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ORIGINAL

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**Agency:** U.S. Nuclear Regulatory Commission
Incident Investigation Team

**Title:** Nine Mile Point Nuclear Power Plant
Information Exchange Meeting

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**ANN RILEY & ASSOCIATES, LTD.**
1612 K St. N.W., Suite 300
Washington, D.C. 20006
(202) 293-3950

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

INCIDENT INVESTIGATION TEAM

Nine Mile Point Nuclear Power Plant

Information Exchange Meeting

Nuclear Regulatory Commission

The Woodmont Building

Room W-100

8120 Woodmont Avenue

Bethesda, Maryland

Saturday, September 7, 1991

The meeting in the above-entitled matter convened, pursuant to notice, in closed session, at 9:10 a.m.

PARTICIPANTS:

JACK ROSENTHAL, NRC/ITT Team Leader

FRANK ASHE, NRC/ITT Team

JOSE IBARRA, NRC/IIT Team

MICHAEL JORDAN, NRC/IIT Team

TOM POHIDA, NRC/ITT Team

JIM STONER, NRC/IIT Team

CHONG CHIU, Failure Prevention, Inc.

JAMES B. RIDDLE, Failure Prevention, Inc.

CARL D. TERRY, Niagara Mohawk

PROCEEDINGS

MR. JORDAN: My name is Michael Jordan. I am with the NRC. I'm out of Region III. I'm the deputy team leader. I'm a section chief in Region III.

MR. POHIDA: My name is Tom Pohida, NRC, Instrumentation and Control Systems Branch and a member of the IIT Team.

MR. IBARRA: Jose Ibarra, member of the IIT, NRR.

MR. TERRY: Carl Terry, Vice President-Nuclear Engineering, Niagara Mohawk.

MR. RIDDLE: James Riddle, Manager Electronics Program for Failure Prevention.

MR. CHIU: Chong Chiu, President of Failure Prevention, Incorporated.

MR. ASHE: Frank Ashe, member of the IIT Team, NRC.

MR. STONER: Jim Stoner, Consultant to the IIT.

MR. ROSENTHAL: Jack Rosenthal. I'm the IIT team leader. My degrees are in nuclear engineering. I am learning an awful lot about electrical engineering, but I am going to have to explain this to the Commissioners some day. So you are going to have to bear with me as I come up to speed. Tom has designed these circuits in prior employment.

Why don't we let you people have the first word.

MR. CHIU: Let me open this session by telling you

why we think it is important we are here and why we think what we are doing today is important.

Looking back in the history of when the event occurred, Failure Prevention, Incorporated, was hired as an independent consultant to make sure all things they look at are encompassing and that we don't miss anything. With that mission, we came into the plant and did an investigation.

As an investigation company, we are really impressed by senior management. I can name a few guys. They don't want to stay on the component level; they want to go down to the sub-component level to explain why some lights are on and some lights are off, so that we can hopefully explain what went wrong or what went the way it went. As a result of it, we can really pinpoint or consider all possibilities, all failure modes, so we don't leave any stone unturned.

With that philosophy, the whole investigation will go full steam. Today what I want to do is first introduce our test rig, how we do our testing. We have a film. Later on we are going to tell you what our test plan is to understand the phenomena a little bit better.

Then we are going to tell you what our results are up to today, give you a status report. Throughout this informal presentation we have a lot of photographs to show you, the chips and how things go. Ask questions any time

you want to.

We may go into the elementary schematics. We don't have a complete set of schematics, which impedes the speed of our investigation somewhat, but we have tried to overcome that by building a test rig and trying to understand the reverse engineering, following it back to see what could happen.

That is a little bit of introduction why we are here and why we think it is important. Any questions so far?

MR. ROSENTHAL: Let me get to the drawings for a second. This was clearly non-safety-related equipment in our designation. Unlike safety-related, it is not surprising to me -- it may be disappointing, but not surprising that we don't have all the drawings readily available. The manual, in my opinion, is a description of the system and is not like a verification or validation type document where it says what the design intent of each component is. That has caused problems for us. We are still gathering elementary drawings from the manufacturer, for better or worse.

Were you going to bring a board with you?

MR. RIDDLE: Yes, a circuit board.

MR. ROSENTHAL: It would be useful to us to do some spot audits of the board. It is not the board that was

in the unit, right? It was a replacement board?

MR. RIDDLE: No. The board that I brought is the UPS 1A A1321.

MR. ROSENTHAL: That was in?

MR. RIDDLE: That was in the 1A UPS.

MR. ROSENTHAL: We would like to do a little bit of checking against the drawings that we have to make sure that even what we think is the latest set of drawings corresponds to the unit.

MR. RIDDLE: There are some modifications on the particular card that are not in the drawings in terms of some cut traces and some jumper wires. We are going to show you several other components. You can actually dig those out of the modification drawings, of which I also have a set.

MR. CHIU: The first thing I would like to do is show you a very short video tape.

MR. ROSENTHAL: We may need copies of stuff.

MR. RIDDLE: I brought duplicate photographs. You can take this. The original of this tape is on 8 millimeter. You guys can have it.

MR. CHIU: This will give you some ideas of how the test rig was set up.

[Videotape "Niagara Mohawk UPS Circuit Board Test" shown.]

MR. CHIU: That will give you some idea about the typical tests we do on the test board. Of course we are going to review other results. That is just one segment.

MR. ROSENTHAL: If I relate it back to here, you have got this signal on.

MR. RIDDLE: Right.

MR. ROSENTHAL: You have got this light. You have got the SSTR. I don't know if it goes high or low. One or the other.

MR. RIDDLE: On the A14, the trip and invert lines, logic flow. Those are three lights I'm showing on that particular board.

MR. POHIDA: Where is the third one?

MR. RIDDLE: One, two, three. These three.

MR. TERRY: One of them is just a trip signal.

MR. RIDDLE: This is a trip. I don't know where it goes, because I haven't found it on the other card.

MR. ROSENTHAL: We have been able to trace that through.

Let's just share for a second. I said CB1, CB2 and CB3 had to open. That means that the shunt trip coil had to be actuated. It's normally 48 volt DC coil. It normally would get 40 volts from the plus or minus power supplies. And it will go at far lower voltages. It doesn't need very much because it just picks a latch and then the

spring will actually transfer the contacts.

You make up the power to that by closing K1, K2, K3. That is shown on the A27 module. We did have a question about the time constant of those relays, which would be small. I just spoke to Niagara and they said maybe you guys knew.

MR. CHIU: The K1?

MR. ROSENTHAL: Remember this power supply picture?

MR. RIDDLE: Yes.

MR. ROSENTHAL: Here are the circuit breakers, CB1, CB2, CB3. I've got to close contacts to energize the shunt trip. In order to do that I've got to pick K1, K2, K3. Those are smaller relays but they are relays. I don't know what the time constants of those relays are. They thought maybe you knew.

MR. RIDDLE: I haven't looked at it.

MR. ASHE: In general, do you?

MR. ROSENTHAL: Pinter this morning said Frank Ashe had asked and he said maybe you guys knew.

MR. RIDDLE: When you say time constant, do you mean the time it takes to respond?

MR. ASHE: Response time.

MR. RIDDLE: Do you have a spec sheet for these things? If I get a part number, we can pull some specs.

MR. ROSENTHAL: We are all up the same kazoo.

MR. RIDDLE: We can read that off the parts, or we can set the board up and measure it.

MR. ASHE: That is what I would be interested in.

MR. ROSENTHAL: That is on the A27 board. Do you have an A27 board with you?

MR. RIDDLE: No.

MR. ROSENTHAL: So conceptually we are thinking of these as rather small relays that work somewhat fast.

So that is sitting on plus 20. The output to the power supply and the battery, and I've got to make up the logic. Electrically that is the only way that these get stroked.

MR. CHIU: By this input.

MR. ROSENTHAL: These go directly to three power transistors, which get poled to ground, Q1, Q2, Q3.

MR. ASHE: A13A1.

MR. ROSENTHAL: On A13A1, Q1, Q2, Q3. There is just one wire out to make up the logic.

Now we go back. What picks Q1, Q2 and Q3 to have them conducting the ground? Now it becomes fancier. One of the things is --

MR. ASHE: SSTR.

MR. ROSENTHAL: It has a different name, unfortunately. It is UPT equal 1 from the A21 card. We

spent some time saying, well, what other signals and where do they come from? Some aren't even installed. As I remember that review, we had convinced ourselves during at least normal operation that you had to get a UPT equal 1 from the A21 board. That was the way these power transistors changed state.

MR. CHIU: Change state and then go to K1, K2.

MR. ROSENTHAL: Now that disappears into the back plane and reemerges from the back plane as SSTR. Then all the trip logic is lower down than SSTR.

Is there mutual agreement that SSTR advertently or inadvertently, but in any case that that signal had to pick? Are you guys there yet?

MR. RIDDLE: Had to pick what?

MR. ROSENTHAL: Had to change state.

MR. RIDDLE: Yes, it would have changed state. If these lamps are on, then this output here is going to drive this and drive that and turn that on.

MR. ROSENTHAL: So based on our design knowledge and review of the drawings and what makes sense to us, if these lights are on, SSTR is on. Although there are a couple of chips in between.

MR. RIDDLE: This has been verified in the movie. I have all three of these on. These two come on; this one always comes on because the output of this drives all that.

MR. CHIU: Unless you have a damaged chip.

MR. RIDDLE: The A card doesn't, because you just saw that all three were on.

MR. ROSENTHAL: The whole puzzle, to me, is why did SSTR signal on the A21 board latch? It could have been advertent, inadvertent, due to any number of things. That is really this morning's meeting. Unless there is something else.

MR. CHIU: We don't think so. Based on our observation, those lights were on. As a result, you can probably assume SSTR was activated during the event.

MR. ROSENTHAL: That's the only way that we see that you actually stroke CB1, CB2, CB3. That we know happened.

MR. RIDDLE: Let me back up a little bit. Initially when I was pulled on to the group the fundamental question was these lights were on and these lights weren't on and this logic is illegal; here is the card; go back and see what you can do with it.

My picture is expanding now to look at these other interconnections and how it ties in the big picture. My background up to this point has been in the microcosm on this board and inside these chips, all the way down to the micron level as far as the examination. So I can't claim expertise on tracking this back out of the system. I want

to make it clear that I spent a whole lot of time with this board and I have several possibilities as far as what can go on. That's in testing at this point.

MR. ROSENTHAL: Of course there is the sheet metal behind that back plate, which is grounded through, as I understand it -- you were there, so help me. There is a little green wire which goes from that back plate metal. As I understand the grounding of that sheet metal back there, there is a small wire from there to some heavier steel and then you actually ground the hinge of that chassis to the frame. One of the grounding guys said he was surprised that there wasn't a flexible braid ground. We didn't see it. Did you?

MR. RIDDLE: I don't recall one and I don't have that in my pictures.

MR. CHIU: Jack, do you recall what pin that ground was coming out from the logic board?

MR. ROSENTHAL: I don't know.

MR. RIDDLE: The grounding scheme is under question at this point. There are some questions about whether or not there are actual grounds, where the grounds are connected, whether the logical ground is the same as the AC ground. Chong is going to be out that way next week, and Kerry, and we will run that down through inspection to make sure that things are grounded, first of all, and what sort

of transient noise suppression is on the line, whether we have independent grounds and come to a common tie point. That is still up in the air and something that we are real concerned about finding out by actually doing a measurement.

I would like to do a measurement from the negative pin of a chip all the way out to the outside of the chassis and find out if there is a true connection from chip to case. Those are pretty easy tests to perform and we can get some real data on that in a couple of days.

MR. ROSENTHAL: We may want to send somebody from the team up there to watch. I assume Niagara doesn't have a problem with that.

MR. TERRY: No.

MR. ASHE: Have you touched base with Warren Lewis, who was at the site there?

MR. RIDDLE: No, I haven't. Let me get his name down.

MR. ASHE: In terms of the actual installation, the physical configuration, how it is actually grounded versus what is on the drawing, he may be extremely helpful to you in exploring that.

MR. ROSENTHAL: The ground from the UPS actually goes over the ground on the maintenance regulating transformer and it is grounded over there.

MR. RIDDLE: These are valid questions that we

could just go out and measure and get hard data on. Chong and I are looking at groundside problems. Some damage that I am going to show you later in some of the chips suggests that some of the noise introduction was through the ground area, so we do want to track that down and make sure that we know where the ground paths are.

MR. CHIU: Jim, do you want to go over the big picture of what tasks you are doing and what you have seen so everybody knows?

MR. RIDDLE: I have got a write-up that I have sent out to Niagara. Did this get to you? I sent this to John Conway and he was going to add it as an addition.

MR. TERRY: It may have yesterday.

MR. RIDDLE: We got it to him yesterday. We can copy it for everybody.

MR. ROSENTHAL: We are also getting Niagara Mohawk's big thick report. It should be arriving about 9:30.

MR. RIDDLE: The first thing we did was some static DC testing on some of the individual chips, 4049, 4011, 4044, 4068 devices. I obtained these from various electronics places and took them off of the new board. From the data sheets there were several possible voltage situations that would cause SCR latch-up, which was one of the first things we wanted to investigate.

MR. POHIDA: I have a question concerning the chips. You said you bought some new chips from Motorola or RCA.

MR. RIDDLE: Motorola.

MR. POHIDA: Do you think they are representative of the parts ten years ago?

MR. RIDDLE: The dies are similar and I tried to match the date codes. Devices are different. The Motorola devices and the RCA devices are a different die layout. They are going to have different susceptibilities to transient introduction because of the placement of the diffusions and such. Again, the protoboard concept. When we come down to testing the chips off the board we want to make sure we have got the test routine down so we are not wiping chips out.

MR. POHIDA: Right, because you don't want to damage the actual chips that are on the board.

MR. RIDDLE: Right. So what I did was buy store-bought chips. I find out when you dump some power into the inputs you blow the chip up. Since during the event things reset and chips worked, we decided we could toss that. You can cause permanent damage, as it is stated here. So we came up with a latch-up scenario, which is one of the first theories you were looking at where the device is introduced a voltage transient in some relationship, inputs and outputs

and power, and goes into a low impedance state. We have documents that I have sent around to explain.

MR. POHIDA: Do we all know by this point what you mean by vss?

MR. RIDDLE: Vss is low ground. In fact it is parenthetic here. Vss is considered ground and vdd is positive.

Output voltage below ground; output voltage above ground; input voltage above, ved, and power supply. That should be vdd, much, much greater than vss, as opposed to vss, much, much less than vdd. This is a typo.

Testing revealed permanent damage was induced by tests C and D. So they were discarded. Test B did not induce latch-up but test A did. What we do in this case is we put a negative going pulse on the output such that we drive it down below ground. We were able to latch the chips, especially the 4049s, very easily, consistently every time.

MR. ROSENTHAL: On the drawing the 4049 is simply an inverter chip.

MR. RIDDLE: Yes, inverter buffer. Buffer driver is what I think it's referred to. There are six of these in each package.

MR. ROSENTHAL: What do you mean by latch?

MR. RIDDLE: There are two forms of latch. I laid

that out in here. There is latch, which is what these do. Latch-up is when the parasitic voltage transients cause the device to form a parasitic circuit, which acts like a silicon control rectifier, an SCR, and puts the whole chip into a low impedance state.

MR. ROSENTHAL: And stays there?

MR. RIDDLE: Yes. It stays there until power is removed.

MR. CHIU: It becomes short-circuited.

MR. POHIDA: It is called an SCR latch, correct?

MR. RIDDLE: Yes.

MR. POHIDA: Sometimes the SCR latch will cause damage and sometimes it will not.

MR. RIDDLE: Yes. Depending on available current. The typical damage that we see on integrated circuits is a fuse bond wire. If it's a gold bond wire, that means the device drew amp. If you replace that bond wire and put it back on the die, the part is good. So it goes to a low impedance state and draws a lot of current. Usually it draws it through the substrate so it can dissipate the power. You don't damage any of the junction structure. You get the part back. There is a fused open portion of the circuit but there is no permanent junction damage. In fact, we have a device that came off a board that exhibits exactly those characteristics.

MR. CHIU: Do you guys all understand how this parasitic comes in? We have a graph showing the PM junction.

MR. RIDDLE: We sent that in.

MR. ASHE: I don't particularly understand down to the PM junction level.

MR. RIDDLE: I will try to bring you up to speed a little bit without going into too much of the detail.

MR. POHIDA: I don't know if going deep into the detail would be meaningful.

MR. RIDDLE: The phenomenon exists.

MR. ASHE: What types of voltages are you applying here?

MR. RIDDLE: These are 5 volts. Operating voltage for these devices is 5 to 20. Most of these tests are done in the 12 volt range and the corresponding output was driven to a negative 2 or 3 volts. Most of the detail stuff is in my notes. We need some time to type that all up.

After the latch-up simulation, which is basically step 1, then we proceeded to some dropout testing. There was some concern that the DC had dropped out and the batteries were low and therefore a dip in the 12 volt supply could cause some problems. We didn't get any kind of latch-up out of that. We didn't get any other kinds of anomalies out of that.

We went in and did board level testing. We had the UPS A, B and G cards and a stock card, which is the newer version, and a test fixture. They say here lamp drivers, et cetera.

The A card, which is the one we brought out here, doesn't have any problems. The U10 4049 was damaged on card B. It turns out that damage is characteristic of latch-up. I have some photographs to show you on that.

No anomalies on card C, although I hadn't had the test fixture built up when I had card C and it may be beneficial to get it back. Card G is right now my current object of interest because the latches will not set on this card. I can introduce an input and you supposedly can take this input away and this thing stays triggered on. This card doesn't do that. There are some problems with the switch. I looked into the K1 relay, which is a reset relay. I took that relay off the board and it's good, but it still doesn't work. So there is some other bad stuff on this G card. We will get back on that tomorrow when I get it back out there.

MR. CHIU: As you recall, the G card performed differently during the event. Some lights didn't come on. The inverter logic light wasn't on after the event. So we tried to go into the board.

MR. RIDDLE: It is definitely curious and there is

definitely something going on on that board.

MR. ASHE: That was reported on the D unit. I thought you said you took the card out of the A unit.

MR. RIDDLE: Which one?

