SCHULZ: They actually are not. And
21 we've gone through an evaluation of the consequences
22 of (unintelligible) out of all those lines. Remember
23 there are two tanks, and either core makeup tank can
24 actuate ADS.

25 In addition to that -- I would have to go

1 back and look at -- I know we looked at that very
2 carefully to make sure that was okay. We lock open
3 the valves, so they can't inadvertently be closed, the
4 root isolation valves.

5 MEMBER LEITCH: I understand yes.

6 MR. SCHULZ: And we have gone through
7 evaluations of what is going to happen here, leaks
8 going out of the --

9 MEMBER LEITCH: -- drops off on one of
10 those root isolation valves, or something like that.

11 MR. SCHULZ: Yes.

12 MEMBER LEITCH: But you do have another
13 complete tank which would also actuate the system?

14 MR. SCHULZ: In either tank can actuate
15 ADS.

16 MEMBER LEITCH: Yes.

17 MR. SCHULZ: -- both tanks have level
18 sensors for low 1 and low 2.

19 MEMBER LEITCH: Yes. Okay, good, thanks.

20 MR. SCHULZ: So from a point of view of a
21 real inadvertent signal coming through to the valves,
22 we think it is incredibly low with all the interlocks
23 and permissives that we have, and redundant switches.

24 Tom Hayes will --

25 MR. HAYES: -- were for sensors, too.

1 MR. SCHULZ: Yes, when I say four sensors,
2 there is A, B, C, D division for each set, okay?

3 MR. HAYES: And we do it two out of four
4 votes.

5 MEMBER RANSOM: What protection do you
6 have against sabotage?

7 MR. CUMMINS: Tom will address it is some
8 respects.

9 MR. SCHULZ: These valves are, of course,
10 inside containment.

11 MEMBER RANSOM: Right. So it is very hard
12 to get to them.

13 MEMBER RANSOM: And where are the
14 switches?

15 MR. SCHULZ: The switches are in the
16 control room.

17 MEMBER RANSOM: Are they located right
18 together, or do they have any interlocks, or any way
19 to prevent --

20 MR. SCHULZ: The switches for the
21 protection system, there is two safety handles in the
22 plant, in the control room. They are not located next
23 to each other. And you have to actuate a switch on
24 both panels, so one person can't do it.

25 The DAS is a little bit different, but

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 there is two switches on a panel that are close
2 together, but there is a separate power switch that
3 you have to turn on to actuate, turn power on to the
4 manual controls.

5 And that is physically separate from the
6 valve control switches. This just gives you a picture
7 of how much bigger the piping and valves get when
8 going from AP600 to AP1000. You can also get a
9 feeling, here, for some of the advantages of the squib
10 valves, relatively compact, compared to a motor
11 operated valve.

12 And a motor operated valve, really,
13 wouldn't meet the functional requirements for this
14 valve, it wouldn't open fast enough. They also
15 wouldn't be diverse from stages 1, 2, and 3. So you
16 probably would have to go to something a bit more
17 exotic than a motor operated valve as an alternative.

18 MEMBER RANSOM: I have a design question.
19 Why isn't the motor operated valve located downstream
20 of the squib valve?

21 MR. SCHULZ: Because we want the squib
22 valve to discharge directly to the containment, to
23 maximize its performance, piping downstream.

24 MEMBER RANSOM: I would think from a
25 leakage point of view -- well, the other thing is

1 maintenance, the motor operated valve, don't you have
2 to once in a while actuate that valve?

3 MR. SCHULZ: No, because it has no safety
4 function.

5 MEMBER RANSOM: But you want it to close.

6 MR. SCHULZ: We would want it to close,
7 but we would not -- there is no in-surface testing
8 requirements for that valve, because it is no safety
9 function valve.

10 Would the valve be exercised? Probably,
11 not necessarily at power.

12 MEMBER RANSOM: Well, you are clearly not
13 at power.

14 MR. SCHULZ: The valves are also flanged
15 in, and with the valve located at the end of the pipe,
16 it is easier to take the valve apart, because you
17 don't have a flange on both sides of the valve, you
18 only have it on the one side.

19 So if you ever actuated the valve, and
20 then wanted to refurbish it, rebuild it for operation
21 again, you have to take the upstream part off, and it
22 is a little easier to do it in this location.

23 MEMBER RANSOM: Well, this is a shear
24 valve, so that you destroy the valve if you open it?

25 MR. SCHULZ: No, it doesn't destroy the

1 valve.

2 MEMBER RANSOM: Well, it destroys its
3 seal?

4 MR. SCHULZ: It cuts part of the valve,
5 engineered shear section inside the valve. We will be
6 showing you what that looks like.

7 MEMBER SIEBER: I presume --

8 MR. SCHULZ: This is a view --

9 MEMBER SIEBER: -- that there are
10 substantial pipe restraints on the ADS lines, too,
11 because of the reaction force, if you use them?

12 MR. SCHULZ: There are.

13 MR. CUMMINS: Put your picture back up.

14 MEMBER SIEBER: Yes, the drawing doesn't
15 show any restriction.

16 MR. CUMMINS: -- the little lips on the
17 end there, those are forced numbers that go right to
18 the steam generator well, so if it goes off, we've
19 designed them so that it could go off at operating
20 pressure, and it wouldn't cause the pipe to wet.

21 MEMBER SIEBER: Right.

22 MR. SCHULZ: This shows you a view of the
23 functional requirements. I mentioned that it is a 14
24 inch pipe. The hole going through the valve has a
25 nine and a quarter inch ID.

1 And, of course, it is a safety seismic
2 class one design, full system pressure design. It is
3 designed to open at full system pressure, and it is
4 also designed to open at very low pressure, which is
5 actually more challenging than the high pressure.

6 Expected opening pressure, as you heard
7 from hydraulic, is somewhere 100 psi, or in fact a
8 little bit lower. The normal water temperature, up
9 against the valve will be hot. It won't be full
10 system pressure because there is a partial loop seal
11 in front of the valve.

12 We are requiring the valve to be designed
13 so that it can tolerate full hot leg pressure. It is
14 flanged upstream, both up and downstream, and it is
15 stainless steel construction.

16 I talked about several of the aspects here
17 of why we selected squib valves. We actually didn't
18 originally have squib valves in AP600. We were
19 thinking of using some gas piston valve of some kind.
20 But we became concerned when we actually started
21 talking to valve vendors about the availability of
22 those valves, and the development issues.

23 So we ended up selecting the squib valves
24 partially, a very strong reason, was that they are
25 very reliable valves. And, of course, this is an

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 important PRA safety function, so that reliability is
2 very important.

3 The ability to use the three independent
4 control circuits, all the ways through the valve, is
5 a unique and very beneficial function. They are very
6 diverse from the motor operated stage 1, 2, and 3
7 valves, again, a PRA benefit.

8 They have a very low chance of inadvertent
9 opening, or leakage. That is a very beneficial
10 function. The in-service testing and inspection is
11 simplified versus motor operated, or air operated
12 valves.

13 They actually are less expensive than air
14 operated valves that we looked at. Even though there
15 is some development costs in coming up with these
16 valves for the ADS-4, there is in our minds less
17 uncertainty and the cost will be lower, than coming up
18 with the -- an alternate valve.

19 And as a final thing, the US utilities who
20 are working with us, when we were developing AP600,
21 actually suggested this to us, and supported the use
22 of the squib valves.

23 The last two slides I have deal with in-
24 service testing and inspection. Both are being --
25 will be performed in accordance with ASME

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 requirements.

2 Basically ASME says that for squib valve
3 you should take 20 percent of the valves, of a given
4 function or design, and every two years replace the
5 propellant, and put it in a test fixture, and fire it,
6 make sure that the pressure developed would have been
7 sufficient to actuate the valve.

8 CHAIRMAN KRESS: So you take one valve
9 every two years and do that?

10 MR. SCHULZ: No, we only have four, so it
11 is actually 25 percent of the valves, because we have
12 four valves.

13 MEMBER RANSOM: What do you do if you find
14 one that doesn't fire?

15 MR. SCHULZ: Then you need to look at, you
16 know, the whole parts of the quality control. And this
17 is, when you make the propellant, initially, you make
18 it in batches, and you do testing of that before you
19 even put the propellant in the valve, to make sure
20 that this was a new manufacture to start with.

21 So there is, also, a propellant that is
22 designed, it is over-designed so that it will work
23 with 80 percent, or something like that, of the design
24 amount of propellant that you put in.

25 So it is very unlikely that that will

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 happen, but not impossible. If something like that
2 happens you need to try to find out what the root
3 cause of the problem was.

4 MEMBER RANSOM: Do you go back and replace
5 all the ones that came from that batch?

6 MR. SCHULZ: That is a definite
7 possibility. If you can't figure out what the problem
8 is, or if you do figure it out, and it is for
9 something with aging, or that was different than when
10 you first made it. So there are some alternatives
11 there that you can take and certainly one of them is
12 to replace the propellant in the other valves.

13 MEMBER LEITCH: One thing that we always
14 did in other squib valve applications was in the
15 storeroom you would test one from each batch before
16 you used it, in actual application, to be sure that
17 that batch did, indeed, fire properly.

18 MEMBER RANSOM: I imagine the manufacturer
19 did something similar --

20 MEMBER RANSOM: Perhaps, I'm not sure what
21 the manufacturer's practices were, but --

22 MR. HAYES: We have a manufacturer here
23 that you can ask.

24 MEMBER RANSOM: Yes.

25 CHAIRMAN KRESS: The test fixture that you

1 test this in, what measures the force, the charge, it
2 measures the --

3 MR. SCHULZ: -- the pressure?

4 CHAIRMAN KRESS: -- the pressure, maybe.

5 MR. FREDERICK: Yes, I will get into the
6 details when I give my presentation, if that is okay.

7 MR. SCHULZ: Another thing that we do is
8 that when we disconnect the wiring from the
9 propellant, and reconnect it, we will do a continuity
10 check to make sure everything is hooked back together
11 and, in fact, that the firing circuit inside of the
12 valve is intact, and it is all connected together.

13 And, of course, the valve position sensor,
14 that is -- in-service inspection, now this relates to,
15 primarily, inadvertent opening of the valve, somehow
16 cracking, rupturing of the valve opening.

17 The shear cap, which we will be seeing in
18 a little bit, is the main issue here. The valve body
19 is a massive chunk of stainless steel, and I don't
20 think there is any issue with it breaking.

21 The flange is connecting the valve body to
22 the piping, are very robust also. So I think that the
23 focus of question of in-service inspection, and
24 potential leakage/rupturing is with the shear cap.

25 And one of the things that we would

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 concentrate on in-service inspection, we would look at
2 that, take the valve apart, inspect it from a
3 dimensions point of view, make sure there was no
4 thinning.

5 We would also look for any cracking in
6 that shear cap. And if there is any problems we will
7 replace it. Once you've got the valve apart it is not
8 that big of a deal.

9 And we anticipate that although this will
10 be done every ten years, that it probably wouldn't be
11 done all four valves every ten years, it would be some
12 kind of a staggered, it would give you intermediate
13 data.

14 CHAIRMAN KRESS: Have you made some sort
15 of analysis to see if that valve is thermally cycled?
16 When you have a dead end off of a hot thing with a --
17 sometimes these things can get thermally cycled, and
18 are you having -- do you have temperature measurements
19 on it, or --

20 MR. SCHULZ: We do not --

21 CHAIRMAN KRESS: -- way to monitor it?

22 MR. SCHULZ: -- measurements in the plant.
23 The piping is big piping.

24 CHAIRMAN KRESS: Yes, 14 inch.

25 MR. SCHULZ: To make it up the top of the

1 hot leg.

2 CHAIRMAN KRESS: Yes.

3 MR. SCHULZ: So we anticipate that it will
4 be uniformly hot.

5 CHAIRMAN KRESS: It is full of liquid, you
6 drain any air out?

7 MR. SCHULZ: That is right.

8 CHAIRMAN KRESS: So you have a dead end
9 with hot liquid coming off the hot leg?

10 MR. SCHULZ: Yes.

11 MR. CUMMINS: If I may, Tom? For AP600,
12 where we did such an evaluation for the dead end pipes
13 like that, for thermal stratification, for AP1000,
14 where we were using the DAC approach, that is a
15 commitment to perform that assessment as part of the
16 final piping design.

17 CHAIRMAN KRESS: Okay.

18 CHAIRMAN WALLIS: You have to vent this
19 pipe, don't you?

20 MR. CUMMINS: I'm sorry?

21 CHAIRMAN WALLIS: Don't you have to vent
22 it, you get electrolytic pulls because you are letting
23 off the gases, the noble gases --

24 CHAIRMAN KRESS: -- hydrogen get up there?

25 CHAIRMAN WALLIS: -- get up there? It

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 probably would. You have to vent any kind of a dead
2 end like that. Otherwise you are likely to
3 accumulate, over a long period of time, hydrogen.

4 MR. SCHULZ: Well, two things. One I
5 don't see that as being a problem.

6 CHAIRMAN WALLIS: It doesn't matter if it
7 pulls the hydrogen --

8 MR. SCHULZ: If there is some up there --

9 CHAIRMAN WALLIS: -- expose the mixture,
10 too, it is radiolysis.

11 MR. SCHULZ: We have some other high
12 points where we do actually have an isobaric chart
13 inlet which is in the CMT inlets, both of those where
14 the presence of hydrogen might, adversely, interact
15 with the natural circulation of the system.

16 We have high point, not only high point
17 vents, but high point gas chambers on top of high
18 points to level sensors, that actually measure. Now,
19 we don't anticipate actually seeing anything up there,
20 okay?

21 But in those -- those functions are much
22 more sensitive to the presence of hydrogen.

23 CHAIRMAN WALLIS: If it did fill up with
24 the explosive mixture of hydrogen and oxygen, and you
25 set off the squib valve, you might set that off, too?

1 You probably would.

2 MR. SCHULZ: I don't think so.

3 CHAIRMAN WALLIS: Why not?

4 MEMBER FORD: -- explosions occurred in
5 some PWR plants, hot legs of PWR plants. But there,
6 I think, there has been an explosive mixture of
7 hydrogen and oxygen, oxygen in your case. And you
8 also need an ignition source.

9 And I'm not too sure, unless the motor
10 operated valve is moving --=

11 MR. SCHULZ: I don't know --

12 MEMBER FORD: Probably the PWR explosion,
13 it doesn't mean --

14 (Everyone speaks at the same time.)

15 MEMBER SIEBER: -- very rapid rate,
16 sometimes it self-ignites when you do that. But
17 these valves start off with hydrogen, and also leaps
18 pretty good, these valves are just a single valve.

19 And no matter how good the manufacturer
20 is, they are probably going to leak a little bit, too,
21 so the hydrogen will probably leak.

22 MR. SCHULZ: I don't think these valves
23 will leak.

24 MEMBER SIEBER: I've never seen a valve
25 that didn't leak a drop or two every month.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. SCHULZ: Well, these aren't your
2 regular valves. Now, two of these valves actually
3 have the --

4 MEMBER SIEBER: Better off --

5 MR. SCHULZ: -- connection off of them.
6 And that would be the ADS 4 tees off horizontally,
7 passive RHR goes straight up.

8 CHAIRMAN KRESS: Yes, but that collects
9 hydrogen.

10 MR. SCHULZ: So that will tend to collect
11 it for that, if it does exist.

12 CHAIRMAN KRESS: The actual design, it
13 would be important, but you can still have thermal
14 stratification in there.

15 MR. SCHULZ: Yes, which we said would be
16 something to look at. That is the end of my portion.
17 Tom Hayes will now talk about the controls of the
18 valves.

19 MR. HAYES: Good afternoon, I'm Tom Hayes
20 from Westinghouse. I'm an electrical engineer, so
21 most of what you are talking about, so far, is foreign
22 to me.

23 I'm here to try to answer the questions
24 about why do we think this valve --

25 CHAIRMAN KRESS: What you say will

1 probably be foreign to us.

2 MR. HAYES: Okay, good. But I'm focusing
3 on the actuation circuit of these valves, and pointing
4 out what we have done to ensure that the valves will
5 receive an actuation signal when necessary, and will
6 not receive an actuation signal when they should not.

7 As Terry mentioned, each of these ADS 4
8 squib valves can be actuated by either of two
9 protection system channels, protection system that
10 carry the initials PMS, but that is the safety grade
11 system.

12 It is a four channel system. So, as Terry
13 mentioned, two of these four valves get an AMC signal,
14 and two of the valves get a B&D signal. And for each
15 of those valves, one of those signals will cause the
16 valve to actuate.

17 The protection system has both automatic
18 and manual means of generating that signal. And then
19 there is a diverse actuation system that also has a
20 manual way of actuating that valve.

21 Each one of these circuits are energized
22 to actuate, driven primarily by the characteristics of
23 the valve. It is not like an AOD that you can have be
24 a fail open valve. It needs energy so that it can
25 actuate, that is just the design of the valve.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 So I would like to first address the issue
2 of the reliability to actuate when you want it to.
3 And we address this by the three separate signals that
4 go to the valve.

5 What I have here is a block diagram of a
6 single ADS 4 valve, the circuits that would actuate
7 it. There are three of them, they are independent all
8 the way out to the valve. Each one of these valves
9 will have three actuators, or three igniters at least,
10 so that any one of those igniters will open the valve.

11 MEMBER WALLIS: What kind of a signal do
12 you send?

13 MR. HAYES: It is a pulse of current.

14 MEMBER WALLIS: One pulse of current?

15 MR. HAYES: One pulse of current.

16 MEMBER WALLIS: So some kind of a fire
17 that caused a short might send a pulse of current?

18 MR. HAYES: We will talk about that in
19 just a minute. You are getting ahead. If you want me
20 to jump ahead, I would be willing to. That would get
21 us back on schedule if I do that.

22 (Laughter.)

23 MR. HAYES: Let me first address how we
24 are addressing the issue of reliability to actuate,
25 and then we will talk about the reliability to not

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 actuate, when you don't want it to, which is what you
2 are asking about.

3 MEMBER WALLIS: A lightning strike, or
4 anything that sends a --

5 MR. HAYES: Certainly a lightning strike
6 would set one of these off.

7 MEMBER WALLIS: It would?

8 MR. HAYES: Inside containment, it has to
9 be inside containment.

10 MEMBER WALLIS: No, no, outside, surge.

11 MR. HAYES: Outside, no. I'm talking
12 about lightning striking through the steel containment
13 into this valve.

14 Okay, so in effect we are triple
15 redundant, and there are three different ways of
16 actuating this valve, three way redundant, two way
17 diverse. The two top halves we show here are from the
18 protection system, the energy for this current that
19 would open the valve comes from the class 1E power --

20 MEMBER WALLIS: The supposed current level
21 is not -- are you talking about what goes from the
22 controller to the valve? I was talking about what
23 comes to the controller, what comes from the side of
24 PMS division to the controller.

25 Is this a piece of digital information, or

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 is it a pulse of current?

2 MR. HAYES: Oh, okay. When you talk about
3 what the controller is -- this box that I have labeled
4 squib valve controller is, basically, a capacitor with
5 interlock circuits, okay?

6 So you charge it up, let's talk about how
7 the controller works. Each controller has what we
8 call an arm and a fire circuit. Now you are getting
9 into this -- the reason we did that is to do
10 everything we can to preclude spurious actuations.

11 Now, what the arm circuit is relatively
12 low current compared to the five amps it takes to fire
13 this valve, it would be something in the less than one
14 amp range, that would charge a capacitor in the
15 controller.

16 When the capacitor is charged, and the
17 armed circuit has been de-energized, there is
18 interlocked circuits to look for that, then the fire
19 circuit, if the controller sees an energy on the fire
20 circuit, this control grade signals --

21 MEMBER WALLIS: Just a pulse of some
22 current in the fire circuit?

23 MR. HAYES: These are not -- the pulse is
24 out here on the fire side. These are just normal
25 digital signals.

1 MEMBER WALLIS: So there is a digital
2 signal that is an encoded signal, with quite a bit of
3 information?

4 MR. HAYES: No, no, it is just an on and
5 off. A digital, to me, is on versus off. It is not,
6 well it is a continuous current.

7 MEMBER WALLIS: It is a very simple thing
8 I'm getting at.

9 MR. HAYES: Yes.

10 MEMBER WALLIS: If it were an encoded
11 digital --

12 MR. HAYES: No, it is not encoded.

13 MEMBER WALLIS: -- signal, then there is
14 much less chance of it being fudged by a short. But
15 if you have just a current, then that could easily be
16 fudged by a short.

17 MR. HAYES: Sure, I understand that. But
18 these are simple signals. It is either energy there,
19 or not energy there.

20 But, remember what I said about this
21 control, what it is, is the capacitor that will charge
22 up. It gets its current from the arm signal, so it
23 gets a half an amp or so, for 30 seconds or so, and
24 charges up the capacitor.

25 And then, when that capacitor is charged,

1 the fire signal will release that pulse of current to
2 go out to the valve.

3 MEMBER SIEBER: I picture what you are
4 describing as a capacitor, SPD switch on it?

5 MR. HAYES: Well, it is a little more than
6 that. Let's talk a minute about what that is.

7 CHAIRMAN KRESS: Okay.

8 MR. HAYES: So each controller has two
9 inputs, an arm signal and a fire signal, and the arm
10 signal is where it gets its energy to charge the
11 capacitor.

12 Now, what are the interlocks we have
13 associated with that? First of all the intended
14 operational sequence is to the arm circuit, to be
15 energized long enough to charge the capacitor, for the
16 arm signal to go away, and then the fire signal to
17 appear. And that will release the energy.

18 Now, in that process we have an indication
19 and alarm to the operator when that capacitor is
20 charged. There are times he wants it charged.
21 Obviously right before he wants the style to open.
22 There are times he wants it not charged, which all the
23 other times.

24 So you need an alarm on that to say that
25 that capacitor got charged, and you didn't mean for it

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 to. So we have a capacitor there that normally it
2 sits there de-energized. We have interlock circuits in
3 this controller box, that says there is nothing you
4 can do on either one of those signal lines to make
5 this capacitor discharge.

6 You send it the fire signal to charge, it
7 will try to discharge, but it has nothing to
8 discharge. You send it the arm signal, with no fire
9 signal, it will charge up the capacitor, and that
10 capacitor will stay charged if that arm signal is
11 still there, but it will never fire, there is never a
12 fire signal.

13 MEMBER WALLIS: It won't let you fire when
14 it is partially charged?

15 MR. HAYES: It will let you try to fire it
16 if you partially charged it, and the arm signal has
17 gone away. You can try to fire it. But it won't stay
18 partially charged, it won't stay charged, or even
19 partially charged very long.

20 It is a matter of minutes, it has a lead
21 resistor that discharge the capacitor back down.

22 MEMBER SIEBER: I take it that it is a big
23 electrolytic capacitor?

24 MR. HAYES: Yes.

25 MEMBER SIEBER: So it has a lifetime, you

1 have to change them out every ten --

2 MR. HAYES: Sure.

3 MEMBER SIEBER: -- or so? Okay.

4 MR. HAYES: They will be tested every
5 refueling for degradation, and probably changed every
6 ten years even if they don't show degradation.

7 MEMBER SIEBER: I would.

8 MR. HAYES: I would too. That is a plant
9 operator issue at this point.

10 MEMBER LEITCH: I'm still a little
11 confused. Can you back up to the level switches? I
12 mean, the level is going down, and at the same level
13 do you actuate both the arm and the fire?

14 MR. HAYES: Well, yes. The level tells
15 the protection system it is time to open the ADS 4
16 valves.

17 MEMBER LEITCH: Right.

18 MR. HAYES: Then what the protection
19 system does, with its own internal timers, is it
20 actuates the arm signal for 30 seconds, then
21 deactivates the arm signal, and then actuates the fire
22 signal.

23 MEMBER LEITCH: Okay. If the arm signal
24 is not de-actuated will it fire?

25 MR. HAYES: No.

1 MEMBER LEITCH: Okay.

2 MR. HAYES: It has to be a coordinated
3 sequence of things that happen into that control.
4 Now, most of this --

5 MEMBER LEITCH: Back up to that again, to
6 the level switches. I'm still a little confused about
7 the logic there. Four level switches?

8 MR. HAYES: Right.

9 MEMBER LEITCH: And they are arranged like
10 in an H pattern, one out of two --

11 MR. HAYES: Two out of four.

12 MEMBER LEITCH: Two out of four, okay.
13 Okay, thanks.

14 MR. HAYES: So you have -- the idea of
15 this controller, now, and it is driven very much by
16 concerns about shorts resulting from fires. Now, we
17 are into the shorts resulting from fires question that
18 came up.

19 If we go back to the picture one more
20 time, I will just pick one of these. If you have a
21 fire that is causing this circuit to hot short. And,
22 by the way, this is what we call a two pole circuit,
23 so it has both wires there, and they are both broken
24 on the upstream end.

25 But you get smart hot short. Both of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 those conductors short to two conductors somewhere
2 else. You can't get an arm signal. And when that arm
3 signal gets in there, and charges the capacitor, the
4 operator will get unarmed.

5 Now it is possible for a fire to cause
6 that to happen. It is possible for that fire to then
7 burn enough to break the conductors and make this an
8 open circuit. It is possible for a fire to, then,
9 cause this fire circuit to do the same thing, two
10 smart hot shorts.

11 However, it is not possible for that to
12 happen instantaneously. That takes a little bit of
13 time. In the meantime there are fire detectors in the
14 room where this might happen, smoke alarms, and the
15 operators have procedures that tell them to go turn
16 the power off in that room if there is a fire.

17 So if you look, from a fire actuated point
18 of view, if you are looking from this box forward,
19 there is nothing to short to. This is all passive
20 stuff with no energy stored.

21 These cables are in trays and could,
22 conceivably, short to another cable, but they are in
23 instrument trays. Instrument circuits are 4 to 20
24 milliamps, 20 milliamps won't fire one of these
25 valves.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 So there is -- although it would be
2 potentially possible for those wires to short to
3 something, there is nothing for them to short to,
4 within the trays they are in.

5 The fire would have to take those wires
6 out of the trays they are in, put them in a different
7 tray, and have these two conductors short. And that
8 is just beyond design basis, in my mind.

9 Now, upstream from these controllers, we
10 now are in areas where there are wires that you could
11 conceivably short to, but that is where you start
12 meeting these coordinated shorts, in multiple places
13 in a single room, or in multiple rooms.

14 And that is where we get into the, by the
15 time that happens, somebody has noticed their plant is
16 on fire, and they've turned the power off. Now, I
17 think I just went through about the next five slides.

18 MEMBER SIEBER: That is good.

19 MR. HAYES: These are just some more of
20 the interlocks that are in the box. Basically
21 attempting to prevent any spurious, reasonable
22 spurious things that could happen as a result of
23 inadvertent things happening.

24 Upstream of the squib valve we have the
25 arm and fire signal coming from two different places,

1 so they are physically separated, at least in the room
2 that they are coming from. The rest of the story I've
3 been through, you turn the power off.

4 This is all energized, actuate stuff, turn
5 the power off when there is a fire. These manual
6 actuation switches, and Terry has already mentioned
7 it, are located at minimum two different places in the
8 control room, where somebody has to be bumping into a
9 switch.

10 The switches are going to be covered.
11 This is, obviously, not a switch you want to have so
12 that the guy can't even inadvertently bump one of
13 them. He is going to have to bump two, and they are
14 going to be in two different places.

15 The only other issue that I can think of,
16 that could cause a problem for spurious actuation is,
17 the protection system is a computer based system.
18 And software does screw up. And what I have to tell
19 you is that this is the best software you are going to
20 get.

21 It is protection grade software, it is
22 class 1E software, and Bill Gates was not involved.
23 Again, I emphasized, the squib valve controller itself
24 has no power, has no stored energy, except for the
25 potential, if you could come up with some possibility

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 that the capacitor gets energized, but that is
2 alarmed.

3 So under normal conditions the controller
4 is sitting there with no energy, no power, no way to
5 generate a signal, absolutely none. I don't care how
6 smart your little rodent that gets in there, or your
7 fire, or whatever.

8 Failures downstream of the controller.
9 Yes, here, what we are looking for is some way of
10 generating the five amps that it takes to actuate one
11 of these valves in some kind of cable to cable fault.

12 And we are simply saying there are no
13 adjacent cables that have the ability to generate five
14 amps. Those circuits just aren't there, they are in
15 other trays.

16 MEMBER SIEBER: Actually, the way I think,
17 it would be better to know what the voltage is,
18 because the amperage is determined by the resistance
19 of the detonator, right?

20 MR. HAYES: Well, the voltage is 48 volts,
21 it is at 24/48.

22 MEMBER SIEBER: Thanks.

23 MR. HAYES: But 24 volts could, I mean,
24 the detonator has very low resistance. So what we
25 have, though, is a power supply internal impedance,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 and 24 volts won't get you five amps.

2 Again, this is basically a summary of what
3 I've been repeating. So, basically, we believe the
4 old possibilities of fires, operator error, equipment
5 failures, and have at least some reasonable belief
6 that this is not likely to have a problem.

7 MR. CARUSO: Are there any on-line
8 monitoring and continuity to this normal operation?

9 MR. HAYES: We are not going to do that
10 because we are worried that that is more dangerous
11 from a spurious actuation point of view.

12 MR. CARUSO: You made a conscious decision
13 not to --

14 MR. HAYES: We made a conscious decision
15 to do that check right after we have done our
16 refueling. The INC system guys are going to make me
17 check the continuity, check all the way up to the
18 squib valve.

19 So what I believe will happen, at the
20 refueling, is a connector will be pulled, we will put
21 on a test device, we will test fire all the way out,
22 so we know the INC is good up to there.

23 MR. CARUSO: A lot of applications in
24 these valves now that put a very small current
25 through, and then they measure continuity.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. HAYES: I know. And those things have
2 all kinds of problems. It is a great theory. In
3 actual practice we are finding that they do,
4 occasionally, generate a spurious trip.

5 Do you have any more questions before I
6 sit down?

7 (No response.)

8 MR. HAYES: Okay. I will introduce Dan
9 Frederick from Conax Corporation, who is the
10 manufacturer of these types of valves.

11 MR. FREDERICK: As was mentioned, I'm Dan
12 Frederick, I'm Vice President of engineering for
13 Conax, and I work directly in design and development
14 of fire wells. So I have a pretty long history of
15 dealing with devices similar to what we are going to
16 discuss today.

17 It is a fine agenda that has been put
18 forth here, is the overview, first of all, by Conax
19 Florida Corporation, just to give you an idea that
20 yes, we have a building, and do exist.

21 Then we will get into the GE development
22 program, follow that up with the AP1000 valve design,
23 and the squib valve reliability will be taken care of
24 at the end.

25 As you can see that is the plant, there is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 actually three buildings involved, and it in St.
2 Petersburg, Florida. Just a quick overview of the
3 company.

4 Conax was founded in 1948, the first
5 development of elector-explosive devices was in the
6 early 1950s. Conax Florida subsidiary was formed and
7 moved to Florida in 1982, it became ISO 9001 certified
8 in 1997.

9 We were purchased by Cobham of England in
10 1998. We have about 150 employees, our annual sales
11 about 30 million dollars. And, as previously noted,
12 we are in St. Petersburg.

13 CHAIRMAN KRESS: Who are your customers?

14 MR. FREDERICK: Virtually all major
15 aerospace corporations, Air Force, Navy, Lockheed,
16 Boeing, etcetera, etcetera.

17 CHAIRMAN KRESS: Is Pyronetics one of your
18 brand names?

19 MR. FREDERICK: I personally came from
20 Pyronetics originally. And so I was there for many
21 years, when Pyronetics was relocated in Denver in
22 1980. Time frame, I headed up the engineering for
23 many, many years, I was with OEA until about 1999,
24 actually.

25 During that time frame Pyronetics was,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 quote, absorbed into OEA, because we were in the same
2 building as OEA, Incorporated. And then the aerospace
3 side became OEA Aerospace, because at the same time
4 the airbag industry was starting, and we had the
5 initiator designs for many of the automotive type
6 companies.

7 And, therefore, it became OEA Aerospace.
8 Since that time Aerospace has been purchased by UPCO,
9 which is now located in Fairfield, California, and
10 that is where I was at before I decided to move down
11 and take the position with Conax.

12 CHAIRMAN KRESS: So it is a different
13 company?

14 MR. FREDERICK: So right now Conax is,
15 obviously, separate from the original Pyronetics, OEA,
16 UPCO. However, we have a license agreement, and we
17 are working directly with them on the sale of
18 pyrotechnic valves.

19 CHAIRMAN KRESS: But one reason for asking
20 who your customers were is they -- the customers
21 generally require some sort of QA/QC specs. And we
22 were interested in what sort of QA and QC you have to
23 have on these.

24 And I presume, from these particular
25 customers, that is --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER SIEBER: That is what ISO 9001 --

2 MR. FREDERICK: ISO 9001, and certified
3 ISO 2000 by October, November time frame of this year.
4 So we are moving forward in the next phase of the ISO
5 certification process.

6 A quick list of some of the products. In
7 addition, we call them, pyrovalves, for the most part
8 pyrovalve and squib valve are virtually the same, they
9 have the same kind of design features.

10 Stored gas systems, water activated
11 systems, pin pullers and cutters, actuation systems,
12 and we even take lots of complex "build to print" jobs
13 in some cases.

14 The advantages of squib valves, they are
15 very fast acting, you have the solid metal seals, you
16 don't really have to worry about leakage over time.
17 They are reliable, environmentally durable, and NASA
18 sponsored and qualified many programs.

19 We build valves because they came to us
20 and said, well, we want these valves to fly on certain
21 missions, and we designed them that way. The other
22 advantage that wasn't noted there, typically a fire
23 valve, just from the nature of it, you are getting so
24 much work from so small an energy source, that you
25 have a very lightweight component, compared to what

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 anything else could put out there, that would do
2 something in similar fashion.

3 We have a Class 10,000 clean room, we get
4 involved with electronic assembly on our lot of our
5 life support programs. We have a model shop that we
6 use for a lot of our prototyping and development work.
7 We do a lot of gas purity testing, we have pure gas
8 bottles if you want to model the main missile systems
9 that are produced today.

10 And we have our own environmental testing
11 that we do in-house, as far as vibration, and altitude
12 testing, etcetera. Obviously it is not to the size
13 you would need for this valve.

14 MEMBER SIEBER: Do you build the
15 controller that Mr. Hayes discussed?

16 MR. FREDERICK: No.

17 MEMBER SIEBER: So that comes from some
18 place else?

19 MR. FREDERICK: I believe it comes from
20 Westinghouse right? Yes, we don't do that.

21 MEMBER SIEBER: And you manufacture the
22 detonator, or do you buy that from someone?

23 MR. FREDERICK: What we are going to be
24 doing, on the detonator, which I was calling an
25 initiator, my background, and booster charge, which is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 the main propellant source, we will be going back to
2 UPCO, who built it previously, for all practical
3 purposes, and they will do it again.

4 MEMBER SIEBER: So these are the -- it
5 will be the same as the General Electric water valves?

6 MR. FREDERICK: Yes, that is exactly
7 right. In fact, I was directly involved with the
8 valve many years ago, and the design activity.

9 Just a brief list, I mean, obviously there
10 is a lot more data up there, and I won't go through
11 those items, but you can see it is a pretty extensive
12 list of things that we are directly involved in.

13 Certification, as I mentioned earlier, we
14 are ISO 9001, in November of 1997, and in January
15 2001, again. And getting into the GE valve development
16 program, just to give you a little history, is what
17 this amounts to.

18 Originally General Electric went out to
19 seven potential bidders to provide a product that
20 would do the work that they needed done. And for all
21 practical purposes that obviously wasn't just going to
22 somebody that made squib valves. That included, from
23 what I recall, going to the Japanese, and getting some
24 kind of a pneumatic system, etcetera, etcetera.

25 But what it really came down to is that at

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 the time we proposed a two inch ID valve that would be
2 upscaled to the required seven inch valve, as the
3 recommended approach for them to use.

4 And we even provided, at that time, a list
5 of our customers. They went out and contacted a bunch
6 of customers because, you know, obviously if you are
7 moving into a big development program on valve, it is
8 always nice to get some input from the people that say
9 we have been working with to understand where we were
10 coming from, that we had the potential to design
11 something of that size.

12 So then we received a contract, and then
13 we moved out to design a seven inch valve. And the
14 Westinghouse AP600 valve is, in fact, the same ID as
15 the GE valve, and the AP1000 valve, the plan would be
16 to scale up the existing GE seven inch valve, to
17 accommodate the slightly larger 9.24 inch ID diameter
18 for the AP1000 valve.

19 This valve, I will just give you a brief
20 description of. This is the two inch valve that led
21 to the GE valve. And from a quick design description
22 here, we will go through the design description here.

23 You can see, on the top of the valve,
24 right at that cavity, which is really not real clear
25 to everybody, where the initiator is located in that

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 valve. There is actually two of them.

2 So if you located it around the other
3 direction you would have one sticking out this side,
4 and one out that side. So they have redundancy built
5 in from two initiators to do the -- just to cover in
6 case you ever had to have two.

7 But in reality the valve was designed to
8 work with one initiator. And this particular valve,
9 based upon the way it was designed, didn't even
10 require booster charge. And so when you fired the
11 initiator you get ballistic pressure that will build
12 up in this cavity.

13 It would build up a high net plunger right
14 here. So when you got to a control pressure, that it
15 took to break that shear section, then this part right
16 here would stroke down, causing this sheared out
17 section to move down, contact the support plate at the
18 bottom, and then just rotates over down to the bottom,
19 creating a full flow open flow passage.

20 MEMBER SIEBER: Is that hinged at the
21 bottom?

22 MR. FREDERICK: Yes, it is, that is a
23 hinge, yes.

24 MEMBER SIEBER: So it doesn't go shooting
25 across the room?

1 MR. FREDERICK: No, no, it is totally
2 contained just like the GE valve that I will show you
3 here in just a second.

4 And in this particular case, which we
5 didn't need on the GE valve, you can see there is
6 metal belts around the outside, because they wanted to
7 prevent any potential for pyrotechnic materials to get
8 out into the system, they were concerned about
9 downstream of the valve.

10 CHAIRMAN KRESS: This thing wouldn't work
11 if you put it in backwards?

12 MR. FREDERICK: That is correct. Yes, it
13 was never intended to be pressurized on this side.

14 MEMBER SIEBER: Well, it wouldn't work
15 anyway.

16 MR. FREDERICK: Depends on what you put in
17 it.

18 MEMBER SIEBER: You would have a hard time
19 bolting it up. There is no flange on the other end.

20 MR. FREDERICK: That is where it all
21 started, that was the valve that we said, hey, we can
22 take that valve and we can stay with that. So let's
23 go to the next slide.

24 So then we took on the design activity,
25 moved forward, and developed the valve that is before

1 you. You can see there is a very large amount of
2 similarity to the two inch valve.

3 MEMBER WALLIS: I presume you made it very
4 high pressure you would have a problem, because you
5 must not fail in tension, but it must fail in shear?

6 MR. FREDERICK: That is correct.

7 MEMBER WALLIS: And so you have been
8 through all that, so there must be some sort of limit
9 to this design if the pressure is too high in the
10 system.

11 MR. FREDERICK: Well, if you got extremely
12 high, you would have a real problem from the
13 standpoint that the higher the pressure, and the
14 bigger the diameter here, the thicker that section --

15 MEMBER WALLIS: That is right, and you
16 have to be able to shear it off.

17 MR. FREDERICK: And then what happens is
18 that you could, but the amount of booster charge up in
19 here, and the size of the valve would be very large.
20 So you just have to work into that.

21 I mean, you could get there if you really
22 wanted to. I'm pretty confident we can open up
23 anything we need to open. But this valve, as I
24 pointed out earlier, is based upon the two inch, and
25 you can see that you have a shear section, again, at

1 this location.

2 You have a hinge pin, where this thing
3 rotates over --

4 MEMBER WALLIS: So you shear it, but you
5 don't first break the hinge?

6 MR. FREDERICK: No. There is a slot right
7 here --

8 MEMBER WALLIS: It impacts on the bottom,
9 then?

10 MR. FREDERICK: It impacts on the bottom,
11 and then it just rotates over with this surface
12 contacting that surface. And you are, again, full
13 open.

14 A tension bolt was added up to the top,
15 and you can see that we have a tension bolt here that
16 you didn't see in the prior valve. And the reason for
17 that is because when you go to the much thicker shear
18 section here, we didn't want to rely on static
19 pressure in order to drive the section open.

20 So we gave it a little dynamic impact, as
21 a result of backing it up, and putting a control
22 depth, or distance, between the bottom of the ramp, or
23 piston, and the top of the part that you are trying to
24 shear.

25 This valve, also, although it didn't have

1 the bevels to prevent any flow lines, in particular
2 case of the nuclear environments, we went to all-metal
3 seals. So all the interfaces on all the assembly has
4 metal type o-ring seals. So you don't have any rubber
5 components on the entire design.

6 And just a little more information on it.
7 The requirements at that time was that there was an
8 external temperature that the valve had to be exposed
9 to, an internal temperature that was in the pipe. And
10 the goal was to keep the booster propellant below 280
11 degrees fahrenheit, which was the set limit for the
12 program, and cooling fans were on the top as well.

13 And we went through the testing and met
14 all the requirements, in that regard, as well. On the
15 bottom, which I don't believe you need on the
16 Westinghouse valve, but it was on the GE valve, ins an
17 electro-mechanical switch.

18 And what that did is it told somebody in
19 the control room that if the valve ever did fire, it
20 would send a signal back into the control room.

21 Here is what it looks like in -- you can
22 see up here the bolts are broken, but the sheared
23 section actually rotates over center, and the contact
24 to the valve body is down here.

25 The valve is designed to be refurbishable.

1 The requirement on the prior programs, within 24 hours
2 you had to take apart the valve, remove all the parts
3 that needed to be replaced, put the valve back
4 together.

5 And so you can see, when you look at the
6 valve, that part obviously has got to be replaced
7 because you sheared out the section. The tension bolt
8 was broken, and there is a few seals, and that type of
9 thing, that go into the refurb process.

10 But GE actually did take the parts that
11 were in Wiley, when we shipped them to Wiley, and
12 actually did do a refurb, and it met the requirement
13 of the 24 hour with no problem.

14 The key feature there is that you can fire
15 the valve, you can do some surveillance testing, and
16 whatever you need to, and you can save all the real
17 high dollar product of parts that are associated with
18 the valve.

19 MEMBER WALLIS: How thick is the shear,
20 the ring of material that is sheared, how thick is it?

21 MR. FREDERICK: This is going from memory.
22 I believe it is a quarter inch on the seven inch
23 valve. And, of course, it would be scaled up because
24 of the bigger diameter and slightly high pressure for
25 the 10 inch in the AP1000 valve.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 Now I will give you a little summary of
2 some of the testing that was done on the previous
3 program, on some of the things that we would go
4 through in order to ensure that we can meet the basic
5 requirements associated with any new program.

6 Of course you always have the examination
7 of product because, obviously, you want to start with
8 meeting your intent and your requirements. We did
9 hydrostatic testing on the sheared out sections, as
10 well as the valve housing.

11 Leakage testing was performed in the inlet
12 pressurizer. We did the thermal exposure testing,
13 which is one I mentioned earlier, where the inlet was
14 at 550, surrounding air at 190, and the booster at the
15 top of the valve had to be below 280, which it was.

16 MEMBER WALLIS: What is the nipple made
17 out of?

18 MR. FREDERICK: In the prior program it
19 was made out of 304L, because that was the material
20 that was chosen at the time. For the AP1000 we have
21 been discussing going to 316L, which is more
22 compatible with what has been used by Westinghouse.

23 But if you look into the material
24 properties, both are very, very close. I mean, 316L,
25 321, 304L are all common materials used in the

1 aerospace business.

2 Other items, we had verification to make
3 sure that everything was the way it was supposed to
4 be. We did development testing. One valve was fired
5 twice, another valve was fired once. And then the
6 units were delivered to GE for additional testing,
7 subsequent to pyronetics testing at that point.

8 If I'm going to fast, let me know, I know
9 we have a real time constraint.

10 CHAIRMAN KRESS: You are doing good.

11 MR. FREDERICK: Some of the testing that
12 is done, or performed, on initiators and boosters,
13 what is called a closed bomb testing. And that is
14 performed at temperature and in some, not all cases,
15 it is performed with unders, and in some other cases
16 perhaps overloaded boosters.

17 Now, closed bomb testing is where you
18 actually put the booster with the initiators in it,
19 and to a metal enclosure of a control volume, you put
20 in a couple of pressure transducers, one on each side
21 of the bomb. You fire the unit, and what you do is
22 you establish what the pressure time curve is.

23 And that data is important because if you
24 get out there, let's say three or four years, after we
25 delivered the first batch of boosters and initiators,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 you can actually go back, pull those out, put them in
2 a closed bomb, if you choose to do that, run a sample
3 test, and verify you have had no degradation of
4 performance as a result of pressure time data curves
5 that are established during the upfront time to the
6 program.

7 In addition, before we would ever ship any
8 boosters, we would also run an in-house, what we call
9 mod acceptance test, where we would pull some samples
10 out of the batch and verify that those units, indeed,
11 do meet the pressure time performance requirements.

12 Under lot sample testing, this is
13 something that you don't normally have to do, most of
14 the time. But you do do it occasionally. And
15 generally you would do it, like if you had a nuclear
16 program, or you are trying to verify that the material
17 properties would go through what you needed them to,
18 under a nuclear condition, or if you are trying to
19 establish a new propellant.

20 CHAIRMAN KRESS: That first bullet just
21 measures the increase in weight with time?

22 MR. FREDERICK: Yes.

23 CHAIRMAN KRESS: And that is a measure of
24 either oxidizing, or picking up moisture?

25 MR. FREDERICK: Yes, that is right. Yes,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 what you are doing here, by running it through this
2 thermal test, and the scanning test, what you are
3 really doing is just looking at this weight loss test.

4 In each of these cases what you are really
5 doing is trying to establish, through that, is there
6 anything unusual that is happening, that gives you an
7 idea that you really don't want to use those
8 materials.

9 And so there are guidelines, that you are
10 looking toward, when you are running those tests, as
11 far as acceptance criteria, so you know what you are
12 going into, and what you are coming out with.

13 And then in this particular case some
14 radiation testing was performed on the boosters, and
15 on the position switch and cables. And those, you can
16 see, is indicated there.

17 In addition boosters were subjected to
18 accelerated thermal aging testing, 25 days at 360
19 fahrenheit would simulate a four year normal life.
20 And the cable assemblies went through a similar type
21 test program. And then a reliability testing is where
22 a lot of boosters were manufactured.

23 And, as I recall, it was over 80. They
24 went through a whole series of tests, they came back
25 to us, we fired them all in closed bombs, and verified

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 that performance was as it should have been.

2 CHAIRMAN KRESS: When you did the
3 radiation testing, what sort of source did you use?

4 MR. FREDERICK: GE did that.

5 CHAIRMAN KRESS: GE?

6 MR. FREDERICK: Yes, we shipped them the
7 product and they ran the testing.

8 MEMBER WALLIS: I presume they are way
9 over designed. You actually had much more booster
10 than you would need to shear off the average nipple,
11 just to make sure that you shear off the more stubborn
12 nipple, you have enough --

13 MR. FREDERICK: Well, that section is
14 extremely controlled by dimensional requirements. And
15 we always size valves to function properly with an 80
16 percent minimum charge.

17 And so we actually demonstrate that, by
18 testing, that we do comply with that requirement.

19 CHAIRMAN KRESS: Is there a potential to
20 have too much charge?

21 MR. FREDERICK: The only potential there
22 would be that yes, you could have too much. And,
23 again, what we would normally do is control it on the
24 top end, which typically is 120 percent maximum.

25 Because, obviously, if you put way too

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 much, you would drive that thing right out of the
2 bottom, and it wouldn't function quite right. So you
3 have to control all those parameters pretty closely.

4 MEMBER FORD: Has anyone, on the sheared
5 nipple, and before, in the closed state, there is a
6 fairly small ligament. What is the tensile state on
7 that ligament, under operating conditions?

8 MR. FREDERICK: That sounds like a simple
9 question, but it isn't, because it depends on all the
10 conditions that you have at the time, because you are
11 designing that particular section, based upon your
12 diameter, and your pressure.

13 MEMBER FORD: Right.

14 MR. FREDERICK: So, again, I'm going from
15 memory. If you go back to the GE valve, it was
16 designed more toward the stress at the yield level,
17 than it was ultimately, because the material strength
18 for 304L, the yield value was extremely low, compared
19 to the ultimate.

20 So you design it down here, because you
21 don't want it to yield, either. And so if the number
22 would have been, say, 28000 as an example for yield,
23 it would have been designed to meet that.

24 Whereas in a lot of the valves that we
25 deal with, we are more concerned not at the yield

1 level because the customer would say, here is approved
2 pressure you have to put on it, here is an ultimate
3 burst pressure.

4 In which case if I'm using titanium, the
5 yield is 120, and the ultimate is 130 so, really,
6 proof is a piece of cake, and the ultimate test is the
7 one you are concerned about.

8 MEMBER FORD: But it is a question to the
9 Westinghouse people. But I agree that 316L is a
10 pretty good choice of material for the primary system.
11 But you can crack 316 L, especially if it is cold
12 worked in any way.

13 Has there been any materials design review
14 taken that this is not going to crack during
15 operational conditions?

16 MR. CORLETTI: Will you be here tomorrow?

17 MEMBER FORD: Why, is there a lot of
18 questions we --

19 (Laughter.)

20 MR. CORLETTI: Can we save that question?

21 MEMBER FORD: Absolutely, of course.

22 MEMBER RANSOM: While we are on that,
23 though, is that valve nipple satisfy all the ASME
24 safety requirements for personnel to be around it, at
25 operating pressure?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. SCHULZ: You can't have people around
2 after --

3 MEMBER RANSOM: Well, presumably startup,
4 things like that, you don't have any people there?

5 MEMBER RANSOM: But it is designed to ASME
6 code, which --

7 MR. FREDERICK: Well, the valve is
8 designed to ASME code, you know, it is a class 1
9 requirement. So there would be no reason why somebody
10 wouldn't be around it. It is just like any other
11 class 1.

12 MEMBER RANSOM: It has sufficient safety
13 margin that you could be around that pressure.

14 MEMBER FORD: Is there any special
15 machining considerations to that nipple region? I
16 mean, are there any criteria put on you as to limiting
17 the final machining operations?

18 MR. FREDERICK: The only thing I can say
19 there is that we control the actual shear-out section.
20 On the inside, obviously, it is a straight section.
21 On the outside it is a curved section, and it is
22 extremely tightly controlled, dimensional.

23 MEMBER FORD: Is it ground, or is it --

24 MR. FREDERICK: That is something that we
25 haven't established on this particular program.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 Because if I go back to this program with GE that was
2 not an issue at the time. The issue there is verify
3 the design concept.

4 So that is some of the things that we
5 would have to work out with when on, exactly, the
6 controls associated with that particular --

7 MEMBER WALLIS: The nipple is made from
8 one piece, or is it a tube that is welded in?

9 MR. FREDERICK: This is one piece, right
10 here, this entire section. So that is a machine made
11 section.

12 MEMBER WALLIS: Machined from solid, or
13 what?

14 MR. FREDERICK: Yes it was. It had to
15 meet certain roundness associated with the program.
16 I believe it was a hot forced --

17 MEMBER WALLIS: Just looking at that
18 beautiful squared edge at the end of that -- to --

19 MR. FREDERICK: Yes, right here?

20 MEMBER WALLIS: Yes.

21 MR. FREDERICK: That is where the sheared
22 out section is -- and this part here is attached from
23 the other side in order to assemble, because you
24 couldn't get it through otherwise.

25 MEMBER FORD: What about machine notched,

1 you have a high strength concentrator, plus the
2 environment?

3 MR. FREDERICK: That is correct.

4 MEMBER FORD: Plus a machined surface for
5 which we don't have the specifications for the
6 machining. I mean, you could have have put residual
7 stress in at that point. It is a beautiful
8 combination.

9 MR. FREDERICK: Yes, in designing valves,
10 you are designing strength.

11 MEMBER FORD: Is that for operating in
12 high temperature water?

13 MR. FREDERICK: That is exactly right.

14 MEMBER FORD: That is my concern. I'm not
15 concerned about mechanical failure, I'm concerned
16 about stress --

17 MR. FREDERICK: That is some of the
18 details that I think we need to look at, as a separate
19 issue.

20 CHAIRMAN KRESS: I just want to interject
21 a comment relative to the cracking issues. One of the
22 points is, and they may address some of this. But the
23 other part was in Terry's presentation, you point out
24 that we will be inspecting it, as part of the
25 inspection process.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 So if there is any indications I think,
2 you know --analysis done as to what is causing it. So
3 I think it is important to realize that it is not just
4 sitting --

5 (Everyone speaks at the same time.)

6 MEMBER FORD: You might have enough damage
7 occurring in the 18 month cycle --

8 MR. FREDERICK: You wouldn't want that.

9 MEMBER FORD: You wouldn't want that,
10 correct.

11 CHAIRMAN KRESS: How does that -- the
12 hinged part? Is it welded?

13 MR. FREDERICK: Not in that particular
14 configuration it wasn't. It was threaded in with a
15 straight machine from one side.

16 CHAIRMAN KRESS: You put the valve in
17 first then put the pin?

18 MR. FREDERICK: Right.

19 MEMBER SIEBER: We probably know more
20 about these valves than we ever wanted to.

21 MR. FREDERICK: And, lastly, we went
22 through the vibration testing actuation and flow
23 testing, that was done at Wiley.

24 Now getting into the AP1000 valve, just to
25 give you a comparison between the seven inch and the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 new AP1000 valve. You can see, initially here, the ID
2 is going from 7 to 9.24, and we discussed the
3 material.

4 Safety and seismic class is the same, the
5 design pressure is higher than previously, the
6 temperature is slightly higher. And the external
7 temperature is quite a bit less.

8 The radiation level for ten years as
9 identified here, versus four year requirement that was
10 on the prior valve. The inlet as previously
11 mentioned, you are down to 1 psi operation. And the
12 design life of boosters here is eight years as a
13 target, and previously they were just shooting for a
14 four year target.

15 MEMBER WALLIS: Go back to the materials,
16 is there some requirement on the chemistry of the
17 water that is in contact with this thing?

18 MR. CUMMINS: It is primary water
19 chemistry --

20 MEMBER WALLIS: Does this valve have some
21 specs that says it has to withstand an environment
22 that sets the chemistry for this period of time?

23 MR. CORLETTI: Yes. But are you saying
24 does the valve impose additional functional
25 requirements?

1 MEMBER WALLIS: Another functional
2 requirement here about the chemistry of the water, and
3 the boron, and all that stuff.

4 CHAIRMAN KRESS: That goes into the
5 initial selection of materials.

6 MR. SCHULZ: This is obviously a small
7 subset of the requirements, many other things that we
8 have specified already.

9 MEMBER WALLIS: Have these things ever
10 been in a reactor environment before? Survived for a
11 long period of time?

12 MR. CUMMINS: I think GE uses squib
13 valves, Westinghouse doesn't.

14 MEMBER WALLIS: Actually in there, so they
15 have been in there for a while?

16 MR. CUMMINS: In their plants. I believe
17 they are small ones, three inch or less.

18 MR. FREDERICK: Moving on to the AP1000
19 design. I mean, obviously it is going to be a scaled
20 up design from the original. Analysis design report
21 for the --

22 MEMBER WALLIS: You no doubt have all the
23 pipe groups, have you?

24 (Laughter.)

25 MEMBER SIEBER: -- question about your

1 hydrostatic test. If I look at the way the valve is
2 built, the shear section is part of the pressure
3 boundary. And so when you do a hydrotest, if you test
4 it to failure, the place that it will fail will be the
5 shear section.

6 And have you done that, and how much
7 overpressure can this valve take before you get a
8 failure in the shear section?

9 MR. FREDERICK: We didn't take it to
10 destruction.

11 MEMBER SIEBER: How far have you got?

12 MR. FREDERICK: That I don't know off
13 hand.

14 MEMBER SIEBER: -- which is one and a
15 half, I guess. And not actually prove too much. I
16 guess it is satisfactory, but I was just curious about
17 what kind of margin you have to avoid a failure of the
18 shear section without the actuator working.

19 Because, you know, if that valve operates
20 your plant is in trouble, I think.

21 MR. FREDERICK: Well, we did some
22 hydrostatic testing at whatever the margin was over
23 and above the --

24 MEMBER SIEBER: Do you test -- you test to
25 code, then, right?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. FREDERICK: -- to code, yes. ADS 4
2 development prototype -- in charge sizing, and
3 hydrostatic, and leap testing, and vibration, and of
4 course actuation with over and under loaded that would
5 be required.

6 Getting into reliability, some of the
7 things that we look at, this is just sort of a
8 heading, and I will discuss it here shortly. High
9 reliability requirements, I mean, most of the
10 aerospace industry, for many, many years, including
11 missile, satellites, and everything else, used
12 pyrovalves because they are highly reliable devices.

13 Failure modes and specs analysis is a
14 standard process that you go through. Ignore that,
15 that was originally a preliminary sample provided to
16 Westinghouse for their review, but it is not in your
17 packet, so if you look for it, it won't be there.

18 So I don't want you to think you are going
19 to find something that maybe isn't there. Look at the
20 design shear section a little more, reliability of
21 squib valves, and then we will get into replacement of
22 charges at the end.

23 First of all, what our customers require
24 is basically higher reliability. We are working on
25 life support programs, aerospace programs. And the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 consequences of failures are high. I mean, it is not
2 always dollars, so to speak, but it is also people.

3 Because a lot of the devices we build are
4 used for life support, and life saving type features.
5 Our procedures control higher reliability. And, as
6 mentioned earlier, we are certified in every way we
7 should be, to meet our standards.

8 Custom valve designs and upscaling is a
9 standard process. The simple valve design reduces
10 problems. I think the key thing there is, like
11 anything else, the fewer parts you have of anything
12 the better off you are.

13 And if you go back and compare a squib
14 valve with anything else that you might use as a
15 substitute, you will find that you have a lot less
16 parts to deal with and, therefore, that reduces your
17 potential for problems.

18 The development process that we have been
19 going through, for many years, is to deliver highly
20 reliable valves, and then it has been proven with what
21 we've shipped.