MR. ASHE: The actual hardware card you have came from the A unit.

MR. RIDDLE: I have two cards now. I have the A and the G card in my possession.

MR. ASHE: You said no logic light. I thought that was reported on the D unit.

MR. RIDDLE: The D and the G.

MR. ASHE: We don't have that on the G unit. As-found data suggests that the logic light was lit on the G unit.

MR. RIDDLE: I am using as my reference there root cause -- let's see. This might have been revised.

MR. CHIU: Yes.

MR. RIDDLE: There is a logic trip on A through D and there was no logic trip here. I am assuming there is no logic trip or they wouldn't have said no logic trip.

MR. ASHE: No logic trip is clearly on D but where is that on G?

MR. RIDDLE: It's not, but the ones that did have a logic trip say a logic trip. Inverter logic alarm is the same, I guess. From my conversation with them, inverter

logic alarm means it is the same as logic trip. You have that on these three; it is not on this one and it is not mentioned on this one. I agree. It's not mentioned on that one. I don't know if that's happened or not.

MR. ASHE: To me each one of these guys had that trip with the exception of D.

MR. CHIU: Only D.

MR. ASHE: Only D did not have it.

MR. RIDDLE: We misread that.

MR. ASHE: That's the way I interpret that.

MR. TERRY: Remember, Frank, D was reset.

MR. ASHE: I understand. It appears to indicate through various sources and onsite testing that D was manipulated a little bit prior that data being generated.

MR. CHIU: So the G card actually performed like an A card. Is that right?

MR. RIDDLE: The ovuv and the voltage differs, which the A card didn't get. We are saying this did have an inverter light.

MR. ROSENTHAL: The ovuv, according to the prints, is not a latching signal. It's a light that was observed at the time that they took the data, which is two hours into the event.

MR. RIDDLE: It shouldn't have been on.

MR. CHIU: It should have been off if there is no

latch.

MR. ASHE: I'm not sure that data was generated two hours into the event. It was generated two hours plus additional information from operations people who were in the area at T plus 30 minutes into the event.

MR. ROSENTHAL: Let's play this again. It's our understanding the people run downstairs. They manipulate 1D. They give up on trying to restore the unit as if it was a starter. They close that breaker. They then fan out and simply close the other CB4. That's our understanding. They try stuff. They give up on the stuff and close CB4. Then they fan out. They said that works. It's our understanding from the interviews that they don't mess with resetting, manipulating switches.

MR. JORDAN: They don't say that they do, but I don't know that we simply asked them each time, did you push any reset buttons. My understanding is they fanned out; once they learned the methodology of getting power back on, they just went back and did it.

MR. ASHE: I think there is evidence, though, the first person in the area clearly opened the cabinet doors.

MR. RIDDLE: All of them?

MR. ASHE: All of them. There is evidence that supports that. What he or she did or what was done once the doors were opened is very hazy.

MR. IBARRA: Who was the first one there?

MR. ASHE: Hansik. Spooner came later but Hansik seems to be the guy that was first on the scene. It is my belief, based on the transcript information and other sources, that he opened all the doors.

MR. ROSENTHAL: And nobody is taking notes at this time.

MR. ASHE: I think the data set that we have and the data set that you have in terms of the as-conditions of the light was generated by Mr. Bob Crandall, who in turn talked to Mr. Hansik, Mr. Spooner, the operators in the area immediately after. So it was based on their memories and what they recall they did or didn't do.

MR. TERRY: I would also add that there were certain observations that Bob Crandall did make.

MR. ROSENTHAL: Yes, but he's down at T plus two hours. He's the systems engineer and he'll do the best job he can. That's different from the operators running down under the stress of getting the unit back. I'm not faulting him.

We spent time with the drawings. It is my understanding that the ovuv and the thing marked "voltage difference" do not latch.

MR. TERRY: They are simply the status.

MR. ROSENTHAL: It's a status light and they see

it lit at that time.

MR. CHIU: So there is some question as to whether they were turned on or not.

MR. ASHE: That's what the bottom line is.

MR. ROSENTHAL: I'm sure they were on when the man looked and said they were on, but that doesn't mean that they were on at T plus 20 or at T plus 100 milliseconds. I forgot now when we were going through the drawings if we even said where they came from. With the unit restored that may be proper.

MR. CHIU: To make sure I understand, the module trip light was out and the inverter logic light was on T plus two.

MR. ASHE: To me the two important lights in all that data are the logic light and the trip light. The other differences are less important. I am not saying they are not important, but to me they are less important.

MR. CHIU: But based on what we observed or your interview notes, G and A,B,C, 3 UPS, those two lights are on.

MR. ASHE: That's correct. The only guy that didn't appear to have that light, which may or may not have been the case two cycles after this thing went down, was 1D. It did not have a logic trip light.

MR. RIDDLE: These might all be common, assuming D

was manipulated.

MR. ASHE: It could well be.

MR. RIDDLE: At the time of the event they could have all been the same.

MR. ASHE: Exactly.

MR. RIDDLE: That is part of why we got pulled in on the project.

MR. ASHE: It appears that we have supporting evidence that the D unit when the cabinet was open may have been manipulated or massaged a little bit more than some of the other units, which may or may not have made the lights disappear, come on, or what have you.

MR. RIDDLE: That supports our mission in that if we do a common mode, there has got to be a common source. That is what we are hunting down on the card chip level.

MR. ROSENTHAL: Just so we all know, the ovuv is on the horizontal set of lights, not on the A21 card, if I am not mistaken. Give me the card cage.

The ovuv is down here, not on this board. The voltage difference is also on -- there it is.

MR. RIDDLE: I haven't looked at how these signals are generated yet.

MR. ASHE: We also have diagrams that show those.

MR. RIDDLE: But your understanding is there is no way to latch those.

MR. ASHE: Basically that's right.

MR. ROSENTHAL: We went through the circuitry. We would have to go back to our transcripts.

MR. ASHE: There is one of these guys that latches up. I'm not sure which one. We will find that out and put it on here.

MR. ROSENTHAL: We looked at the drawings and the designers tell us that voltage difference and ovuv are not latching, according to my notes.

MR. ASHE: It's the transfer guy that latches, I believe; ovuv transfer will latch.

MR. ROSENTHAL: But output ovuv, no.

MR. RIDDLE: That's worth following up.

MR. ASHE: Why don't we pull the drawing.

MR. ROSENTHAL: Let's pull the drawing and resolve this.

MR. ASHE: I think that portion of the drawing was pretty simple.

Voltage difference. That's one guy. Output ovuv. That's two guys. Voltage difference and output ovuv. Let's trace this guy and see how he comes in here. He comes through here, through here, through here, and there is really nothing that latches.

MR. ROSENTHAL: But what is it looking at? What's its input?

MR. ASHE: That's all over here. Critical bus sensing, at least one.

What I think we are looking for in terms of a latch is a bistable that holds it in that condition. Clearly there isn't one that is associated with this guy. Would you agree, Jim? Do you see anything that could hold these guys?

MR. ROSENTHAL: At the time you make the observation CB1, CB2 and CB3 are open. So is it proper that you would have in fact seen it? If that's the case, why don't you see it on all of them?

MR. ASHE: I'm sorry, Jack. I didn't understand the question.

Jim, you don't see any latches in there.

MR. RIDDLE: I'm tracking it. I don't see any. I'm convinced there are no latches from there.

MR. ROSENTHAL: Three of the units were reinstated, were powered back up, restored.

MR. ASHE: That's how I understand it.

MR. ROSENTHAL: So at T plus two hours, why do I expect to see a light?

MR. TERRY: At T plus two hours they weren't restored. They made these observations before they were restored.

MR. ROSENTHAL: I'm sorry. Just before they were

restored the output of the inverter is zero and the transfer bus is powering everything. If they are looking at the normal output, they should see zero and you get a light by design. Is that consistent for undervoltage?

MR. CHIU: By why don't the other UPS's see that same thing?

MR. ROSENTHAL: You have got it on 1C, 1D, 1G; you do not have it on 1A and 1B.

MR. CHIU: And the rest of it has it.

MR. ROSENTHAL: Ovuv is on C, D and G.

MR. CHIU: So ovuv is C, D and G, not 1A and 1B.

MR. ROSENTHAL: According to our notes.

MR. CHIU: How confident are you with your notes? This could indicate there is an anomaly there. You interviewed a lot of people.

MR. JORDAN: This data came from Niagara Mohawk. When they went down there, supposedly the systems engineer gathered this data, like Frank said, either by visual observation before they transferred or by conversations with the people that went down there at T plus 30 minutes.

MR. ASHE: The ovuv could have well appeared on the 1D unit and not been captured at all.

MR. JORDAN: That data did not come out of interviews. We were not at that level.

MR. TERRY: I'm not sure either whether it was

two-hour data. I know on the others we based it more on what was observed a couple hours later and the fact that the operators indicated they didn't notice any of those status lights. It's worth checking.

MR. JORDAN: This data should reflect the same data that you have in your report; is that correct?

MR. TERRY: Yes. That's consistent. There were inconsistencies on ovuv in terms of what was observed.

MR. ROSENTHAL: What module is this on?

MR. ASHE: There is no number.

MR. ROSENTHAL: The drawing number is 110071222. It is the static bypass logic control card.

MR. RIDDLE: That slides in underneath. It is built in the back of there probably.

I think it is worth following up in that either all of them should have done it or none of them should have done it.

MR. ROSENTHAL: As I say, we can't see where they latch.

MR. POHIDA: What two voltages is the circuit looking at?

MR. IBARRA: The critical bus sensor.

MR. POHIDA: Is it the inverter output versus the maintenance bus?

MR. ASHE: Exactly.

MR. ROSENTHAL: What is it?

MR. IBARRA: Critical bus.

MR. ASHE: He's saying the voltage difference alarm, what is it monitoring?

MR. CHIU: Upstream so we can trace back to see if there is any latch upstream.

MR. ROSENTHAL: We can do that, maybe. We'll try. It's looking at this voltage versus what?

MR. ASHE: Versus the maintenance bus.

MR. ROSENTHAL: Is it?

MR. ASHE: Yes.

MR. ROSENTHAL: Or is it looking at this relative to a reference?

MR. ASHE: There is no reference there.

MR. ROSENTHAL: There could be a constant voltage drop in here.

MR. ASHE: But you have no v reference here.

MR. ROSENTHAL: I believe this is va to B; vc to A; vb to C.

MR. RIDDLE: This is monitoring the AC and then the different phase.

MR. ROSENTHAL: That's the bypassing sensing.

MR. RIDDLE: This card is symmetrical. You have two different channels you are looking at. You are looking at bus to bus. Is the input structure the same? That's the

same; that's the same; that's the same; that's the same. It sort of diverges a little bit after that. They probably come together and do common logic somewhere.

MR. ASHE: To make it really simple, it has got to be looking at the differences.

MR. RIDDLE: It's looking at the differences.

MR. ROSENTHAL: Phase by phase.

MR. ASHE: Yes.

MR. ROSENTHAL: The three phases are summed.

MR. ASHE: You are going to lock the transfer out.

MR. ROSENTHAL: This is AC over here and here I have got DC. So here I've got to build in some summing.

MR. RIDDLE: This is going to be a DC input to this. This is not going to be an AC. This is an op amp. This comparison circuitry vc to A is out here somewhere, because this is going to be a DC input.

MR. ASHE: I don't believe we have the drawings for that circuitry here either. What that is going to probably be is some type of sensing element that goes to those phases.

MR. RIDDLE: Yes, a differential amplifier.

MR. ROSENTHAL: We played games going back to this master drawing. I think that we had concluded, at least with the designers, that they didn't latch. Why don't we go on and if we have time, we can come back to that.

MR. CHIU: If you have a drawing, we can trace that back.

MR. RIDDLE: If this is getting a DC input that compares these two, that's going to be an analog feature. It's not going to be a digital feature back here somewhere driving an analog input.

MR. ASHE: But I'm not sure we go all the way back. These drawings will not go all the way back to exactly where it's sensed and the actual primary sensing element.

MR. RIDDLE: That is probably going to be an inductor, a coil around a phase wire somewhere.

MR. ASHE: And we don't have that.

MR. RIDDLE: Analog stuff usually doesn't latch.

MR. ASHE: I would like to offer a suggestion. Maybe we could trace it down on the break and see if we really have it or not.

MR. CHIU: We can do that. Whenever you have a drawing, we can trace that.

MR. RIDDLE: That is quite useful. Looking at ovuv, I can expand the scope of what I am doing around that.

Do you want me to finish my review?

MR. CHIU: Yes.

MR. RIDDLE: Like I said, my problem child here is the G board right now. I had that out. I tested the K1.

The push-button switch, when you release it, it should go closed, and it doesn't go closed. You have to really tap on the thing; it's crudded up inside. That is going to keep the latches from resetting.

MR. CHIU: Jim, at this point you are measuring the B board 4049 latch-up. Do you want to show them some pictures?

MR. RIDDLE: I will show you what is going on with the 4049. One of the reasons that Chong and I are definitely interested in coming back to the grounding scheme and groundside problems is that the damage that is on this particular chip and a couple of the others -- I have got three of each of these, so I am going to break them up into sets. I want Niagara to have a set and I want you guys to have a set.

This is the integrated circuit die. This guy here with the cutout is pin 1.

MR. ASHE: This was generated on a couple of the chips that were known bad?

MR. TERRY: There was some damage that occurred after this.

MR. ASHE: Recognizing that this is really not relatable to the event, though.

MR. RIDDLE: It is not related to the event?

MR. ROSENTHAL: Let's talk this out.

MR. CHIU: We had two chips analyzed. One chip is on the A20 board. Whether that is related to the event we don't know. But on A21 is the 4049. That's the chip here.

MR. ASHE: The only point I am trying to make is that the unit, after the event, was brought back up; it was working fine prior to failure of two chips. I am just passing that along.

MR. RIDDLE: One chip actually failed. The other, it turned out that it had not failed; it was just removed at the same time. That's the A20 failure, the two chips I got originally.

MR. ROSENTHAL: What UPS are we talking about now? The 1C?

MR. ASHE: That's correct.

MR. RIDDLE: This chip came out of the B unit.

MR. CHIU: And this chip is not one of the two chips you sent us.

MR. RIDDLE: I will go through the chronology of what happened. They sent me two burned up chips which they said were from an A20 card. We are still in the process of getting a good drawing. Then they sent me a new board. Then they sent me the B board. Then they sent me the G and the A boards. I sent the B board and the new board back.

Of the first two chips that I got, the 4049 was burned up and seriously overstressed. The first two chips

from the A20 were a 4049 and a 4011. The 4011 is a good chip. Basically they just shotgunned everything in the circuit path, which were those two, of which the 4049 is dead.

MR. ROSENTHAL: I want to get this on the transcript, because we are going to be re-reading this. As I remember it, we are troubleshooting the 1C.

MR. RIDDLE: Yes, those came out of the 1C.

MR. ROSENTHAL: It had been restored after the event and it was all running fine. We are putting cycles on the unit as we are testing it, right?

MR. RIDDLE: Yes.

MR. ROSENTHAL: A week later, or whatever it is, we pop what we thought were a couple of chips. Now you are saying one chip.

MR. RIDDLE: Yes. They removed chips, one of which is damaged.

MR. ROSENTHAL: So at least on the 1C those original two chips that we sent you failed. They may have been degraded all along.

MR. RIDDLE: That's what we presume.

MR. ROSENTHAL: At least one of them failed while we were doing troubleshoot testing a week after the event, or whatever it was.

MR. RIDDLE: Right. Apparently it was after a

series of tests and the system was sitting there. No one was manipulating the system when it zapped.

MR. ROSENTHAL: Right. We were physically there at the time.

MR. RIDDLE: We are operating under the assumption that the part was degraded. Let's go back to that before we go on to this.

On this device we have what is considered to be long-term heating, very long-term heating. This particular damage here, this is a plastic encapsulated part. This black material over here is indicative of the pyrolization of the plastic over the device. It takes seconds or minutes for this to cook in and pyrolize into carbon. This kind of damage where the metal alloys into the silicon took a long time. The initiating stress for this may have been a voltage transient, for which I don't have high mags here at this point. We are looking into a vdd to ground, some transient that initiated this, and this stuff took hold later on.

MR. JORDAN: When you say long term, are you talking about minutes or are you talking about months or are you talking about years?

MR. RIDDLE: Several seconds to a day. Not years. Years would be much more extensive with broad alloying over greater distances.

MR. ASHE: Do you have a slicing machine that slices the chip open? How do you get it open?

MR. RIDDLE: Crack the tops off. I break the top off and go into high magnification to look at it. On the plastic encapsulated ones you have to hit them with fuming nitric acid and basically dissolve away the plastic over the top.

On this 4049 we have evidence of some long-term overheating. Nothing on the 4011.

MR. ROSENTHAL: What temperature should these chips run at?

MR. RIDDLE: They should run at spec. They are rated from minus 55 to plus 125, or whatever. You can run them at 70 or 80 degrees C. I wouldn't run them above 100 degrees C for very long. CMOS doesn't dissipate a lot of power; it doesn't do a lot of self-heating. As long as you keep the junctions down below 125 or 150 C you're fine.

MR. POHIDA: What was the temperature inside the unit?

MR. CHIU: We don't know. We don't have the data.

MR. RIDDLE: I think it was 130.

MR. TERRY: I think they took some measurements back when they asked the vendor about it. I think Bob Crandall indicated it was around 130 F.

MR. ROSENTHAL: That is not necessarily the card

cage ambient temperature.

MR. RIDDLE: It is somewhat outside of where all the heat generating stuff is, all the transformers and stuff. The card cage is actually outside of that.

MR. ROSENTHAL: It's up above it and to the left.

MR. RIDDLE: But its ventilation is coming from the other side of the metal panel.

MR. ASHE: To make it clear and simple, these photos are from the 1B unit.

MR. RIDDLE: Right. The 1B card was sent to me; it didn't work; I took the chip out. This is classic SCR latch-up where metals fused. This is a die shot. One piece of the ground metal is fused right here. Ground metal also goes elsewhere. It comes out over here; it comes out over there; it goes through this.

One portion of the ground connection, right here, is fused open. I probed -- this is probing damage that I did. I set a needle down on here and measured. Both sides of this open circuit are connected to good junctions; no short circuits on the inboard side of any of this. If I reconnected this little piece of metal here, this part would work.

That is characteristic of latch-up that came in on the ground side, a transient that initiated the latch-up from the ground side. Again, the predominant damage on that

first chip is on the ground side as opposed to, say, zapping from inputs to outputs or a power overload from the plus side. That is what is leading us to wanting to go back and look pretty seriously at the grounding scheme, to make some ground measurements and calculate where the ground could have gone in a transient, raising the ground up over a long period of time or just a short period transient through the ground. I wouldn't say this is an open and shut case here. More analysis is required of the chip, but this is classic.

That is where that chip testing has led us and why we are curious about the ground setup.

MR. ROSENTHAL: That's the 4049 chip, also marked U10 on their drawings, on the A21 board of UPS 1B.

MR. RIDDLE: Yes.

We did some SEM shots just to prove that. This glass on here is really thick. It actually took us 40 kilovolts to punch through the glass. This is very old design. The date codes on these things are '79, '80 and '81. CMOS has been around for a while.

Another interesting point is older CMOS is more susceptible to latch-up. They have made design changes in the layout on these chips. Checking the new chips is just the first step. You have to go back to the same vintage chips.

MR. CHIU: The summary of those two tests -- On

the first chip, 1C, we don't know whether it was during the test or during the event. That's unknown. The second chip came in. At that point we went back to review their test sequence to see whether they ever opened up the ground lead or injected voltage through the ground side to do some tests. We have been told there is no such test. So that led us to the fact in order to have that ground side get zapped it has to have a voltage.

MR. RIDDLE: There are enough clues in this damage to indicate that things happened on the ground side.

MR. POHIDA: You are saying that you are convinced that there was something on the ground based on the boards that you have seen?

MR. CHIU: Yes.

MR. TERRY: At some point in time.

MR. RIDDLE: We are convinced that the damage to these chips was initiated by some upset on the ground side of the chip. Where the ground side of the chip is in relation to the big ground or the digital ground, that still has to be followed up.

MR. ASHE: Could that have occurred on restoration, though?

MR. RIDDLE: Perhaps. I haven't looked at that.

MR. ASHE: You can't pinpoint the time at which it occurred, though, can you?

MR. RIDDLE: No.

MR. ASHE: It could have occurred during manipulations of the unit during restoration, particularly by people who are not familiar perhaps with the intricate steps and details necessary to do it.

MR. RIDDLE: This damage, yes. This may not be relevant, but we have to follow through on it.

MR. CHIU: The point is we don't know if the damage was done during transient or during a manipulation, but we do know somehow the voltage goes through the ground side, goes to a transistor. If you design circuitry right, you should not have voltage come through the ground and hit your transistor like that. Just like your computer. You always have a surge protector to protect your ground side. It's the same logic.

MR. POHIDA: The operators shouldn't be able to damage the logic if they follow procedures, if the unit is designed correctly.

MR. ASHE: They had no procedure to do this with, so they are off normal procedure. The issue about procedures with specific steps, I think we pretty much understand that aspect.

MR. RIDDLE: In terms of generating overstress on this particular chip and no other, you will note that this chip is buried in the circuitry. You have to go through

several chips from either direction to get to this guy to blast him. This chip doesn't see the outside world. It's connected to another chip on one side and this other chip on that side. There are no outside pins where somebody could grab on and zap it or that sort of thing.

One of the other points about SCR is even with this fused open this chip could work marginally. What this multiple ground lines metalization does is it interties a portion of the circuit to make sure they have a hard and fast ground connection between them. When that is fused open, the device becomes very much more sensitive to latch-up. So this could in fact work in this condition unless it got a mild upset, like a switching condition.

MR. ASHE: There is no way to pinpoint the time, though.

MR. RIDDLE: On this, no.

MR. ASHE: If the unit was working from the outside satisfactorily, this could have been there two days before the event and nobody would have known anything.

MR. RIDDLE: That's possible. It would not make my day. It's physically possible. In fact, I have another chip, which I didn't bring the data on. It is evident that it is internally contaminated, which happened during manufacture. I haven't actually analyzed that particular foreign material, but there is a big splotch of junk on

there. From my military background, that can cause stray leakage through that chip. That's random type damage. Having that on all five UPS's is a very low probability.

Your point is well taken in that this may be latent. I took the U10 chips off of the A unit and the G unit and opened them up. Even though the A and the G unit work, I took these particular chips off and opened them up. No damage. So we are following that logical trail there. I took the same components -- one is a Motorola and one is an RCA -- off of two other units, de-lidded them; didn't see any anomalies.

That is the kind of reasoning we are applying to this and testing that we are formulating. When we do see something like this, we run it to ground.

MR. ASHE: Let me understand what you have. I'm not sure I understand exactly the hardware that you actually have from the units that were in operation during the event. I know for a fact you got two chips. I know for a fact you have two batteries. What else besides that do you have from the actual units that were installed?

MR. RIDDLE: A21 from the A unit, the B unit and the G unit. The B card has been returned. I changed this chip, confirmed that the board worked, and sent it back to Niagara Mohawk. I think they are going to send it to Exide and confirm that the board is fully functional.

MR. ASHE: So really they have replaced all those boards in the unit now. The ones that you took have replacements on site now, physically installed.

MR. TERRY: Right.

MR. RIDDLE: They got some new boards and plugged them in.

I have two boards now. I had B. I returned it. I have A and G. I haven't seen C and D. We have proposed to look at all of them.

MR. ASHE: You are talking A20 boards?

MR. RIDDLE: These are all A21 boards, this board here.

MR. ASHE: The A21 board from A and G units is what you have now.

MR. RIDDLE: Currently. The A card is here. We can look at that. The G unit is the one that doesn't latch. I am working on that problem.

MR. ROSENTHAL: The postulate that I am now hearing is that by design you would have generated a PSF signal which would have latched the 4044 chip, which would have ultimately resulted in an SSTR signal and the observed phenomena. Under that condition we should have had the D9 light as well as the other logic lights. Now the postulate is, wait a minute, maybe you never generated the PSF signal, but rather the 4049 chip changed state.

MR. RIDDLE: Based on a transient introduction from power.

MR. ROSENTHAL: That would have lit the logic lights, caused the units to trip out. These RS chips would never have changed state and these lights would never have come on.

MR. CHIU: That is just one scenario.

MR. RIDDLE: That is one scenario.

MR. CHIU: We have other scenarios.

MR. TERRY: You guys are postulating that PSF was never generated.

MR. RIDDLE: That's not one we have considered but that is just as valid, that these chips burned up downstream or latched up downstream.

MR. ROSENTHAL: If I have A10, the 4049 chip, changing state due to a ground fault or other phenomena, that will cause the SSTR to generate a signal and it will trip out the units, as we observed, or light those lights.

MR. RIDDLE: That's possible.

MR. ROSENTHAL: When I come back I see these lit; I don't see that lit; I'm happy.

MR. POHIDA: In this scenario the 20 volt supply may not have dropped down to the 16 or 17 volt range. Right, Frank?

MR. ASHE: That is what it is leading to as a

possibility.

MR. ROSENTHAL: On the millisecond or the first couple of cycles or less, this perturbation caused this to latch, which caused the unit to trip off, and I never generated this which caused this light to come on, and that's why I never observed this light. Is there another way? I thought that is what I was hearing from you.

MR. CHIU: Let's look at it from a distance to see what refuting evidence there is on this scenario. That's a possibility.

MR. ROSENTHAL: If a cycle or two later or a fraction of a cycle later the PSF was generated, then that should have changed the 4044 and flipped that light on.

MR. RIDDLE: The first hypothesis that we started to follow up was that the PSF was generated. These were reset by transient means; these were latched up by the same transient means. So you got a signal. These were set. You got a system upset with noise injection either through ground or between the phases, and that reset these guys and locked these guys up. The direct evidence is going to tell us whether this was on or off. The direct evidence is these are on and this isn't on and it should be. So there are two ways. You can come in upstream and blast it or you can come in through here, set everything, and then knock this out.

MR. CHIU: Right. There are two possibilities.

MR. RIDDLE: And his possibility, which is a third one, which is nothing ever happened.

The original first point was the 4049's are the most susceptible chip to latch-up. From my testing, they are the easiest chips to make go off. They are the first thing in this circuit -- well, there are a couple down here. These are driving timers, though.

MR. CHIU: One question. You are leading us in terms of system data. When the transient occurred, the AC power dropped. At the same time the DC power was dropped. Do you know how low the DC power dropped? We don't have a power supply.

MR. ROSENTHAL: We have asked for that.

MR. RIDDLE: Your 6 cycle, 100 millisecond event, the capacitor C4 will hold that power supply up for 100 milliseconds. It will hold the card up. The card doesn't draw too much juice.

MR. ASHE: I think we have concluded that through other ways. We are on that same trail and we have concluded that. To answer your question, an exact value of how low it actually dropped we don't have.

MR. CHIU: Do we have any way we can have that power supply to supply a DC transient, 6 cycle, 9 cycle, 10 cycle, to see the DC power drop? I tried to obtain that data. I don't have that power supply. Some of our

consultants will tell you that you will never drop that voltage down to 17 volts. Some other thought processes are, hey, it will drop. It is almost like everybody has an opinion but no data.

MR. RIDDLE: Another thing on your hit list going out there is to go through the ground thing and go through the power supply stuff out there.

MR. ROSENTHAL: Jim, why don't you give us a couple of minutes. We kept hearing 6 cycles to clear and 6 cycles to reload. When you were looking at the UAT, it was a little different already.

MR. STONER: The breaker on the 13 KV switchgear is a 5 cycle breaker as opposed to a 2 cycle breaker. So you would expect the generator to maintain the voltage after the Scriber breaker opens. So you are really talking about 3 cycles until the voltage is restored from the other source. Of course that voltage won't drop to zero because you have induction machines which become induction generators.

MR. CHIU: Jim, do you have any idea or data to see how maintenance power dropped, voltage dropped? Do you have data?

MR. STONER: We have no recorded data. We have calculated data from Niagara Mohawk.

MR. ROSENTHAL: You have that information.

MR. RIDDLE: I think it has been provided to us.

MR. TERRY: I would like to go back to this time thing. We did some testing on a unit where we dropped power on a quick pulse and we measured it. That was between 100 and 200 milliseconds. That will trip the units. We got all the indications. We got PSF and everything else on that.

MR. CHIU: So you do have test data.

MR. TERRY: We were talking timing. I just wanted to make that clear. With no batteries in there, if you do a quick switch -- granted, that is not the exact pulse; we all understand that -- but I think there was some question on whether it would drop fast enough, 100 or so milliseconds. What our test data tells us is, yes, with degraded batteries that could cause the PSF to be initiated.

MR. ROSENTHAL: But the lights always work, as you would expect.

MR. TERRY: That was the anomaly, right. I'm just talking about the trip signal, the timing.

MR. ROSENTHAL: On the 1C we dropped the 110 v phase input voltage with a VARIAC slowly down and it trips out and K5 never transfers, et cetera. Then we do a test where we bring the voltage back up.

MR. ASHE: You have a crank-down test.

MR. ROSENTHAL: Crank-down test.

MR. ASHE: You crank it down all the way until the

K5 relay drops out. That is one voltage value of 45 volts AC, approximately.

The other thing that was meaningful in the drop-down test, PSB1 and PSB2 have a sharp drop-off following a decrease in voltage from approximately 96 or 95 volts. In other words, they seem to be well regulated as long as the voltage stays above 95 or 96 volts. Once you decrease their input to below that value it tends to drop off very sharply.

MR. ROSENTHAL: That is a quasi-static test.

MR. ASHE: It is not simulating the event at all but it is some actual testing information.

MR. ROSENTHAL: Niagara's calculations are that it would have dropped below that voltage but above the K5. That is 65 volts.

MR. TERRY: That's the best average. We had a range.

MR. ROSENTHAL: Now you turn the VARIAC back up and you are at 110 volts?

MR. ASHE: 120 volts.

MR. ROSENTHAL: There is a little toggle switch on the VARIAC. They flipped it. As I remember the scope traces at the time, that is about 150 milliseconds.

MR. TERRY: I think the quickest we could do it was closer to 100 or around 200. That's right. The nominal value is about 150.

MR. ROSENTHAL: It was dual traced. The power supply goes and you generate the PSF. These lights work and you trip the unit out on the 1C.

On the 1D, you do the VARIAC, drop the voltage. Everything is consistent. Bring it back up, you flip the toggle switch, and as I remember, it didn't trip out.

MR. ASHE: That's correct.

MR. POHIDA: You didn't generate a PSF.

MR. ROSENTHAL: We didn't have a lead on PSF. I'm a lot smarter now than I was two weeks ago.

MR. ASHE: The reason the unit didn't trip on the 1D is believed to be because when that test was repeated on 1D the PSB DC voltage of 20 volts did not decrease below the trip value. How do we know the trip value? The trip value on the 1D was experimentally determined with actual installed equipment. You slowly crank down the VARIAC input to PSB-1, and then at the value that the thing tripped you record it.

MR. ROSENTHAL: That value is what, 16 or 17 volts DC?

MR. ASHE: I don't recall exactly what the value is. We had a range of values of 16.5 to 17.3 for trip values.

On the fast test, after that value had been determined on the 1D experimentally by connecting up

oscilloscopes and digital voltmeters, the fast test was done. The unit did not trip. It was determined with the scope, however, that the DC output never dropped below its experimentally determined trip value.

MR. CHIU: So some capacitor was holding it up.

MR. ASHE: Something was holding it up.

MR. ROSENTHAL: Now I have a postulate here that is cockamamie, and it goes something like this. You degrade the power input to the power supply. The power supply is still putting out some number of amperes. You deplete the stored energy in the capacitor of that power supply. It's all charged up. If you do it fast enough, you never deplete the stored energy in that capacitor and you don't generate the PSF. If it's a cycle or two later into the event, you are still holding up all these loads, you still have 12 volts, you still have 5 volts, but you are draining down the capacitor on the power supply, and then if you do it, it might flip again. So that is why we have asked -- and Exide was staring at us like we were nuts -- for the schematic for the power supply, the little 20 volts, which they buy as piece parts.

MR. ASHE: By the way, we didn't get that.

MR. ROSENTHAL: We don't have it yet?

MR. ASHE: We did not get that.

MR. TERRY: They said they were going to look and

see if they had one. They said they came in a box.

MR. ASHE: Right. It was my understanding they were going to go back to Raleigh. On the box with the power supply, the details of that schematic is there, and they were going to give us one of those off the box.

MR. ROSENTHAL: That may explain the differences between the simulated test on the C and the D.

MR. CHIU: This is crucial data. Carl was mentioning that Exide has one of the simulation channels. Maybe we can go to the simulation channel and measure the transfer function between AC and DC. Once you get that transfer function you will know a lot of things.

MR. ROSENTHAL: But none of that explains the light bulbs.

MR. ASHE: As a point of information it may be helpful. The 1C and 1D units had the most testing in terms of actual recorded data or scope traces. The remaining units have had less extensive testing.

MR. RIDDLE: The B unit was reset and operated and then no testing was done on it before I obtained the card that had this chip on it, right? None of this up and down?

MR. TERRY: Right.

MR. ROSENTHAL: Wait a minute. I thought we quarantined it.

MR. ASHE: No. He's talking about what testing

was done. The transient testing with the switches was terminated after 1D. That's our understanding. If he has a different understanding, then we need to clarify that.

MR. TERRY: That's right.

MR. ASHE: We did the transient testing on 1C; we did it on 1D. After that, the other units weren't subjected to that.

MR. ROSENTHAL: We still dropped the voltage slowly in those games.

MR. ASHE: With the exception of 1G.

MR. ROSENTHAL: We didn't want to kill 1G, and 1A and 1B have such critical loads that we didn't want to put the plant in another transient.

MR. ASHE: Basically, the other units have three tests.

There was verification that power supply was coming in on the B phase; actual verification with instrumentation that's coming in on the B phase.

There was verification of the DC trip value.

MR. RIDDLE: Where is that?

MR. ASHE: The DC trip value. We are talking about plus or minus 20 volts.

MR. RIDDLE: But you measured that in terms of the AC dip.

MR. ASHE: You measured the actual DC at which it

tripped. The way you did that was to crank down on the AC and as the power supply lost its regulation it couldn't hold the DC, so the DC would come down.

MR. ROSENTHAL: You had your digital voltmeter right across the output.

MR. ASHE: Plus or minus 20.

MR. RIDDLE: This is plus 20 and this is ground.

MR. ROSENTHAL: I'm between ground and plus 20.

MR. RIDDLE: You've got it. Which is the same as right here.

MR. ASHE: We are going to the 20 volt input. The plus and minus DC value was measured and that varied from 19.9 to 21.5 with some variation as you moved from unit to unit.

That is three tests and there was another one on it, too. It was the dropout on K5. That was another one. You verified the actual AC input voltage required for K5 to drop out.

MR. CHIU: In essence, what we have here is PSF could have been generated for all five UPS. We don't have refuting evidence.

MR. ASHE: Not if you say 100 percent.

MR. TERRY: We don't know exactly what was there. We do know if the voltage had dropped off that it would generate that PSF and we were able to demonstrate that you

with a quick, short pulse you could generate the PSF where all the lights were right and all that kind of stuff. That's kind of what we know. That is part of the dilemma here. Exactly what was happening at the event is confusing because of the fact that a couple lights were lit and one light wasn't.

MR. ASHE: My bottom line through all the testing may be helpful to you. The reason we couldn't duplicate the actual tripping in the unit is because we weren't simulating the conditions close enough. That may be helpful; it may not. The testing that was done on the units, in my view, does not simulate physical insight into the event since there is really no recorded data in plant that I'm aware of.

MR. RIDDLE: That was confirmed with our testing. We did DC dropout in a more controlled fashion with square wave pulses, dumping those on the DC, bringing the output down from 20 milliseconds out to a couple seconds. We could never get the card to do what it was reported to have done with this light off and those indications on. We basically did the microscopic version of what you did on the whole system on the card using the test rig that was shown.

MR. ROSENTHAL: When you drop the 20 volts here, what do you get in terms of 12 volts here?