22 Some of the things that we go through, as
23 far as how to build in high reliability, we look at
24 past experience, lessons learned. We performed design
25 analysis, I call it design analysis here because

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 generally in prior valve, it was a design analysis
2 report, a lot of customers would call up, like stress
3 analysis report where you are doing the same type of
4 thing.

5 Examination and analysis of the drawings
6 in the FMEA, and reliability analysis, obviously, is
7 required. Under testing --

8 MEMBER WALLIS: Do you do the --

9 MR. FREDERICK: We do. We have an AFSCRAM
10 program that we have some people that --

11 Under testing, we get involved with
12 development and prototype units. Margin testing, as
13 I've mentioned over and under loads. Obviously we
14 have to do acceptance and qualification tests.

15 Acceptance being something you would do on
16 everything you build, and then qualification testing
17 is generally samples that you pull out of that
18 acceptable batch.

19 MEMBER WALLIS: To get back to my
20 question, I would think you would have to control that
21 sharp corner pretty carefully, the way you machine
22 that little sharp corner.

23 MR. FREDERICK: That shear out section is
24 really not a corner, as such, it is a radius.

25 MEMBER WALLIS: It must be a radius.

1 MR. FREDERICK: But it is a radius, it is
2 very well --

3 MEMBER WALLIS: And you specify that very
4 clearly?

5 MR. FREDERICK: Yes. Under design for
6 shear out section, the shear section is a standard
7 pyrovalve design feature. Again, it has been in
8 valves as long as I have worked on valves.

9 So it even dates back, even some of the
10 valve designs that I incorporated in 1980, date back
11 to the late '60s, that were designed for Lockheed
12 Martin and some of the early space programs.

13 The concept has been proven many times,
14 thousands of times with valves. To my knowledge there
15 is no leakage ever reported on a delivered product,
16 through the sheared out section, or the shear section.
17 And I have designed valves as small as three-
18 thousandths of an inch, in some applications for
19 pyrovalves.

20 The concept proposed for the AP1000 is
21 really the same as the AP600, and the SBWR, same
22 design there, as far as the design concept. And the
23 designs, the basic design proposed would meet the ASME
24 codes, as identified.

25 And there would be a design by analysis

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 for NB3200.

2 CHAIRMAN KRESS: What is the propellant?
3 Is it proprietary?

4 MR. FREDERICK: Technically it is. It
5 does show up in the Department of Transportation, I
6 believe, or the Department of Energy report someplace
7 along the line. But it was intended to be a
8 proprietary item.

9 So even though you know the name it is not
10 a big deal, because you still have to know how to put
11 it together to get there. So I won't bring that out
12 here, so it is originally considered to be a
13 proprietary item.

14 Getting into corrosion affects, we have
15 discussed this somewhat and I think we all agree that
16 there is more work to be done in that area, as far as
17 corroding effects, and any effects of 316L and the
18 intended application.

19 And in-service inspection, obviously, is
20 something that we have discussed, and obviously there
21 has to be something in place to cover that.

22 Under reliability summary I have it listed
23 here, and I have to give you a few specifics on what
24 the numbers mean, otherwise they won't mean what you
25 think they mean.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 Under UPCO reliability, again, I gave you
2 the track record of what UPCO means relatively to what
3 we are doing today. But they have manufactured more
4 than 64,000 valves, fired 5,300, and the reliability
5 numbers are stable.

6 Under Conax reliability, what I did, was
7 accumulated a bunch of numbers. Conax had not kept
8 records from the beginning of time on valves. So what
9 I had to do is try to accumulate as much information
10 as I could.

11 And there is at least greater than 25,000
12 initiators that have been put out in the field, which
13 went with basic valves at the same time, to no
14 reported failures coming back associated with the
15 valve itself.

16 Sandia reliability numbers, I've included
17 those in there, that is input information that was
18 given to me by Westinghouse, and I just inputted that
19 for information purposes, and it is the intent of
20 Westinghouse to get more details into some of the
21 Sandia information, which will be forthcoming after my
22 presentation.

23 CHAIRMAN KRESS: Is that based on the same
24 25,000 and no failures? It is just a different
25 statistical analysis?

1 MR. SCHULZ: We don't know. Sandia has a
2 data base, the manufacturers have a data base, there
3 is some overlap.

4 MR. FREDERICK: This is what I was given
5 probably, I don't know, maybe a month or two ago,
6 prior to all the new information that was just
7 received from Sandia, to support this meeting.

8 MEMBER FORD: I think, since it is on the
9 record, I should just mention, you can crack 316L in
10 PWR primary water, dependent on what the stress is,
11 what the surface condition is.

12 And as you correctly pointed out, more
13 work needs to be done.

14 MR. FREDERICK: Finally here, squib valves
15 have high inherent reliability. I think that is safe
16 to say based upon the thousands of units that are out
17 in the field.

18 Reliability for smaller valves is
19 applicable for larger valves. And, again, some more
20 discussion will follow my presentation in that regard.
21 The same design standards that are basically
22 established for programs, you have engineering
23 analysis, various test requirements, we've got those
24 identified.

25 And design concepts, similar shearing

1 material in all cases. It is a standard squib valve
2 design characteristic that you want to have.

3 And, lastly, again to my knowledge, no
4 failures associated with shear section cracking under
5 constant high pressure and temperature. To qualify
6 that, in the applications that we worked in,
7 obviously.

8 CHAIRMAN KRESS: Thank you very much.

9 MR. FREDERICK: That is it for me.

10 MEMBER LEITCH: I have a question.
11 Reliability data is based on the thousands that are
12 commonly manufactured, and I take it that is normally
13 about two inches, or do you have considerable
14 experience with anything larger than that?

15 MR. FREDERICK: Two inches is generally
16 about the largest that we have made. I may be able to
17 backtrack in Conax, and they may have one that is two
18 and a half or something.

19 But, again, it is different, it is a
20 little bit different, but it is the same type of thing
21 where you are shearing off --

22 MEMBER LEITCH: The seven inch valve you
23 referred to is not in the --

24 MR. FREDERICK: No, I don't even include
25 that --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER LEITCH: -- manufactured? Yes,
2 okay.

3 MR. FREDERICK: Thank you.

4 (Telephone interruption.)

5 MR. SANCAKTAR: My name is Selim
6 Sancaktar, I'm in the reliability and risk assessment
7 group at Westinghouse.

8 I wanted to summarize, for you, a few
9 thoughts and facts. I can keep it as short as you
10 want, you can catch up if you want.

11 But we previously discussed with, at
12 least, the PRA, what we did with AP1000. And
13 summarize it on some of my slides. Afterwards
14 basically -- I will give you first the high level
15 summary.

16 We sought, by function, and all of that
17 information came from Conax. The other part of the
18 information, we went to Sandia Laboratories, and we
19 commissioned them to review what we are doing, and
20 what they are doing in the squib valve area, and tell
21 us what they think of what we are doing.

22 They contact the clients --

23 (Laughter.)

24 MR. SANCAKTAR: But I don't know what they
25 talk about. Sandia sent us a report, unfortunately it

1 arrived two days ago. So I'm not going to present
2 that, can't give it a fair representation. They also
3 sent us a presentation slides, which you have in your
4 hand, right?

5 CHAIRMAN KRESS: When you say Sandia, do
6 you have a name associated with that?

7 MR. FREDERICK: Yes, it was Ruby Latham
8 was the name of the person. They wanted to make sure
9 that it was independent from the NRC contracts that
10 they had.

11 MR. SANCAKTAR: So all of these slides,
12 the things I noticed are, first of all, unfortunately
13 there are no slide numbers here, but towards the end,
14 there are two tables like this. And included at the
15 bottom there is a failure risk assessment of two minus
16 four, which is equal or lower than their previous
17 estimates, which we used for AP1000.

18 In fact, in their report, they use these
19 numbers to estimate the failure probability we used
20 for AP1000, and it goes down a little bit. So the
21 point is, if you look at it numerically, things are as
22 good as before, or better, according to Sandia's
23 information available to Sandia.

24 Before you asked whether their 25,000
25 valves is the same as Conax 25,000 valves. I don't

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 think there are many manufacturers, so I'm sure there
2 are only so many valves around.

3 Sandia did a subset that includes Conax',
4 and UPCO's, and so on, so it is all the same
5 information --

6 MR. FREDERICK: Sandia, over the years,
7 have been directly involved with their own type of
8 analysis that -- so how it all ties together, I don't
9 know. But I don't believe the numbers I put out are
10 totally different.

11 MR. SANCAKTAR: So the bottom line of the
12 Sandia report is, what they said before, and we used,
13 is still valid, or even better. Moreover, they looked
14 at the concern about the structural, possible
15 structural failures, and upscaling failures.

16 And, again, their conclusions, they didn't
17 find anything new. They don't think there is a
18 problem in upscaling, or with respect to the operating
19 temperatures and pressures, which coincide with what
20 Conax also said.

21 So the bottom line is, we still believe
22 that AP1000 calculations are reasonable and the
23 conclusions based on the AP1000 PRA about the risk,
24 contribution to plant risk of these valves is still
25 valid.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 And my personal opinion is that I feel
2 more comfortable, I think, with this slightly better.
3 But not enough information exists to make a big deal
4 out of it.

5 MEMBER FORD: Except that none of these
6 tests that they evaluated have been conducted where
7 high temperature water has been one side of the seal,
8 is that correct?

9 MR. SANCAKTAR: Well, obviously a lot of
10 testing has been done under various conditions, but
11 not to the temperatures that we are talking here. I
12 mean, when we build valves with pyro pressures than
13 24, 2,500, we have a valve with 10,000 psi operating.

14 MEMBER FORD: These are the reliability of
15 the valves in the highest produced condition, not in
16 after-service? Do you understand the difference?
17 After-service. So my question still stands, then.

18 None of these data points relate to after-
19 service in high temperature water.

20 MR. SCHULZ: The boiling water reactor or
21 the --

22 (Everyone speaks at the same time.)

23 MR. SCHULZ: -- concern of failure to open
24 after service?

25 MEMBER FORD: No, I'm really concerned

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 about premature opening. Okay, I didn't understand
2 the --

3 MR. SCHULZ: These are addressing the
4 issue of reliability to open on demand.

5 MEMBER FORD: Got you, okay.

6 MR. SANCAKTAR: But they also tell us
7 something about other failures, lesser failures of
8 that nature, that they didn't show themselves yet. So
9 we are not certain about (unintelligible) ten minus
10 four.

11 But there aren't any best crossed line
12 beyond what has been reported. So we know they are
13 ten to minus two or three. So we know the level, the
14 threshold that are established with other failures.
15 But how much we know, we don't know.

16 They may be equal to, or it might be
17 (unintelligible). That it is ten minus twelve, or
18 anything like that.

19 So, now, the best, I think go through the
20 presentation, or I can let you ask questions. I will
21 give you a choice, whatever you like.

22 MR. SCHULZ: You could skip to the
23 premature opening, the structural valve --

24 (Everyone speaks at the same time.)

25 MR. SANCAKTAR: I just addressed, the last

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 two minutes the --

2 MR. SCHULZ: Right.

3 MR. SANCAKTAR: It is telling us that the
4 structural failure aspect that cannot be purely
5 addressed. We have addressed it with situations in
6 generalized operational proportion, and design
7 proportions, and (inaudible).

8 And then you also -- lack of evidence says
9 that it is at the level of whatever evidence they give
10 us for a lot of failure model (inaudible) report.

11 But just for the sake of getting a feeling
12 for it, if you say that these valves are as reliable
13 as a piece of pipe, as a segment of pipe
14 (unintelligible) of a ten foot piece.

15 So if you say that this is like a segment
16 of pipe, each valve, and you only have definitions of
17 failures, and so on, you follow the same process for
18 these valves. We will end up with, four the four
19 valves, for the year, six times minus six previous
20 failure, from just some catastrophic structural
21 failure.

22 This is about ten percent of what we have
23 assigned now. So this might be -- so if you say, go
24 back and say this is twice as bad as a pipe, so you
25 get stresses. If you say it is ten times as bad as a

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 pipe, you will get -- this number will be about six
2 times to the sixth, which is, which will be equal to
3 what we assigned to premature opening due to spurious
4 signal.

5 So we have the same orders of magnitudes.
6 And then we have other slide -- there, that is the
7 one. And what would that mean? For example, if we
8 double the failure to open (unintelligible) we see a
9 15 percent increase in the base PRA.

10 If you don't reach your opening we see an
11 increase of about twelve percent. So if you
12 (unintelligible) a factor of two, about the 25 percent
13 increase, you must be estimated.

14 CHAIRMAN KRESS: Is this small, is this
15 large, is the next question. I will leave it to you,
16 it is not small, it is not large either.

17 MR. SANCAKTAR: I've seen people worrying
18 about small percentages (unintelligible) to me is --
19 by a factor of two we are in the same, we agree.

20 CHAIRMAN KRESS: About 10 to the minus 6?
21 Ten to minus 7, that is pretty small.

22 MEMBER FORD: Would you mind going back to
23 slide 32? It should be ten -- eight times
24 (unintelligible) for R?

25 MR. SANCAKTAR: Yes.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER FORD: And the first bullet, and
2 I'm trying to -- I read the phrase, squib valve
3 considers some of the pipe segments. What are the
4 assumptions in that?

5 MR. SANCAKTAR: If they were, let's say it
6 this way, if they were, assumed to be as (inaudible)
7 that is what I would tell them, with the same
8 assumptions of other numbers in the same PRA, just to
9 get some sort of a point to refer to.

10 I'm not saying they are, I'm not saying
11 they are not. But once you get this number, then I
12 can move up and down and say, well, they are not --
13 obviously I cannot say they are more reliable than a
14 piece of pipe.

15 CHAIRMAN KRESS: But you are saying even
16 if it is ten times less reliable it doesn't matter?

17 MEMBER WALLIS: Clearly it is not a pipe.

18 MR. SANCAKTAR: So I have to relate it to
19 something that is existing in the PRA, but the number
20 for it, and try to get some numerical thing out of it,
21 other than there is no other intention. Does that
22 answer your question?

23 MEMBER FORD: Yes, I just read the
24 statement, and my natural thought was to challenge it.
25 I'm not really sure why I'm challenging it.

1 (Laughter.)

2 CHAIRMAN KRESS: That is always his
3 natural thought.

4 (Everyone speaks at the same time.)

5 MEMBER FORD: I can understand your
6 reasoning, and I can understand Tom's reasoning and
7 say, even if you increase it by a factor of ten, but
8 what about a factor 1,000? Because of stress
9 concentrators, whatever.

10 MR. SANCAKTAR: Yes.

11 MEMBER FORD: And I hadn't thought it
12 through.

13 MR. SANCAKTAR: I mean, if it is a
14 thousand times worse, it is worse, then we would be in
15 a domain where we would start seeing failures in other
16 places.

17 So the conclusions basically are that we
18 don't have any new information that considerably
19 differs from what had calculated, because we had
20 calculated slightly (unintelligible) failing to open,
21 valves prematurely opening, it is a good as estimate,
22 as best estimate as you can come up with without too
23 much (unintelligible).

24 CHAIRMAN KRESS: These 25,000 valves are
25 part of the data base, are they two inch valves?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. SANCAKTAR: Yes.

2 CHAIRMAN KRESS: So they are small
3 compared to --

4 MR. SANCAKTAR: Yes. And for me the
5 important things that gave me confidence were that
6 both parties are mentioned, said that upscaling was
7 not a problem, and then they didn't see
8 (unintelligible) in this particular case, a subject
9 that would really make a big difference.

10 CHAIRMAN KRESS: So by both parties you
11 mean Conax and Sandia?

12 MR. SANCAKTAR: And Sandia, right. So we
13 think that the conclusions of the, for the AP1000 PRA
14 with respect to (unintelligible) failure of squib
15 valves are still valid, it is reasonable.

16 Just as a side point, if there is a
17 spurious opening, MOVs are three, can be
18 (unintelligible), and we don't want to be in that
19 situation.

20 MEMBER WALLIS: They can close on the full
21 flow? They have to close on the full flow?

22 MR. SCHULZ: They are not designed to do
23 that, no. So I'm not sure (unintelligible). And
24 squib valve opening.

25 MEMBER WALLIS: So they wouldn't shut it

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 in time to do any good?

2 MR. SCHULZ: It probably would get you
3 into a --

4 MEMBER WALLIS: -- stay open, because once
5 you are into that LOCA you want to stay --

6 MR. SCHULZ: It is a large break LOCA for
7 us.

8 MR. SCHULZ: Eventually you can close one
9 or --

10 (Everyone speaks at the same time.)

11 MEMBER WALLIS: Well, it seems a bit --
12 let's see, fragile, the reasoning. Fragile reasoning.
13 This thing is not a pipe, it is more like a disk, or
14 something. There is no reason that experience with
15 pipes has anything to do with the experience with
16 squib valves.

17 MR. SANCAKTAR: And we do use it. I mean,
18 we know the AP1000 --

19 MEMBER WALLIS: You don't use it anyway?

20 MR. SANCAKTAR: Anyway.

21 MEMBER WALLIS: So let's forget it.

22 MR. SANCAKTAR: I just want to give you a
23 feeling about the numbers --

24 MEMBER WALLIS: -- is what you would get?

25 MR. SANCAKTAR: Yes, just to give you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 (unintelligible). Just to give you a feeling, but I
2 don't have a number to give you. So (unintelligible)
3 on the table --

4 CHAIRMAN KRESS: But basically the
5 reliability numbers come from 25,000 two inch squib
6 valves, out there, in operation, none of which have
7 failed, gives you a reliability for that, and
8 expectation that scale-up wouldn't change that, nor
9 the operational conditions would change that.

10 So that is the --

11 (Everyone speaks at the same time.)

12 MEMBER WALLIS: -- but the opening
13 unexpectedly is different.

14 CHAIRMAN KRESS: Yes, it is a different
15 thing too, yes.

16 MR. CORLETTI: We have addressed at least
17 part of it in regards to the (unintelligible).

18 MEMBER WALLIS: Let the PRA people argue
19 about it.

20 MR. CUMMINS: I just want to be able to
21 explain this to Steve --

22 (Everyone speaks at the same time.)

23 CHAIRMAN KRESS: Are we ready for a break,
24 then? We will take a 15 minute break, and be back by
25 20 after.

1 (Whereupon, the above-entitled matter
2 went off the record at 3:05 p.m. and
3 went back on the record at 3:20 p.m.)

4 CHAIRMAN KRESS: I guess we are ready to
5 start again, and now we will talk about aerosols in
6 the containment? I guess this was, primarily, a
7 question that came from Dana Powers, where he was a
8 bit astounded that the size of the lambda they used,
9 to remove aerosols from containment, and in particular
10 I think he was questioning the diffusio-thermophoresis
11 part of it.

12 Partly because it wasn't clear to him that
13 the rate of steam condensation on the walls was always
14 there at the same time the aerosols were. But,
15 anyway, I just thought I would throw that perspective
16 out, as to where the concern came from. So with that
17 I will turn it over to Dr. Li.

18 MR. LI: Good afternoon. My name is Jun
19 Li, an associate at Polestar Applied Technology.
20 Today I'm going to talk about the calculation, the QA
21 calculation of post-LOCA containment aerosols
22 deposition for AP1000.

23 As an introduction, I would like to
24 mention a few things first. First of all, Polestar
25 has performed a QA calculation for the containment

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 aerosol deposition which also is referred to as a
2 containment Lambda.

3 Several years ago for AP600, as a part of
4 AP600 design certification in that calculation the
5 lambda for the best estimated scenario to consider, at
6 the same time an extensive study of the sensitivity
7 of the radial parameter that will affect the
8 containment lambda has also been performed.

9 So we will talk about that later. And
10 similar to AP600, as we all know, that AP1000
11 containment has a very large steel shell that is
12 cooled from outside. So that we will expect very much
13 higher heat transfer rate as compared to AP600
14 operating framework, where the walls (unintelligible).

15 As a result of that, we would expect a
16 much higher natural aerosol removal than what would
17 exist in -- from the sedimentation alone.

18 MEMBER WALLIS: That depends on the ratio,
19 it is not obvious that condensation is going to drag
20 aerosols to the wall, which I suppose is what you are
21 talking about, faster than sedimentation, until you
22 look at the relative rates of the --

23 MR. LI: Yes, that is true. But for
24 everything given the same, for example, the same
25 amount of aerosol, the same volume, and so on and so

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 forth, if you only have sedimentation, you don't have
2 a condensation, then the lambda is going to be smaller
3 than the case where you have both.

4 MEMBER WALLIS: You don't know about how
5 much?

6 MR. LI: Yes, we don't know about how
7 much. That is the purpose of this calculation.

8 CHAIRMAN KRESS: But the containment
9 effective height for AP1000 is bigger than AP600. So
10 that reduces your sedimentation level?

11 MR. LI: Yes, you can now say that without
12 kind of assumption, for example, if you have same
13 amount of aerosol --

14 CHAIRMAN KRESS: Yes, for the --

15 MR. LI: -- certainly your sedimentation
16 is going to be smaller. But if you have, you increase
17 the volume, but at the same time you increase more the
18 amount of aerosol, the sedimentation lambda
19 (unintelligible).

20 So it is not like a -- yes, in this case
21 it just so happens the AP600, the AP1000 has a 75
22 percent more thermal energy, as well as 75 percent
23 more aerosol -- I mean, diffusion -- therefore, you
24 know, 75 percent higher, 75 percent more aerosol in
25 the containment than AP600.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealgross.com

1 Now, for the volume only increase by 20
2 percent. Therefore --

3 CHAIRMAN KRESS: So you have the initial
4 concentrations?

5 MR. LI: Initial -- yes, the concentration
6 actually is higher, therefore the sedimentation lambda
7 will be higher.

8 CHAIRMAN KRESS: Yes, they will cross
9 over, you are right.

10 MR. LI: Yes. So we will talk about,
11 because as I said, you know, the third point I want to
12 make is that since the AP1000, and the AP600 have
13 similar design, so this calculation is pretty much the
14 repetition of AP600 calculation, except that we use
15 AP1000 parameters, like a geometry surface, modeling,
16 and the amount of aerosol that (unintelligible) to
17 AP1000 design.

18 At the same time we use AP1000 thermal-
19 hydraulics, because the AP1000 the thermal power is
20 higher, so the thermal-hydraulic condition is going to
21 be different.

22 But in terms of the sensitivity of
23 containment lambda, we are going to rely on our
24 sensitivity study done on the AP600, which we will
25 discuss later, to assess the possible variation on the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 AP1000.

2 CHAIRMAN KRESS: Westinghouse does this
3 for the --

4 MR. LI: Yes.

5 CHAIRMAN KRESS: They use a code, they are
6 using -- you use the containment code?

7 MR. LI: Yes, it is --

8 CHAIRMAN KRESS: For the aerosols.

9 MR. LI: For aerosol we use what is called
10 STARNAUA, QA code, which is the one we use for the
11 AP600 calculation.

12 CHAIRMAN KRESS: Which code was it to use?
13 What is the name of the code, again?

14 MR. LI: The name of the code is STARNAUA.

15 CHAIRMAN KRESS: Is that one that you guys
16 at Polestar developed?

17 MR. LI: Yes, that is right.

18 CHAIRMAN KRESS: I'm not familiar with it.

19 MR. LI: It is the one -- the last three
20 pages summarize the --

21 CHAIRMAN KRESS: The model?

22 MR. LI: The STARNAUA -- originally from
23 (unintelligible) which --

24 CHAIRMAN KRESS: Oh, it comes from the
25 NAUA?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. LI: Yes.

2 CHAIRMAN KRESS: Okay, I'm sorry, I didn't
3 understand.

4 MR. LI: Yes, it is -- then it becomes a,
5 actually when I was at Stanford, but I took the NAUA
6 code, because EPRI was the sponsor of my program. So
7 we basically changed the NAUA code to include other
8 kind of --

9 CHAIRMAN KRESS: Well, basically the
10 aerosol models there are the same ones that are in
11 containment?

12 MR. LI: Yes, exactly, exactly. It was
13 just additional feature like -- in STARNAUA we start
14 to consider a spray.

15 So now I would like to, also as a part of
16 introduction, I would like to put the aerosol removal
17 in some kind of perspective. Basically we -- what we
18 have here is tightly sealed containment, which the
19 design is 1.183 percent that was given by
20 Westinghouse.

21 Then we have this, the larger containment,
22 outside we have a water plume to cool the containment.
23 And on the inside we also have a condensate plume
24 running on the inside surface.

25 And as a result we have a pretty high heat

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 transfer, which I think some early (unintelligible)
2 talks to that. And then in the containment there will
3 be steaming, turbulence situation, and we can kind of
4 visualize that there is a pretty favorable environment
5 for aerosol removal, as we will show, you know, in the
6 calculation later.

7 Basically because of the (unintelligible),
8 we are basically arguing that there is no way the
9 aerosol can bypass those mechanisms to leak out
10 directly, because they have to get to the surface.
11 And the leakage, there is a leak (unintelligible), and
12 it has to be at the surface.

13 So if you have a warning the aerosol stay
14 there, then it cannot leak. So once there is a leak,
15 then it gets to the surface and this (unintelligible)
16 starts to take place.

17 Now, we are going to basically use the
18 AP600 calculation that we have done previously, as a
19 basis to explain what we did for AP1000. So this is
20 the time that we want to show the comparison, and so
21 we will know what we are looking for.

22 Now, compared to AP600, as I said earlier,
23 the thermal power is at 75 percent higher. And,
24 therefore, the amount of aerosol is 75 percent more.
25 Volume is increased by 20 percent, which I was told

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 that it just makes that taller, therefore the
2 sedimentation area doesn't change.

3 So now we certainly know, with higher --
4 with higher thermal powers mean that higher decay
5 heat, therefore there is higher total heat transfer
6 out of the containment, and we expect a higher
7 diffusiophoresis, and a higher thermal phoresis.

8 CHAIRMAN KRESS: At the same time?

9 MR. LI: No, not at the same time, because
10 sometimes -- it is a competing process. But it is just
11 that conceptually --

12 CHAIRMAN KRESS: Conceptually, if you have
13 thermophoresis, if you have diffusional phoresis you
14 don't have thermal phoresis, so if you don't have
15 thermophoresis, you can have thermal phoresis?

16 MR. LI: Yes. I think that usually those
17 mechanisms are -- the combined mechanism tends to be
18 like one minus, you know, something and .1 minus, the
19 other -- you know, it is not like -- it is a product,
20 rather than --

21 MEMBER WALLIS: What is thermal phoresis?

22 MR. LI: Thermal phoresis is the particle
23 movement driven by the temperature gradient.

24 MEMBER WALLIS: So how about the
25 condensation, doesn't that drag particles to the --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 CHAIRMAN KRESS: Absolutely, that is why
2 diffusional phoresis --

3 MR. LI: Yes, that is called --

4 MEMBER WALLIS: That is actually dragging
5 by flow?

6 CHAIRMAN KRESS: Yes, that is -- it is
7 misnamed, it should be called step and flow --

8 MR. LI: Yes.

9 CHAIRMAN KRESS: It is misnamed.

10 MEMBER WALLIS: Diffusion takes place,
11 anyway, and --

12 MR. LI: Exactly, which is the reason why
13 it is not --

14 (Everyone speaks at the same time.)

15 MEMBER WALLIS: -- account of the
16 condensation?

17 MR. LI: Yes, exactly.

18 MEMBER WALLIS: Another question, is this
19 aerosol charged?

20 CHAIRMAN KRESS: That is always a question
21 that is never answered. The feeling is with all the
22 steam in there, that it sort of dilutes the charge.

23 MEMBER WALLIS: Does it?

24 CHAIRMAN KRESS: Well, the aerosols are
25 hygroscopic, and they are sort of wet, and that tends

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 to do something to neutralize the charge.

2 MEMBER WALLIS: Well, the charges on them,
3 it doesn't come off, unless it leaks off somewhere?

4 CHAIRMAN KRESS: Well, they are venting
5 all that water, it sort of neutralizes it.

6 MEMBER WALLIS: It doesn't neutralize it
7 unless there is an equal and opposite charge of some
8 sort, from somewhere. So there is probably a charged
9 cloud in there, I don't know.

10 CHAIRMAN KRESS: Well, that has always
11 been an unanswered question in the aerosol business,
12 are these things charged, and do they affect anything
13 if they are.

14 And that has never been answered.

15 MR. LI: So basically all of the three
16 mechanisms increase the removal rate, rather than
17 decrease it. Therefore we would expect higher
18 containment level for AP1000 than for the AP600.

19 Now, how do we do the calculations? The
20 procedure is like this. First of all, we would select
21 an accident sequence for AP1000 based on relatively
22 high probability. In this case we choose a
23 (unintelligible) -- sequence out of that.

24 And also the sequence has a timing, in
25 terms of aerosol release, that matches, are similar to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 NRC Regulatory Guide 1.183, timing for PWR fission
2 product release. So that is the criteria.

3 So we selected a sequence, and we used
4 what is called MAAP4 computer code. Actually it is
5 done by Jim in Westinghouse to simulate the accident
6 to produce the thermal-hydraulic conditions.

7 And once we get the thermal-hydraulic
8 condition, then we use that and input, and use the
9 Polestar QA code, STARNAUA, which I talk a little bit
10 about earlier, to calculate the natural aerosol
11 removal under those conditions.

12 CHAIRMAN KRESS: Now, when you look at Reg
13 Guide 100, it specifies a fission product fractional
14 release, and has an option for the timing for that,
15 and it specifies you use the large break LOCA sequence
16 to get the pressure, and the thermal-hydraulics.