MR. POHIDA: You will still get 12 volts until it comes down to 14 volts or so.

MR. RIDDLE: Correct. You have this capacitor here holding that up.

MR. ROSENTHAL: C1 or C4?

MR. RIDDLE: C1 is holding up the 20 volts.

MR. ROSENTHAL: C4 is holding up the 12?

MR. RIDDLE: Yes. That is after the post-regulator. Your 20 volts comes in here. This is a 5 volt regulator. It goes off to a 5 volt bus. The only thing that drives is the lamps. Then it goes to the 12 volt regulator. It is held up right here, and that drives all the chips.

MR. ROSENTHAL: So I have got good plus 12 to the chips until I get 14 volts here, but I get 17 volts here, which will drive this.

MR. TERRY: You will get a PSF at about 17. A little less, maybe.

MR. RIDDLE: PSF is one of the lines that disturbs me, because it doesn't have the 12; it doesn't have the pull-up to the 12 volts. Floating inputs on CMOS bugged me. There's was another one. This WF knot has the same problem, no pull-up. Why all of the other ones do and these two don't is another lead.

MR. ROSENTHAL: You know that on the board?

MR. RIDDLE: Yes. I measured it. There's no resistor here. I measured the 12 volts to the input here.

On the specific board it has been confirmed that that is the case. My CMOS background says you don't want to float inputs. Depending on what happened backstream on the A20 board, this could cause some problems.

MR. CHIU: What kind of problem could it cause?

MR. RIDDLE: If you float the input, it will invalidate this logic. I am going to bring in another concept here for CMOS, which is tristate. Tristate is a condition when you have -- I will just draw a voltage chart. It won't be exact in terms of numbers.

On tristate, you have a logic thing here, input here, output here. Starting out at zero volts and then, say, for sake of argument, 5 volts here so you can use TTL numbers, you will have a range here and a range here. This is true; this is false; and the same with the output. True and false here. What this does to the output is it makes the output high impedance, i.e., open. If the high impedance goes open and there is no resistor here to pull this PSF up, then this input sees high impedance. This could see whatever it wants to see, but it could see enough to bring it into this region and play games all the way down the circuit.

The way to get that light to go off and have the other ones stay on, I think, since I had lowered the voltage down to about 4.5 volts, I had driven a bunch of these chips

into tristate mode when I lifted the ground. I haven't analyzed exactly what is going on in the movie. I presented that more or less as a clue, previews of coming attractions, so to speak. This tristate region can generate strangeness on the output in terms of this high impedance.

You were following this up as well with Exide. What did they have to say about it?

MR. POHIDA: I brought up the issue of floating inputs to CMOS gates. I wasn't concerned with PSF. It was on some other board where they had designed the unit to possibly be controlled from the controller which they weren't using.

MR. RIDDLE: Not plugged in, right?

MR. POHIDA: It was not plugged in.

MR. RIDDLE: What you need to do is terminate pins that you are not using. You have to tie them off. It is stated in that little write-up on reliability. It says one of the design guidelines for CMOS is "thou shall not float."

MR. POHIDA: You talk about this tristate effect. My experience with CMOS is if you let it float, an input float, the voltage can then float to any voltage. If it floats to a threshold voltage, I thought that the CMOS could start to oscillate.

MR. RIDDLE: That's possible.

MR. POHIDA: Then that can permeate through all

the circuitry through noise, I would think.

MR. RIDDLE: Yes.

MR. POHIDA: Also, the power consumption of that chip goes up.

I just think the fact that they have inputs floating is just asking for trouble.

MR. RIDDLE: Yes.

MR. POHIDA: I don't know about PSF. I don't really know where it comes from. We keep saying A20. We tried to track that yesterday.

MR. ROSENTHAL: Why don't we take a break.

[Recess.]

MR. CHIU: One thing I want to just clarify, and I worked with Jim for a long time. When we go into the circuitry -- and often times Jim will get excited and it we have adjectives that come out. It will be all adjectives. We only look at data impossibilities.

MR. RIDDLE: Nobody designs a perfect circuit. So, every designer will say there's something wrong with everybody else's design.

MR. CHIU: It's very common, and especially being a failure analyst there is a tendency of doing that. We are not criticizing the 1972 design as long as it works. We take all the anomalies, the cause for anomaly -- that's the purpose.

MR. RIDDLE: I think we are looking at possibilities in terms of the tristate mode, the latchup mode, the power imbalance oscillation mode. I think those should be run down. They may occur during this unusual event, and they may give us some clues back to what our lighting scheme is. In general, the circuit works.

MR. CHIU: Do you want to go through that? That's part of our testing later on. Maybe we can go through these three pages.

MR. RIDDLE: Do you want to finish the rest of that?

MR. CHIU: Yes, let's finish that, so you know where we are at this time.

MR. RIDDLE: Where were we, at Page 2. We did the functional testing on A and we were able to do the tests that you had seen on the video there. My feeling is now, although I have to go back and confirm it, that we may be in a tristate mode to make that happen. High speed transient testing is one of the things that we want to follow up on, especially on the power inputs and in reference to ground, to follow up some of the background that Chong is doing in terms of ground loops and those type of problems.

I guess the preliminary conclusions from the chip data or the negative voltage on the outputs of the 4049's will invariably cause the chips to latchup. That is clue

number one, the 4049's are susceptible and they are very susceptible from the ground side. Injecting negative voltage into the output is the same thing as raising the ground voltage above the output. Those are identical functions. You are biasing the same diodes.

We know the 4049's are susceptible. We have two blown 4049's to demonstrate that they can be blown in this circuit probably by that means, since that is the simplest and most direct means. We can duplicate the initial failure condition and reported lamp settings but the unlikely conditions have to be initiated to do that, although it does indicate the circuit can be coaxed into misbehaving.

The following samples here have been submitted for lab analysis: the battery pack; the two IC's; the 4049 from B, A and G; and, the relay in the switch from G are going to be extracted. That has been done looking at that, and the G still has a problem in that the latches won't latch. Then it goes to the results.

One of the batteries has been analyzed thoroughly and just determined that it just failed -- died out from old age. We added water to it to recharge it and it wouldn't hold a charge.

MR. CHIU: It's plated out of --

MR. RIDDLE: It's plated out to the point where you can't break it down anymore and reverse the reaction and

turn it back into sulfuric acid. This is typical of old age, where that has been confirmed.

4011 from the A20 is good. The 4049 is bad, catastrophic failure. The damages induced into the power lines VSS or VVD, that hasn't been completely clarified. Circuit analysis is pending on that. The electrical testing, you have seen the pictures of that, of the latchup characteristic coming from the negative side.

We did electrical testing on two other 4049's from the same -- these were from the A and the G board. We opened them up and didn't get any damage. Then we go into the UPSG, has an intermittent open circuit. Normally closed condition to provide continuous signals for 4044's to reset through K1. That is indicated by the fact that I can't set any of the lamps on the G card. We are continuing analysis on that.

The preliminary conclusions are there that of the two damaged 4049's they seem to be more on the ground side, indicative of latchup and possibly transients. Again, from the ground side, a conclusion would be that at least one of the batteries failed due to old age. The UPSG failure seems to have a problem with the push button switch. I know from after I wrote this up now that there are also some other problems on the board. We are on those next week.

That's basically what our situation here is. I

think the thing that we have put off -- we have gone back and done a bunch of this slow voltage dropout testing. It might be useful to do that on this board and a few other boards where people have questions and get some real hard DC values in terms of how long it takes for the 12 volts to dropout and such. What I would like --

MR. TERRY: Which board do you mean, the A21?

MR. RIDDLE: This board here, the A18 and maybe the A21. We are having questions about several boards. At least it plugs some numbers in. What I would really like to do is get back onto the high speed noise transient testing, dumping high frequency garbage in on the power lines and the inputs and outputs and see if I can get something to happen in terms of concept of oscillation or the concept of inducing the latchup downstream on the A21 board.

I see those as immediate actions. It looks like our scope is expanding to look at how some of these other boards are interacting.

MR. CHIU: What it does is, this is in early plant that we have. It is weird. It was asked by Nine Mile Point senior management is to go down to the detail level, subcomponent level, turn every stone. In our early plant we do have this transient as part of our plant and tristate, those are the things we plan to do.

We may look at other boards because we set up a

board cast, and it may be easy to do that with other boards if possible with Nine Mile Point's agreement. The bottom line there is hopefully in about a week or two weeks we can explain the anomaly -- that's the key. The next stage Carl and myself was talking about is -- after we are done with board test we find a scenario which are more feasible than the others, and that scenario will be brought to the simulation channel and turn it on.

MR. RIDDLE: The manufacturer has a system that we can go in and beat up on.

MR. CHIU: Yes, simulation channel.

MR. TERRY: At Raleigh, yes. Something pretty close, I think. At least something that has this control kind of thing. One of the things -- when we talked today we need to look at this thing probably as a system more so than each board at a time. There is a lot going on during these transients. We are just coming up with plausible explanations right now. It's not really the full --

MR. ASHE: Your preliminary analysis on the chip level, what is the key? Is there anything that you have identified that is concrete that would lend itself to the trip not functioning?

MR. RIDDLE: Which trip?

MR. ASHE: The chip, chip level.

MR. RIDDLE: The chip not functioning or the trip

not functioning?

MR. ASHE: The chip itself. In other words, a chip can be degraded but it can still function.

MR. RIDDLE: Yes.

MR. ASHE: In your preliminary analysis, have you come up with one, two, three items in which you feel that a chip itself -- of the ones that you have looked at -- may suggest that there are other chips that may not do their functions?

MR. RIDDLE: The latchup testing could be extreme -- I mean the latching up of a chip can cause various degrees of damage to where it's melted open traces or thinned out traces. There is always a possibility of some damage. However, looking at some of the other chips from the same circuit locations as the failed chips, we didn't see any damage at all.

The chips that do have the damage are catastrophically degraded. I would say the chip was hit and there was enough power available so that the chip is going to be bad. The damage on the two chips that we have analyzed is in sense, enough to make the chip totally non-functional as opposed to degraded. That would come up just during a basic exercise of all functions.

We have talked to Nine Mile about it. You might want to exercise the logic and just walk through it.

MR. ASHE: What I am going to is, there is no real reason to expand the chip investigation at this time; take more chips?

MR. RIDDLE: No, not at random. There is reason to investigate the G Board and find out what's going on, that there might be a chip problem there. I wouldn't want to start pulling boards out and taking chips apart just statistically. There, I don't see any --

MR. ASHE: I was thinking maybe there may have been two points that you saw in the ones that you did do that may suggest something about a lot of the ones that you haven't even looked at. I think what you are saying is that at this point you need to look into the G Board a little bit further. In terms of one or two issues there doesn't seem to be anything at this time identified.

MR. RIDDLE: I don't see anything that I would say wow, we are at big risk here, there may be something wrong with all these chips. I haven't seen any evidence of that to where I would raise a big alarm flag and say wow, we have to take every chip apart and find out what's going on. There are some failure mechanisms and types of damage where you look at it and go yes. For instance, lateral arc overs, inputs and outputs, that type of a problem. Once you see those on a couple of chips you know that they have scurried around the whole circuit.

I haven't seen any of that, so that doesn't scare me right now. We will see what happens.

MR. ASHE: Do you have direct access to Exide?

MR. RIDDLE: No. I guess I need permission from these guys.

MR. TERRY: We will work with them on that.

MR. ASHE: Okay.

MR. RIDDLE: I don't know how much I want to expand my scope. There is probably some pretty hot shot designers over at Exide. My expertise is in the failure analysis side of it. I don't really want to go in there and start beating up on the guys that designed the board. That's not my area of expertise.

MR. ASHE: Some of the things in terms of just information might be helpful.

MR. RIDDLE: Yes.

MR. ASHE: Not in a critical sense, but just obtain information. That's the kind of light I was using that in, not so much that you are going to go in there and criticize somebody's design. It may be helpful if you got one or two pieces of information about it. I was just curious that you have direct access.

MR. RIDDLE: I guess I can get that. My mission is still from John, is to look at the lights to go on and off and all the possibilities to follow that up on, which is

-- I am doing that in a diligent manner.

MR. CHIU: That is our mission. If it requires to go to Exide to review their data sheet or expand the study a little bit more another board, that would be part of the mission. Our job is to turn every stone, to make sure we don't leave anything out. That mission is still on. We don't discount possibilities at all. Don't mistake my earlier statement about we try to -- it just from our point of view we are failure analysts, we are not designers.

I want to make sure that everybody understands where is our limit. Knowing that limit, we can do our mission in a more effective way.

MR. ROSENTHAL: I am very glad that you are working the problem out. I feel if you weren't working the problem we would have to find somebody to assist us to work the problem. It may be appropriate for me over time for me to fly some people out to you. We would always -- we will work through Niagra Mohawk just to keep the communications going. I have no problem with that. As time goes by, that may be very appropriate. Similarly, if you go down to Raleigh to Exide doing some testing, I think I would like to accompany that.

Can you give me just a couple of minutes again on tristate and latchup.

MR. CHIU: There's a blackboard if you want to use

it.

MR. ROSENTHAL: I understood the C-MOS logic, if you ride around the point you could oscillate on the input. I always thought that meant the output we go hard one, hard zero, and oscillate back and forth. What you are telling me is that there is another mode.

MR. RIDDLE: Let me see if they have a work estimation here that I can derive. I am not a designer, so I don't want to explain this in an incorrect way.

MR. ROSENTHAL: If that's public literature, maybe all you do is xerox it and share it with us.

MR. RIDDLE: I already sent a fax of this to you that talks to you in technical -- it basically goes through all of the parameters here. Let's see if there's a section here on the tristate. There's a section here, 119, on the SCR latchup mode.

MR. TERRY: Jack, if I understand your question, just looking at this input here, let's say this was switching back and forth. Your question is, does that mean that this keeps switching back and forth and that keeps switching back and forth, and on and on down?

MR. ROSENTHAL: Right. I thought that this would --If this sits right around the transition point, I was under the impression that this would go hard high, hard low but oscillate. Now what I think I am hearing is, no there

is still another mode where there is nothing.

MR. CHIU: Which board is that?

MR. RIDDLE: A18.

MR. TERRY: I am just taking that as a starting point. I think there was a question, maybe this was changing. So what does that mean -- I am just taking that as an example on downstream.

MR. ROSENTHAL: It seems to me the only way that you can explain it is to say that a PSF was not generated --

MR. CHIU: We have three scenarios.

MR. RIDDLE: There are three possible scenarios.

MR. CHIU: We will write it down for you.

MR. ROSENTHAL: He's going to use the board. The professor, go ahead.

MR. CHIU: If you have any more scenarios, let us know and we will discuss it. One, the PSF not be generated. In 4049 you can latchup. That's what the problem was. The second one is PSF generated, lamp on the PS light reset by K1. MR. ROSENTHAL: By K1 on the A21 board.

MR. CHIU: A21 board, yes. That can also cause the situation we see. The third one is the board characteristic, which is dual transient. I hear you talk about oscillating -- OPS oscillating -- tristate. There is only three possibilities that we talk about.

MR. ROSENTHAL: On the third one with the board

doing its funny thing, PSF would not be generated again or may or may not have been?

MR. CHIU: Maybe the board do funny things. PSF may generate it but the DS light doesn't get generated. You oscillate and signals the PSF, but didn't trigger everything else. So, only one signal goes through PSF, turn on all the lights. All the rest of it does not turn up because they are just not reaching that state.

MR. ROSENTHAL: SSTR, the output of the A21 board, was generated. Do we all think that occurred and stated its switch position long enough to pick up K1, 2, 3 on the A27 module. Is there any doubt over that?

MR. CHIU: We did review that, but it looks for one reason it's illogical.

MR. TERRY: We know the breakers change, we know that.

MR. CHIU: That one I think is based on what data you have. That leaves the from our study and your study, there is no reason to doubt it right now. There is no reason to doubt that, we didn't have none.

MR. POHIDA: Number three includes ground transients.

MR. CHIU: Actually, this one and this one, both.

MR. POHIDA: Number two, DS light. I am sorry, I don't know --

MR. CHIU: DS light is all those lights that are the light right here.

MR. POHIDA: On the card?

MR. CHIU: On the card.

MR. TERRY: They are directly connected to that 4044 latch through --

MR. POHIDA: How do you explain what is reset by K1. I guess I don't understand that.

MR. CHIU: What we can do is, we can -- Jim, you did some test on reset. Can you mention that? The test was reset of K1.

MR. RIDDLE: K1, when you drop a voltage down below a certain -- I have some inconsistencies there -- essentially you have a K1 relay here that is powered. You drop the DC down. When it's powered up this is held open. Then, when you drop the power this closes and that goes in and resets all of the latches. This goes to the set.

MR. POHIDA: K1 is just the reset.

MR. RIDDLE: It's just a reset button. It also uses it for a lamp test, so it has been wired up. On the newer version you have two push buttons and one is a lamp test and one is a reset. On the older version here you have a mod -- the older version, this is the switch one and K1 relay here. On the older version they have done this jumper mod where they have cut this trace and wired into the

switch.

MR. ASHE: Why did they do that wire mod in the back, do you know?

MR. RIDDLE: Because they wanted to be able to do a lamp test and reset at the same time.

MR. ASHE: Got it.

MR. RIDDLE: On the newer version on the universal board, there is two of these buttons next to each other.

MR. POHIDA: You are saying that K1 may have been affected by voltage drop?

MR. RIDDLE: K1 drops out at 12 or something volts. It will drop out and reset all this stuff.

MR. ROSENTHAL: Just so that we have our notes, on the 21 board?

MR. TERRY: Right.

MR. RIDDLE: When I lower the voltage down below 12 volts on the new card and blow ten volts on the old cards these all reset. Unfortunately, that resets everything downstream there. In terms of a voltage dropout, strictly a voltage dropout down at ten or eight volts, if it can be sustained at these 12 volts past these regulators it will reset all of these.

The numbers I got on this board about 10.2, 10.3 volts on the DC. Basically the way you test that is, you lower the DC voltage and you move the wire over to set the

light. You take the wire off and the light goes back out. You put the wire back in and the light comes back on. If the voltage were -- if you put the wire over and the light comes on, you take it out and move it back and the light stays on, that means that the latches are now free to set. That's how I made that measurement.