17 Is that what you did here?

18 MR. LI: Yes, we used the NRC Reg Guide
19 1.183. You use the release fraction, and the release
20 timing for -- which is the (unintelligible) release of
21 25 percent.

22 CHAIRMAN KRESS: So this is a design basis
23 space you are dealing with?

24 MR. LI: Yes, exactly. And a maximum
25 release for 1.3 hours, then a release fraction like

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 iodine 25 percent, cesium hydroxide 35 percent. So we
2 use the fraction as the -- for our aerosol
3 specification.

4 CHAIRMAN KRESS: Now, in the PRA space
5 there is no need to do all this, the MAAP code
6 calculates all that for you, right?

7 MR. LI: Yes.

8 CHAIRMAN KRESS: So this is strictly
9 dealing in the design basis?

10 MR. LI: This is design basis.

11 MR. SCOBEL: I think the answer to your
12 question is thermal-hydraulically we did not use the
13 design basis LOCA environment, we used the severe
14 accident environment. I think that was the question
15 that you asked --

16 CHAIRMAN KRESS: Yes, that would --

17 MR. SCOBEL: -- pressure and the
18 temperature --

19 CHAIRMAN KRESS: Yes, that was one of the
20 parts of the question.

21 MR. SCOBEL: We didn't use the design
22 basis LOCA, we used the severe accident. That is why
23 we used the MAAP code to generate the environment.

24 CHAIRMAN KRESS: And I guess the question
25 is, is that acceptable way to deal with design basis

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 space, to you guys over there? I mean, it is a
2 departure from -- it is almost a redefinition of large
3 break LOCA.

4 MR. SCOBEL: But it is actually the same
5 methodology that we used for AP600, to separate the
6 lambda for AP600. And the reasons, actually, that we
7 did that to relate what you were saying were Dr.
8 Power's concerns, where he didn't think that there
9 would be as much condensation at the time when you
10 would have the aerosol, in a small basis LOCA, that is
11 not true, you always have the condensation.

12 CHAIRMAN KRESS: Yes, it is all at the
13 same time, isn't it, in design basis?

14 MR. SCOBEL: Well, we don't have these
15 kind of aerosols generated in a design basis LOCA for
16 the very reason that you have core cooling going on
17 the entire time.

18 But in a severe accident, when you are
19 melting the core, then you tend to not be producing so
20 much steam because you --

21 CHAIRMAN KRESS: -- space.

22 MR. SCOBEL: Right. So you have a drop in
23 the mole fraction of steam in the containment, and
24 your condensation rate goes down, which you can
25 actually see in the package of the thermal-hydraulic

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 conditions.

2 CHAIRMAN KRESS: So, basically, you are
3 actually picking an accident that probably is worse
4 than the design basis space?

5 MR. SCOBEL: If we had used the design
6 basis we would have gotten better lambdas, that is
7 correct, exactly.

8 CHAIRMAN KRESS: Okay, thank you for that
9 clarification.

10 MEMBER WALLIS: I would think that if you
11 can predict the condensation rates you have a pretty
12 good handle on the diffusiophoresis.

13 MR. LI: Sure, that is exactly --

14 MEMBER WALLIS: The particles are dragged
15 by the steam, there is no mechanism for giving any
16 relative velocity, or anything.

17 CHAIRMAN KRESS: That is right. If you
18 have this condensation rate, you can pin down the
19 diffusiophoresis. So that is the secret there, have
20 you got the right condensation rate.

21 MEMBER WALLIS: Well, you know the rate at
22 which you are boiling, and that is the rate you are
23 condensing, pretty well. If you say state --

24 CHAIRMAN KRESS: Yes, pretty much, you are
25 right.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER WALLIS: So just from the decay
2 heat --

3 CHAIRMAN KRESS: But if the pressure is
4 going to change, and there may be some --

5 (Everyone speaks at the same time.)

6 MEMBER WALLIS: Is this benchmarked by
7 TMI, or anything like that?

8 CHAIRMAN KRESS: It has been benchmarked
9 by large aerosol containment tests, but not TMI.
10 There were no aerosols in TMI.

11 MEMBER WALLIS: Not at all?

12 CHAIRMAN KRESS: No.

13 MEMBER WALLIS: Wonderful, it didn't get
14 that far.

15 CHAIRMAN KRESS: Had some noble gases.

16 MR. LI: So, as I said, we have -- so
17 using the MAAP code, we can get into (unintelligible)
18 for the containment vessel removal calculation. And,
19 also, since we know that the removal process also
20 depend on the aerosol characteristics, we sample
21 (unintelligible) certainly the heavier, the larger
22 particle, the faster they will settle.

23 And so in our calculation those are the
24 assumptions we made.

25 CHAIRMAN KRESS: That is the log normal

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 distribution?

2 MR. LI: Yes, it is log normal
3 distribution, because this is also the assumption we
4 used for AP600. And there is log normal situation,
5 the geometric mean really is .22 micron, sigma is 1.8,
6 which produced a mass mean diameter of 1.3 micron.

7 And we could do this pretty much
8 conservative, because even in the Sandia National Lab
9 study, done by Dana Power, the mass mean diameter they
10 used an extension of 1.5 microns to 5.5. So we used
11 the smaller in the lower end.

12 The efficient power ratio is 1.5 to 1, and
13 we basically neglected the hygroscopicity, because we
14 know that there is a controversy about, you know, what
15 kind of a chemical form this aerosol particle will be.

16 But if there were cesium iodide, we know
17 those are soluble materials, but we neglected the
18 hygroscopicity. The packing fraction, we used .8.

19 CHAIRMAN KRESS: And that translates into
20 dynamic shake factor?

21 MR. LI: Yes, that translates into --
22 because of, you know, there is a concern that the
23 particle, even though they are the type they are --

24 CHAIRMAN KRESS: Basically is reduced to
25 density by that much?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. LI: Yes, exactly, to reduce the
2 density. Because we believe, you know, those aerosol
3 will generate at very high temperature, which they are
4 pretty much liquid and then, when -- you know, so that
5 it should be close to one, but which was .8 at the
6 best estimate, and we do a sensitivity study.

7 CHAIRMAN KRESS: What that does is
8 reduces, actually, your lambda, doesn't it?

9 MR. LI: Yes, that is right.

10 CHAIRMAN KRESS: It makes it smaller?

11 MR. LI: Yes.

12 CHAIRMAN KRESS: What was your sensitivity
13 study on that, too?

14 MR. LI: The release fraction and timing,
15 as I said earlier, that we used an NRC Regulatory
16 Guide 1.183 --

17 CHAIRMAN KRESS: Now, the question I have
18 about that is, when did you start it, in the accident
19 sequence, to MAAP?

20 MR. LI: We started at -- the
21 (unintelligible) we take it is from Reg calculation,
22 we start at the core uncover, the MAAP started at
23 core uncover.

24 CHAIRMAN KRESS: You waited until core
25 uncover?

1 MR. LI: Yes, because what happened is
2 that before that, if there is a lot of steam, a lot of
3 condensation --

4 CHAIRMAN KRESS: Yes, that is when you get
5 all that --

6 MR. LI: -- credit for that, because the
7 core is not even uncovered. So all the time you see
8 in a tape, the --

9 CHAIRMAN KRESS: And you say at the point
10 of core uncovering, do you mean top of the active fuel,
11 or bottom of the active fuel, or --

12 MR. SCOBEL: It would be top of active
13 fuel.

14 CHAIRMAN KRESS: Top of active fuel.

15 MR. SCOBEL: -- mixture level to dryout.

16 MR. LI: Now, the removal mechanism I
17 think is pretty much a standard -- basically
18 (unintelligible) as I said, there is also a removal by
19 spray, into the STARNAUA, but that wasn't used.

20 So the screen mechanism is a sedimentation
21 diffusiophoresis, and thermophoresis. So we can see
22 that the sedimentation is the one that is pretty much
23 sensitive to the sides.

24 And if that is a spherical solid
25 (unintelligible), then fine, the denominator is one.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 (Everyone speaks at the same time.)

2 MR. LI: If the packing fraction is
3 smaller than one, then the phi is going to be larger
4 than one, that is going to affect the sedimentation.

5 Now, as we can see that the
6 diffusiophoresis and the thermophoresis are not that
7 sensitive to the particle size, especially the
8 diffuser. Thermophoresis, there is some small
9 dependency on the particle size, as you can see it,
10 because the number is in there.

11 But other --

12 MEMBER WALLIS: Now, this has nothing
13 about condensation?

14 MR. LI: Yes, the Q (unintelligible) is --

15 MEMBER WALLIS: Just like conduction. I
16 don't see any HFG, or anything like that.

17 MR. LI: HFG?

18 MEMBER WALLIS: This doesn't come into it,
19 the latent heat of the --

20 MR. LI: That will come into the --

21 (Everyone speaks at the same time.)

22 MEMBER WALLIS: Why? Doesn't that affect
23 thermophoresis? Where is that in the thermophoresis?
24 Or the diffusiophoresis? That is where it is, okay.

25 MR. LI: That doesn't come out --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER WALLIS: I'm sorry, now I
2 understand.

3 MR. LI: Yes.

4 CHAIRMAN KRESS: The temperature gradient
5 is carried forward --

6 (Everyone speaks at the same time.)

7 MR. LI: So basically what it says is
8 acceptable sedimentation, the diffusiophoresis, and
9 the thermophoresis are pretty much dependent on the
10 decay heat.

11 So whatever amount of decay heat you have,
12 as long as you want to let those heat out of the
13 containment, that is going to drive particle. So what
14 you make the lambda calculation, pretty much robust,
15 because we all know that, you know, sooner or later it
16 is the decay heat that basically -- and the removal
17 process is directly related to that.

18 So there are some dependency on the
19 pressure and temperature, because they will affect the
20 coefficient. But the dependency on the temperature
21 pressure is not as high as on directly the heat
22 transfer rate, on the condensation line.

23 So this is the calculated result. The red
24 curve is for AP1000, and the green curve is for --

25 CHAIRMAN KRESS: Now, do you have that

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 broken down by components for these three mechanisms?

2 MR. LI: Not for this curve, but in the
3 next one, yes.

4 MEMBER WALLIS: I don't understand
5 fraction per hour. And if you remove a fraction of one
6 it is all gone. So what are you talking about?

7 CHAIRMAN KRESS: It is a fraction of what
8 is left.

9 MR. LI: Whatever fraction --

10 (Everyone speaks at the same time.)

11 CHAIRMAN KRESS: It is either the amount
12 of --

13 (Everyone speaks at the same time.)

14 CHAIRMAN KRESS: It is like a decay --

15 MR. LI: If there is no source, only by
16 removal, then the concentration is going to decrease,
17 N is equal to N at a time certain, certain time --

18 (Everyone speaks at the same time.)

19 MR. LI: -- to the minus λT .

20 MEMBER WALLIS: But one is a pretty high
21 number then, isn't it?

22 MR. LI: One is -- let me give you some --
23 I know you probably heard that LACE experience
24 performed, and so they measured the concentration as
25 function of time, in their -- for example, LACE

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 (unintelligible).

2 And their measurement was that the lambda
3 for insoluble particles, which is magnum oxide is
4 around 1.3, 1.4. And the lambda for the soluble
5 material, which is cesium hydroxide, is 1.8.

6 MEMBER WALLIS: But you have a lambda of
7 1 here, for AP1000.

8 MR. LI: Yes.

9 MEMBER WALLIS: Which means in four hours
10 it is turned down to eight to the minus four,
11 presumably?

12 MR. LI: Yes.

13 CHAIRMAN KRESS: That is about right.

14 MEMBER WALLIS: Something like that?

15 MR. LI: Again, in the LACE, as example,
16 they call it half life -- 23 minutes everything cuts
17 by half. So it is a -- yes, you are right.

18 MEMBER WALLIS: Well, this is like a very
19 rapid removal rate.

20 CHAIRMAN KRESS: It is pretty rapid.

21 MR. LI: It is, it is. And, as I said,
22 that is what --

23 MEMBER WALLIS: Most of it by the
24 condensation?

25 CHAIRMAN KRESS: I think in general most

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 of it is sedimentation, but here it may be the
2 condensation.

3 MR. LI: Yes. In LACE experience it is
4 pretty much done by sedimentation because LACE is kind
5 of a heat transfer, insoluble and soluble.

6 Now, if you want to see the contribution
7 from different removal mechanisms, on the right hand
8 side is AP600, and on the left side is AP1000. Now,
9 for AP600, it just so happen that three mechanisms,
10 basically they kind of contribute.

11 But for AP1000, because as I said earlier,
12 in the presentation, because we have a 75 percent
13 higher heat transfer rate, therefore basically during
14 the competing process, the heat transfer rate
15 basically removes most of the particles, which this is
16 the result.

17 MEMBER WALLIS: So what is this Q double
18 dash?

19 MR. LI: Q double dash is a sensible heat
20 transfer.

21 MEMBER WALLIS: It can't be condensation,
22 it must be just the sensible.

23 MR. LI: Yes, it is sensible, yes. It is
24 basically driven by --

25 MEMBER WALLIS: I just wanted to be sure

1 you weren't using the total heat transfer.

2 MR. LI: No.

3 MEMBER WALLIS: I'm surprised it is so
4 big.

5 MR. LI: It is. But if the sensible heat
6 transfer drops, then the condensation has to come out,
7 because they have to, the decay heat has to get out.
8 So --

9 MR. SCOBEL: I believe one of the things
10 that you are seeing here is that because you do have,
11 for a period of high aerosol concentration, you have
12 a drier containment due to --

13 (Everyone speaks at the same time.)

14 MR. SCOBEL: -- the sensible heat transfer
15 go up.

16 CHAIRMAN KRESS: And I can see why the
17 sedimentation may be a little lower, because it is
18 pretty high effective containment, and that is --

19 MR. LI: Actually because we are assuming
20 it is well mixed, so --

21 (Everyone speaks at the same time.)

22 MR. LI: -- doesn't play much role.

23 CHAIRMAN KRESS: Yes, it does, it is
24 directing the lambda. Even though you are well mixed,
25 you still get H -- you still have to follow that

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 height?

2 MR. LI: Yes, that is right. In fact, the
3 assumption is actually making it worse, because --

4 CHAIRMAN KRESS: And it would come out
5 faster.

6 MR. LI: Yes, because basically, you know,
7 part of the basis is we move downward. So we are
8 assuming well mixed, so basically it put them up
9 again. Every time, you know, they move down a little
10 bit, and --

11 CHAIRMAN KRESS: That is why the height
12 enters into it?

13 MR. LI: Yes, that is right, yes. But as
14 I said, because there are more -- if you see the
15 equation, in the end it is (unintelligible) in the
16 containment.

17 CHAIRMAN KRESS: Well, what enters into
18 the exponential is the ratio of the volume to the
19 area.

20 MR. LI: Yes, that is right.

21 CHAIRMAN KRESS: And you call that height?

22 MR. LI: Yes.

23 (Everyone speaks at the same time.)

24 MEMBER WALLIS: It seems to me it doesn't
25 make any difference. Well, I guess you are

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 superimposing the mixing on the surface sedimentation?

2 CHAIRMAN KRESS: Yes.

3 MEMBER WALLIS: It is not as well mixed as
4 the drift relative to the sedimentation.

5 MR. LI: Yes.

6 MEMBER WALLIS: -- also there is a drift
7 going on.

8 MR. LI: Yes, if there is not, one reason
9 is -- pretty much more concentrated --

10 MEMBER WALLIS: -- do it all mixed up so
11 much there is only a little air near the bottom, which
12 is kind of stagnant, where you get sedimentation at
13 all.

14 MR. LI: But actually what happened is one
15 mix, then you have a removal rate down there, so it is
16 just the velocity times the temperature -- the --

17 MEMBER WALLIS: Superimposed, yes.

18 MR. LI: Yes. So if this get removed, so
19 you have a, you know, an air that has no particle any
20 more, but then the well mix is going to provide
21 particle. So in that sense --

22 CHAIRMAN KRESS: It comes out because you
23 are removing aerosols as particular velocity, on a
24 particular area. But you are removing those out of
25 the -- so it is volume over air, it looks like a

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 height.

2 MR. LI: Yes.

3 CHAIRMAN KRESS: And that is where it
4 shows up.

5 MEMBER WALLIS: Yes, so you have bigger
6 area, you get more out of it.

7 CHAIRMAN KRESS: Yes. That is
8 interesting.

9 MR. LI: So about sensitivity, as I said
10 earlier, we didn't do a sensitivity study for AP1000,
11 because we are going to borrow the result from AP600.
12 So let's take a look at the sensitivity for the AP600.

13 MEMBER WALLIS: Sorry, isn't there some of
14 alutriation, that the big particles come out first,
15 and the tiny particles are left behind?

16 MR. LI: Yes.

17 MEMBER WALLIS: It is not just quite so
18 simple.

19 CHAIRMAN KRESS: Yes, you get a lambda for
20 each particle size. Now, what they are doing is
21 getting an average lambda --

22 (Everyone speaks at the same time.)

23 MEMBER WALLIS: Check the average.

24 CHAIRMAN KRESS: What they get is find out
25 total mass, and then back out the lambda from the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 total mass.

2 MR. LI: Yes, exactly. What we did is we
3 divide the aerosol distribution into multiple bins.

4 MEMBER WALLIS: Okay, now it makes sense.

5 MR. LI: So each bin you calculate its own
6 removal, and the total removal of lambda --

7 MEMBER WALLIS: The effects of lambda are
8 averaged over these things, but the change in the
9 weight, because you have different proportions in the
10 bins as you --

11 MR. LI: Yes, that is right. But remember
12 that the particle also agglomerate.

13 MEMBER WALLIS: Yes, I was going to ask
14 you that, too.

15 MR. LI: Yes. And so the --

16 MEMBER SIEBER: Well, how do you treat
17 that? How do you treat the agglomeration? Because
18 then you are --

19 MEMBER WALLIS: It is a random process,
20 where they --

21 MR. LI: It is not a random process,
22 actually -- originally --

23 (Everyone speaks at the same time.)

24 MR. LI: The original German code, you
25 know, distribution, by sedimentation, and pretty --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 CHAIRMAN KRESS: There is some turbulence?

2 MR. LI: Yes, turbulence.

3 MEMBER WALLIS: What is the source of the
4 turbulence?

5 CHAIRMAN KRESS: It is natural convection.
6 And you have to characterize the turbulence level from
7 the --

8 MR. LI: So for sensitivity study we
9 changed the diffusion path to inner mass ratio from .5
10 to 3.

11 CHAIRMAN KRESS: Just out of curiosity,
12 what did you use for a sedimentation area?

13 MR. LI: Sedimentation area?

14 CHAIRMAN KRESS: Yes. The cross section
15 of the containment, or did you actually look at all
16 horizontal surfaces? So you did do that, and looked
17 at all horizontal surfaces?

18 MR. LI: Yes. That tends to --

19 MEMBER SIEBER: Did you consider angular
20 flow?

21 CHAIRMAN KRESS: You can take the
22 horizontal, the grid is in there, and there is
23 equipment that had horizontal surface, you can gather
24 all those up.

25 MEMBER WALLIS: Do you have convection

1 flowing down the walls --

2 MR. LI: Yes.

3 MEMBER WALLIS: I imagine a few feet a
4 second. And as you concentrate particles in that
5 boundary, they don't all go to the walls, some of them
6 go down along the floor?

7 MEMBER SIEBER: Right.

8 MEMBER WALLIS: And then they are more
9 likely to settle out as they are closer to the floor?

10 MEMBER SIEBER: Well, making the turn.

11 MEMBER WALLIS: Making the turn to the
12 inertial separation.

13 (Everyone speaks at the same time.)

14 MR. LI: -- because of the void fraction.
15 And the things blow out of the core, you know, that
16 they --

17 CHAIRMAN KRESS: Probably coming out the
18 ADS 4 valve?

19 MR. LI: Yes. So we thought that was a
20 conservatism. And, also, even when they got to the
21 past and we believed, you know, when it goes through
22 the tortuous path, there should be some -- you know --

23 CHAIRMAN KRESS: Actually, this is design
24 basis space, and they specify an aerosol source that
25 they should use. And in picking that source the Staff

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 rightly decided that there would be things like that,
2 so they don't really use the full core inventory,
3 they've reduced it quite a bit.

4 But they take into account this inertia
5 stuff that they don't know how to calculate, and take
6 account for things like that. So it is built into --
7 that kind of thing is actually built into the source
8 that is specified.

9 MEMBER WALLIS: It must be very sensitive
10 to the size of the particles.

11 CHAIRMAN KRESS: Yes, but that gets
12 speared out real fast by the agglomeration process.
13 I mean, you can put them in small, but they will
14 change in a hurry. They don't get that big. Some of
15 them are like 10 to 20 microns, they get pretty big.

16 MEMBER WALLIS: Unless you want to keep
17 them out going around, scrubbing out more.

18 CHAIRMAN KRESS: Well, that has been
19 proposed, that you artificially put aerosol --

20 MEMBER SIEBER: For a small break, though,
21 the biggest hole you have in the system is the ADS 4,
22 which is -- which is a chimney. So you are going to
23 have a big circulation --

24 CHAIRMAN KRESS: You have plenty of
25 natural convection.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. LI: The sensitivity result for AP600,
2 because of the way -- we think that the NRC time for
3 the diffusion path, but we also know that there will
4 be inner material that will also be releasing the
5 contaminant, not equal to a more inner material that
6 would tend to make the concentration higher, so you
7 have a higher agglomeration that you have to remove.

8 So the -- how many we will allow into the
9 containment to calculate the lambda will have some
10 effect. So in our -- as I said, we've assumed 1.5 in
11 the ratio, but we did a sensitivity study by changing
12 the -- I'm sorry (unintelligible) mass ratio from .5
13 to 3, and we see the change of 5 to 6 percent in total
14 leakage.

15 Now, we didn't compare the lambda, because
16 lambda is basically a function of time. But after the
17 wall we are actually more interested in the leakage
18 out of the containment. So the lambda can change in
19 time, but this is like integral effect on --

20 MEMBER WALLIS: Where is it leaking from?

21 CHAIRMAN KRESS: That is unspecified.

22 MEMBER WALLIS: This is just design --

23 MR. LI: Yes, it is .1 and --

24 (Everyone speaks at the same time.)

25 CHAIRMAN KRESS: In design basis space you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 take this design basis leak rate, like .1, but you up
2 the leak rate by the pressure that you get out of
3 design basis LOCA. And I was just wondering if you
4 guys actually did that, too.

5 MR. GRESHAM: The containment leak rate is
6 design basis is based on operation, or based on
7 conditions --

8 MEMBER SIEBER: It is the LOCA peak
9 pressure.

10 MR. GRESHAM: It is at peak pressure
11 containment, yes.

12 MEMBER SIEBER: And so it starts at that .1
13 and goes down, as containment depressurizes.

14 MR. GRESHAM: The NRC's guidance is assume
15 the design basis for the first 24 hours. And then no
16 further reduction.

17 MR. LI: Now, if you cut the sedimentation
18 area in half, then you can increase the leak rate by
19 13 to 14 percent. And, remember, this is for AP600,
20 where the sedimentation, it will only affect
21 sedimentation.

22 Now, the sedimentation in AP600
23 calculation contribute about 30 percent. So if we cut
24 this sedimentation area by half, the leakage increase
25 by 13 to 14 percent, which means you cut the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 sedimentation in half, because 30 percent times .5 is
2 around 14 percent.

3 So we know, for AP1000, it is going to be
4 five percent, because it only contribute
5 (unintelligible). Another thing we did is reducing
6 the packing fraction from .8 to .1, which kind of
7 exaggerate a little bit. Then it increases the liquid
8 about 14 percent.

9 Again, sooner, because it only affect the
10 -- pretty much only affect the sedimentation. So for
11 AP1000 we expect to be five percent, too.

12 Now, in smaller value of RG, because
13 already I said that, you know, we use RG and sigma,
14 that is already at the lower end of the Sandia that
15 has been looking, we reduced that further, we get the
16 leakage increase by an order of five percent, which is
17 small.

18 Then, again, if for AP1000, because it is
19 also the fact that, again, only sedimentation, and it
20 should be like two percent, three percent. So that is
21 why we are saying that AP1000 lambda derivation should
22 be lower than on the average.

23 Now, the conservatism that we think in
24 this lambda calculation, on top of that we think, you
25 know, by neglecting the hygroscopicity, our lambda is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 a conservative, because we know cesium hydroxide and
2 cesium (unintelligible) are solid.

3 And we also neglected the inertial
4 impaction on wet surface, and we will discuss that.
5 And we also neglected the aerosol retention in the
6 leak paths, when they leak out through the
7 (unintelligible).

8 CHAIRMAN KRESS: That is not exactly
9 neglected, because some correction to the source term
10 is built into it. The actual specified source term
11 has some recognition that there was some retention in
12 the leak path.

13 MR. LI: You mean in the leak path?

14 CHAIRMAN KRESS: Yes. I'm sorry, you are
15 talking about leaking out of the containment? I'm
16 sorry.

17 MR. LI: Yes, in there they haven't
18 considered the retention in the primary section. We
19 only take what is coming out of the primary system
20 into the containment.

21 CHAIRMAN KRESS: Okay, I'm sorry.

22 MR. LI: And our purpose are that we
23 choose to use a small set (unintelligible) we use the
24 MMD=1.3 micron, and the Sandia work assumes, you know,
25 1.5.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 So the conclusion is that we saw that the
2 lambda for AP1000 is 1.1 per hour. The result is
3 robust because there is a combination of removal
4 mechanisms, and we discussed this around the
5 conservatism.

6 So again, that is the end of my
7 presentation.

8 CHAIRMAN KRESS: There is no surprise to
9 me there is the large contribution to thermophoresis.
10 And I guess your explanation of that, the dry phase,
11 and you still have to get the decay heat out, and do
12 you have higher power than AP1000, does make sense.

13 MR. LI: Actually I have thermal-hydraulic
14 data, it connects --

15 CHAIRMAN KRESS: It is strictly a matter
16 of plugging in that thermophoresis equation to the
17 thermal-hydraulics.

18 MEMBER WALLIS: Well, presumably you have
19 radioactive material which is gaseous, which is not in
20 the form of aerosols. Not just noble gases, but other
21 things that have vapor pressure enough to evaporate --

22 CHAIRMAN KRESS: No, just the --

23 (Everyone speaks at the same time.)

24 MEMBER WALLIS: Only the noble gases. It
25 seems to be because noble gases, you know, you sort of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 vent them anyway.

2 MR. GRESHAM: After 24 hours the noble
3 gases are down to about one percent of their --

4 MEMBER WALLIS: Just because of the
5 leakage?

6 CHAIRMAN KRESS: Yes, they are leaking.

7 MR. GRESHAM: No, because of decay.

8 (Everyone speaks at the same time.)

9 MR. GRESHAM: However, even when the small
10 fraction of iodine seems to be in organic form, and
11 thus gases are at 5 percent, there still is a
12 formidable source.

13 CHAIRMAN KRESS: And the aerosols have
14 settled out, and unless you control the PH of that
15 water, the iodine can come back out. So it is not a
16 question of can you open it just --

17 (Everyone speaks at the same time.)

18 CHAIRMAN KRESS: It could be, that element
19 is organic.

20 MEMBER WALLIS: You want to solidify once
21 it gets to --

22 CHAIRMAN KRESS: It would be nice to hold
23 it there.

24 MR. SCOBEL: I have a presentation at this
25 time, the analysis currently in the AP1000 is not

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 based on this calculation of removal coefficients, it
2 is based on the removal coefficients that were
3 calculated for AP600. So there is --

4 CHAIRMAN KRESS: I see, you went ahead and
5 used the same lambda?

6 MR. SCOBEL: We used the same lambda.

7 CHAIRMAN KRESS: So you are saying you
8 would be in the conservative --

9 MR. SCOBEL: Well, I'm just saying, it is
10 conservative. We have this information earlier --

11 CHAIRMAN KRESS: But you still meet the
12 criteria?

13 MR. SCOBEL: Yes.

14 CHAIRMAN KRESS: So that is all you --

15 MR. SCOBEL: We have --

16 (Everyone speaks at the same time.)

17 MR. SCOBEL: I have a presentation on the
18 thermal-hydraulics of what we use if you feel that you
19 want to see that. It just discusses the sequence that
20 we used, why, which I've already told you, and then
21 have a presentation of the plot, and with a comparison
22 to AP600, they look a little different, and there is
23 some reason.

24 But if you want to see that I would be
25 glad to present it. If you don't, we can move on.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 CHAIRMAN KRESS: I think the consensus
2 here is we would like to hear that.

3 MR. SCOBEL: Sure.

4 MR. GRESHAM: I think before Jim starts
5 the presentation it would be worth -- it is worth
6 pointing out that all the curves on here, that have a
7 time of zero hours, that is zero hours is the time
8 when you have uncovering of the active fuel. It is
9 initiation of the accident.

10 MEMBER WALLIS: I was just looking at the
11 handout from Polestar. We have this heat transfer
12 rate, which has these mountains in it, peaks?

13 MR. GRESHAM: That is what Jim is going to
14 talk about.

15 MEMBER WALLIS: So I'm always ahead of
16 you.

17 (Everyone speaks at the same time.)

18 MR. SCOBEL: Like I said, we used the
19 severe accident environment to generate the
20 environments for the containment, because it addresses
21 the dragging -- it reduces condensation and heat
22 transfer.