Yes, you can in the dropout -- voltage dropout across the K1 relay, that will reset this business. The problem is that it doesn't explain what is going on. I can't keep this stuff on.

MR. ROSENTHAL: You can't keep this on without keeping this on.

MR. RIDDLE: Right, by just using a DC dropout.

MR. TERRY: Jim, I think all three of the scenarios that were outlined there require some form of latchup or hangup or something.

MR. RIDDLE: Yes, right.

MR. TERRY: On that down --

MR. RIDDLE: That's why we are chasing it so hard.

MR. TERRY: There really isn't any scenario that --

MR. RIDDLE: There is no static or now power supply dropout by itself failure that can make this -- can explain this whole thing.

MR. TERRY: Right.

MR. CHIU: That's very --
MR. RIDDLE: We are throwing out possibilities as to what that --
MR. TERRY: There are three ways which you could -- with some kind of a latchup -- explain the light inconsistency. That's all we have been able to come up with.
MR. RIDDLE: We came up with another today, which is an unbalanced power supply driving --
MR. TERRY: True, but still --
MR. ROSENTHAL: Let me get back to the unbalanced power supply. Let's just say that by 1991 standards this 1970-ish --
MR. RIDDLE: Late 1970's.
MR. ROSENTHAL: May not have been --
MR. RIDDLE: 7851 --
MR. ROSENTHAL: May not have been -- the drawings are -- the design goes back to --
MR. TERRY: The first one is 1972. That's the vintage design. I think Exide indicated they developed it between 1968 and 1972, that timeframe.
MR. ROSENTHAL: Without arguing whether it could have been better done or worse done -- this thing sits there for five years, right?
MR. TERRY: Right. It sits there in operation --

MR. ROSENTHAL: It sits there in operation. If there was under at least normal operation a problem with watching the output of the 20 volt power supplies by the electronics on the 18 board, that would have been generating or could have been generating, then PSF signals which would have been tripping those units out.

MR. TERRY: Yes, unless they were associated with --

MR. ROSENTHAL: You have to find something to associate with this specific transient. Of course, all that does is generate a PSF which does not explain why. One reason my blood pressure either goes up or down is when I first told my management my initial findings they said it's the batteries. They said whoa, and I have not been able to explain there were other things. There was a press brief.

I said I thought that this was a contributing factor, and people again -- light off on the batteries, because that's something that people can understand. Unfortunately, we are still in a mode where, if problems with these others things and PSF was not generated, then we haven't fixed the problem.

MR. CHIU: You have to understand, Nine Mile Point's modification, could the power into the inverter power which supplied constant power -- next time we have a transient we don't have voltage dropout. That is a big job.

MR. ROSENTHAL: It will make it far less susceptible, except for my grounding issues.

MR. CHIU: Except which we are tracing very hard.

MR. TERRY: I guess I would like to clarify for you maybe where we are coming from. It is one of those situations where I guess it's impossible to rule out almost anything because we have this darn anomaly. Looking at the circuit design and the voltages that we looked at and what we have done in terms of the power supply, everything tells us that PSF should have been generated. Granted, we don't know that it was not, but everything tells us that it should have been.

MR. ROSENTHAL: Yes.

MR. TERRY: On that kind of a voltage dip. That's not impossible but in my own mind at least, a very low probability. The other things are very conceivable. The idea of getting a PSF and eliminating it, to me, is very viable.

MR. ROSENTHAL: Yes.

MR. TERRY: It's the downstream lights that remain a mystery. Having that happen, that K1, we are in a range where it's possible if all it takes is a momentary latching --

MR. RIDDLE: Latching --

MR. ROSENTHAL: But that delatches the 4044's.

MR. TERRY: That's what I say. So, that --

MR. ROSENTHAL: That doesn't account for the higher level --

MR. RIDDLE: It's a good explanation for half the answer, but it doesn't go back and address the other lights.

MR. CHIU: What we do here is first in our subcomponent review is, we try to make sure all those low probability things can be all identified and ruled out, and all the things we cannot explain downstream and we will recommence everything that may prevent it from happening if we really go the route. Later on we will have an even higher reliability.

The first thing we done is put a better power supply in, change the battery at least from the designer's point of view, Exide's point of view we return that back to design. There is other glitches maybe to stall us there, lights worked. We tried to see whether there's any one of them can later on generate not UPS and not trip off, some glitches. We want to make sure the reliability can even be higher. That's why the study is doing.

We not try to refute -- okay, we didn't review so far -- we don't have a data review of the root causes being done together which we would have review that root cause analysis. We will add on more.

MR. ROSENTHAL: By the way, it is conceivable to

me that on different time scales -- what we discussed this morning --later on or two milliseconds later, you do pick up the PSF. Those are distributing factors.

MR. RIDDLE: That makes our analysis complicated. To expand on what Chong is saying, we looked at the power supply dropout thing, we looked at the mods, we seemed to be covering that as far as protection of the DC side. We want to follow up on the ground side if there is already recommendations out of the text as part of protecting the ground surge suppression, zener diodes and stuff like that, take care of something that comes in from the ground side, from the transient side.

I think we want to finish our testing on the transient noise injection, et cetera situation, and make sure we knock that out. We haven't -- like I say, we haven't come up with anything inconsistent with their root cause and their corrective action. We haven't really found anything that is way out in left field. A lot of this is speculation about the latchup and about the operating and high impedance mode.

That is worth tracing. We don't have any hard evidence -- we have hard evidence that this chip went into latchup, but like I say, that may have happened during subsequent testing. We are still pretty speculative about everything that we are coming up with. We are not saying it

has to be a transient, it came in through the ground line. We are not trying to sell that line.

MR. TERRY: We have hard evidence on one chip, right?

MR. TERRY: Right.

MR. TERRY: Went into latchup and then --

MR. RIDDLE: We have hard evidence that went into latchup.

MR. TERRY: C-MOS latchup.

MR. ROSENTHAL: C-MOS latchup -- where the output is indeterminate, this high impedance.

MR. RIDDLE: No.

MR. TERRY: That's a different --

MR. RIDDLE: C-MOS latchup is when the power supplies short circuit and cause the whole device to short circuit. That's going to make it so that, depending on which direction it is, whether it's on the high side or low side, everything is going to be high. Every inverter has high input and a low input or a low input and high output.

We get into a situation where you have a high input and a high output or low input and low output, depending on which direction it latches, towards the ground or toward the high side or both.

MR. ROSENTHAL: On the one that delatched, what was--

MR. RIDDLE: On the ground side, so it pulled

everything towards ground. On the determinate mode, that depending on what sort of noise -- you saw that. Remember where I did that demonstration where I touched my baby finger on that input pin, floating input, the thing latched straight up. Then I shorted -- there was enough current that I could pick up from scuffing my feet on the floor to put this chip into a latchup mode.

MR. TERRY: This was on the 4049?

MR. RIDDLE: Yes, stock 4049 from the store. If it turns out to be a noise problem, just go through and make sure that all the inputs are terminated. I don't see any major -- what I am saying is that major design flaws or major rebuilds and fixes and exhaustive circuit analysis is going to be necessary at this point. We are all in agreement that we had a transient problem and a power dropout problem. The power dropout problem has already been corrected several different ways in terms of the batteries and switching it over.

Running down the transient thing, I think, is going to be straightforward as well.

MR. ROSENTHAL: Boeing does sneak circuit analysis; are you familiar with their work?

MR. RIDDLE: Boeing?

MR. ROSENTHAL: Boeing --

MR. CHIU: Circuit board modeling; that's what you

are talking about?

MR. ROSENTHAL: Whatever they fixed up, bar doors were flying open and they chased that down. I think a rocket went off and they chased it down to the umbilical cord on the rocket separating but all the pins didn't quite make and break at the right time. Clearly, they have heavy-weights too. Are you familiar with their work.

MR. CHIU: Last year I was hired by NASA to do the--

MR. ROSENTHAL: Yes, I understand that.

MR. CHIU: I deal with some of the heavy duty simulation, try to simulate how all those can occur. That's probably what you are talking about. Here, I think we -- the way they do it is board, they give us drawing. They really simulate through computer. It doesn't have a board, but simulate the whole thing in computer. You can have various input left and right and to see how performance occurs.

We think that's probably not warranted at this time because we have a board.

MR. RIDDLE: I am familiar with the Boeing product there, Patterson and Charlie and some of the reliability people up at Seattle. They also have a lab that does essentially what we do; take chips apart and find out what the damage is, do a physical analysis first, analyze failed

components, lay everything out to find out which way the damage points in terms of the failure mechanism is and then go after corrective action on those.

We are pretty much down the road as far as damaged chips. I would like to look at the other boards that I haven't looked at. If we have anymore bad chips, ferret them out, get them analyzed, get pictures of everything and see if there is a common trend on the damage. And then start basic corrective action, this and this and this could cause that damage, and just knock all three of those out. Putting transient suppressors here didn't take care of the noise problem, we will beef up the battery replacement schedule, take care of the DC dropout problem, terminate the inputs in order to take care of the noise problem and you are done.

Whether or not a combination of those two or three, we may never be able to simulate exactly which order -- like your point about it may have happened at different times during the vent work, it was a power thing and then a transient thing and a latchup thing -- a latchup thing and a transient, that can turn into a real complicated thing.

If we identify the key contributing factors and just do something about all three of those, we have enhanced the reliability of the system immensely.

MR. ASHE: Just a couple of things. Are you

planning to look at the 4049 chip on the A21 board on the other UPS's?

MR. RIDDLE: I would like to. I have requested that, yes.

MR. TERRY: I think --

MR. ROSENTHAL: We better find something that goes times five.

MR. TERRY: That's sort of been our -- we know we had the 4049 failed but it doesn't go times that.

MR. RIDDLE: There's one that's good and one that's bad.

MR. ROSENTHAL: That's an answer.

MR. TERRY: I think that's true. I guess I don't know the status of that, probably a better answer.

MR. ROSENTHAL: You are going up to Nine Mile again, I take it. Let us know when, and we may want to accompany you. I would appreciate it if you looked literally at the ground -- I think it was Mr. Lewis but I'm not sure and Frank may remember -- who I think was working for Exide at the time, a sub-sub. He just commented that he was surprised not to see a nice big braided copper strap across the hinge on the card cage and just screw to screw on the hinge.

Instead, it may be possible that the sheet metal ferreted cage -- whatever you want to call it -- is in fact

just got a number 16, number 20 wire to another spot on it, and that the grounding -- at least that is grounded through the hinge and the paint on the hinge. It sounds flaky, but --

MR. RIDDLE: There's another possibility is what you and I talked about, on the interlock channel. All these boards are tied together through an interlock. If that happens to go to ground and you get noise transients on the ground, the interlock comes back in through here, bypasses all this circuitry and comes back in through here and comes out here.

If you have a noise blast through your interlock it would come in, and if it caused latchup of this 4049 or this 4049 here, it's going to turn these three lights on independent of whether or not that fits into the PSF never generated. It comes back in through the outside here.

MR. CHIU: There's a scenario --

MR. RIDDLE: That's another scenario that is a possibility. Now, the interlock does have a pull up resister that's going to help with its noise immunity. But if it gets a significant enough spike through the input that might be possible. Unfortunately, that requires putting a transient in the input which has caused permanent physical damage on at least the low speed stuff. That is something also to follow up there. That will help -- that's a

possibility as well.

We don't know where the interlock goes. Either it ties them in together or does it go to ground, does it go high. We need to look at that. There are some things in the cabinet that I think Chong is going to run down for us next week. We will be able to knock those down one by one.

MR. ROSENTHAL: Jim Stoner was saying that at start up they had measurable -- pre-start up. The whole ground plane was two-tenths of a gnome.

MR. STONER: Right, two-tenths of a gnome. I don't think that it had been checked recently, at least I didn't get an indication they had. That might be something that you might want to have tested, impedance of the entire grounding system.

MR. RIDDLE: We do have some conflicting or at least incomplete information about where all the ground wires go. I think that was your number one action as far as when you go out there.

MR. CHIU: Yes, we transmitted a request, I think to Nine Mile Point. I think they are looking at that data.

MR. STONER: Just as a clarification, two-tenths of a gnome at ground is a good reading.

MR. RIDDLE: Yes, a very good reading.

MR. CHIU: Very good reading.

MR. STONER: The only question in my mind is, is

it still at that low value or has it changed.

MR. RIDDLE: Is that between the UPS cabinet and the center of the switchyard.

MR. CHIU: I think that we have -- as you guys already know -- we have a professor, T.C. Chen from University of Southern California. He's well known internationally. I feel that he is on our team, so we are not taking that loosely. MR. IBARRA: Chong, if you were to go and find some anomalies in the grounding tomorrow within the UPS units, is that going to help you in linking up what happened; this common mode to the trip?

MR. RIDDLE: That would support the ground transients coming in and disrupting the chips, failure mode.

MR. CHIU: That would support one and two volts, because you see the second mechanism, PSF generated -- we don't have a light on DS light. That can cause a ground transient and latchup a PSF right there. K1 reset everybody else.

MR. IBARRA: Your analysis has centered only on one board, right?

MR. CHIU: Right.

MR. IBARRA: You still have to trace out and make sure that --

MR. RIDDLE: How that leaves that board --

MR. IBARRA: Right. There is still a link there

that would have to be made.

MR. CHIU: Right. That schematic will help us and compare with what they really have.

MR. IBARRA: It would go a long way in trying to explain the --

MR. CHIU: Yes, go a long way.

MR. TERRY: I should comment here that from Niagra's overall look at this thing, frankly, we have eliminated elevation of the ground voltage.

MR. ROSENTHAL: Good.

MR. TERRY: Based on a few things. First off, we looked at the ground current. It is fairly low. We have the data on that, around 1,200 amps I think, which is a relatively low thing. We also have indications within the plant in terms of the generator relaying and things of that nature that give us pretty positive indication that the ground fault did not go outside of the yard.

I think the third thing, while all of us agree that the grounding elevation can cause all kinds of weird things including damage to these chips, it would not just go in and selectively pick out U10, CD4049. Rather, we would see extensive damage. You will be getting our root cause I think today.

MR. ROSENTHAL: It came, and that was that little yellow slip that came.

MR. TERRY: We talked with Dr. Chiu and reviewed it. That's not to say that something could have been going on inside of the cabinet.

MR. IBARRA: Internally, yes.

MR. TERRY: Internally. So, I am not trying to tell you that. What I am talking about here is -- and we will certainly take a look at this impedance to make sure. There are all kinds of real good indication that the ground mat is fine and that there was not a general elevation of the ground mat during this fault. I think we have good evidence on that.

Fortunately, we have measurements and other data that would tell us otherwise if that were not the case.

MR. CHIU: I support that on my calculation. What the professor from USC looked at is the ground scheme, things that are more than outside cabinet. That's his analysis.

MR. TERRY: We know during a trip inside of these cabinets there could be certain circuits or circulating currents or other ground currents being generated.

MR. STONER: Based primarily on internal wiring --

MR. TERRY: Internal wiring and localized elevations of grounding is really where we are in terms of that. Because the other side of that is so far during

testing really it takes this either elevation of ground voltage or the output voltage or power supply voltage going negative or something like that to create this inverted differential between the ground voltage and the voltage to the chip. That has been pretty well established also during testing.

Frankly, we use that as part of our rationale as to why it couldn't have been a general elevation of ground levels. Consistently you won't just pick one 4049 or something, you will burn out a lot of C-MOS and other things if you have a general elevation of ground voltage.

MR. CHIU: You also have --

MR. TERRY: We are convinced of that.

MR. CHIU: -- feedwater control system and other system. You could probably talk roughly about 10 voltage system. We will see some rather large glitches if we have general ground elevation.

Let me ask a question now. You guys are ahead in terms of circuitry, elementary ahead of me at least. What do you think about direction. Is there anything that you see obviously incorrect or we are down a wrong path, or chasing a ghost, or we are not chasing deep enough. I want to get your feedback, because I work with Carl and his people and we try to think about a lot of things to make sure we uncover all stones.

But it is always good to see some great minds telling us what work --

[Laughter.]

Let us know, so we can correct ourselves or make it better, go deeper, go shallower, ghost.

MR. IBARRA: We had Exide come here with all of their drawings and there were several of their people. We did trace out the logic. We ran through it, and it does make sense of how it should work.

MR. CHIU: How it supposed to work.

MR. ROSENTHAL: I guess if you go back, I am very convinced that the SSTR signal was in fact generated times five. That pretty much goes to a power transistor and on, and that it would have had to be generated for at least a couple of cycles in order to have fit the shunt core. What they were talking, at least multiple -- 1630 milliseconds.

You are right on the A21 board, and it makes sense to me. It makes a lot of sense. I guess I was talking to your licensing guy and he thought that actually these people might know some of the response times. Do you have any idea what the response time of this K1, 2, 3 on the A21, A1 board would be?

MR. TERRY: I think you asked that earlier, and I don't think we --

MR. ASHE: Probably a more important one is K5.

MR. ROSENTHAL: At least it starts establishing time.

MR. ASHE: The K5.

MR. RIDDLE: Is that the big relay.

MR. ASHE: Yes. We know that these units have been switching back and forth. What we don't know -- successfully, with dead batteries.

MR. TERRY: Total loss.

MR. ASHE: That's right. What we don't know is a time. We are trying to get a fixed -- how long --

MR. RIDDLE: Is that a big old --

MR. ASHE: No.

MR. RIDDLE: We will run some numbers on them.

MR. ROSENTHAL: It's bigger than this and smaller than that. It's half the size of this cup.

MR. RIDDLE: You could probably just get that information from the data sheet from the relay itself. Read the manufacturers name on it, call the manufacturer.

MR. TERRY: We have looked at that, and I just don't know what it is right now.

MR. CHIU: If you know the data sheet or model number and we can try to find the time constant for you.

MR. TERRY: Bob Crandall has all of that.

MR. CHIU: Otherwise, we could do --

MR. ROSENTHAL: I think we are talking about -- I

forgot what it was -- 100 millisecond, 200 millisecond. That sort of range, that sort of number.

MR. CHIU: You already did a test or something.

MR. ROSENTHAL: Remember that the other thing is, we do have -- if you go to change analysis and you say wait a minute these units are always running, there have been other trips where there were clean transfers --

MR. ASHE: Transfer.