23 And it is also the same methodology that
24 we use for the AP600. We used the dominant core
25 damage sequence from the risk assessment, because it

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 is a double-ended break in the DVI line. The RCS is
2 fully depressurized, and you fail gravity injection.

3 There is successful cavity flooding on the
4 outside of the vessel to prevent the vessel from
5 failing. And as a result you reflood back into the
6 reactor vessel, through the break. And in the
7 sequence we also produced a significant amount of
8 hydrogen, and the hydrogen ignitors are turned off.

9 MEMBER RANSOM: -- the injection phase,
10 just assumption, or --

11 MR. SCOBEL: This is what creates the
12 severe accident, as opposed to a data base accident.

13 MEMBER WALLIS: Is there any mechanism
14 that --

15 MR. SCOBEL: The mechanism is that it is
16 the dominant sequence in the PRA, the failure --

17 (Everyone speaks at the same time.)

18 MR. SCOBEL: -- the squib valves, there is
19 squib valves in that line, in that gravity injection
20 line. And you have simultaneous failure of multiple
21 squib valves.

22 And this is just a list of the T&H input
23 parameters required for the NAUA code. The first one
24 is containment temperature, and the spikes you see
25 there, that is hydrogen burning at the igniters.

1 And as opposed to the AP600 case where,
2 apparently, we did not have the igniters turn on. The
3 next one is containment pressure. And this one is
4 kind of interesting. There is -- you know, you can
5 see this difference between AP600 and AP1000, and it
6 is kind of -- you would expect AP1000 to be higher
7 than AP600, and also you have this depression here,
8 that is different than AP600.

9 And the reason for that is that AP1000 has
10 a higher core power density. And what you see, then,
11 in the results is that the core melt, at the time that
12 you reflood the core, is a lot more severe, and the
13 core is all kind of plugged up, and blocked up.

14 And so you end up cutting off your water
15 ingress into the core debris, in the core, inside
16 the vessel. And so in AP600, where you had a
17 pressurization due to heat transfer from the core
18 debris to the water, in AP1000 what you are seeing is
19 you are not getting that heat transfer.

20 And so the pressure is coming down because
21 the steaming is going down. So this is, actually,
22 with respect to creating steam, is conservative. But
23 now you have more superheat in the --

24 MEMBER WALLIS: This is a gauge pressure,
25 isn't it?

1 MR. SCOBEL: This is the atmosphere.

2 MEMBER WALLIS: So it goes almost down to
3 one atmosphere?

4 MR. SCOBEL: Yes. Because you are not
5 getting much steam from the core region at that point.
6 And you can see that in the steam low fraction going
7 out here.

8 The other thing I wanted to mention about
9 the pressure is that we also have an effect from
10 hydrogen combustion, because you are taking the
11 partial pressure of hydrogen, which you had almost
12 1,000 kilograms of hydrogen in the containment.

13 You are taking that out of the
14 containment, and it is also taking oxygen out of the
15 containment, so it had an effect on the containment
16 pressure over all, during meltdown.

17 So, anyway, during this initial period of
18 time with the aerosols, before four hours, you can see
19 that there is a substantial decrease in the
20 condensation rate, due to the fact that we are not
21 getting the steaming.

22 CHAIRMAN KRESS: It is interesting, all
23 these hydrogen burns helps you here. It gives you
24 more condensation, it gives you more thermophoresis,
25 and doesn't affect your sedimentation.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER WALLIS: It stirs things up.

2 MEMBER SIEBER: Why does it give you more
3 condensation, just because of --

4 MR. SCOBEL: Say that again?

5 MEMBER SIEBER: Why does it give you more,
6 the hydrogen burn, you get the water from the burn?

7 CHAIRMAN KRESS: You get steam, you get
8 hydrogen, you get steam from the --

9 MEMBER SIEBER: The burn?

10 (Everyone speaks at the same time.)

11 MEMBER WALLIS: How much oxygen is there
12 in there to burn all this hydrogen?

13 MEMBER SIEBER: It is a big containment.

14 MR. SCOBEL: There is enough to burn that
15 amount of hydrogen.

16 MEMBER WALLIS: A thousand kilograms?

17 MR. SCOBEL: Sorry?

18 MEMBER WALLIS: A thousand kilograms
19 sounds like a --

20 CHAIRMAN KRESS: They keep track of the
21 oxygen content, and that is when they decide when this
22 is going to burn, is when the hydrogen oxygen -- well,
23 I think that the thousand is spread out over --

24 (Everyone speaks at the same time.)

25 CHAIRMAN KRESS: When you get up to 12

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 percent --

2 MR. SCOBEL: The hydrogen, also, it would
3 be about 4 to 6 percent.

4 CHAIRMAN KRESS: Four to six, that is
5 right, you are just burning, you are not exploding.

6 MR. SCOBEL: I've actually seen
7 calculations where you have poor concrete interaction,
8 and stuff going on, and you have containment heat
9 removal that is really substantial, and you start to
10 get negative pressures in the containment.

11 You actually have a continuous hydrogen
12 source, over several hours, because the core is still
13 -- you still have multi core -- even though it is
14 flooded with water, the water is not getting into this
15 core mass, kind of like TMI.

16 MEMBER WALLIS: And it suddenly gets in
17 and you produce --

18 MR. SCOBEL: No, you are accumulating it
19 in the containment as it is being produced.

20 (Everyone speaks at the same time.)

21 CHAIRMAN KRESS: Burns real fast.

22 MEMBER WALLIS: But it has to produce a
23 certain concentration before you get ignition again?

24 MR. SCOBEL: Yes, you have to have the
25 right combination of hydrogen and oxygen.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER WALLIS: It seems to me that you
2 have just about enough oxygen --

3 MR. SCOBEL: The oxygen will come down,
4 yes, significantly.

5 MEMBER WALLIS: What is the rough order of
6 magnitude calculation?

7 MR. SCOBEL: I have actually seen
8 calculations where you have poor concrete interaction,
9 and stuff going on, and you have containment heat
10 removal that is really substantial, and you start to
11 get negative pressures in the containment for
12 hydrogen.

13 MEMBER SIEBER: Right. Now, you are
14 assuming this debris all stays in the vessel?

15 MR. SCOBEL: All the debris is in the
16 vessel.

17 MEMBER SIEBER: And you don't have any
18 core interaction?

19 MR. SCOBEL: And, in fact, you would
20 expect -- the sequence is flooded both inside and
21 outside the vessel, it is not just -- it is not the
22 classic sequence that you are --

23 CHAIRMAN KRESS: You are right, it is not
24 flooding in both places?

25 MR. SCOBEL: Yes, it is flooded inside and

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 out.

2 CHAIRMAN KRESS: Yes, you are right.

3 MEMBER SIEBER: Well, again, the break is
4 at the direct injection nozzle?

5 MR. SCOBEL: A direct injection line
6 break, yes. And you end up flooding the compartment.

7 MEMBER SIEBER: Up to that, and then it
8 goes into there.

9 MR. SCOBEL: The PXS compartment floods,
10 and then you refilter through the break.

11 CHAIRMAN KRESS: Actually these hydrogen
12 peaks in the heat transfer rate, probably have almost
13 negligible effect on the thermophoresis -- sharp
14 compared to the -- I would suspect you get more
15 thermophoresis just from the averaging them out. The
16 time they are there is so short.

17 MR. SCOBEL: Any way, thank you.

18 CHAIRMAN KRESS: Thank you.

19 MEMBER WALLIS: Thank you.

20 MR. ZAVISCA: I'm Mike Zavisca from ERI,
21 and I hope to give you a brief overview of some of the
22 general results of the severe accident analysis that
23 we performed using MELCOR 1.85.

24 MR. ZAVISCA: We performed a number of
25 severe accident analyses for a number of AP1000 core

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 damage sequences, in order to support the NRC in
2 formulating positions on a number of severe accident
3 issues.

4 But if I were to list some of the main
5 objectives we were after in these analyses, it would
6 be -- first of all, we wanted to obtain some data to
7 support our independent analysis of the IVR issue.

8 Second, we wanted to look at what the
9 results would be of molten core concrete interaction,
10 get a picture of what the containment conditions would
11 be, relevant to the hydrogen combustion issue.

12 CHAIRMAN KRESS: Did Westinghouse specify
13 the type of concrete they were going to use?

14 MR. ZAVISCA: We -- well, we performed
15 sensitivity to a number of different types of
16 concrete. And in addition, just to get a general idea
17 of the timing of the accident progression, and a
18 number of other general issues.

19 We selected a number of sequences for
20 analysis, which we named according to the definition
21 of ASME as used by Westinghouse. We had four base
22 cases, and a number of sensitivities in addition.

23 Our 3BE scenario was a safety injection
24 line break. And this is similar to the scenario that
25 Jim just described. It is a scenario which is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 expected to lead to successful in-vessel recovery. So
2 this scenario will be used -- we ran mainly to support
3 the IBR analysis.

4 And we also had a number of sensitivities
5 to this case, regarding things like efficiency of PCCS
6 operation. Then there was a traditional large LOCA
7 type sequence to 3BR, which is similar to one of the
8 top sequences in the PRA.

9 I should say that in this table we
10 analogized some of our sequences, to sequences that
11 show up in the Westinghouse PRA, however, they are not
12 identical in all respects.

13 First of all because some details of
14 system availability in the PRA were, in some cases,
15 not mentioned, or left ambiguous, we just did not have
16 information on those, so we had to guess. Or, in some
17 cases, we adjusted things deliberately in order to be
18 able to look at aspects we wanted to examine.

19 An example of which is for the 3BE
20 scenario, where Westinghouse allowed water ingress
21 back into the vessel. We disallowed that because we
22 wanted to obtain boundary conditions for no water
23 ingress.

24 And we have a set of 3D scenarios, which
25 are spurious opening of ADS valves. These are

1 partially depressurized sequences which, therefore,
2 would not be expected to lead to successful in-vessel
3 recovery, so you have injection of debris to the
4 containment.

5 And these are the scenarios we mainly used
6 to analyze multi core concrete interventions in a
7 number of sensitivities to this, with regards to
8 things like concrete type, conditions in the cavity,
9 etcetera.

10 So you have injection of debris to the
11 containment. And these are the scenarios we used to
12 analyze multi core concrete interventions in a number
13 of sensitivities, with regard to things like concrete
14 type conditions in the cavity, etcetera.

15 And then, lastly, high pressure transient,
16 initiated by loss of heat water, designated sequence
17 (inaudible).

18 Just a few brief words about the MELCOR
19 model employed. We -- I guess the main point here is
20 that we modeled all safety systems, documents, and the
21 general level of the organization, of the RCS and
22 containment, is basically equivalent to that, that was
23 used in the MELCOR model used by Westinghouse.

24 And the information used in developing
25 this model came from the various design documents. In

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 some cases from parameters in the MELCOR model, and
2 specific responses to RNX.

3 One thing that was not included was molten
4 of the core barrel, during the core damage
5 progression. And this has something to do with some
6 boundary conditions for the lower plenum (inaudible).

7 We also did some things to enhance
8 conductivity in the lower debris, in the debris in the
9 lower plenum to model --

10 MEMBER WALLIS: -- the chemical reactions
11 with the debris, from the shroud?

12 MR. ZAVISCA: That is right. So we are
13 underestimating the amount of steel that is in danger
14 as a result of that. This is one of the things we
15 mentioned as future work, which could be done later.

16 CHAIRMAN KRESS: Can you explain that last
17 slide just a little more. When we made that mixing of
18 the -- does that mean the question is whether or not
19 you have stratified steel, or metal over ceramic, or
20 what do you mean by the mixing?

21 MR. ZAVISCA: This is really related to
22 the fact that in the MELCOR model of the lower plenum,
23 it has a number of radial rings, and basically mixing
24 between those rings is only done in order to equalize
25 the level.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 There is no sort of advective mixing of
2 the molten debris between rings. We wanted to model
3 a little bit of the effect somehow equalizing the
4 composition and decay heat content of the material
5 between the rings of the lower --

6 CHAIRMAN KRESS: Is that to decide whether
7 the --

8 MR. KHATIB-RAHBAR: Let me explain this.
9 This is the molten core convection in a sense, because
10 MELCOR does not model multiple convection. The idea
11 was to get a mixing of the debris, because if you do
12 not have the conductivity, you get debris side by side
13 with very different --

14 CHAIRMAN KRESS: So this is to decide when
15 it melts through the vessel?

16 MR. KHATIB-RAHBAR: Yes.

17 CHAIRMAN KRESS: That is what it is for,
18 okay, now I understand.

19 MEMBER WALLIS: How do you know how much
20 to enhance the conductivity?

21 MR. KHATIB-RAHBAR: Well, this actually
22 does not affect the result, if you look at that
23 separate IBR issues of this -- it does not affect any
24 of the things that we do later. This was just done
25 because we wanted to get somewhat of a realistic

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 vessel wall temperatures, otherwise it would confuse
2 temperatures far exceeding the vessel melting
3 temperature.

4 This is not official (inaudible) and
5 without this it would compute large temperature
6 gradients within the neighboring parts of the lower
7 plenum.

8 We just do it to get (unintelligible).

9 MEMBER WALLIS: In order to get a pretty
10 uniform temperature?

11 MR. KHATIB-RAHBAR: Precisely.

12 MEMBER WALLIS: And this is realistic?

13 MR. KHATIB-RAHBAR: No. Well, realistic
14 yes, from the standpoint of mixing in -- next
15 presentation.

16 MEMBER WALLIS: In fact this may be the
17 worse case scenario, is that right? What is the
18 implication of having that restriction?

19 MR. ZAVISCA: The implication of that in
20 MELCOR is that we have less -- the implication of --
21 in the MELCOR model is, of course, we have less steel
22 in the melt. But as we will see later, that
23 assumption was not carried over into the IVR analysis.

24 So we did not assume, in the IVR --

25 MEMBER WALLIS: But it is not necessarily

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 conservative, steel reacts --

2 CHAIRMAN KRESS: It is not conservative
3 with respect to -- it is not conservative with respect
4 to the MCCI. So I think that is why they are telling
5 us they didn't do it.

6 MR. BASU: But I think it is conservative
7 with respect to the focusing effect.

8 CHAIRMAN KRESS: Yes, with respect to the
9 focusing and melting through the vessel is
10 conservative, so it depends on what you are interested
11 in.

12 MEMBER RANSOM: We actually want to look
13 at that, because that is -- this is not tested as part
14 of the code, so we didn't want to do something --

15 MEMBER WALLIS: Does MELCOR use oloearian
16 representation of these core materials? Oloerian?

17 MR. ZAVISCA: It is actually very simple,
18 it is a point model, so it doesn't do any of that
19 sophistication. It takes a particular mass, it heats
20 it up. And you divide it up into nodes --

21 (Everyone speaks at the same time.)

22 MR. ZAVISCA: -- after the LOCA. It
23 reaches the -- it goes down to the next one.

24 MR. KHATIB-RAHBAR: Exactly, to the next
25 node.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. ZAVISCA: Automatically.

2 MEMBER RANSOM: So it is an olearian
3 representation?

4 MR. ZAVISCA: Pseudo, yes. The next slide
5 is a schematic to sort of give an idea of -- our first
6 objective to obtain boundary conditions to the IVR
7 analysis. I showed you some of the main results.

8 Actually I say here these are 3BE, but
9 these were -- when in the MELCOR column these are
10 results of low pressure best cases we performed in
11 MELCOR.

12 And I show the comparison, the range of
13 MELCOR MAAP4 results that we documented for the DBE
14 IVR classes. And I don't want to say that we are --
15 we performed these -- we did not perform this analysis
16 in order to perform an exclusive comparison with MAAP,
17 we didn't intend to do that. But this is just for
18 information purposes, we want to see how it compares.

19 So core progression between one and two
20 hours, core plate fails at 2.6-3.7 hours, at which
21 time the debris, you get the first relocation of
22 debris to the lower plenum, that is 2.6-3.7 hours.

23 Later you get gross melting of the core
24 plate, 3 to 4 hours. Dryout of all the water in the
25 lower part of the RPV shortly thereafter.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER WALLIS: Does the core plate fail
2 by melting, or by softening, or by stresses in
3 breaking, or what?

4 MR. ZAVISCA: Well, in the MELCOR model it
5 simply is assumed to fail to provide structural
6 supports once it reaches a certain temperature.

7 MEMBER WALLIS: So it softens then?

8 MR. ZAVISCA: Yes.

9 MEMBER WALLIS: It becomes very weak, and
10 it doesn't have to melt?

11 (Everyone speaks at the same time.)

12 MR. ZAVISCA: So at the time of the core
13 plate failure, in MELCOR, we get 80 percent of the
14 core, which is then in the form of debris, sitting on
15 top of it, slumps down into the lower plenum.

16 And this mass contains about -- includes
17 about 27 tons of steel, and 11 to 12 tons of
18 unoxidized zirconium metal.

19 MEMBER WALLIS: About 100 tons, or
20 something?

21 MR. ZAVISCA: This is -- I think there are
22 about 100 tons.

23 MEMBER WALLIS: Something like that, a
24 rough order --

25 MR. ZAVISCA: Some of the corresponding

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealgross.com

1 figures I couldn't extract from the MAAP results.
2 But, as I mentioned, we did not model core rationality
3 here, so this figure is kind of low.

4 I think in the Rome analysis that was done
5 by Westinghouse, they had between 50 and 70 tons. It
6 is basically the lower support plate, and some small
7 mass of structural steel inside the core.

8 The scenario is analyzed from the
9 standpoint of multi core interactions, mainly
10 partially depressurized spurious ADS sequences, which
11 included a number of sensitivities to a concrete type.
12 And conditions in the reactor cavity.

13 And I think I will skip ahead to this
14 slide, because the overall penetrations, concrete
15 penetrations distances we observed, and also a
16 comparison with the Westinghouse results from MAAP4.

17 And this shows that the main difference
18 between our results is we are predicting much lower
19 penetration, much lower concrete penetration as
20 compared with MAAP4.

21 MEMBER WALLIS: No source of groundwater,
22 or anything like that?

23 MR. ZAVISCA: No.

24 MEMBER WALLIS: Just like a big
25 difference, presumably.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. ZAVISCA: As far as I could tell the
2 initial conditions, and the boundary conditions for
3 these were identical between ours and the MAAP
4 analysis.

5 CHAIRMAN KRESS: Now, MAAP tends to eat
6 down and across, and MELCOR just goes down. Is that
7 the end of --

8 (Everyone speaks at the same time.)

9 CHAIRMAN KRESS: Yes, but MAAP does it
10 more, I think.

11 MR. BASU: That depends on the concrete
12 diversity --

13 MEMBER WALLIS: So how far does it go in
14 a year?

15 CHAIRMAN KRESS: It stops.

16 MEMBER WALLIS: Looks like quite a long
17 way.

18 MR. KHATIB-RAHBAR: Yes, the model is not
19 designed to calculating such a long time.

20 MEMBER WALLIS: I know.

21 MR. ZAVISCA: So basically within about 60
22 hours one meter penetration in MELCOR, about 2.5
23 maximum in MAAP4. We reiterated here that the graph
24 was for limestone based concrete.

25 For the softest concrete we get, again,

1 significantly less penetration in MELCOR, as compared
2 with MAAP4. Core concrete interactions debris between
3 roughly 1 and 3 tons of hydrogen within 60 hours.
4 Also large quantities of carbon monoxide and carbon
5 dioxide.

6 The larger quantities of hydrogen results
7 from the use of the basaltic concrete. And latest
8 containment pressures in the presence of CCI between
9 two and --

10 MEMBER WALLIS: Doesn't the concrete break
11 into chunks and flow to the surface?

12 CHAIRMAN KRESS: No, it melts.

13 MEMBER WALLIS: It actually melts, it
14 doesn't interact with the water in the concrete?

15 (Everyone speaks at the same time.)

16 CHAIRMAN KRESS: It goes up as gas. The
17 water gets released and gets converted to CO and CO2,
18 reacting with the --

19 MEMBER WALLIS: The thermal stresses don't
20 just shatter the concrete?

21 CHAIRMAN KRESS: No. Basically it is
22 melting. They did it at Sandia, it was pretty
23 accurate.

24 MR. ZAVISCA: With regard to hydrogen
25 deflagration, in most of these sequences we observed

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 a general early behavior at the release, the initial
2 release occurs to some part of the lower containment,
3 IRWST, or the access compartment, or one of those
4 confined compartments in the lower containment.

5 And so hydrogen initially develops at
6 higher concentrations there, and burns there.
7 Eventually it will migrate up to the -- the open part
8 of the containment and possibly burn there.

9 So in the early phase we typically see
10 lots of very small burns occurring in the --

11 MEMBER WALLIS: If each one is 10 percent
12 H₂, then you can calculate just how much oxygen you
13 are removing with each burn.

14 MR. KHATIB-RAHBAR: That is how we did it.

15 CHAIRMAN KRESS: That is automatic.

16 MR. ZAVISCA: We did some calculations
17 assuming -- but in the MELCOR it will still burn
18 whenever it reaches a specified concentration within
19 a particular compartment, 7 percent, or 10 percent.

20 In the scenarios that involve multiple
21 core concrete interactions, we get vast quantities of
22 hydrogen and carbon monoxide in the late time frame,
23 so you observe one or more relatively large
24 degradations in the late time frame, in the upper part
25 of the containment.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 Because sometimes some of the hydrogen
2 results, across the different MELCOR calculations that
3 we performed, you get between 44 and 65 percent
4 equivalent core zirconium oxidized, which corresponds
5 to around 420 to 650 kilograms.

6 And the MAAP4 results are similar, there
7 are many more calculations that they performed, so
8 there is a wider range. But averages --

9 MEMBER WALLIS: -- by water, steam?

10 MR. ZAVISCA: This is oxidation of the
11 cladding during --

12 MEMBER WALLIS: Steam?

13 CHAIRMAN KRESS: Steam.

14 MR. ZAVISCA: Containment loads as a
15 result of early combustion were never higher than
16 three and half, that we observed. In the
17 probabilistic AICC calculations that Westinghouse
18 performed it was an upper bound of 4.3.

19 CHAIRMAN KRESS: Now, does that
20 containment design 60 psi? I'm trying to remember.

21 MR. BASU: It is 59.

22 CHAIRMAN KRESS: So we didn't even get up
23 to the design pressure, much less --

24 MR. ZAVISCA: That is correct. Now, in
25 the late time frame, with all this additional gas

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 release from MCCI, we sometimes calculate some
2 relatively large deflagrations in the upper
3 containment.

4 CHAIRMAN KRESS: Now, that is getting
5 close to two times design pressure?

6 MR. ZAVISCA: Well, this is -- this limit
7 here corresponds, approximately, to the service level
8 C, which is about 1 percent condition of probability
9 of containment failure.

10 But this is what we obtained. What
11 determines this upper limit is the amount of available
12 oxygen. Take all the oxygen in containment and burn
13 it all at once in the late time frame, that is about
14 what you get, that is the upper limit.

15 As far as the general timing of events,
16 some of these have been mentioned before. One
17 additional thing we did for the high pressure scenario
18 was calculate a time to rupture of the steam generator
19 tubes using integrated time to failure from -- with
20 failure parameters.

21 And we determined that the tubes would
22 fail around 7.4 hours, which is a little longer than
23 was calculated, but a little later than was calculated
24 by MAAP. But we reached the same conclusion, that for
25 the high pressure sequences, and pre-rupture of the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 tubes is a likely outcome prior to vessel -- reactor
2 vessel failure.

3 CHAIRMAN KRESS: Well, but that doesn't
4 create a bypass, or does it?

5 MR. ZAVISCA: Yes. In the PRA I believe
6 there are sequences of one hundred percent chance --

7 MEMBER WALLIS: What is in the secondary
8 at that time when you bypass --

9 MR. ZAVISCA: It is dry.

10 MEMBER WALLIS: It is dry?

11 MR. ZAVISCA: Yes. And the late
12 containment loads, except for brief loads caused by
13 hydrogen combustion, they are generally below 2 bar,
14 very low.

15 And what we obtained from this, first of
16 all, what will deflagration does not challenge the
17 containment in any case. Even the maximum theoretical
18 possible burn only barely reaches the --

19 MEMBER WALLIS: You store up hydrogen and
20 then you wait for it to go?

21 MR. ZAVISCA: PCCS is successful in
22 preventing lower pressure containment, as determined
23 by the low late quasi-static load can be calculated.
24 And based on penetration, it is not predicted within
25 3 days, which is the longest calculation that we

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 performed.

2 We predict, actually predict the steel
3 liner will be reached within about 30 hours, I think,
4 but full penetration (inaudible). And in general
5 there are no surprises from accident timing or general
6 results.

7 CHAIRMAN KRESS: This MCCI calculations
8 assume dry --

9 MR. ZAVISCA: They are both dry and with
10 wet --

11 MR. ESMAILI: Tom, if you know, in the
12 MELCOR world it makes a little difference if it got
13 wet or not?

14 CHAIRMAN KRESS: -- unless you do an
15 aerosol calculation, but in effect -- so what we get
16 from this is using MELCOR you get results that are not
17 too different than MAAP, and that severe accidents
18 that involve a multitude of reactor vessel, don't
19 really challenge containment very much?

20 MR. ZAVISCA: That is correct.

21 CHAIRMAN KRESS: So this turns into some
22 sort of a -- this kind of thing, when you look at all
23 the accident sequences, converts into an initial
24 containment failure probability that is pretty low?

25 MR. SCOBEL: It is .08.

1 CHAIRMAN KRESS: That is what I thought.

2 MR. ZAVISCA: The most challenging thing
3 we ever observed was one of those late --

4 CHAIRMAN KRESS: This just is a
5 confirmation that what they do with MAAP is probably
6 pretty good, is that your message?

7 MR. ZAVISCA: I think in most cases, if
8 anything, the MAAP results will be more conservative.

9 CHAIRMAN KRESS: Very good.

10 MR. ESMAILI: My name is Esmaili, I'm from
11 ERI, and I will be talking about the in-vessel
12 retention of core decay externally cooled by the
13 cavity water, and the potential impact of excess of
14 steam explosions or fuel coolant interactions through
15 the vessel failure.

16 Now, the objectives of the study were two-
17 fold. The first one was to examine the IVR issue in
18 order to determine the likelihood and the location of
19 vessel breach.

20 Following this IVR analysis we also found
21 that it provided some insights into this type of a
22 failure. The second objective was to formulate the
23 FCI scenarios, and quantify the impulse loads on the
24 cavity wall, and on the pressure vessel itself.

25 And the approach that we used in this for

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 AP600, AP1000, was basically the same as the approach
2 that we used for AP600 over six years ago.

3 Now, the first step was to develop a one-
4 dimensional mathematical model based on our ERI two
5 dimensional model that we used for AP600, and we had
6 to modify this in order to be able to compare our
7 results with the DOE results that they did for AP600,
8 and the INEEL results.

9 Basically we are looking at two
10 configurations. The first configuration that you see
11 here is a molten pulse surrounded by a crust, a
12 solidified crust, in an overlying molten-like metal
13 layer on top of it.

14 Now, this was the base model that we used
15 in AP600 and DOE used for AP600 also. Now, the second
16 configuration is a little bit more challenging. This
17 involves a molten ceramic pool that is sandwiched
18 between heavy metal layer at the bottom, right here,
19 and a light molten metal layer on the top of it.

20 CHAIRMAN KRESS: Now, in Dr. Powers' --
21 this was strictly a thermal analysis, or did you have
22 metal interactions with --

23 MR. ESMAILI: This was strictly a thermal
24 analysis. I'm going to mention later on --

25 MEMBER WALLIS: In reality the steel

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 interacts with the ceramic, doesn't it?

2 CHAIRMAN KRESS: Not much.

3 MEMBER WALLIS: Isn't there a thermal
4 reaction with the --

5 MR. ESMAILI: That is true. The uranium
6 dissolved in oxidized zirconium, it makes it heavier,
7 it sinks to the bottom. But you are looking at a
8 quasi-steady process by the time that the relocation
9 has occurred and, you know, there is heat transfer to
10 the vessel wall, and the cavity wall.

11 So we are looking at it strictly from a
12 thermal point of view.

13 CHAIRMAN KRESS: Now, the outside of the
14 vessel you used the same heat transfer that you got
15 for the AP600? The boiling on the outside?

16 MR. ESMAILI: On the outside it is -- I'm
17 going to get to that discussion on the next slide.

18 If it does not exceed the critical heat
19 flux, so --

20 CHAIRMAN KRESS: Yes.

21 MR. ESMAILI: Now, for the critical heat
22 flux they used the lower head configuration V. At the
23 time that they did the study, the data and correlation
24 was not available for this lower head configuration.

25 But we assumed that CHF was higher by a

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 factor of 1.44, compared to configuration 3 that was
2 reported by Westinghouse. And the reason we did that
3 was that in general that configuration IV was higher
4 by about 20 to 30 percent, the CHF was higher between
5 20 to 30 percent compared to configuration III.

6 And, overall, configuration V was higher
7 by 20 percent, compared to configuration IV. So that
8 is why we used this factor of 1.44. And this is, as
9 you can see, the comparison between -- I apologize,
10 this is the configuration of the CHF for configuration
11 of III, and the higher CHF for configuration V, which
12 is at an angle of about 90 degrees is about 2.1
13 megawatts per meter square.