MR. ROSENTHAL: Transfer and they have ridden out, don't lose site of that.

MR. ASHE: For clarification, do you --

MR. ROSENTHAL: Does that mean that if you lose the turbine -- the units are sitting on the unit auxillary transformer and will switch to the reserve auxillary transformer, there will be some perhaps very small perturbation and that's seen down at the UPS level that they would be riding those out.

MR. TERRY: This is the first thing we can come up with where we have had this like 100 or 200 milliseconds, kind of a dip. We have had a fast reduction and know they work there. This is obviously the first time they have all five gone off.

MR. CHIU: Maybe that's another thing because the Nine Mile Point test -- if you have a really deep, steep transient, they all work. Only this gray area -- that may

be less --

MR. RIDDLE: That's right.

MR. IBARRA: In fact, that is what we have come to conclude, that if it was loading the K, that cause the problem not being there or being there. There not being there wouldn't have caused the problem.

MR. CHIU: I tend to agree with that, based on what I know about it.

MR. TERRY: Also, I think based on -- there is some question I agree, on exactly what did that voltage look like at the boards. None of us really know for sure. We just have calculation.

MR. RIDDLE: Exactly.

MR. TERRY: It sure looks like even in the ranges of the voltages that we have looked at from a minimum of around 50 up to I think like 65 volts, that whole entire band based on testing of the relays that we had out there, none of that, either 50 volts or 65 volts is still enough to keep K5 sealed in.

MR. ROSENTHAL: When you said slowing decaying, we are talking about the output of these power supplies slowly coming down, while Jim is telling me that the AC almost step changed from --

MR. STONER: From rated --

MR. ROSENTHAL: From rated to that degraded.

MR. TERRY: That would follow pretty much --

MR. ROSENTHAL: Based on the oscillograms and what not.

MR. TERRY: Right.

MR. CHIU: You guys think -- my question is, do you think we are on the right track?

MR. ROSENTHAL: Yes.

MR. IBARRA: You are saying system-wide where we are more further along than you are. We can also say from minute point of view, you are further along than we are.

MR. CHIU: Yes.

MR. IBARRA: Whatever work you are doing, it seems to be good work. We still have to make the link if that's possible.

MR. ROSENTHAL: Times five.

MR. IBARRA: Yes, times five.

MR. CHIU: We have to do a link pretty soon. All those things that we talk about, the future tests, transient generation, noise going to the input, the grounding tracing, the board characteristic analysis hopefully, we will make a link closer and closer. Hopefully, at a certain point we can all say we have a link. You move toward our direction and we will move toward your direction.

MR. ROSENTHAL: Jim was saying that -- I quizzed him at length about RF on the AC or a higher harmonics. You

thought that was unlikely.

MR. STONER: No, I said there could be a signal riding on the wave -- as far as the ground loop, I didn't see a ground.

MR. TERRY: By the way, we also --

MR. ROSENTHAL: Every transformer is good for so many -- ten DB or more.

MR. STONER: But there is no positive indication that that occurred, but just because of the nature of the arcing in the transformer the potential is there.

MR. TERRY: We would expect the RF was generated at the transformer.

MR. IBARRA: At the source.

MR. TERRY: At the source. The spark and generating a wide spectrum of RF, we all know that. We also looked at that and really, the path has some just tremendous attenuation on it. So, in terms of getting any meaningful signal there through the power feed, that really isn't viable. We concluded there just isn't any way to get it there. We have a number of people --

MR. ROSENTHAL: Because, you are saying it's 1020 DB across every transformer.

MR. ROSENTHAL: Right.

MR. ROSENTHAL: Five, or --

MR. TERRY: That's right.

MR. ROSENTHAL: Is that the logic?

MR. TERRY: That, plus the cables themselves frankly have a lot of attenuation also. Just the transformers alone going through three or four transformers, it's at least 1,000 times attenuation at each transformer. It's really very, very -- it's a good suppressor of RF signals. It's just not designed for that. It is for other things.

MR. CHIU: We will look at RF from two point of views. One is your sparking that goes through air, goes through what we will call radiative interference, pickup by pigtail. Lan going to the signal. What we did is, we get a simplified calculation of how much voltage you can generate into the RF in terms of voltage you can use. Lan going to antenna, the maximum we can get, just micro volt. So, it couldn't cause all this phenomena, latchup. We need like ten volt to get this thing going.

So, the magnitude -- not all magnitude -- times difference in terms of what it can do, we eliminate that. Another one we look at is, if high frequency transients shoot a spark that go through the roof and go through the ground -- go over input signal line and come in, that wouldn't because the high impedance -- inductance. Inductance just keep occurring constant.

MR. RIDDLE: It's already a noisy environment in there anyway with all these SCR's firing, as far as --

MR. ROSENTHAL: Apparently, they had also done some pre-OPS and keying of --

MR. TERRY: They tried transmitters in front of it, right. That's where he was saying if you open the doors and set off a walkie talkie, they could get the unit to trip that way. But you close the doors and there's immunity.

MR. RIDDLE: That could be the case, and it's grounded fairly well. At least it is grounded fairly well.

MR. ROSENTHAL: If I go down today -- in fact I remember mentioning it to somebody that we didn't do it -- to key his portable radio you would expect nothing to happen and if you would open the doors and repeat that, it would probably trip.

MR. TERRY: I think Crandall indicated that that was the experience. That's a good question; was it repeatable or was it sometimes. That, I don't know.

MR. RIDDLE: It would be nice to do that down at the manufacturer.

MR. CHIU: My experience, I chase noise quite a bit before RF. What it does is, RF when you radio -- for example mega hertz you are talking micro volt. When you go into a cabinet, even though you have what we call the perfect antenna goes restless, they have effect of 1,000

amplify. You are talking about mini volt maximum.

Only mini volt can activate things. In the past experience I have chasing ground chicken noise, you have like a module. The signals is mini volt. You give a little mini volt and activate -- fact of 100 change. Nuclear, NIS system. Those are mini volt systems to begin with. You interject one mini volt. This system you look at circuitry there are ten voltage.

One thing this guy is susceptible, based on just my --

MR. TERRY: Not the 4049.

MR. CHIU: Not 4049.

MR. TERRY: All we are saying is that the unit is susceptible if you leave the door open and if you stand in front of it with a walkie talkie. That's not unique, by the way at Exide. We have done that other places.

MR. CHIU: Some other system.

MR. RIDDLE: Turbine control system.

MR. CHIU: Yes, turbine control system.

MR. TERRY: Turbine control guys doing it and hit it.

MR. CHIU: Mini volt.

MR. TERRY: It can cause it, and it is certainly a plausible thing to look at, and that's why we looked at it as a way of possibly tripping the unit. We had to look at it.

MR. ASHE: Are you familiar with the DTL's of the transmitter, when that was actually done?

MR. TERRY: I am not.

MR. ASHE: Power level, higher frequency, carry waves, side band -- you are not familiar with any of these?

MR. TERRY: No, I am not.

MR. ROSENTHAL: Of course, that's totally the wrong frequency also here. Here, we are talking higher harmonics of 60 cycles --

MR. ASHE: Not any arcing, no.

MR. TERRY: The arcing could be any part of the spectrum.

MR. RIDDLE: Broad spectrum.

MR. CHIU: The arcing you have a wide band spectrum up to 2.5 mega hertz. It's between zero and 2.5, you always have noises.

MR. RIDDLE: You would have to sweep it.

MR. ROSENTHAL: Except that, as I go through the transformers the attenuation of the higher is even more.

MR. TERRY: Right.

MR. ROSENTHAL: Ten, 20 DB is like an average number.

MR. TERRY: As a common all five thing, that is what we are --

MR. ROSENTHAL: Right. Does anybody have anything

else to say?

[No response.]

MR. ROSENTHAL: Okay, we are concluded.

[Whereupon, at 12:25 p.m., the meeting concluded.]

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission

in the matter of:

NAME OF PROCEEDING: Nine Mile Point Nuclear Power Plant Information Exchange Meeting

DOCKET NUMBER:

PLACE OF PROCEEDING: Bethesda, Maryland

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.

Mary C. Lark

Official Reporter
Ann Riley & Associates, Ltd.

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[signature]

Official Reporter
Ann Riley & Associates, Ltd.

07-522B-91

# OFFICIAL TRANSCRIPT OF PROCEEDINGS

**Agency:** U.S. Nuclear Regulatory Commission
Incident Investigation Team

**Title:** Nine Mile Point Nuclear Power Plant
Information Exchange Meeting

**Docket No.**

**LOCATION:** Bethesda, Maryland

**DATE:** Saturday, September 7, 1991 **PAGES:** 1 - 101


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1612 K St. N.W., Suite 300
Washington, D.C. 20006
(202) 293-3950


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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

INCIDENT INVESTIGATION TEAM

Nine Mile Point Nuclear Power Plant

Information Exchange Meeting

Nuclear Regulatory Commission

The Woodmont Building

Room W-100

8120 Woodmont Avenue

Bethesda, Maryland

Saturday, September 7, 1991

The meeting in the above-entitled matter convened, pursuant to notice, in closed session, at 9:10 a.m.

PARTICIPANTS:

JACK ROSENTHAL, NRC/ITT Team Leader

FRANK ASHE, NRC/ITT Team

JOSE IBARRA, NRC/IIT Team

MICHAEL JORDAN, NRC/IIT Team

TOM POHIDA, NRC/ITT Team

JIM STONER, NRC/IIT Team

CHONG CHIU, Failure Prevention, Inc.

JAMES B. RIDDLE, Failure Prevention, Inc.

CARL D. TERRY, Niagara Mohawk

P R O C E E D I N G S

MR. JORDAN: My name is Michael Jordan. I am with the NRC. I'm out of Region III. I'm the deputy team leader. I'm a section chief in Region III.

MR. POHIDA: My name is Tom Pohida, NRC, Instrumentation and Control Systems Branch and a member of the IIT Team.

MR. IBARRA: Jose Ibarra, member of the IIT, NRR.

MR. TERRY: Carl Terry, Vice President-Nuclear Engineering, Niagara Mohawk.

MR. RIDDLE: James Riddle, Manager Electronics Program for Failure Prevention.

MR. CHIU: Chong Chiu, President of Failure Prevention, Incorporated.

MR. ASHE: Frank Ashe, member of the IIT Team, NRC.

MR. STONER: Jim Stoner, Consultant to the IIT.

MR. ROSENTHAL: Jack Rosenthal. I'm the IIT team leader. My degrees are in nuclear engineering. I am learning an awful lot about electrical engineering, but I am going to have to explain this to the Commissioners some day. So you are going to have to bear with me as I come up to speed. Tom has designed these circuits in prior employment.

Why don't we let you people have the first word.

MR. CHIU: Let me open this session by telling you

why we think it is important we are here and why we think what we are doing today is important.

Looking back in the history of when the event occurred, Failure Prevention, Incorporated, was hired as an independent consultant to make sure all things they look at are encompassing and that we don't miss anything. With that mission, we came into the plant and did an investigation.

As an investigation company, we are really impressed by senior management. I can name a few guys. They don't want to stay on the component level; they want to go down to the sub-component level to explain why some lights are on and some lights are off, so that we can hopefully explain what went wrong or what went the way it went. As a result of it, we can really pinpoint or consider all possibilities, all failure modes, so we don't leave any stone unturned.

With that philosophy, the whole investigation will go full steam. Today what I want to do is first introduce our test rig, how we do our testing. We have a film. Later on we are going to tell you what our test plan is to understand the phenomena a little bit better.

Then we are going to tell you what our results are up to today, give you a status report. Throughout this informal presentation we have a lot of photographs to show you, the chips and how things go. Ask questions any time

you want to.

We may go into the elementary schematics. We don't have a complete set of schematics, which impedes the speed of our investigation somewhat, but we have tried to overcome that by building a test rig and trying to understand the reverse engineering, following it back to see what could happen.

That is a little bit of introduction why we are here and why we think it is important. Any questions so far?

MR. ROSENTHAL: Let me get to the drawings for a second. This was clearly non-safety-related equipment in our designation. Unlike safety-related, it is not surprising to me -- it may be disappointing, but not surprising that we don't have all the drawings readily available. The manual, in my opinion, is a description of the system and is not like a verification or validation type document where it says what the design intent of each component is. That has caused problems for us. We are still gathering elementary drawings from the manufacturer, for better or worse.

Were you going to bring a board with you?

MR. RIDDLE: Yes, a circuit board.

MR. ROSENTHAL: It would be useful to us to do some spot audits of the board. It is not the board that was

in the unit, right? It was a replacement board?

MR. RIDDLE: No. The board that I brought is the UPS 1A A1321.

MR. ROSENTHAL: That was in?

MR. RIDDLE: That was in the 1A UPS.

MR. ROSENTHAL: We would like to do a little bit of checking against the drawings that we have to make sure that even what we think is the latest set of drawings corresponds to the unit.

MR. RIDDLE: There are some modifications on the particular card that are not in the drawings in terms of some cut traces and some jumper wires. We are going to show you several other components. You can actually dig those out of the modification drawings, of which I also have a set.

MR. CHIU: The first thing I would like to do is show you a very short video tape.

MR. ROSENTHAL: We may need copies of stuff.

MR. RIDDLE: I brought duplicate photographs. You can take this. The original of this tape is on 8 millimeter. You guys can have it.

MR. CHIU: This will give you some ideas of how the test rig was set up.

[Videotape "Niagara Mohawk UPS Circuit Board Test" shown.]

MR. CHIU: That will give you some idea about the typical tests we do on the test board. Of course we are going to review other results. That is just one segment.

MR. ROSENTHAL: If I relate it back to here, you have got this signal on.

MR. RIDDLE: Right.

MR. ROSENTHAL: You have got this light. You have got the SSTR. I don't know if it goes high or low. One or the other.

MR. RIDDLE: On the A14, the trip and invert lines, logic flow. Those are three lights I'm showing on that particular board.

MR. POHIDA: Where is the third one?

MR. RIDDLE: One, two, three. These three.

MR. TERRY: One of them is just a trip signal.

MR. RIDDLE: This is a trip. I don't know where it goes, because I haven't found it on the other card.

MR. ROSENTHAL: We have been able to trace that through.

Let's just share for a second. I said CB1, CB2 and CB3 had to open. That means that the shunt trip coil had to be actuated. It's normally 48 volt DC coil. It normally would get 40 volts from the plus or minus power supplies. And it will go at far lower voltages. It doesn't need very much because it just picks a latch and then the

spring will actually transfer the contacts.

You make up the power to that by closing K1, K2, K3. That is shown on the A27 module. We did have a question about the time constant of those relays, which would be small. I just spoke to Niagara and they said maybe you guys knew.

MR. CHIU: The K1?

MR. ROSENTHAL: Remember this power supply picture?

MR. RIDDLE: Yes.

MR. ROSENTHAL: Here are the circuit breakers, CB1, CB2, CB3. I've got to close contacts to energize the shunt trip. In order to do that I've got to pick K1, K2, K3. Those are smaller relays but they are relays. I don't know what the time constants of those relays are. They thought maybe you knew.

MR. RIDDLE: I haven't looked at it.

MR. ASHE: In general, do you?

MR. ROSENTHAL: Pinter this morning said Frank Ashe had asked and he said maybe you guys knew.

MR. RIDDLE: When you say time constant, do you mean the time it takes to respond?

MR. ASHE: Response time.

MR. RIDDLE: Do you have a spec sheet for these things? If I get a part number, we can pull some specs.

MR. ROSENTHAL: We are all up the same kazoo.

MR. RIDDLE: We can read that off the parts, or we can set the board up and measure it.

MR. ASHE: That is what I would be interested in.

MR. ROSENTHAL: That is on the A27 board. Do you have an A27 board with you?

MR. RIDDLE: No.

MR. ROSENTHAL: So conceptually we are thinking of these as rather small relays that work somewhat fast.

So that is sitting on plus 20. The output to the power supply and the battery, and I've got to make up the logic. Electrically that is the only way that these get stroked.

MR. CHIU: By this input.

MR. ROSENTHAL: These go directly to three power transistors, which get poled to ground, Q1, Q2, Q3.

MR. ASHE: A13A1.

MR. ROSENTHAL: On A13A1, Q1, Q2, Q3. There is just one wire out to make up the logic.

Now we go back. What picks Q1, Q2 and Q3 to have them conducting the ground? Now it becomes fancier. One of the things is --

MR. ASHE: SSTR.

MR. ROSENTHAL: It has a different name, unfortunately. It is UPT equal 1 from the A21 card. We

spent some time saying, well, what other signals and where do they come from? Some aren't even installed. As I remember that review, we had convinced ourselves during at least normal operation that you had to get a UPT equal 1 from the A21 board. That was the way these power transistors changed state.

MR. CHIU: Change state and then go to K1, K2.

MR. ROSENTHAL: Now that disappears into the back plane and reemerges from the back plane as SSTR. Then all the trip logic is lower down than SSTR.

Is there mutual agreement that SSTR advertently or inadvertently, but in any case that that signal had to pick? Are you guys there yet?

MR. RIDDLE: Had to pick what?

MR. ROSENTHAL: Had to change state.

MR. RIDDLE: Yes, it would have changed state. If these lamps are on, then this output here is going to drive this and drive that and turn that on.

MR. ROSENTHAL: So based on our design knowledge and review of the drawings and what makes sense to us, if these lights are on, SSTR is on. Although there are a couple of chips in between.

MR. RIDDLE: This has been verified in the movie. I have all three of these on. These two come on; this one always comes on because the output of this drives all that.

MR. CHIU: Unless you have a damaged chip.

MR. RIDDLE: The A card doesn't, because you just saw that all three were on.

MR. ROSENTHAL: The whole puzzle, to me, is why did SSTR signal on the A21 board latch? It could have been advertent, inadvertent, due to any number of things. That is really this morning's meeting. Unless there is something else.

MR. CHIU: We don't think so. Based on our observation, those lights were on. As a result, you can probably assume SSTR was activated during the event.

MR. ROSENTHAL: That's the only way that we see that you actually stroke CB1, CB2, CB3. That we know happened.