14 CHAIRMAN KRESS: This is responsive of the
15 angle from the bottom --

16 MR. ESMAILI: From the bottom of the
17 vessel all the way to -- yes, exactly. That is all
18 the way up to the top of the vessel.

19 MEMBER LEITCH: I don't understand what
20 you mean by these various configurations.

21 MR. ESMAILI: This is the configuration of
22 the insulation around the vessel lower head, but they
23 changed it so they make it more streamlined, so that
24 they would increase the critical heat flux.

25 MR. SCOBEL: The configurations relate to

1 the open tests that were bounded to determine this
2 critical heat flux, and configuration V actually does
3 a good job of modeling the geometry of the AP1000
4 reactor vessel insulation, and the vent at the top of
5 the insulation, which a higher critical heat flux that
6 we need to get for AP1000, over AP600.

7 MR. KHATIB-RAHBAR: It is not to be
8 confused with the ERI melt configuration, we have two
9 configurations, I and II. So there are Westinghouse
10 configurations, and ERI configurations. So keep that
11 in mind.

12 MR. ESMAILI: Now, as far as the heat
13 transfer in the molten pool region for configuration
14 I, all the model PRI, DOE, and INEEL, basically used
15 for the top metal layer, we used the Globe-Dropkin for
16 the heat transfer to the vertical, to the horizontal
17 surfaces.

18 And Churchill-Chu for the vertical
19 surfaces, for the side wall of the reactor vessel.
20 For the ceramic pool, at the time of the study for
21 AP600, they used Mayinger's correlation for heat
22 transfer downward into the ceramic pool, and the
23 Kulacki-Emara correlation for the heat transfer upward
24 towards the top metal layer.

25 Now, DOE used the correlation, the Mini-

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 ACOPO correlation, which was a one-eighth scale test
2 facility, and subsequently used the ACOPO correlation
3 which increased the range of the numbers, and that was
4 a one-half scale facility.

5 MEMBER WALLIS: What is the problem -- is
6 it very small, or something?

7 MR. ESMAILI: The problem number for
8 ceramic materials is typically about .5, .6, or -- for
9 metal it is very low, it is about .1, yes. It is
10 about .12 for a metal.

11 Now, the solution method for configuration
12 I was based on the non-linear Newton-Raphson method,
13 and we also allowed for a temperature dependence of
14 viscosity in the molten pool, and in the steel layer.

15 And this was just to be consistent with
16 DOE and INEEL models. The material properties that we
17 used basically the INEEL has documented them very,
18 very well. And we just used those material properties
19 along with the uncertainties in the material
20 properties in the report for AP600.

21 The decay heat partitioning was based on
22 the amount of uranium that was in the ceramic layer,
23 and in the bottom metallic layer, the heavy metallic
24 layer.

25 Now, the first was to verify a model,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 benchmark our model against the DOE and INEEL results,
2 and in order to do that we basically used the DOE heat
3 transfer correlation, and you see the comparisons for
4 the heat flux to water, and the vessel wall thickness
5 here.

6 Now, we did another additional calculation
7 where we used our own default, which was heat transfer
8 correlation. And all that does is just shift the
9 distribution of heat flux inside the ceramic pool.

10 So where there is lower heat transfer in
11 the ceramic pool, there is a higher heat transfer in
12 the metallic. So that is all it does. But since we
13 got our data from the INEEL reports, of the comparison
14 of our predictions, shows excellent agreement with the
15 INEEL results.

16 But there is some discrepancy between the
17 DOE results. As a matter of fact I saw the same
18 discrepancy in the metallic layer, as we can see here.

19 MEMBER WALLIS: This is all theory?

20 CHAIRMAN KRESS: No.

21 MEMBER WALLIS: Is this all theoretical?

22 CHAIRMAN KRESS: No, the correlations come
23 out of experiments.

24 MEMBER WALLIS: There is no data --

25 MR. ESMAILI: That is correct.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER WALLIS: I don't understand the
2 other figure about vessel wall thickness.

3 MR. ESMAILI: This is -- you see here,
4 because of the heat flux is lowest at the bottom of
5 the vessel, and highest towards 90 degrees, towards
6 the top of the molten pool.

7 So that is why you see the vessel
8 thickness is about --

9 CHAIRMAN KRESS: What is happening is the
10 vessel is melting to -- and getting thinner to
11 accommodate the heat flux.

12 MR. KHATIB-RAHBAR: -- heat transfer on
13 the --

14 MEMBER WALLIS: It looks to me that you
15 are predicting the vessel thickness, which you already
16 know.

17 CHAIRMAN KRESS: No, this is thickness
18 versus position to accommodate the heat flux at that
19 location.

20 MEMBER WALLIS: So it is actually melting?

21 MR. ESMAILI: It is actually melting,
22 right.

23 MEMBER WALLIS: This is how far it would
24 melt given that heat flux, until it --

25 MR. ESMAILI: About 6 centimeters less.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 CHAIRMAN KRESS: And that is what is left
2 to have structural integrity. And the question is,
3 now, do the loads on that fail?

4 MR. KHATIB-RAHBAR: That is the key issue
5 here, how much of the vessel wall do you have.

6 CHAIRMAN KRESS: Yes.

7 MR. ESMAILI: Okay. We also predicted the
8 metal pool temperature within a few degrees of both
9 INEEL and DOE results. And, as a matter of fact, the
10 top at the crust, the interface between the ceramic
11 pool and the metal layer was within --

12 MEMBER WALLIS: Must be a pretty happy
13 vessel with that temperature inside, and boiling water
14 on the outside.

15 (Laughter.)

16 MEMBER WALLIS: There must be thermal
17 stresses --

18 CHAIRMAN KRESS: They are accounted for in
19 the loads.

20 MR. ESMAILI: We can see the top of the
21 vessel is melting, you know, the inside temperature of
22 the vessel can reach up to 1,600, 1,700. And on the
23 outside it is practically saturation temperatures of
24 about 400.

25 MEMBER WALLIS: There are no

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 discontinuities, this is just a nice hemispherical --
2 penetrations, or anything like that?

3 CHAIRMAN KRESS: Not in the AP1000.

4 MR. SCOBEL: There is a drain right in the
5 middle. You have a drain line somewhere in the --

6 CHAIRMAN KRESS: I must be thinking of --

7 (Everyone speaks at the same time.)

8 MR. ESMAILI: Now, as far as uncertainties
9 in the late phase progression, some differences in
10 design between AP1000 and AP600, specifically the
11 power is increased by about 75 percent to 3,400
12 megawatts in AP1000.

13 Now, the reflector in the AP600 is
14 replaced by a thinner core shroud in AP1000 to allow
15 for a lower core site, and there is a thicker lower
16 core support plate.

17 As I showed you before, we considered two
18 bounding melt configurations. Melt configuration I
19 was the molten ceramic with an overlaying metal pool.
20 The second configuration, the melt configuration II is
21 the ceramic pool sandwiched between two metallic
22 layers, one is heavier than the other.

23 Now, INEEL also considered a third
24 configuration, and that was the configuration where
25 there is a ceramic pool, there is a thin metal layer,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 and there is an additional ceramic pool on top of
2 that.

3 We did not consider that very important
4 and the reason is because, you know, the challenge to
5 the vessel is really due to the thin metal layer
6 associated with the focusing -- so you have to take
7 care of, you know, the thin metal layer first.

8 CHAIRMAN KRESS: How did you decide how
9 much material was in the bottom heavy metallic layer?

10 MR. ESMAILI: Yes, I'm coming to that, it
11 is coming.

12 CHAIRMAN KRESS: Okay.

13 MR. ESMAILI: Now, this is the -- when we
14 talked about the ERI, it only accounts for thermal
15 interactions, chemical reactions with the vessel wall
16 is not considered, we have not considered it. And we
17 may have to do it some time in the future, but at this
18 point we have not --

19 MR. KHATIB-RAHBAR: Let me add something.
20 Due to chemical energy addition, as you will see later
21 on, with configuration II, which is the heavier metal
22 layer in the bottom, because of the ratio of the heat
23 flux is so small, even if you were to add the chemical
24 reaction heat it would not make a big difference.
25 But the eutectic issue still remains.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER SIEBER: Since you don't consider
2 the chemical reactions of the fuel, and internals when
3 they are melting, would you expect largely different
4 compositions in layer thicknesses, from an actual melt
5 experiment that included chemical reactions, as
6 opposed to one that just looks at thermal effects?

7 MR. ESMAILI: Well, they do consider
8 chemical reaction during the core melt progression.

9 MEMBER SIEBER: Chemical reactions with
10 other things, but not within the core itself?

11 MR. ESMAILI: Not within the core, right.
12 Once the pool is formed you assume a quasi-steady.
13 Now, it is possible that because of chemical reaction,
14 heat-up reaction, etcetera, there are periods that the
15 actual, the heating of the material may produce some
16 temperature excursion, but --

17 MEMBER WALLIS: But isn't the eutectic
18 thing that Dana is worried about the real source of
19 heat, isn't it?

20 CHAIRMAN KRESS: Yes, one of the things,
21 but --

22 (Everyone speaks at the same time.)

23 CHAIRMAN KRESS: -- question I always had
24 about that is it does have crust layer protection from
25 that.

1 MR. KHATIB-RAHBAR: And the ceramic layer
2 is actually the whole issue, the crust affects the
3 vessel.

4 CHAIRMAN KRESS: Yes. You have a crust
5 there, too. Well, maybe -- maybe not.

6 MR. ESMAILI: We basically considered four
7 uncertainty distribution. The first one as the decay
8 heat, because that is where we define the four
9 relocations to the lower plenum.

10 The second was the amount of zirconium
11 oxidation, the third one was the actual amount of core
12 relocation to the lower plenum, and the fourth one was
13 the metal content. And the metal content is really
14 the molten core uncertainty here.

15 In terms of the decay heat, our decay heat
16 distribution was based on the results of plant-
17 specific MELCOR calculations that showed, if you
18 remember from the previous presentation, that the
19 timing of core relocation varied from two and a half
20 to three and a half hours, 3.6 and 3.7 hours.

21 And that is how we based our most probable
22 range in terms of power density. We also considered
23 a high power density up to about three cubic meter,
24 and that is because we relied on the MAAP4 calculation
25 that showed an earlier relocation, about two hours

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 into the lower plenum.

2 But here we considered only the residual
3 property for this higher power.

4 CHAIRMAN KRESS: How did you decide on the
5 distribution, that is not normal --

6 MR. ESMAILI: No, it is not normal. It
7 is, actually, if you go back -- yes, it is -- okay, we
8 assume the most probable range was between, let's say,
9 in terms of the core flow decay, between 23 megawatts
10 and 29 megawatts, okay?

11 And it assigned lower probability anything
12 above 29 megawatts, also about 38 megawatts, depending
13 on the core relocation. Also combined the timing of
14 core relocation decay heat to come up with this
15 distribution for -- it is an accumulated probabilistic
16 distribution, for the Westinghouse is a probability
17 density function.

18 But this showed that the lower bound of
19 decay heat is 1.3 compared to Westinghouse and our
20 analysis, as a matter at the median is also 2.1
21 megawatts and it is the same for Westinghouse.

22 But, as I mentioned to you, because we
23 considered relocation we have a higher upper bound
24 here. Now, the second uncertainty distribution
25 oxidation fraction in vessel, is also based mainly on

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 the results of MELCOR calculation that we just saw
2 earlier, that showed that the most probable range was
3 about 50 percent for that, but there is a different
4 calculation that showed that it could range from 44
5 all the way to 65 percent.

6 So we assigned a most probable range
7 between 40 to 60 percent, but we also assigned some
8 probability for 60 to 70, and a residual probability
9 between 70 to 80 percent. And the reason we stopped
10 at an upper bound of 80 percent was because under very
11 degraded core conditions there is a limited amount of
12 steam and the core is really degraded, so there is not
13 a lot of chance for oxidation of the entire zirconium.

14 CHAIRMAN KRESS: What I don't understand
15 is how you decided what probability to assign. You
16 just got a bunch of people together and --

17 MR. KHATIB-RAHBAR: No.

18 CHAIRMAN KRESS: How did you come up with
19 that .5?

20 MR. ESMAILI: This one here?

21 CHAIRMAN KRESS: Yes.

22 MR. ESMAILI: This was based on the
23 results of MELCOR calculation. The MELCOR calculation
24 that we did mostly predicted 50 percent zirconium
25 fraction oxidation.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. KHATIB-RAHBAR: Tom, I just thought of
2 something similar to what -- where you say my most
3 likely regime was that zirconium oxidation is going to
4 be between 40 percent to 60 percent.

5 CHAIRMAN KRESS: So then you reduce a
6 factor of 10 to get the --

7 MR. KHATIB-RAHBAR: Exactly.

8 CHAIRMAN KRESS: Now I understand what you
9 did.

10 (Everyone speaks at the same time.)

11 MR. KHATIB-RAHBAR: -- that form the
12 probability level. But in order to show them here,
13 because people have a difficult time understanding
14 what the probability level means, we converted it to
15 power density function, which is more --

16 CHAIRMAN KRESS: Most people understand
17 probability -- but this was decided on, just like --

18 MR. ESMAILI: Absolutely, yes.

19 CHAIRMAN KRESS: Now I understand.

20 MR. ESMAILI: And now we have this 30 to
21 40 percent range, if you remember the math calculation
22 that showed that the zirconium oxidation factor can be
23 as low as 30 percent, although it has a lower
24 probability.

25 Now, one of the most important condition

1 is the relocation of ceramic material to the lower
2 plenum. Now, the MELCOR calculation predicted about
3 80 percent --

4 (Telephone interruption.)

5 MR. ESMAILI: The MELCOR calculation
6 predicted that about 80 percent of the core melt and
7 relocation to the lower plenum.

8 We also 25 probabilistic distribution, we
9 also relied on some insights from the SCDAP/RELAP
10 calculation that they did for AP600 at the time. Now,
11 SCDAP/RELAP calculation for AP600 showed that the
12 initial relocation of the debris can take only about
13 50 percent of the core debris.

14 Subsequently the second debris relocation
15 involved an additional 35 percent. So the final
16 relocation was about 85 percent. But what is
17 important is the timing between the first relocation
18 and the second relocation, depending on how -- the
19 modeling approach you use in this code, this can be
20 between 13 minutes to over an hour, depending on how
21 you model this.

22 So, therefore, we said okay, the most
23 probable range for our core relocation to the lower
24 plenum is somewhere from 60 percent to 80 percent, but
25 we cannot rule out the lower relocation, because there

1 is enough time for the debris to form, you know, to
2 dry out the lower plenum and reformat the molten pool.

3 So, therefore, we provided some
4 probability in the 50 to 60 metric ton range. And
5 this is in light of the fact, actually, because the
6 vessel, the entire vessel is cooled, so there is heat
7 transfer from the entire vessel by radiation to the
8 core --

9 MEMBER WALLIS: So that is a RELAP5?

10 MR. ESMAILI: So that might delay the
11 timing of the second debris relocation.

12 I'm going to talk about the MAAP4
13 calculation, also about the initial relocation, and
14 about 50 percent of the core, but the relocation was
15 more gradual and eventually a greater proportion of
16 the core relocated downwards.

17 Now, one of the most important
18 uncertainties is the amount of metal. Now, since this
19 directly has to do with the focusing effect, we felt
20 that the amount of steel in the lower plenum had to be
21 dependent on the amount of core that relocated into
22 the lower plenum.

23 Now, if there is not sufficient amount of
24 ceramic material in the lower plenum, it does not
25 touch the lower core support, so in that case the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 amount of steel would have to be limited.

2 And this one we assigned somewhere from 50
3 to 60 metric tons, we assigned 3 metric tons to 8
4 metric tons of steel. Now, the lower 3 metric tons is
5 just the steel that is in the lower head.

6 And the addition of 5 metric tons, over 8
7 metric tons, is due to 25 percent melting of the core
8 barrel. In the MAAP calculation the testing they
9 predicted that 25 percent of the core barrel on the
10 AP1000 PRA has melted and come down.

11 Now, you need about 50 metric tons of
12 ceramic material to touch the --

13 (Pause due to computer problems.)

14 MR. ESMAILI: Okay. Now, as soon as you
15 reach threshold for the core ceramic material, about
16 60 metric tons, it starts to touch the core support
17 plate, and the lower metallic blocks. So if you go a
18 little bit further it is possible to melt the entire
19 core support plate, and substantial amount of the
20 lower blockage.

21 So that is why you see this shift of the
22 steel metal from about 60 metric tons to about 40, and
23 then it goes all the way up to about 60 metric tons.
24 And the way we came up with this 40 to 60 is we said,
25 okay, and we assumed that --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 (Telephone interruption.)

2 MR. ESMAILI: And so for the 60 to 80
3 metric tons what we have is that we assumed the entire
4 lower plenum melts along with the core support plate,
5 and 50 percent of the core shroud, the barrel. And,
6 of course, this is not very important, but for the
7 upper bound they include the entire mass of steel in
8 the reactor vessel, which is about 70 metric tons.

9 Now, just to give you a comparison, you
10 see that in Westinghouse's, the height of this
11 metallic layer varies from .6 meter all the way to
12 about 1 meter, okay? So this is a very thick metal
13 layer.

14 Because of the thin metal layer assumption
15 that they used, and associated with low ceramic
16 relocation, in our case this red line here is the
17 height of the metal layer that varies somewhere from
18 .2 meters all the way to 1 meter.

19 Now, the one meter in both cases are the
20 same, because the amount of steel is the same. But
21 the important thing is that we have some probability
22 of very, very thin metal layers.

23 MR. SCOBEL: Are you saying that when --
24 you are assuming that when the oxide touches the lower
25 support plate, that you only get a part of the lower

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 support plate in through the --

2 MR. ESMAILI: I'm just saying because the
3 core support plate is a solid material, so you just
4 need very, very little -- I mean, once you hit it at
5 the bottom, it is a very, very little amount of UO2,
6 or ceramic material to really submerge the lower
7 support plate.

8 MR. KHATIB-RAHBAR: I think Jim is asking
9 a different question. He is concerned about the lower
10 bound metallic plate, right?

11 MR. SCOBEL: Yes, I'm looking at the metal
12 mass as a function of the UO2 mass, and it gradually
13 increases from 60 up to 80 percent. And I was just
14 trying to understand, so you are saying when you
15 contacted at 60 percent, when you contact the lower
16 support plate at 60 percent, you are saying that it
17 actually gradually melts into --

18 You know, at 60 percent if you contact the
19 lower support plate, I would say that you are going to
20 have the lower support plate, and the core shroud down
21 there really fast, because --

22 MR. ESMAILI: That is why I think -- I
23 don't know whether -- that is why you see -- at 50,
24 you know, it is --

25 MR. SCOBEL: Oh, I see.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. ESMAILI: Do you see what I'm saying?
2 So there is this discontinuity.

3 MR. SCOBEL: I'm sorry, I see.

4 MR. ESMAILI: Yes.

5 CHAIRMAN KRESS: The probability you have
6 in the next curve are actually the probabilities of
7 having the given amount of core melt, and you just --
8 you take the correlation and translate it into --

9 MR. ESMAILI: Exactly. It translates into
10 this, correct. It translates into this type of
11 probability for the height of the metal layer.

12 So you can see for that

13 MR. KHATIB-RAHBAR: What it shows is that
14 you need to reach, first you need to reach the bottom
15 of the core plate. Once you reach it, then they
16 become very similar. That is why you see this double
17 hump behavior.

18 MR. ESMAILI: And this one here
19 corresponds to that --

20 CHAIRMAN KRESS: Sixty percent?

21 MR. ESMAILI: Right. Now, in order to
22 study this, probabilistically, of course we used the
23 LHS computer code, and we generated about 1,000 random
24 samples from those four distributions that I showed
25 you earlier, in addition to the uncertainties in the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 material properties.

2 These have all been fed into the one-
3 dimensional heat transfer model, and these are the
4 final results. This is a probability, this is a
5 critical, this is the heat flux ratio that is the
6 ratio of the local heat flux to the critical heat
7 flux, and this shows the probability at three
8 different regions.

9 One is at the bottom of the vessel, so
10 that you can see that this is at the bottom of the
11 vessel, you know, in the ceramic pool. The red line
12 is at top of the oxide layer.

13 Still in the oxide layer, but at the top,
14 where the heat flux is degraded. But even then you
15 can see that the heat flux does not even reach .8.
16 So there is no probability of failure in the ceramic
17 pool region.

18 But you can see, in the top metal layer,
19 the critical heat flux reaches 1 at about .85. So --

20 CHAIRMAN KRESS: Now, this is your case
21 for --

22 MR. ESMAILI: That is configuration 1,
23 that is right, the two layers, one is the ceramic, and
24 one is the metallic layer, right.

25 And so the estimate of condition of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 failure probability, and the figure of merit here is
2 exceeding critical influx of .151. That means that
3 out of these 1,000 samples, out of these 1,000
4 calculations, 150 of these resulted in failure of the
5 vessel, because the critical heat flux was exceeded.

6 Now, we also did some sensitivity
7 calculations to bound this range of the failure
8 probability. The first thing we did, actually, was to
9 add a decay heat in the top metallic layer, and using
10 the approach that was proposed in the report for
11 AP600, we assigned 10 percent to 20 percent of the
12 decay heat that was residing in the top metallic
13 layer.

14 Now, the first thing to notice is that if
15 you compare case -- because there are three things
16 here to notice. One is the focusing effect. That
17 means that the probability of having a very, very low
18 thin metal layer.

19 And this we can see by comparing case 1
20 and case 5, or case 6 and case 9. In case -- well,
21 let's concern the cases with the decay heat in the top
22 metal layer.

23 The case six is the base case plus the
24 decay heat in the top metal layer. The CFT is about
25 .27. But if I decrease the probability of load max

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 relocation, essentially saying that we have a very low
2 probability of having a very thin metal layer, the
3 failure probability is decreased by four-fold, from 27
4 percent to about 7 percent.

5 This is true whether you have decay heat
6 in the upper metal layer, or you don't. The second
7 thing is that in the base case we did not have decay
8 heat in the metal layer.

9 And the presence of the decay heat always
10 increases the -- always increases the failure
11 probability, but it also depends on what heat transfer
12 correlations you use.

13 Now, if you compare cases 6, 7, and 8,
14 which was our heat transfer correlations, the DOE and
15 INEEL heat transfer correlation, you see that the
16 failure probability increases from 27 percent to 31
17 percent.

18 After some point it is difficult to
19 increase the failure probability, because what you do
20 is that instead of having the decay heat in the
21 ceramic pool, you are putting this into the metallic
22 pool, so you are actually decreasing the amount of
23 heat that is coming from the bottom into the metallic
24 pool.

25 So at some point it -- yes?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER WALLIS: CFP is the conditional
2 failure probability?

3 MR. ESMAILI: That is right.

4 MEMBER WALLIS: And this is saying that
5 the vessel is going to fail at the metal layer?

6 MR. ESMAILI: At the metal layer, right,
7 the metal layer. Because the critical heat flux is
8 exceeded here. But there is no CFP for the ceramic
9 layer, it is basically zero.

10 Another thing would be that, you know, the
11 density did not consider any variations in material
12 properties, you know, there were like 20 material
13 properties in there. And there is a very, very
14 insignificant change in terms of, you know, failure
15 probability.

16 So the material property does not play an
17 important role. And this is very obvious here. The
18 only thing that makes a difference here is the amount
19 of steel that is relocated in the lower plenum, and
20 this is how we quantify it.

21 Now, the case 2 with the melt
22 configuration 2, where we have a ceramic pool
23 sandwiched between a heavy layer, and a light metallic
24 layer, is a little bit more challenging.

25 Now, we did a parametric calculation for

1 this particular case, we assumed a conservative
2 estimate. It said that, okay, in case that there is
3 a decay heat in the lower metallic layer, the worse
4 that you can -- the temperature has to -- the highest
5 temperature has to occur at the interface.

6 So, therefore, in the limit, the top
7 surface of the bottom layer has to be insulated, okay?

8 So all the decay heat that is generated in the bottom
9 metallic layer have to be going into the vessel.

10 So this is how they did the parametric
11 calculation. But they also required some additional
12 condition which -- in order to make sure that the
13 saturation is greater than one, so that bottom
14 metallic layer is heavier than the outside layer.

15 And the mass fraction of the uranium in
16 the bottom layer was 6.4, this was in response to the
17 peer review of the original AP600 by one of the peer
18 reviewers.

19 And all they had to do was just change the
20 fraction of the U that is in that oxide form, that
21 means change how much uranium is in the bottom layer,
22 versus what is in the ceramic pool.

23 And the partitioning of decay heat was
24 based, was proportional to mass ratio of uranium.
25 And here are the results. For this faction of U in

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 oxide form that translates into the mass of uranium in
2 the bottom layer, changing from 3,000 kilograms, all
3 the way to about 9,000 kilograms.

4 And for this , the three-fold increase in
5 the mass of uranium, you see that the critical heat
6 flux ratio, the heat flux ratio, varied from .22 to
7 .36. So there is not a big difference in terms of
8 heat flux ratio.

9 As a matter of fact, even under -- at the
10 upper bundle, at about 36.36, it is well below one.
11 So, therefore, we conclude that the failure of the
12 lower head, at the bottom location is not likely.

13 MR. KHATIB-RAHBAR: And this also is a
14 typical reaction issue, adding additional heat would
15 probably not do very much.

16 CHAIRMAN KRESS: Yes, I can see it.

17 MR. ESMAILI: There is a big margin in
18 terms of --

19 CHAIRMAN KRESS: You have a lot of margin
20 to critical heat flux.

21 MR. ESMAILI: Not only that, you will see
22 that even if the vessel fails at the bottom, you know,
23 the FCI loads are more benign than --

24 CHAIRMAN KRESS: How did you decide that?

25 MR. ESMAILI: We make a calculation, I

1 will show you. We assumed that even if the vessel
2 fails at the lower head, at the bottom of the vessel,
3 because of the difference on the cavity wall, that the
4 loads on the cavity walls are much lower than if it
5 fails at the side wall location. I will show you the
6 results.

7 Now, the specifications of the issue and
8 boundary conditions for ex-vessel FCI, we used the
9 calculation for the IVR analysis that we did. So as
10 far as core composition, and core temperature was
11 concerned, this was -- this came directly from the IVR
12 analysis that shows that the core has to be metallic,
13 the temperature we estimated at slightly over 2,000K.

14 Now, the lower head failure size we used
15 lower head failure size of about 40 centimeter. And
16 the reason we did that was our best estimated decay
17 heat density, power density, we can have a metal layer
18 as thick as about 35 centimeters, 40 centimeters, and
19 still fail the vessel.

20 But that is why for the base we assumed a
21 40 centimeter failure site. Now, the containment
22 pressure was, according to MELCOR calculation, and the
23 cavity water was 50 degrees subcooled, and lower head
24 was fully submerged, there was a deep water level up
25 to about, I think, a depth of about six meters.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER WALLIS: Does this make sense? The
2 vessel suddenly failed with a hole of four meters, or
3 doesn't it slowly grow?

4 (Everyone speaks at the same time.)

5 CHAIRMAN KRESS: When that molten stuff
6 goes through that hole it just goes, shooo, like this.

7 MR. ESMAILI: The whole thing could come
8 down, the whole thing could come zip. There are
9 different scenarios, the whole thing could come zip
10 and come down, it would unhinge.

11 But as far as the FCI is concerned, their
12 only concern is with the first second or so. You
13 know, because most of the explosion occurs once the --

14 MEMBER WALLIS: Very quickly.

15 CHAIRMAN KRESS: Yes.

16 MEMBER WALLIS: It flows it right back
17 into the vessel.

18 (Laughter.)

19 MR. ESMAILI: -- hydrostatic nothing might
20 come out, so that is another possibility.

21 For the calculation matrix, for the AP600
22 we did a lot of calculations for FCI. In this case,
23 because the lessons learned from the AP600, we only
24 did five calculations, actually.

25 This involved the most important

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 uncertainties in terms of melt progression
2 uncertainties that involves melt pour composition, and
3 failure size, and variability in the modeling of the
4 fuel coolant interactions.

5 We used the PM-ALPHA/ESPROSE computer code
6 to calculate the impulse loads on the cavity walls.
7 Now, the case one was the best case, case two was the
8 assume the ceramic pool at high temperature of 3,100.
9 That means that the -- ceramic material.

10 Case three was a failure size of .06
11 meters. The reason we showed this .06 meter is --
12 well, it worked out fine because of the nodalization
13 of the lower head. But at the same time at the
14 higher, at the upper end of the decay heat, you can
15 support a metal layer as thick as 53 centimeter, and
16 still retain the vessel.

17 So we went to the larger pool size of
18 about 60 centimeters. Now, case 4 had to do with the
19 modeling, different particle diameter of .1 compared
20 to .01 in the base case, and the fragmentation rate of
21 400 kilogram per second, compared to 4 --

22 MEMBER WALLIS: When it comes out, it is
23 assumed it has a diameter of .4 meters? It is a big
24 jet, and then it has to shatter it.

25 MR. ESMAILI: Yes, but once it goes in the

1 water, presumably, it breaks up, the particles break
2 up, the jet breaks up.

3 Now, there is another code, there is a
4 one-dimensional Texas computer code, actually, that we
5 used for AP600. And that one predicts, you know, the
6 particle breakup.

7 So we came up with this particle size
8 based on the particle size that was predicted with the
9 Texas code. So as the jet goes through the water it
10 breaks up into these small particles, according to the
11 calculation.

12 Now, the case 5 is the bottom failure of
13 the lower head, the one I just discussed. Now, the
14 problem nodalization was similar to the AP600. The
15 model said high vessel lower head, up to a distance of
16 about 6 meter.

17 The only difference was that the lower
18 head was now about -- only about one meter away from
19 the cavity flow, so we had to drop the lower head.
20 This blue line that you see here, these are the actual
21 boundaries of the computation, okay?

22 It is supposed to be the boundaries of the
23 reactor vessel itself. Now, inside here I should
24 mention that I show this -- inside the vessel itself
25 we don't do any calculations, because it is just

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 solid, okay? So all the calculations are done outside
2 of the boundaries of the reactor vessel.

3 I think we are running out of time, so I
4 will just show you -- I will go over this very
5 quickly, these are the results of the three mixing
6 calculations in terms of --

7 MEMBER WALLIS: Well, what are the units
8 on this --

9 MR. ESMAILI: Pardon?

10 MEMBER WALLIS: What are the units on --

11 MR. ESMAILI: This is a melt point
12 fraction, of the melt. In the (inaudible) I think the
13 discussion came up from the previous. So you have to
14 specify the melt volume fraction.

15 MEMBER WALLIS: In what, in the water?

16 MR. ESMAILI: You don't see the vessel
17 wall here, because it is yellow, but -- these are the
18 results of the explosion calculation, and you can see
19 that the explosion starts right here and it propagates
20 to the water.

21 MEMBER WALLIS: What are the colors here,
22 these are still --

23 MR. ESMAILI: No, these are not -- these
24 are the pressures.

25 MEMBER WALLIS: I thought they must be,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 yes.

2 MR. ESMAILI: These are the pressures, and
3 I was just going to go over this very quickly.

4 This is about a millisecond, there is
5 still no -- at one millisecond these are the
6 pressures, there is no explosion.

7 CHAIRMAN KRESS: What triggers the
8 explosion?

9 MR. ESMAILI: What triggers the explosion?
10 The trigger is the high pressure cell at the bottom of
11 the vessel.

12 CHAIRMAN KRESS: When it hits the bottom
13 of the vessel?

14 MR. ESMAILI: Yes, yes.

15 MEMBER WALLIS: Now, what kind of
16 explosion is this?

17 CHAIRMAN KRESS: It is just a thermal
18 explosion.

19 MEMBER WALLIS: A thermal explosion?

20 (Everyone speaks at the same time.)

21 MR. KHATIB-RAHBAR: Rapid heat transfer.
22 We have a particle that punches and transfers all the
23 heat to the water, and you have --

24 MEMBER WALLIS: You can see it.

25 MR. ESMAILI: This is at two milliseconds,

1 three milliseconds, four milliseconds, and goes all
2 around the vessel, you know, and then from the -- up
3 around the vessel.

4 Now, here you can see that these are the
5 wall pressures, these are a location of the function
6 of time. You can see the pressures of the lower half,
7 and the interaction between cavity wall and --

8 CHAIRMAN KRESS: What would happen if that
9 melt didn't trigger, when it hit the bottom, that more
10 and more came up, and built up, and then you've got --

11 MR. ESMAILI: Yes, but that is the thing.
12 Because more and more can settle on the cavity floor.
13 But it is very, very -- one of the conditions required
14 for a steam explosion is to mix this melt.

15 CHAIRMAN KRESS: It has to be mixed with
16 what?

17 MR. ESMAILI: Mixed with water right.
18 Now, you have a stratified -- on the cavity floor you
19 would have a stratified situation. You know, there is
20 not a mixing involved in melting for the water --

21 CHAIRMAN KRESS: Well, that is debatable,
22 because I just -- it comes down you have container
23 instabilities, and you have --

24 MR. ESMAILI: Absolutely, yes.

25 CHAIRMAN KRESS: And you have other

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 instabilities that entrap water in there. And there
2 could be some water mixed in with that bottom layer.

3 MR. ESMAILI: It could be, but I think
4 stratified explosions are always more benign than --

5 CHAIRMAN KRESS: Well, that has been the
6 experience, you are right.

7 MR. ESMAILI: Another thing is that a lot
8 more time for it to cut down, you would produce much
9 higher vapor void fraction. And which increases the -
10 - you know, there is vapor there, so there is no --

11 CHAIRMAN KRESS: But basically the hole
12 size, with the jet coming down, and the distance to
13 the bottom fixes the amount of melt that interacts
14 after that?

15 MR. ESMAILI: That is right.

16 MR. KHATIB-RAHBAR: That is why this is
17 lower, as you will see, the bottom failure, they are
18 low in AP600 because the distances.

19 CHAIRMAN KRESS: Distances, sure.

20 MR. ESMAILI: The area under the curve so
21 I get the impulse loads that we use. For the best
22 case you see about 85 kPa-s. And finally - now, for
23 these five scenarios, the impulse -- see the bottom
24 failure of the lower head is about 9 kPa-s. So you
25 basically do not have any challenge to containment.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 And compared to the 85 and using ceramic
2 melt at a higher initial internal energy, of course
3 you get much higher, about 300 kPa-s.

4 Now, these results, the only --

5 MEMBER WALLIS: Go back, what does that
6 mean? The bottom head failure that number means what?

7 MR. ESMAILI: This number?

8 MEMBER WALLIS: Yes.

9 MR. ESMAILI: This is just the impulse
10 load.

11 MEMBER WALLIS: That is what is required
12 to break the --

13 CHAIRMAN KRESS: That is the location of
14 the failure, and that is the impulse load you get, it
15 is not saying what impulse load has failed.

16 MR. ESMAILI: No, I'm not saying that at
17 all. That is the calculation. This just shows what
18 the wall experiences in terms of --

19 CHAIRMAN KRESS: It is sort of the maximum
20 in --

21 (Everyone speaks at the same time.)

22 MR. ESMAILI: Now, for AP600 we did a
23 calculation for this scenario for the subcooled pool
24 with the RPV model. For the AP600 we saw that the
25 maximum impulse load was about 600 Kpa-s.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 Now, consistently the results of AP1000
2 showed that it is a -- it is a factor smaller than
3 AP600. And the reason is because the vessel is
4 sitting a little closer for AP1000, and also the
5 initial reaction of the melt coming into the water was
6 higher in the AP600 because of a higher initial
7 pressure inside the RCS. So velocity was higher by a
8 factor of 2, also.

9 Finally, so the results of the

10 (Everyone speaks at the same time.)

11 MR. ESMAILI: -- focusing effect for
12 configuration 1, so we have more --

13 CHAIRMAN KRESS: So you end up with more
14 melt, that is why we saw --

15 MR. ESMAILI: Yes, absolutely. So we see
16 that the likelihood of failure goes from 4 percent to
17 30 percent. There is no likelihood of failure for the
18 bottom layer. And the side failure of the lower head
19 always results in a higher impulse load, and the
20 bottom failure is not reached.

21 CHAIRMAN KRESS: And did you decide what
22 impulse load the cavity could take, or is that
23 somebody else's job?

24 MR. KHATIB-RAHBAR: That is somebody
25 else's job.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. BASU: For AP600 the impulse load
2 showed -- that it still lower than --

3 CHAIRMAN KRESS: Lower than --

4 MR. BASU: So if you compare the AP1000,
5 I don't know what the -- presuming it is the same. It
6 is even better.

7 CHAIRMAN KRESS: Thank you.

8 MR. CUMMINS: One comment, the slide that
9 we have just seen made a statement that these slides
10 may contain information proprietary to Westinghouse.
11 Westinghouse has reviewed these slides, and they do
12 not contain proprietary information.

13 CHAIRMAN KRESS: Thank you. So we can
14 take them and show them to people?

15 MR. CUMMINS: Yes.

16 CHAIRMAN KRESS: Where are we -- we have
17 another hour to go?

18 MEMBER SIEBER: We are just getting
19 started.

20 MR. CUMMINS: The next presentation is on
21 seismic and structural design --

22 CHAIRMAN KRESS: Does that announcement
23 get kicked out, the one over the PA that said we had
24 15 minutes left?

25 (Pause.)

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. ORR: My name is Richard Orr, I'm
2 responsible for the structural design and seismic
3 analysis, responsible for AP600 and now for AP1000. It
4 seems I always get the end of the agenda, so I will do
5 my best to -- I know I can't meet adjournment by 5:30,
6 but I will try not to go for an hour.

7 I will go fairly quickly. If you have
8 questions please interrupt and let me know.

9 What I want to cover is the Staff
10 structural configuration changes from the AP600. We
11 have an excellent staffing point with the AP600 design,
12 there were relatively few changes, and so we were able
13 to do our seismic analysis, and structural design with
14 a good start.

15 I will then cover the structural design
16 basis, the seismic analysis of the nuclear islands, I
17 will get into the structural design of some of the
18 critical sections, and I will briefly talk about the
19 Staff review, and the remaining open items, and a few
20 slides at the end for seismic margins.

21 CHAIRMAN KRESS: Now, some of the members
22 have expressed concern about how structure with a
23 heavy mass of water on top --

24 MR. ORR: I have a little bit in the
25 presentation on it, I will try to sort of emphasize it

1 when I get to it.

2 CHAIRMAN KRESS: Okay, thank you.

3 MR. ORR: The primary change for AP1000
4 from the structural point of view, is that we have to
5 increase height of containment. Containment is
6 increased in height by 25'6", the shield building
7 went up with it.

8 And because of the increase of heat loads
9 we increased the size of the PCS tank to 800,000
10 gallons. We made minor changes at the air inlets, we
11 got exactly the same air flow, but we made the opening
12 slightly higher by 25'6", 12' wide, and 16', in order
13 to get more column in between the air inlets.

14 The capacity of the polar crane increased
15 because the steam generators are much heavier. And
16 this is, primarily, the bridge itself. It probably
17 has the same capacity, and the load is the same.

18 All of the RCS equipment increased in
19 size, and the walls, the shield walls above the
20 operating deck, around the steam generators and the
21 pressurizer compartment, the steam generator walls
22 were raised 5 feet, the pressurizer wall was 7 feet.

23 There was a minor change in the elevation
24 of the fuel pit floor, because the fuel is 14 feet,
25 instead of 12 feet.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 We use these slides to show that there is
2 really no changes in the --

3 CHAIRMAN KRESS: Now this --

4 MR. ORR: -- is AP600, the right-hand one
5 is AP1000.

6 CHAIRMAN KRESS: Now, this is more
7 vulnerable than the east-west direction?

8 MR. ORR: Yes. In the east-west direction
9 the footprint from this wall, the east side to the
10 west side, is about 160 feet, or so. The containment
11 is about 150 outside of the shield building. And so
12 this is about 165 in the north-south direction it is
13 256 feet.

14 So most of the seismic results are worse
15 in the east-west direction than in the north-south
16 direction. This just shows a comparison in elevation.
17 Again, the cross sections are pretty much the same.
18 The containment vessel has increased in height, the
19 shield group has gone up.

20 The auxiliary building is virtually
21 identical. And one thing to mention, when we get into
22 structural configuration behavior, we have tied the
23 walls and floors of the auxiliary building directly
24 into the shield building cylinder.

25 The containment vessel is separate from

1 the shield building, there is a 4 foot 6 gap between
2 the containment vessel, and the concrete cylinder.
3 The containment vessel sits in the base mat, and the
4 containment internal structures sit inside the
5 containment, the bottom head.

6 Above grade the structures, the
7 containment internal structures, the containment
8 vessel, and the shield building are independent.

9 MEMBER SIEBER: Why is the bottom of the
10 containment building rounded?

11 MR. ORR: Because we -- the containment
12 vessel is an ASME vessel. The steel head is capable
13 of taking pressure on its own. If it weren't
14 surrounded by concrete, the steel head would be
15 adequate for 59 psi.

16 The other option is to put, effectively,
17 a flat head, design it as a reinforced concrete base
18 mat, and we looked at it a little bit. Some of the
19 details you get into, are try to anchor down a steel
20 vessel into concrete, are difficult to construct.

21 Changes to the containment vessel, the
22 diameter is the same. The height, as I said, went up
23 25 foot 6. Design code is the same. Material has
24 changed. For AP600 we used SA537 material. Here
25 we've got SA738 grade B.

1 One of them is 18 KSIA ultimate, the SA738
2 is a 85KSI ultimate, so there is a slight increase in
3 allowed stress. This was a material that was not in
4 the code in the mid-'90s. It is a material being
5 used successfully by CPI on a lot of non-nuclear
6 vessels, and effectively is going to be replacing the
7 SA537 material that would have been used for AP600.

8 We increased the thickness from an inch
9 and five-eighths on AP600 to inch and three quarters
10 on AP1000. This is the maximum with heat treatment,
11 and in response to one of the NRC's issues, we have
12 actually increased the thickness of the lowest course
13 from inch and three quarters, to inch and seven
14 eighths, to provide additional margin in the
15 transition region, where the vessel is imbedded, and
16 goes down into the concrete.

17 We did the same thing on AP600, but we
18 were only going up to an inch and three quarters, so
19 we didn't have any increased -- this is just two views
20 of the PCS roof tank. As I said, we went from 540,000
21 gallons to 800,000 gallons.

22 We did this by increasing the diameter
23 from 80 feet to 89 feet. The height is pretty much
24 the same, but because it slid down, the conical roof,
25 we get slightly more volume.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 The seismic design basis, firstly it is
2 generally the same as AP600, 0.30gSSE. However, for
3 current design certification purposes, we are only
4 looking at hard rock sites.

5 CHAIRMAN KRESS: This prevents you from
6 building one in Japan?

7 MR. ORR: No, in Japan almost all of their
8 sites are hard rock. Oh, .3, yes. We have actually
9 looked at cases with seismic isolation, there were
10 also the options of operating it a little bit.

11 We have used the same response spectrum,
12 parameter response spectrum, as we used for AP600.
13 This was REG guide 160, which was in existence in the
14 mid '80s and used for most plants. We reviewed it,
15 and then in 1990, and we put in some application of
16 high frequencies, particularly at 25.

17 Some of the recent data in east coast site
18 shows that there is significant amplification around
19 that frequency. We did a series of finite element
20 models for AP1000.

21 This was a similar approach to what we did
22 on AP600. We do finite element models of the
23 buildings, and I will show you two typical ones,
24 shortly, that are used in static analysis, and also in
25 model analysis, and we use those model analysis

1 results to come up with a simplified stick model of
2 the, for dynamic purposes.

3 These stick models are created
4 individually for the auxiliary and shield building,
5 for the containment internal structures, for the
6 containment vessel, and polar crane, and for the
7 reactor coolant loop.

8 The stick models have been combined in the
9 time history analysis.

10 This now is the typical finite element
11 model of the shield building, and the auxiliary
12 building, which has been described. These are
13 integral structures. It extends all the way from the
14 base mat up to the top of the shield building group,
15 where the refinement of the model sufficient for
16 dynamic behavior.

17 We did a more detailed model that we used
18 in the static analysis.

19 CHAIRMAN KRESS: Are the dots on there
20 where you concentrated --

21 MR. ORR: Yes. The stick model, the dots
22 represent either masses or in some cases just the
23 connecting links between a series of sticks. The
24 circles are masses, the open circles are the centroid
25 of the section, and the X's are the shear centers.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 We developed a similar model inside
2 containment, very detailed, and the same model was
3 used both in the dynamic analysis, the model analysis,
4 and the static analysis.

5 This particular view represents the
6 portion of concrete inside the containment vessel, and
7 all of the concrete structures, including the module
8 structures that you saw in the presentation at lunch
9 time.

10 The seismic analyses that were done,
11 firstly, on the fairly detailed finite element models,
12 we do model analysis to get frequency and effective
13 mass of the dynamic properties.

14 We also use those models to create
15 properties for the simplified sticks, and we check the
16 stick models, the frequencies, and the mass in the
17 stick models against those in the detailed shell
18 models.

19 The stick models are used in a modal
20 analyses time history that results in responses at
21 each of the models, time history responses. The
22 typical responses we look at are maximum acceleration
23 and relative deflection of the load relative to the
24 ground.

25 And we create floor response spectra from

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 the acceleration time histories for use in equipment
2 design. This typical flow response spectra is at the
3 top of the shield building roof, in the horizontal
4 direction.

5 At the zero period acceleration this is,
6 effectively, the maximum acceleration response of the
7 structure. We have an acceleration of about one point
8 HG at the top of the shield building roof.

9 The response spectra represent the
10 response of a single degree of freedom attached to the
11 structure. If it is in resonance with the structure,
12 for instance here at about 3 hertz, you get very large
13 amplification.

14 This 3 hertz frequency is the fundamental
15 frequency in the east-west direction of the shield
16 building. The smaller peak, at about 8 hertz, 7 or 8
17 hertz, is a local mode of the shield building roof.
18 This is the tank rocking on the conical roof.

19 So when we looked at the design of the
20 tank we are looking at, effectively, these
21 accelerations for the structure, of about 1.7G, and we
22 qualify the building structure for that.

23 In addition we looked at the water in the
24 tank, and we looked at the slushing mode of the tank,
25 and we see movement of the free surface, I think it is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 about 4 or 5 feet.

2 But we have that amount of freed water in
3 the tank, so it does not impact on the outer side.

4 MEMBER SIEBER: You could have added
5 baffles in there, right?

6 MR. ORR: We could have added baffles,
7 yes. I'm not sure how effective they would be,
8 because right now the frequency of the water slushing
9 is at .13 hertz, about 8 seconds. As you get baffles
10 it is going to increase that frequency.

11 We are very well off by the fact that the
12 frequency is so low, that it does not get excited by
13 the 3 hertz contents of there shear.

14 MEMBER SIEBER: Okay.

15 MR. ORR: For AP600 we had extensive
16 structural design. And in our review, with NRC, we
17 established a series of critical sections that were
18 really based on our judgement. We said this is going
19 to be the locations, most congested, most difficult to
20 design.

21 We did the detail design calculations, NRC
22 reviewed those. We have done the same thing for
23 AP1000. There are 22 critical sections. This is just
24 some examples of the shield building roof, and there
25 are actually three critical sections here.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 One is the columns between the area, and
2 that is -- the second is immediately above them, is
3 what we call the tension range, running around
4 immediately above the air inlets. And then there is
5 the lower portion of this cylindrical wall.

6 We do static calculations on the detailed
7 finite element models, using the accelerations from
8 the time history analysis. This is just one example
9 of models that we created from the shield building
10 roof.

11 We actually also have models, this is 180
12 degrees, we have models at 360 degrees, we have models
13 at 90 degrees. The one at 90 degrees is the one we
14 used in the detailed design calculations, with
15 considerably more requirements than shown in this
16 portion.

17 From the detailed plant model we get a
18 number of forces in all of the elements, and go into
19 hand calculations and processes, to calculate the
20 amount of reinforcement.

21 This is an example of the reinforcement in
22 this tension rail, and in the column between the air
23 inlets. They are congested, but that won't be
24 feasible. This was redone for AP1000, but really the
25 changes are not that significant in the quantities of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 reinforcement between the two plants.

2 In the early stages of AP1000 we had a
3 pre-application review, and I think at that time I
4 presented something to ACRS. We were requesting that
5 we could do much of the seismic analysis and the
6 structural design to the combined license applicant.

7 And we had lots of discussion and we were
8 permitted to do that work. So that is the work that
9 we did last year, and we had extensive meetings with
10 NRC. First we had a one week meeting in November,
11 secondly the one week meeting in April.

12 The first meeting was primarily seismic
13 analysis, the second meeting was primarily the
14 structural design. Resulting from that there are
15 still a few open items, but we think we made excellent
16 progress.

17 In the areas that I am responsible for
18 firstly there are five open items in chapter 2 that
19 address the geotechnical interface of the site. Most
20 of that is that we maintain the information from AP600
21 in the interim there was a new standard review plan
22 that was issued, so we have now revised the DCD to
23 reflect the new standard review plan, that should be
24 resolved with no great problem.

25 In the section on seismic analysis,

1 section 3.7, there are seven open times. We have
2 responded to all of them. The most significant one
3 was a discussion we had with the Staff, actually since
4 the beginning of this year, that we resolved in a
5 meeting in April, related to the assumption of the
6 stiffness of concrete to be used in the seismic
7 analysis.

8 And after extensive discussion we agreed
9 to do additional analyses, and having done those
10 additional analyses we have actually revised all of
11 the seismic results in the DCD.

12 Changes, we have reduced the stiffness of
13 the concrete by a factor of .8, the changes, the
14 frequencies by about 10 percent, and changes to some
15 of the responses more than 10 percent.

16 Because we changed the stiffness of the
17 concrete we do not change the stiffness of the steel
18 vessel, and the relative frequency between the two now
19 changes, and that does change the overall response.

20 MEMBER SIEBER: I don't know hardly
21 anything about concrete, except that I always was
22 under the impression that it doesn't bend. And,
23 therefore, how do you change the stiffness?

24 Is there differences in composition, or
25 are you really looking at rebar --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MR. ORR: No, this is an analysis
2 assumption of the material property of the concrete,
3 the elastic --

4 MEMBER SIEBER: The space it --

5 MR. ORR: -- is used in the past, in most
6 analyses. Recently there has been a change in the
7 state of the art, various FEMA documents that
8 recommend something less, and we have now sort of used
9 actually the 80 percent.

10 MEMBER SIEBER: Okay.

11 MR. ORR: I think it is probably giving us
12 a better estimate of expected behavior than we got in
13 the past.

14 MEMBER SIEBER: If it is a better
15 estimate, does that mean you are better off, or worse
16 off?

17 MR. ORR: Not really. If it is more
18 likely to be -- it is a best estimate, and then we
19 broaden the floor response spectra plus minus 15
20 percent from that.

21 MEMBER WALLIS: Does the concrete fail, do
22 they get pulled back --

23 MR. ORR: Well, what happens is -- the
24 only reason we have reinforcement is because we know
25 that concrete cracks. If it didn't crack, we wouldn't

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 need reinforcement.

2 MEMBER WALLIS: For these transients, does
3 it actually open up and then close?

4 MR. ORR: Yes.

5 MEMBER WALLIS: It does, okay.

6 MEMBER SIEBER: Well, I always sort of
7 pictured it as the rebar being the basic structural
8 element with the concrete being a lot of mass that is
9 hanging on the rebar.

10 MR. ORR: From a strength point of view
11 you are relying entirely on reinforcement. From a
12 stiffness point of view, generally, the concrete is
13 more significant than the reinforcement.

14 MEMBER SIEBER: Right. But it is the mass
15 of the concrete, as opposed to the continuity of it,
16 right?

17 MR. ORR: Well, it is also the continuity
18 because what happens is you get cracks every two or
19 three feet.

20 MEMBER SIEBER: Right.

21 MR. ORR: Between that you've got
22 uncracked concrete. So you've actually got a
23 combination of --

24 MEMBER SIEBER: A series of plates.

25 MR. ORR: -- uncracked concrete and

1 cracked concrete.

2 MEMBER SIEBER: Right, okay, thank you.

3 MR. ORR: The third section is the
4 structural design DCD sections 3.8. There we have 14
5 open items on all of the seismic and the structural
6 open items we have provided a response to NRC. We
7 believe that those responses are substantially
8 adequate.

9 We will have at least one further meeting
10 with NRC staff. One of the open items relates to
11 design of containment vessel. We had not presented as
12 much design of the vessel as NRC staff felt was
13 necessary.

14 Since then we have done additional work
15 and the information is available for them to review.

16 CHAIRMAN KRESS: Is the purpose of the
17 seismic to develop some sort of confidence in the
18 probability that the containment will fail? That is
19 the basic purpose, right?

20 MR. ORR: Of the design work?

21 CHAIRMAN KRESS: Of the calculations and
22 the design.

23 MR. ORR: We have originally said that the
24 level of information for containment vessel would
25 basically be design specifications, similar to an ASME

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 design specification and all of their allowable
2 stresses.

3 NRC staff wants to -- wants a
4 demonstration that the vessel can be designed to those
5 requirements meeting ASME. So that is what we are now
6 doing.

7 As part of the application in the PRA
8 report there is a section related to seismic margins.
9 We did an evaluation for AP600, we updated it for
10 AP1000, and this report is in the PRA report.

11 As part of that we established the high
12 confidence low probability of failure values for each
13 of the safety related structures, and for the systems
14 and components.

15 For the buildings we have evaluated the
16 shield building, and the auxiliary building, the
17 containment vessel, and the interior containment
18 structure. That is also the IRWST tank, because the
19 tank is integrated into the structure.

20 MEMBER SIEBER: Are you folks designing
21 pipe supports, or does somebody else do that?

22 MR. ORR: We have, in the seismic margins
23 evaluation, we include piping and pipe supports.

24 MEMBER SIEBER: For the modules?

25 MR. ORR: Everything, yes.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 MEMBER SIEBER: But there are other parts
2 of the plant that aren't really built as modules,
3 right?

4 MR. ORR: This is -- so not just the
5 modules.

6 MEMBER SIEBER: Okay.

7 MR. ORR: We evaluate mechanical
8 equipment, a lot of this is based on generic data, and
9 the valves and the electrical equipment. The basic
10 requirement is that we demonstrate that we meet, at
11 least a review level of .5G.

12 What we found for AP1000 is
13 generally our margins are a little lower, because we
14 have higher response for the AP1000. But it is not
15 significantly different.

16 And .5G we have a number of items there.
17 We think the lowest one, same as on AP600, is around
18 .5.

19 MEMBER SIEBER: Let me ask you the
20 question that goes way back to the beginning. You are
21 designing for a hard rock site, and it is my
22 understanding that more than half of the sites, the
23 potential sites in the U.S. are hard rock.

24 On the other hand you can take one that
25 superficially is in hard rock, and put in franki

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 valves, and things like that. Is that an acceptable
2 alternative to finding a near surface hard rock
3 formation?

4 MR. ORR: One of the open items in the
5 DSER that we just responded to relates to that. That
6 we had the capability in AP600, and we now put it into
7 AP1000, that allows the combined license applicant to
8 do site-specific analyses of AP1000, and make
9 comparisons of floor response spectra at certain key
10 locations.

11 MEMBER SIEBER: Okay.

12 MR. ORR: If he can demonstrate that these
13 spectra are less than that, or he can demonstrate that
14 any exceedences he has made appropriate changes, then
15 this design can be applied directly.

16 MEMBER SIEBER: But do you know the
17 margins? You know, you are going to find, perhaps,
18 exceedences of your findings, which aren't exceedences
19 of the overall criteria, right?

20 So the licensee, the COL licensee is
21 allowed to use your margins, correct?

22 MR. ORR: As far as I know.

23 MR. CUMMINS: Say your question again.

24 MEMBER SIEBER: I picture -- you have
25 multiple structures here. And if you look at, for

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 example, selected equipment, or selected buildings,
2 you are going to find some better able to withstand a
3 .5G seismic event, than other ones.

4 So all the COL licensee applicant has to
5 do is to make sure that those areas that don't -- that
6 are on his site exceed your hard rock analysis, are
7 still within the .5G.

8 MR. ORR: This seismic margin is
9 different. This is the one that says, okay, you've
10 designed for an SSE of .3G. I want you to demonstrate
11 that you are not right at the edge of a cliff, and if
12 the earthquake is .31G everything falls down.

13 So you are demonstrating, all the way up
14 to .5, that the plant hangs together.

15 MR. CUMMINS: And you have to still do
16 that at COL stage. So the margin is really owned by
17 the NRC, not by the applicant, and their customers.

18 MR. ORR: If you have a site .5G, and our
19 design is .3G, then you've got that margin to play
20 with in some manner.

21 Some of our evaluation of seismic margins
22 now is based on a paper plot, and so there are certain
23 commitments that are required for the combined license
24 applicant. He is, obviously, going to demonstrate
25 that the seismic response at his site is lower or

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS

1323 RHODE ISLAND AVE., N.W.

WASHINGTON, D.C. 20005-3701

(202) 234-4433

www.nealrgross.com

1 equal to the ones we've used in design.

2 There are certain equipment choices still
3 to be made, one of them being the electromechanical
4 relays, that he has to demonstrate are robust. And
5 then as you build it, there are always some changes,
6 there are always some things you find, as you do the
7 first walk-down.

8 And so the combined license applicant is
9 required to do the seismic walkdown exactly as has
10 been done on many of the existing plants.

11 MEMBER SIEBER: But that is really
12 intended to do things like tie switch gear together,
13 and --

14 MR. ORR: It is also --

15 MEMBER SIEBER: -- as opposed to a
16 reanalysis?

17 MR. ORR: It is also to do a walkdown and
18 see, well, are there certain other interactions there
19 that you didn't quite realize when you were doing the
20 design.

21 MEMBER SIEBER: Right, okay.

22 MR. CUMMINS: But it is not supposed to be
23 reanalysis.

24 MEMBER SIEBER: Right. But there might be
25 in some instances.

1 MR. CUMMINS: Yes.

2 MR. ORR: We are continuing some work on
3 the seismic margins in response to the open items. As
4 I mentioned, we have changed the assumption of
5 stiffness of concrete, and hence we have changed some
6 of our seismic results.

7 We are looking to see if that affects the
8 seismic margins.

9 MEMBER SIEBER: Let me ask another real
10 quick question. You probably do your seismic pipe
11 design in hangars by analysis. But you can't possibly
12 review every pipe in the plant. What is the minimum
13 size pipe that you do by analysis, as opposed to using
14 templates, or something like that?