MR. RIDDLE: Let me back up a little bit. Initially when I was pulled on to the group the fundamental question was these lights were on and these lights weren't on and this logic is illegal; here is the card; go back and see what you can do with it.

My picture is expanding now to look at these other interconnections and how it ties in the big picture. My background up to this point has been in the microcosm on this board and inside these chips, all the way down to the micron level as far as the examination. So I can't claim expertise on tracking this back out of the system. I want

to make it clear that I spent a whole lot of time with this board and I have several possibilities as far as what can go on. That's in testing at this point.

MR. ROSENTHAL: Of course there is the sheet metal behind that back plate, which is grounded through, as I understand it -- you were there, so help me. There is a little green wire which goes from that back plate metal. As I understand the grounding of that sheet metal back there, there is a small wire from there to some heavier steel and then you actually ground the hinge of that chassis to the frame. One of the grounding guys said he was surprised that there wasn't a flexible braid ground. We didn't see it. Did you?

MR. RIDDLE: I don't recall one and I don't have that in my pictures.

MR. CHIU: Jack, do you recall what pin that ground was coming out from the logic board?

MR. ROSENTHAL: I don't know.

MR. RIDDLE: The grounding scheme is under question at this point. There are some questions about whether or not there are actual grounds, where the grounds are connected, whether the logical ground is the same as the AC ground. Chong is going to be out that way next week, and Kerry, and we will run that down through inspection to make sure that things are grounded, first of all, and what sort

of transient noise suppression is on the line, whether we have independent grounds and come to a common tie point. That is still up in the air and something that we are real concerned about finding out by actually doing a measurement.

I would like to do a measurement from the negative pin of a chip all the way out to the outside of the chassis and find out if there is a true connection from chip to case. Those are pretty easy tests to perform and we can get some real data on that in a couple of days.

MR. ROSENTHAL: We may want to send somebody from the team up there to watch. I assume Niagara doesn't have a problem with that.

MR. TERRY: No.

MR. ASHE: Have you touched base with Warren Lewis, who was at the site there?

MR. RIDDLE: No, I haven't. Let me get his name down.

MR. ASHE: In terms of the actual installation, the physical configuration, how it is actually grounded versus what is on the drawing, he may be extremely helpful to you in exploring that.

MR. ROSENTHAL: The ground from the UPS actually goes over the ground on the maintenance regulating transformer and it is grounded over there.

MR. RIDDLE: These are valid questions that we

could just go out and measure and get hard data on. Chong and I are looking at groundside problems. Some damage that I am going to show you later in some of the chips suggests that some of the noise introduction was through the ground area, so we do want to track that down and make sure that we know where the ground paths are.

MR. CHIU: Jim, do you want to go over the big picture of what tasks you are doing and what you have seen so everybody knows?

MR. RIDDLE: I have got a write-up that I have sent out to Niagara. Did this get to you? I sent this to John Conway and he was going to add it as an addition.

MR. TERRY: It may have yesterday.

MR. RIDDLE: We got it to him yesterday. We can copy it for everybody.

MR. ROSENTHAL: We are also getting Niagara Mohawk's big thick report. It should be arriving about 9:30.

MR. RIDDLE: The first thing we did was some static DC testing on some of the individual chips, 4049, 4011, 4044, 4068 devices. I obtained these from various electronics places and took them off of the new board. From the data sheets there were several possible voltage situations that would cause SCR latch-up, which was one of the first things we wanted to investigate.

MR. POHIDA: I have a question concerning the chips. You said you bought some new chips from Motorola or RCA.

MR. RIDDLE: Motorola.

MR. POHIDA: Do you think they are representative of the parts ten years ago?

MR. RIDDLE: The dies are similar and I tried to match the date codes. Devices are different. The Motorola devices and the RCA devices are a different die layout. They are going to have different susceptibilities to transient introduction because of the placement of the diffusions and such. Again, the protoboard concept. When we come down to testing the chips off the board we want to make sure we have got the test routine down so we are not wiping chips out.

MR. POHIDA: Right, because you don't want to damage the actual chips that are on the board.

MR. RIDDLE: Right. So what I did was buy store-bought chips. I find out when you dump some power into the inputs you blow the chip up. Since during the event things reset and chips worked, we decided we could toss that. You can cause permanent damage, as it is stated here. So we came up with a latch-up scenario, which is one of the first theories you were looking at where the device is introduced a voltage transient in some relationship, inputs and outputs

and power, and goes into a low impedance state. We have documents that I have sent around to explain.

MR. POHIDA: Do we all know by this point what you mean by vss?

MR. RIDDLE: Vss is low ground. In fact it is parenthetic here. Vss is considered ground and vdd is positive.

Output voltage below ground; output voltage above ground; input voltage above, ved, and power supply. That should be vdd, much, much greater than vss, as opposed to vss, much, much less than vdd. This is a typo.

Testing revealed permanent damage was induced by tests C and D. So they were discarded. Test B did not induce latch-up but test A did. What we do in this case is we put a negative going pulse on the output such that we drive it down below ground. We were able to latch the chips, especially the 4049s, very easily, consistently every time.

MR. ROSENTHAL: On the drawing the 4049 is simply an inverter chip.

MR. RIDDLE: Yes, inverter buffer. Buffer driver is what I think it's referred to. There are six of these in each package.

MR. ROSENTHAL: What do you mean by latch?

MR. RIDDLE: There are two forms of latch. I laid

that out in here: There is latch, which is what these do. Latch-up is when the parasitic voltage transients cause the device to form a parasitic circuit, which acts like a silicon control rectifier, an SCR, and puts the whole chip into a low impedance state.

MR. ROSENTHAL: And stays there?

MR. RIDDLE: Yes. It stays there until power is removed.

MR. CHIU: It becomes short-circuited.

MR. POHIDA: It is called an SCR latch, correct?

MR. RIDDLE: Yes.

MR. POHIDA: Sometimes the SCR latch will cause damage and sometimes it will not.

MR. RIDDLE: Yes. Depending on available current. The typical damage that we see on integrated circuits is a fuse bond wire. If it's a gold bond wire, that means the device drew amp. If you replace that bond wire and put it back on the die, the part is good. So it goes to a low impedance state and draws a lot of current. Usually it draws it through the substrate so it can dissipate the power. You don't damage any of the junction structure. You get the part back. There is a fused open portion of the circuit but there is no permanent junction damage. In fact, we have a device that came off a board that exhibits exactly those characteristics.

MR. CHIU: Do you guys all understand how this parasitic comes in? We have a graph showing the PM junction.

MR. RIDDLE: We sent that in.

MR. ASHE: I don't particularly understand down to the PM junction level.

MR. RIDDLE: I will try to bring you up to speed a little bit without going into too much of the detail.

MR. POHIDA: I don't know if going deep into the detail would be meaningful.

MR. RIDDLE: The phenomenon exists.

MR. ASHE: What types of voltages are you applying here?

MR. RIDDLE: These are 5 volts. Operating voltage for these devices is 5 to 20. Most of these tests are done in the 12 volt range and the corresponding output was driven to a negative 2 or 3 volts. Most of the detail stuff is in my notes. We need some time to type that all up.

After the latch-up simulation, which is basically step 1, then we proceeded to some dropout testing. There was some concern that the DC had dropped out and the batteries were low and therefore a dip in the 12 volt supply could cause some problems. We didn't get any kind of latch-up out of that. We didn't get any other kinds of anomalies out of that.

We went in and did board level testing. We had the UPS A, B and G cards and a stock card, which is the newer version, and a test fixture. They say here lamp drivers, et cetera.

The A card, which is the one we brought out here, doesn't have any problems. The U10 4049 was damaged on card B. It turns out that damage is characteristic of latch-up. I have some photographs to show you on that.

No anomalies on card C, although I hadn't had the test fixture built up when I had card C and it may be beneficial to get it back. Card G is right now my current object of interest because the latches will not set on this card. I can introduce an input and you supposedly can take this input away and this thing stays triggered on. This card doesn't do that. There are some problems with the switch. I looked into the K1 relay, which is a reset relay. I took that relay off the board and it's good, but it still doesn't work. So there is some other bad stuff on this G card. We will get back on that tomorrow when I get it back out there.

MR. CHIU: As you recall, the G card performed differently during the event. Some lights didn't come on. The inverter logic light wasn't on after the event. So we tried to go into the board.

MR. RIDDLE: It is definitely curious and there is

definitely something going on on that board.

MR. ASHE: That was reported on the D unit. I thought you said you took the card out of the A unit.

MR. RIDDLE: Which one?

MR. ASHE: The actual hardware card you have came from the A unit.

MR. RIDDLE: I have two cards now. I have the A and the G card in my possession.

MR. ASHE: You said no logic light. I thought that was reported on the D unit.

MR. RIDDLE: The D and the G.

MR. ASHE: We don't have that on the G unit. As-found data suggests that the logic light was lit on the G unit.

MR. RIDDLE: I am using as my reference there root cause -- let's see. This might have been revised.

MR. CHIU: Yes.

MR. RIDDLE: There is a logic trip on A through D and there was no logic trip here. I am assuming there is no logic trip or they wouldn't have said no logic trip.

MR. ASHE: No logic trip is clearly on D but where is that on G?

MR. RIDDLE: It's not, but the ones that did have a logic trip say a logic trip. Inverter logic alarm is the same, I guess. From my conversation with them, inverter

logic alarm means it is the same as logic trip. You have that on these three; it is not on this one and it is not mentioned on this one. I agree. It's not mentioned on that one. I don't know if that's happened or not.

MR. ASHE: To me each one of these guys had that trip with the exception of D.

MR. CHIU: Only D.

MR. ASHE: Only D did not have it.

MR. RIDDLE: We misread that.

MR. ASHE: That's the way I interpret that.

MR. TERRY: Remember, Frank, D was reset.

MR. ASHE: I understand. It appears to indicate through various sources and onsite testing that D was manipulated a little bit prior that data being generated.

MR. CHIU: So the G card actually performed like an A card. Is that right?

MR. RIDDLE: The ovuv and the voltage differs, which the A card didn't get. We are saying this did have an inverter light.

MR. ROSENTHAL: The ovuv, according to the prints, is not a latching signal. It's a light that was observed at the time that they took the data, which is two hours into the event.

MR. RIDDLE: It shouldn't have been on.

MR. CHIU: It should have been off if there is no

latch.

MR. ASHE: I'm not sure that data was generated two hours into the event. It was generated two hours plus additional information from operations people who were in the area at T plus 30 minutes into the event.

MR. ROSENTHAL: Let's play this again. It's our understanding the people run downstairs. They manipulate 1D. They give up on trying to restore the unit as if it was a starter. They close that breaker. They then fan out and simply close the other CB4. That's our understanding. They try stuff. They give up on the stuff and close CB4. Then they fan out. They said that works. It's our understanding from the interviews that they don't mess with resetting, manipulating switches.

MR. JORDAN: They don't say that they do, but I don't know that we simply asked them each time, did you push any reset buttons. My understanding is they fanned out; once they learned the methodology of getting power back on, they just went back and did it.

MR. ASHE: I think there is evidence, though, the first person in the area clearly opened the cabinet doors.

MR. RIDDLE: All of them?

MR. ASHE: All of them. There is evidence that supports that. What he or she did or what was done once the doors were opened is very hazy.

MR. IBARRA: Who was the first one there?

MR. ASHE: Hansik. Spooner came later but Hansik seems to be the guy that was first on the scene. It is my belief, based on the transcript information and other sources, that he opened all the doors.

MR. ROSENTHAL: And nobody is taking notes at this time.

MR. ASHE: I think the data set that we have and the data set that you have in terms of the as-conditions of the light was generated by Mr. Bob Crandall, who in turn talked to Mr. Hansik, Mr. Spooner, the operators in the area immediately after. So it was based on their memories and what they recall they did or didn't do.

MR. TERRY: I would also add that there were certain observations that Bob Crandall did make.

MR. ROSENTHAL: Yes, but he's down at T plus two hours. He's the systems engineer and he'll do the best job he can. That's different from the operators running down under the stress of getting the unit back. I'm not faulting him.

We spent time with the drawings. It is my understanding that the ovuv and the thing marked "voltage difference" do not latch.

MR. TERRY: They are simply the status.

MR. ROSENTHAL: It's a status light and they see

it lit at that time.

MR. CHIU: So there is some question as to whether they were turned on or not.

MR. ASHE: That's what the bottom line is.

MR. ROSENTHAL: I'm sure they were on when the man looked and said they were on, but that doesn't mean that they were on at T plus 20 or at T plus 100 milliseconds. I forgot now when we were going through the drawings if we even said where they came from. With the unit restored that may be proper.

MR. CHIU: To make sure I understand, the module trip light was out and the inverter logic light was on T plus two.

MR. ASHE: To me the two important lights in all that data are the logic light and the trip light. The other differences are less important. I am not saying they are not important, but to me they are less important.

MR. CHIU: But based on what we observed or your interview notes, G and A,B,C, 3 UPS, those two lights are on.

MR. ASHE: That's correct. The only guy that didn't appear to have that light, which may or may not have been the case two cycles after this thing went down, was 1D. It did not have a logic trip light.

MR. RIDDLE: These might all be common, assuming D

was manipulated.

MR. ASHE: It could well be.

MR. RIDDLE: At the time of the event they could have all been the same.

MR. ASHE: Exactly.

MR. RIDDLE: That is part of why we got pulled in on the project.

MR. ASHE: It appears that we have supporting evidence that the D unit when the cabinet was open may have been manipulated or massaged a little bit more than some of the other units, which may or may not have made the lights disappear, come on, or what have you.

MR. RIDDLE: That supports our mission in that if we do a common mode, there has got to be a common source. That is what we are hunting down on the card chip level.

MR. ROSENTHAL: Just so we all know, the ovuv is on the horizontal set of lights, not on the A21 card, if I am not mistaken. Give me the card cage.

The ovuv is down here, not on this board. The voltage difference is also on -- there it is.

MR. RIDDLE: I haven't looked at how these signals are generated yet.

MR. ASHE: We also have diagrams that show those.

MR. RIDDLE: But your understanding is there is no way to latch those.

MR. ASHE: Basically that's right.

MR. ROSENTHAL: We went through the circuitry. We would have to go back to our transcripts.

MR. ASHE: There is one of these guys that latches up. I'm not sure which one. We will find that out and put it on here.

MR. ROSENTHAL: We looked at the drawings and the designers tell us that voltage difference and ovuv are not latching, according to my notes.

MR. ASHE: It's the transfer guy that latches, I believe; ovuv transfer will latch.

MR. ROSENTHAL: But output ovuv, no.

MR. RIDDLE: That's worth following up.

MR. ASHE: Why don't we pull the drawing.

MR. ROSENTHAL: Let's pull the drawing and resolve this.

MR. ASHE: I think that portion of the drawing was pretty simple.

Voltage difference. That's one guy. Output ovuv. That's two guys. Voltage difference and output ovuv. Let's trace this guy and see how he comes in here. He comes through here, through here, through here, and there is really nothing that latches.

MR. ROSENTHAL: But what is it looking at? What's its input?

MR. ASHE: That's all over here. Critical bus sensing, at least one.

What I think we are looking for in terms of a latch is a bistable that holds it in that condition. Clearly there isn't one that is associated with this guy. Would you agree, Jim? Do you see anything that could hold these guys?

MR. ROSENTHAL: At the time you make the observation CB1, CB2 and CB3 are open. So is it proper that you would have in fact seen it? If that's the case, why don't you see it on all of them?

MR. ASHE: I'm sorry, Jack. I didn't understand the question.

Jim, you don't see any latches in there.

MR. RIDDLE: I'm tracking it. I don't see any. I'm convinced there are no latches from there.

MR. ROSENTHAL: Three of the units were reinstated, were powered back up, restored.

MR. ASHE: That's how I understand it.

MR. ROSENTHAL: So at T plus two hours, why do I expect to see a light?

MR. TERRY: At T plus two hours they weren't restored. They made these observations before they were restored.

MR. ROSENTHAL: I'm sorry. Just before they were

restored the output of the inverter is zero and the transfer bus is powering everything. If they are looking at the normal output, they should see zero and you get a light by design. Is that consistent for undervoltage?

MR. CHIU: By why don't the other UPS's see that same thing?

MR. ROSENTHAL: You have got it on 1C, 1D, 1G; you do not have it on 1A and 1B.

MR. CHIU: And the rest of it has it.

MR. ROSENTHAL: Ovuv is on C, D and G.

MR. CHIU: So ovuv is C, D and G, not 1A and 1B.

MR. ROSENTHAL: According to our notes.

MR. CHIU: How confident are you with your notes? This could indicate there is an anomaly there. You interviewed a lot of people.

MR. JORDAN: This data came from Niagara Mohawk. When they went down there, supposedly the systems engineer gathered this data, like Frank said, either by visual observation before they transferred or by conversations with the people that went down there at T plus 30 minutes.

MR. ASHE: The ovuv could have well appeared on the 1D unit and not been captured at all.

MR. JORDAN: That data did not come out of interviews. We were not at that level.

MR. TERRY: I'm not sure either whether it was

two-hour data. I know on the others we based it more on what was observed a couple hours later and the fact that the operators indicated they didn't notice any of those status lights. It's worth checking.

MR. JORDAN: This data should reflect the same data that you have in your report; is that correct?

MR. TERRY: Yes. That's consistent. There were inconsistencies on ovuv in terms of what was observed.

MR. ROSENTHAL: What module is this on?

MR. ASHE: There is no number.

MR. ROSENTHAL: The drawing number is 110071222. It is the static bypass logic control card.

MR. RIDDLE: That slides in underneath. It is built in the back of there probably.

I think it is worth following up in that either all of them should have done it or none of them should have done it.

MR. ROSENTHAL: As I say, we can't see where they latch.

MR. POHIDA: What two voltages is the circuit looking at?

MR. IBARRA: The critical bus sensor.

MR. POHIDA: Is it the inverter output versus the maintenance bus?

MR. ASHE: Exactly.

MR. ROSENTHAL: What is it?

MR. IBARRA: Critical bus.

MR. ASHE: He's saying the voltage difference alarm, what is it monitoring?

MR. CHIU: Upstream so we can trace back to see if there is any latch upstream.

MR. ROSENTHAL: We can do that, maybe. We'll try. It's looking at this voltage versus what?