15 MR. ORR: I believe that the -- we are
16 analyzing all of the large bore, greater than two
17 inch. I think some of the less than two inch high
18 energy lines we do analysis on, others will be a space
19 table type of --

20 MEMBER SIEBER: But all the way down to
21 two inches?

22 MR. ORR: Yes, sir.

23 MR. CUMMINS: I think your answer is for
24 safety related piping.

25 MR. ORR: Yes.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER SIEBER: Right.

2 MR. CUMMINS: This is seismic one piping.

3 MEMBER SIEBER: Right, which is better
4 than top --

5 MR. ORR: I believe all --

6 MEMBER SIEBER: And that is better than
7 industry practice had been up to this point, in plants
8 under construction, to my knowledge.

9 MR. ORR: The last item we are doing, as
10 we review the seismic margin, we are updating some of
11 the calcs because we now have better design
12 information on AP1000 than when we did the original
13 seismic margin update.

14 What I would expect is that this is going
15 to increase many of our HCLPFs. We will still meet
16 the requirement of .5.

17 I think I managed to get through in less
18 than my allotted time.

19 CHAIRMAN KRESS: We are adjourned.

20 (Whereupon, at 6:22 p.m., the above-
21 entitled matter was adjourned.)

22

23

24

25

CERTIFICATE

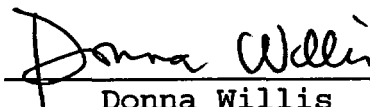
This is to certify that the attached proceedings
before the United States Nuclear Regulatory Commission
in the matter of:

Name of Proceeding: Advisory Committee on
Reactor Safeguards
Subcommittee on Future Plant
Designs

Docket Number: n/a

Location: Monroeville, PA

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.



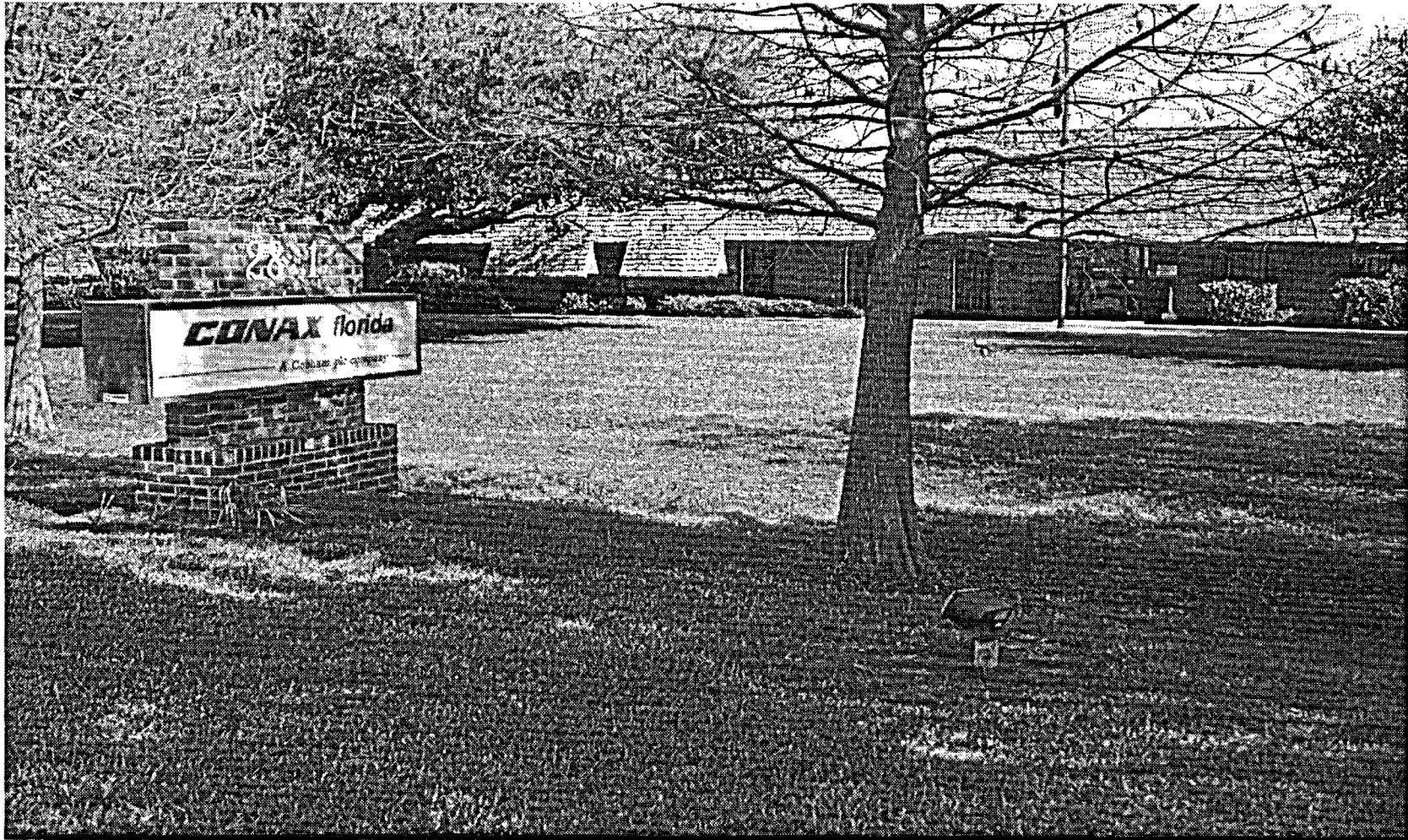
Donna Willis
Official Reporter
Neal R. Gross & Co., Inc.

SQUIB VALVE

AGENDA

- Overview of Conax Florida Corporation
- GE SBWR ADS (AP600 ADS 4) Valve Development
- AP1000 ADS 4 Valve
- Squib Valve Reliability

OVERVIEW OF CONAX FLORIDA CORP.



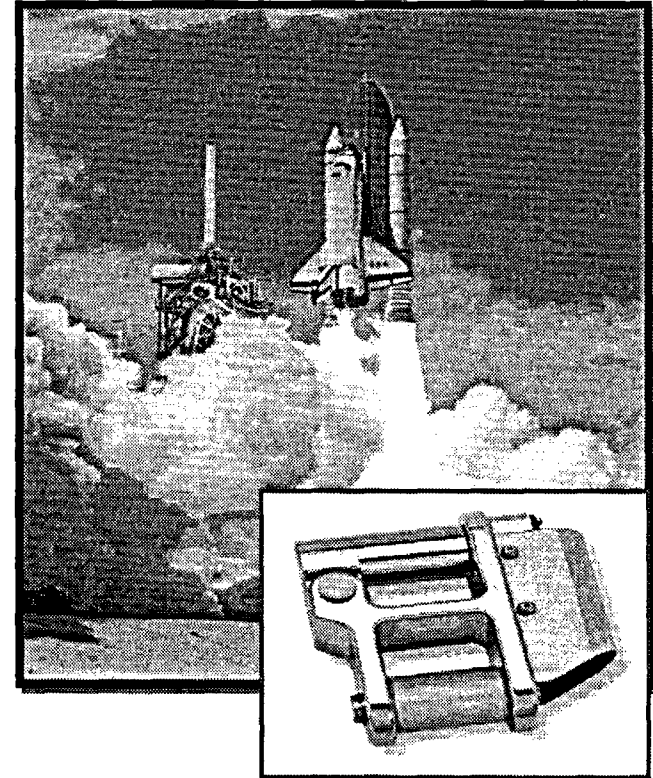
CORPORATE OVERVIEW

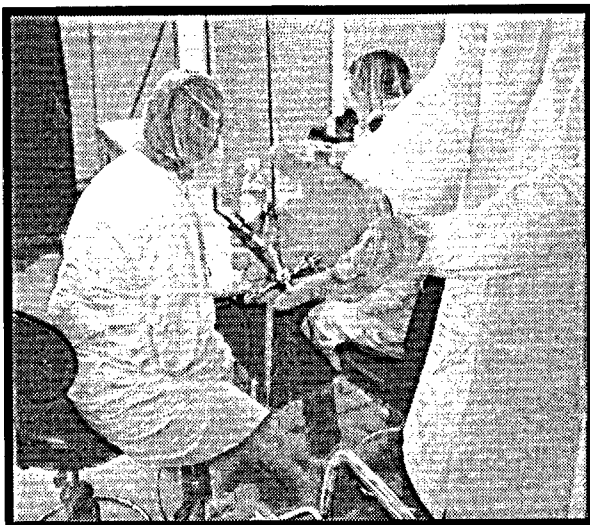
- Conax was founded in 1948.
 - First developed electro-explosive devices in early 1950's.
 - Conax Florida subsidiary was formed and moved to Florida in 1982.
 - Facility was ISO 9001 certified in September 1997.
 - Conax was purchased by Cobham plc of Dorset, England in 1998.
 - Employ approximately 150 people.
 - \$30 million in annual sales.
 - Located in St. Petersburg, Florida
-

CONAX florida
A Cobham plc company

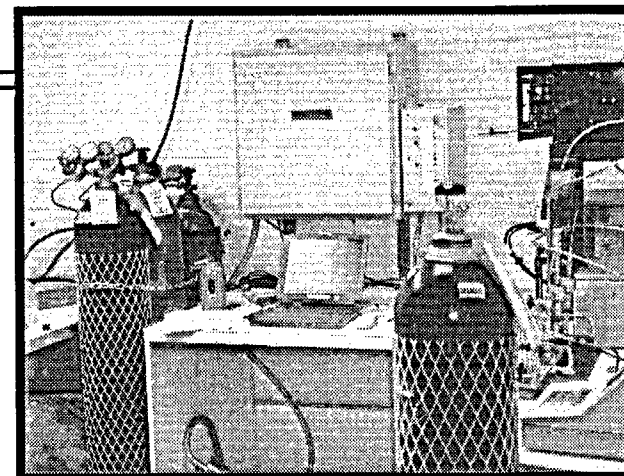
Aerospace Systems

- Utilize Conax's proprietary electro-explosive technology to actuate and control critical systems.
- Conax Products Include:
 - Pyrovalves
 - Stored Gas Systems
 - Water Activated Systems Systems
 - Pin Pullers & Cutters
 - Actuation Systems
 - Complex "Build to Print"
- Advantages:
 - Fast Acting
 - Solid Metal Seal
 - Reliable & Environmentally Durable
 - NASA Sponsored & Qualified

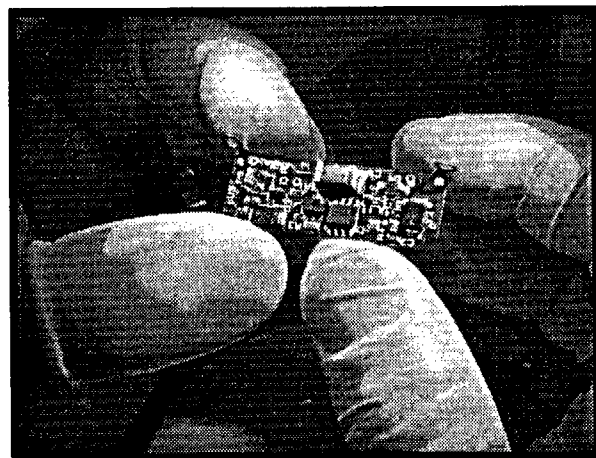




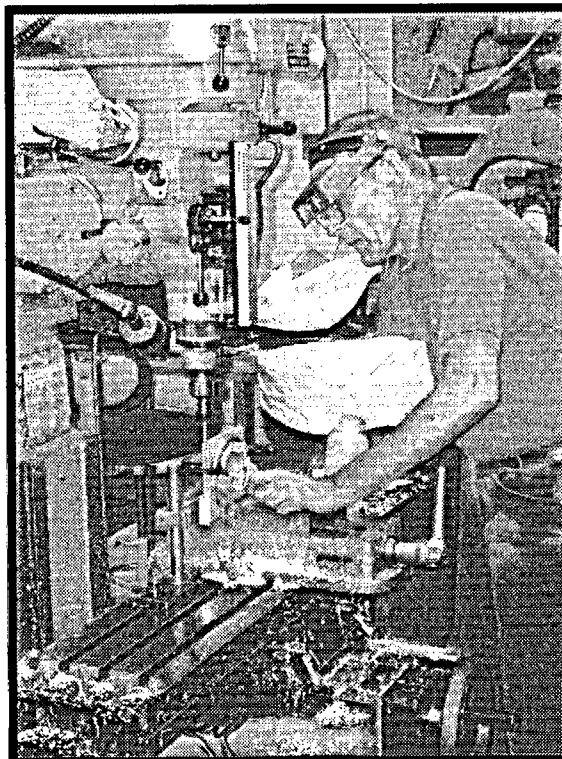
Class 10,000 Clean Room



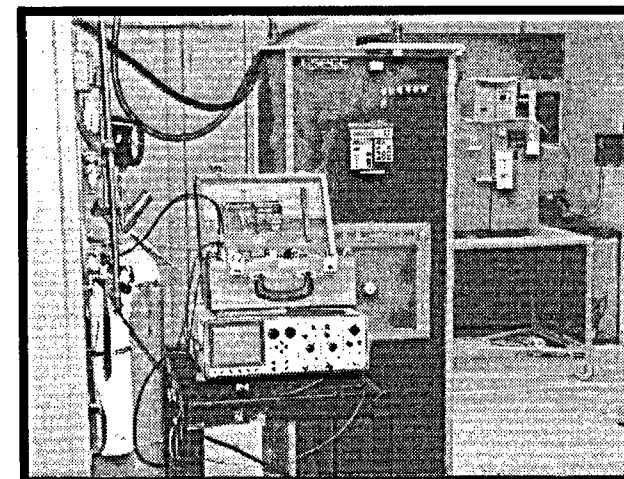
Gas Purity Testing



Electronic Assembly



Prototype Shop



Environmental Testing

CONAX MAJOR PROGRAMS

Space Systems

Atlas
Titan
Space Shuttle
Centaur
EELV
Delta
Taurus
Pegasus
AXAF
A2100
HS601
HS702
Mars Surveyor
PanAm Sat
NSTARC

Under Sea

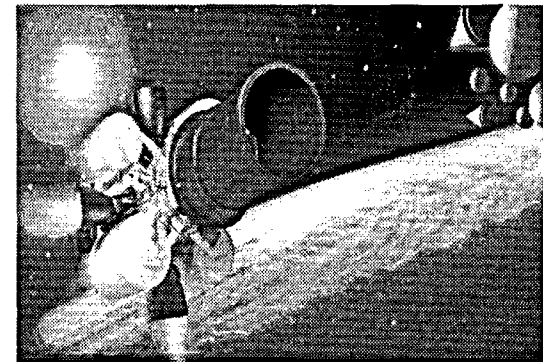
MK-46 Torpedo
MK-48 Torpedo
MK-50 Torpedo
MK-67 (SLMM)
ADCAP Mine Torpedo
Arctic Buoy
CCAPS

Build To Print

Acoustic Counter-Measure
Submarine Separable Cover
Javelin Flex Assy.
Torpedo Nose Assy.
Smoke Generator

Missile Systems

Javelin
EKV
BAT
THAAD
Tomahawk
Tactical Tomahawk
Standard Missile
Minuteman
MX



CONAX florida
A Cobham plc company

CONAX QUALITY ASSURANCE

Certification

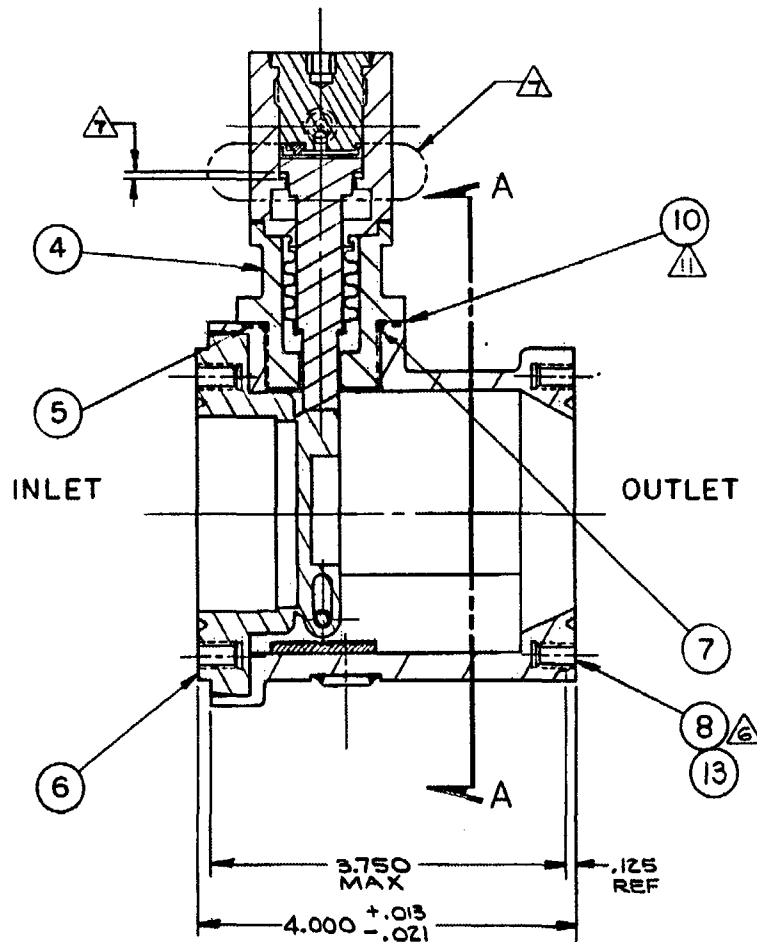
- Quality Assurance System ISO-9001 Certified
 - November 1997
 - January 2001
- Quality System in Compliance with AS-9100
 - International Aerospace Quality Group

GE SBWR ADS VALVE DEVELOPMENT

- General Electric initiated contact with established valve suppliers throughout the world (7 bidders)
 - Pyronetics proposed valve simplest design approach
 - Based upon Pyronetics 2" ID flow passage valve
 - General Electric provided a list of Pyronetics customers
 - Some of Pyronetics customers contacted
 - General Electric concluded OEA Pyronetics was capable of designing, manufacturing and testing squib valves (7" ID)
 - Contract awarded to Pyronetics
 - Westinghouse AP600 ADS 4 is same ID as GE valve
 - Westinghouse AP1000 ADS 4 is simply scaled-up AP600 / GE SBWR valve
-

2" ID OEA DESIGN

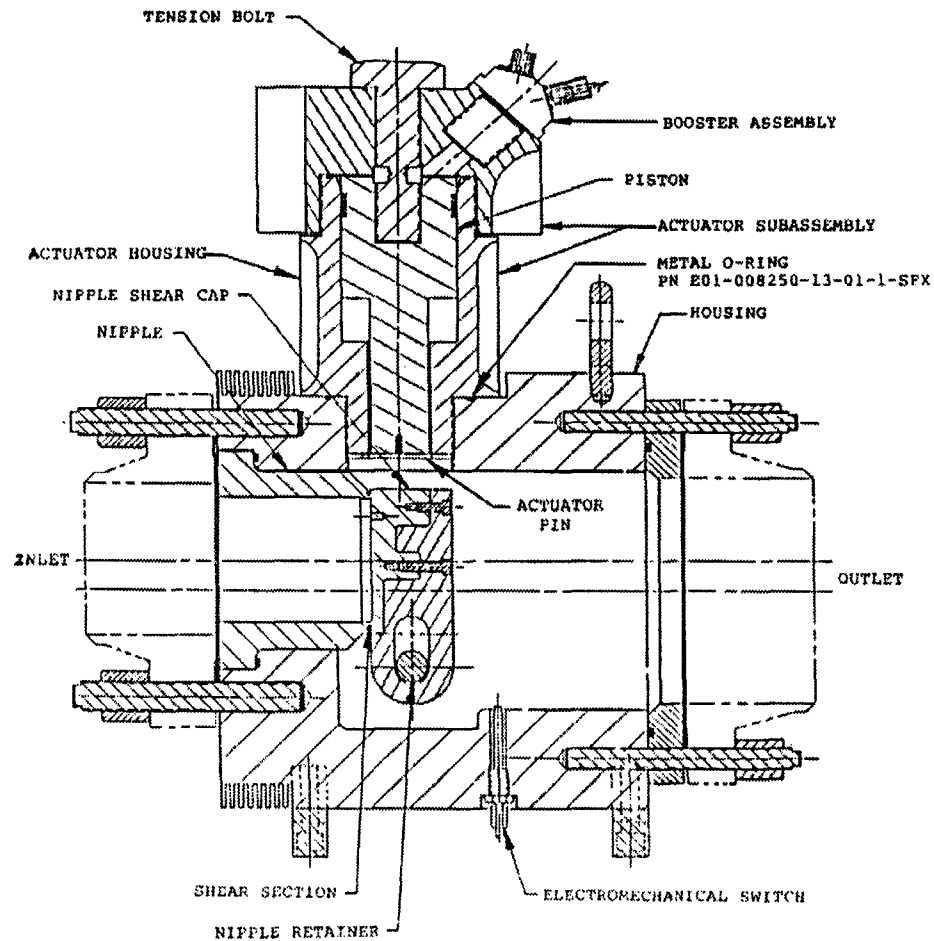
Design of 2" ID flow passage valve



CONAX florida
A Cobham plc company

GE SBWR ADS DESIGN

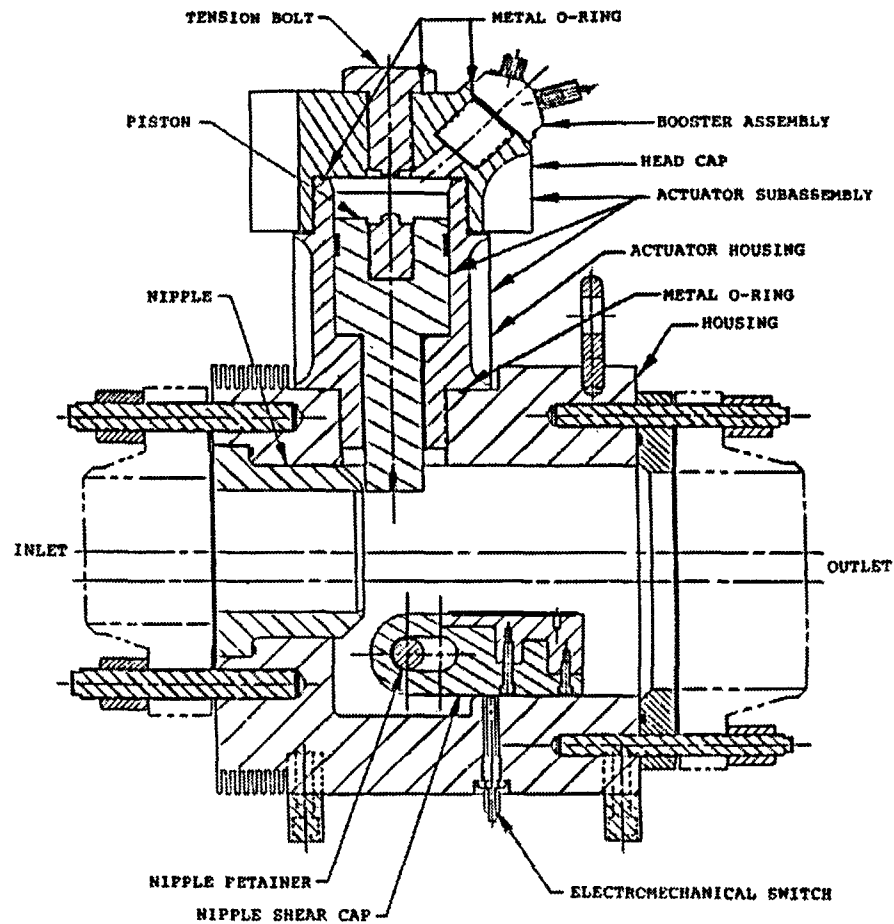
Design of SBWR ADS (7" ID) - closed



CONAX florida
A Cobham plc company

GE SBWR ADS DESIGN

Design of SBWR ADS (7" ID) - open



TEST PROGRAM PERFORMED

Acceptance Tests

- Examination of Product (full size, pressure rating)
- Hydrostatic Testing
- Leakage (inlet pressurized)
- Thermal Exposure – Inlet conditioned to 550°F and surrounding air temperature 190°F (actuator met <280°F requirement)
- Cleanliness Verification

Valve Development Test Sequence

Development Tests ⁽¹⁾	SERNO 1	SERNO 2
First Actuation	1	1
Second Actuation	2	

⁽¹⁾ Both units delivered to GE for additional testing subsequent to Pyronetics testing

TEST PROGRAM PERFORMED ON INITIATOR BOOSTER

Closed Bomb Testing:

- At temperature
- 100% and 80% booster load

Lab Samples Testing:

- Thermo Gravimetric Analysis (TGA) scans to determine thermal degradation as a function of time and temperature,
- Differential Scanning Calorimetry (DSC) tests to determine change of state temperature and temperature regimes of interest,
- Isothermal tests to determine the amount of weight loss.

Radiation Testing:

- Boosters: 2.31×10^7 rads Total Integrated Dose (TID)
- Position switch and cables 5.6×10^7 Rads TID

INITIATOR/BOOSTER TESTING (con't)

Accelerated Thermal Aging:

- Boosters: 25 days at 360°F (simulating four year normal life)
- Cable Assemblies: 69 days at 374°F (simulating ten year normal life)
 - Did not meet requirement. Design changed to use different epoxy.
- Position Switch: 54 days at 360°F (simulating ten year normal life)

Reliability Testing:

- All units met performance requirements

SBWR ADS VALVE TESTING

Seismic and other dynamic loads evaluated

- Vibration Testing
- Actuation / Flow

AP1000 ADS 4 VALVE

PERFORMANCE REQUIREMENTS

	AP1000 ADS 4	SBWR ADS
Nominal Size	Inlet: 14 inch Min ID: 9.24	Inlet: 8 inch Min ID: 7.00
Valve Body Material	SS (316L)	SS (304L)
Safety/Seismic Class	1 / 1	1 / 1
Design Pressure	Inlet: 2485 psig Temp: 650°F	Inlet: 1500 psi Temp: 595°F
Seat DP, Forward	Inlet: 2500 psig	Inlet: 1500 psig
External Temperature Range, Normal	120°F to 50°F	190°F
Radiation Level	.5x10 ⁷ RAD (ten years)	2.31x10 ⁷ RADS (four years)
Open Pressure Range	Inlet: 1 to 2500 psig	Inlet: 1 to 1500 psig
Design Life of Booster	8 years target	4 years

AP1000 ADS 4 VALVE DEVELOPMENT

1. Design

- Scale up design from SBWR ADS valve
- Analysis Design Report (ASME Code)

2. Development/Prototype

- Testing similar to previous SBWR ADS program.
- Tests planned:
 - Charge sizing
 - Inspection
 - Hydrostatic and Leak Testing
 - Vibration
 - Actuation (over and under loaded boosters)

RELIABILITY

- **High Reliability Requirements**
- **FMEA (preliminary sample)**
- **Design Shear Section**
- **Reliability of Squib Valve**
- **IST Replacement of Charges**

HIGH RELIABILITY IS REQUIRED

- Our customers require high reliability
 - Life Support programs
 - Aerospace programs
 - Consequences of failures are high
- Conax procedures control high reliability
- Custom Valve Designs / Up-Scaling is Standard Process
 - Simple valve design reduces problems
 - Development process is able to deliver highly reliable valves

HIGH RELIABILITY IS BUILT IN

Design / Analysis

- Past experience with similar products (lessons learned)
- Design analysis of new design
- Examination and analysis of drawings
- FMEA
- Reliability analysis

Testing

- Development and prototypes units
- Margin testing (over and under loaded boosters)
- Acceptance and qualification
- On propellants (powder form and in initiators and booster)

Quality Assurance: ISO 9001 Certification

CONAX florida
A Cobham plc company

DESIGN SHEAR SECTION

Design:

- Shear section is standard pyrovalve design feature
- Concept proven on thousands of valves
 - No leakage ever reported on delivered product
 - Thickness as small as 0.003 inch and thicker
- Concept same as for AP600 / SBWR ADS
- Designs meets ASME code Section III, Class I
 - NB3200, Design by analysis

DESIGN SHEAR SECTION

Corrosion Affects

- 316 L Material selected for the con-o-cap (i.e. shear section):
 - Material compatible with planned system media
 - Not subject to stress corrosion cracking like numerous other materials

In Service Inspection

- Designed for ease of removal for inspection

RELIABILITY SUMMARY

- **UPCO reliability of:**
 - .999568 at 90% confidence
 - .999437 at 95% confidence
 - Valves manufactured: 64,690
 - Total quantity fired: 5,324

 - **Conax reliability of:**
 - .9998169 at 90% confidence
 - Based upon:
 - Total initiators >25,000
 - Valves manufactured: >25,000

 - **Sandia reliability of:**
 - .999839 at 90% confidence
 - Based upon:
 - Initiators manufactured: 25,000
-

RELIABILITY

- Squib valves have high inherent reliability
 - Reliability for smaller valves applicable for larger valves
 - Same design standards established
 - > Engineering Analysis
 - > Proof and Leak Testing
 - > Over and under loaded boosters used during testing
 - > Design concept similar (shearing material) in all cases.
 - No failures associated with shear section cracking under constant high pressure and temperature