MR. ASHE: Versus the maintenance bus.

MR. ROSENTHAL: Is it?

MR. ASHE: Yes.

MR. ROSENTHAL: Or is it looking at this relative to a reference?

MR. ASHE: There is no reference there.

MR. ROSENTHAL: There could be a constant voltage drop in here.

MR. ASHE: But you have no v reference here.

MR. ROSENTHAL: I believe this is va to B; vc to A; vb to C.

MR. RIDDLE: This is monitoring the AC and then the different phase.

MR. ROSENTHAL: That's the bypassing sensing.

MR. RIDDLE: This card is symmetrical. You have two different channels you are looking at. You are looking at bus to bus. Is the input structure the same? That's the

same; that's the same; that's the same; that's the same. It sort of diverges a little bit after that. They probably come together and do common logic somewhere.

MR. ASHE: To make it really simple, it has got to be looking at the differences.

MR. RIDDLE: It's looking at the differences.

MR. ROSENTHAL: Phase by phase.

MR. ASHE: Yes.

MR. ROSENTHAL: The three phases are summed.

MR. ASHE: You are going to lock the transfer out.

MR. ROSENTHAL: This is AC over here and here I have got DC. So here I've got to build in some summing.

MR. RIDDLE: This is going to be a DC input to this. This is not going to be an AC. This is an op amp. This comparison circuitry vc to A is out here somewhere, because this is going to be a DC input.

MR. ASHE: I don't believe we have the drawings for that circuitry here either. What that is going to probably be is some type of sensing element that goes to those phases.

MR. RIDDLE: Yes, a differential amplifier.

MR. ROSENTHAL: We played games going back to this master drawing. I think that we had concluded, at least with the designers, that they didn't latch. Why don't we go on and if we have time, we can come back to that.

MR. CHIU: If you have a drawing, we can trace that back.

MR. RIDDLE: If this is getting a DC input that compares these two, that's going to be an analog feature. It's not going to be a digital feature back here somewhere driving an analog input.

MR. ASHE: But I'm not sure we go all the way back. These drawings will not go all the way back to exactly where it's sensed and the actual primary sensing element.

MR. RIDDLE: That is probably going to be an inductor, a coil around a phase wire somewhere.

MR. ASHE: And we don't have that.

MR. RIDDLE: Analog stuff usually doesn't latch.

MR. ASHE: I would like to offer a suggestion. Maybe we could trace it down on the break and see if we really have it or not.

MR. CHIU: We can do that. Whenever you have a drawing, we can trace that.

MR. RIDDLE: That is quite useful. Looking at ovuv, I can expand the scope of what I am doing around that.

Do you want me to finish my review?

MR. CHIU: Yes.

MR. RIDDLE: Like I said, my problem child here is the G board right now. I had that out. I tested the K1.

The push-button switch, when you release it, it should go closed, and it doesn't go closed. You have to really tap on the thing; it's crudded up inside. That is going to keep the latches from resetting.

MR. CHIU: Jim, at this point you are measuring the B board 4049 latch-up. Do you want to show them some pictures?

MR. RIDDLE: I will show you what is going on with the 4049. One of the reasons that Chong and I are definitely interested in coming back to the grounding scheme and groundside problems is that the damage that is on this particular chip and a couple of the others -- I have got three of each of these, so I am going to break them up into sets. I want Niagara to have a set and I want you guys to have a set.

This is the integrated circuit die. This guy here with the cutout is pin 1.

MR. ASHE: This was generated on a couple of the chips that were known bad?

MR. TERRY: There was some damage that occurred after this.

MR. ASHE: Recognizing that this is really not relatable to the event, though.

MR. RIDDLE: It is not related to the event?

MR. ROSENTHAL: Let's talk this out.

MR. CHIU: We had two chips analyzed. One chip is on the A20 board. Whether that is related to the event we don't know. But on A21 is the 4049. That's the chip here.

MR. ASHE: The only point I am trying to make is that the unit, after the event, was brought back up; it was working fine prior to failure of two chips. I am just passing that along.

MR. RIDDLE: One chip actually failed. The other, it turned out that it had not failed; it was just removed at the same time. That's the A20 failure, the two chips I got originally.

MR. ROSENTHAL: What UPS are we talking about now? The 1C?

MR. ASHE: That's correct.

MR. RIDDLE: This chip came out of the B unit.

MR. CHIU: And this chip is not one of the two chips you sent us.

MR. RIDDLE: I will go through the chronology of what happened. They sent me two burned up chips which they said were from an A20 card. We are still in the process of getting a good drawing. Then they sent me a new board. Then they sent me the B board. Then they sent me the G and the A boards. I sent the B board and the new board back.

Of the first two chips that I got, the 4049 was burned up and seriously overstressed. The first two chips

from the A20 were a 4049 and a 4011. The 40II is a good chip. Basically they just shotgunned everything in the circuit path, which were those two, of which the 4049 is dead.

MR. ROSENTHAL: I want to get this on the transcript, because we are going to be re-reading this. As I remember it, we are troubleshooting the 1C.

MR. RIDDLE: Yes, those came out of the 1C.

MR. ROSENTHAL: It had been restored after the event and it was all running fine. We are putting cycles on the unit as we are testing it, right?

MR. RIDDLE: Yes.

MR. ROSENTHAL: A week later, or whatever it is, we pop what we thought were a couple of chips. Now you are saying one chip.

MR. RIDDLE: Yes. They removed chips, one of which is damaged.

MR. ROSENTHAL: So at least on the 1C those original two chips that we sent you failed. They may have been degraded all along.

MR. RIDDLE: That's what we presume.

MR. ROSENTHAL: At least one of them failed while we were doing troubleshoot testing a week after the event, or whatever it was.

MR. RIDDLE: Right. Apparently it was after a

series of tests and the system was sitting there. No one was manipulating the system when it zapped.

MR. ROSENTHAL: Right. We were physically there at the time.

MR. RIDDLE: We are operating under the assumption that the part was degraded. Let's go back to that before we go on to this.

On this device we have what is considered to be long-term heating, very long-term heating. This particular damage here, this is a plastic encapsulated part. This black material over here is indicative of the pyrolization of the plastic over the device. It takes seconds or minutes for this to cook in and pyrolize into carbon. This kind of damage where the metal alloys into the silicon took a long time. The initiating stress for this may have been a voltage transient, for which I don't have high mags here at this point. We are looking into a vdd to ground, some transient that initiated this, and this stuff took hold later on.

MR. JORDAN: When you say long term, are you talking about minutes or are you talking about months or are you talking about years?

MR. RIDDLE: Several seconds to a day. Not years. Years would be much more extensive with broad alloying over greater distances.

MR. ASHE: Do you have a slicing machine that slices the chip open? How do you get it open?

MR. RIDDLE: Crack the tops off. I break the top off and go into high magnification to look at it. On the plastic encapsulated ones you have to hit them with fuming nitric acid and basically dissolve away the plastic over the top.

On this 4049 we have evidence of some long-term overheating. Nothing on the 4011.

MR. ROSENTHAL: What temperature should these chips run at?

MR. RIDDLE: They should run at spec. They are rated from minus 55 to plus 125, or whatever. You can run them at 70 or 80 degrees C. I wouldn't run them above 100 degrees C for very long. CMOS doesn't dissipate a lot of power; it doesn't do a lot of self-heating. As long as you keep the junctions down below 125 or 150 C you're fine.

MR. POHIDA: What was the temperature inside the unit?

MR. CHIU: We don't know. We don't have the data.

MR. RIDDLE: I think it was 130.

MR. TERRY: I think they took some measurements back when they asked the vendor about it. I think Bob Crandall indicated it was around 130 F.

MR. ROSENTHAL: That is not necessarily the card

cage ambient temperature.

MR. RIDDLE: It is somewhat outside of where all the heat generating stuff is, all the transformers and stuff. The card cage is actually outside of that.

MR. ROSENTHAL: It's up above it and to the left.

MR. RIDDLE: But its ventilation is coming from the other side of the metal panel.

MR. ASHE: To make it clear and simple, these photos are from the 1B unit.

MR. RIDDLE: Right. The 1B card was sent to me; it didn't work; I took the chip out. This is classic SCR latch-up where metals fused. This is a die shot. One piece of the ground metal is fused right here. Ground metal also goes elsewhere. It comes out over here; it comes out over there; it goes through this.

One portion of the ground connection, right here, is fused open. I probed -- this is probing damage that I did. I set a needle down on here and measured. Both sides of this open circuit are connected to good junctions; no short circuits on the inboard side of any of this. If I reconnected this little piece of metal here, this part would work.

That is characteristic of latch-up that came in on the ground side, a transient that initiated the latch-up from the ground side. Again, the predominant damage on that

first chip is on the ground side as opposed to, say, zapping from inputs to outputs or a power overload from the plus side. That is what is leading us to wanting to go back and look pretty seriously at the grounding scheme, to make some ground measurements and calculate where the ground could have gone in a transient, raising the ground up over a long period of time or just a short period transient through the ground. I wouldn't say this is an open and shut case here. More analysis is required of the chip, but this is classic.

That is where that chip testing has led us and why we are curious about the ground setup.

MR. ROSENTHAL: That's the 4049 chip, also marked U10 on their drawings, on the A21 board of UPS 1B.

MR. RIDDLE: Yes.

We did some SEM shots just to prove that. This glass on here is really thick. It actually took us 40 kilovolts to punch through the glass. This is very old design. The date codes on these things are '79, '80 and '81. CMOS has been around for a while.

Another interesting point is older CMOS is more susceptible to latch-up. They have made design changes in the layout on these chips. Checking the new chips is just the first step. You have to go back to the same vintage chips.

MR. CHIU: The summary of those two tests -- On

the first chip, 1C, we don't know whether it was during the test or during the event. That's unknown. The second chip came in. At that point we went back to review their test sequence to see whether they ever opened up the ground lead or injected voltage through the ground side to do some tests. We have been told there is no such test. So that led us to the fact in order to have that ground side get zapped it has to have a voltage.

MR. RIDDLE: There are enough clues in this damage to indicate that things happened on the ground side.

MR. POHIDA: You are saying that you are convinced that there was something on the ground based on the boards that you have seen?

MR. CHIU: Yes.

MR. TERRY: At some point in time.

MR. RIDDLE: We are convinced that the damage to these chips was initiated by some upset on the ground side of the chip. Where the ground side of the chip is in relation to the big ground or the digital ground, that still has to be followed up.

MR. ASHE: Could that have occurred on restoration, though?

MR. RIDDLE: Perhaps. I haven't looked at that.

MR. ASHE: You can't pinpoint the time at which it occurred, though, can you?

MR. RIDDLE: No.

MR. ASHE: It could have occurred during manipulations of the unit during restoration, particularly by people who are not familiar perhaps with the intricate steps and details necessary to do it.

MR. RIDDLE: This damage, yes. This may not be relevant, but we have to follow through on it.

MR. CHIU: The point is we don't know if the damage was done during transient or during a manipulation, but we do know somehow the voltage goes through the ground side, goes to a transistor. If you design circuitry right, you should not have voltage come through the ground and hit your transistor like that. Just like your computer. You always have a surge protector to protect your ground side. It's the same logic.

MR. POHIDA: The operators shouldn't be able to damage the logic if they follow procedures, if the unit is designed correctly.

MR. ASHE: They had no procedure to do this with, so they are off normal procedure. The issue about procedures with specific steps, I think we pretty much understand that aspect.

MR. RIDDLE: In terms of generating overstress on this particular chip and no other, you will note that this chip is buried in the circuitry. You have to go through

several chips from either direction to get to this guy to blast him. This chip doesn't see the outside world. It's connected to another chip on one side and this other chip on that side. There are no outside pins where somebody could grab on and zap it or that sort of thing.

One of the other points about SCR is even with this fused open this chip could work marginally. What this multiple ground lines metalization does is it interties a portion of the circuit to make sure they have a hard and fast ground connection between them. When that is fused open, the device becomes very much more sensitive to latch-up. So this could in fact work in this condition unless it got a mild upset, like a switching condition.

MR. ASHE: There is no way to pinpoint the time, though.

MR. RIDDLE: On this, no.

MR. ASHE: If the unit was working from the outside satisfactorily, this could have been there two days before the event and nobody would have known anything.

MR. RIDDLE: That's possible. It would not make my day. It's physically possible. In fact, I have another chip, which I didn't bring the data on. It is evident that it is internally contaminated, which happened during manufacture. I haven't actually analyzed that particular foreign material, but there is a big splotch of junk on

there. From my military background, that can cause stray leakage through that chip. That's random type damage. Having that on all five UPS's is a very low probability.

Your point is well taken in that this may be latent. I took the U10 chips off of the A unit and the G unit and opened them up. Even though the A and the G unit work, I took these particular chips off and opened them up. No damage. So we are following that logical trail there. I took the same components -- one is a Motorola and one is an RCA -- off of two other units, de-lidded them; didn't see any anomalies.

That is the kind of reasoning we are applying to this and testing that we are formulating. When we do see something like this, we run it to ground.

MR. ASHE: Let me understand what you have. I'm not sure I understand exactly the hardware that you actually have from the units that were in operation during the event. I know for a fact you got two chips. I know for a fact you have two batteries. What else besides that do you have from the actual units that were installed?

MR. RIDDLE: A21 from the A unit, the B unit and the G unit. The B card has been returned. I changed this chip, confirmed that the board worked, and sent it back to Niagara Mohawk. I think they are going to send it to Exide and confirm that the board is fully functional.

MR. ASHE: So really they have replaced all those boards in the unit now. The ones that you took have replacements on site now, physically installed.

MR. TERRY: Right.

MR. RIDDLE: They got some new boards and plugged them in.

I have two boards now. I had B. I returned it. I have A and G. I haven't seen C and D. We have proposed to look at all of them.

MR. ASHE: You are talking A20 boards?

MR. RIDDLE: These are all A21 boards, this board here.

MR. ASHE: The A21 board from A and G units is what you have now.

MR. RIDDLE: Currently. The A card is here. We can look at that. The G unit is the one that doesn't latch. I am working on that problem.

MR. ROSENTHAL: The postulate that I am now hearing is that by design you would have generated a PSF signal which would have latched the 4044 chip, which would have ultimately resulted in an SSTR signal and the observed phenomena. Under that condition we should have had the D9 light as well as the other logic lights. Now the postulate is, wait a minute, maybe you never generated the PSF signal, but rather the 4049 chip changed state.

MR. RIDDLE: Based on a transient introduction from power.

MR. ROSENTHAL: That would have lit the logic lights, caused the units to trip out. These RS chips would never have changed state and these lights would never have come on.

MR. CHIU: That is just one scenario.

MR. RIDDLE: That is one scenario.

MR. CHIU: We have other scenarios.

MR. TERRY: You guys are postulating that PSF was never generated.

MR. RIDDLE: That's not one we have considered but that is just as valid, that these chips burned up downstream or latched up downstream.

MR. ROSENTHAL: If I have A10, the 4049 chip, changing state due to a ground fault or other phenomena, that will cause the SSTR to generate a signal and it will trip out the units, as we observed, or light those lights.

MR. RIDDLE: That's possible.

MR. ROSENTHAL: When I come back I see these lit; I don't see that lit; I'm happy.

MR. POHIDA: In this scenario the 20 volt supply may not have dropped down to the 16 or 17 volt range. Right, Frank?

MR. ASHE: That is what it is leading to as a

possibility.

MR. ROSENTHAL: On the millisecond or the first couple of cycles or less, this perturbation caused this to latch, which caused the unit to trip off, and I never generated this which caused this light to come on, and that's why I never observed this light. Is there another way? I thought that is what I was hearing from you.

MR. CHIU: Let's look at it from a distance to see what refuting evidence there is on this scenario. That's a possibility.

MR. ROSENTHAL: If a cycle or two later or a fraction of a cycle later the PSF was generated, then that should have changed the 4044 and flipped that light on.

MR. RIDDLE: The first hypothesis that we started to follow up was that the PSF was generated. These were reset by transient means; these were latched up by the same transient means. So you got a signal. These were set. You got a system upset with noise injection either through ground or between the phases, and that reset these guys and locked these guys up. The direct evidence is going to tell us whether this was on or off. The direct evidence is these are on and this isn't on and it should be. So there are two ways. You can come in upstream and blast it or you can come in through here, set everything, and then knock this out.

MR. CHIU: Right. There are two possibilities.

MR. RIDDLE: And his possibility, which is a third one, which is nothing ever happened.

The original first point was the 4049's are the most susceptible chip to latch-up. From my testing, they are the easiest chips to make go off. They are the first thing in this circuit -- well, there are a couple down here. These are driving timers, though.

MR. CHIU: One question. You are leading us in terms of system data. When the transient occurred, the AC power dropped. At the same time the DC power was dropped. Do you know how low the DC power dropped? We don't have a power supply.

MR. ROSENTHAL: We have asked for that.

MR. RIDDLE: Your 6 cycle, 100 millisecond event, the capacitor C4 will hold that power supply up for 100 milliseconds. It will hold the card up. The card doesn't draw too much juice.

MR. ASHE: I think we have concluded that through other ways. We are on that same trail and we have concluded that. To answer your question, an exact value of how low it actually dropped we don't have.

MR. CHIU: Do we have any way we can have that power supply to supply a DC transient, 6 cycle, 9 cycle, 10 cycle, to see the DC power drop? I tried to obtain that data. I don't have that power supply. Some of our

consultants will tell you that you will never drop that voltage down to 17 volts. Some other thought processes are, hey, it will drop. It is almost like everybody has an opinion but no data.

MR. RIDDLE: Another thing on your hit list going out there is to go through the ground thing and go through the power supply stuff out there.

MR. ROSENTHAL: Jim, why don't you give us a couple of minutes. We kept hearing 6 cycles to clear and 6 cycles to reload. When you were looking at the UAT, it was a little different already.

MR. STONER: The breaker on the 13 KV switchgear is a 5 cycle breaker as opposed to a 2 cycle breaker. So you would expect the generator to maintain the voltage after the Scriber breaker opens. So you are really talking about 3 cycles until the voltage is restored from the other source. Of course that voltage won't drop to zero because you have induction machines which become induction generators.

MR. CHIU: Jim, do you have any idea or data to see how maintenance power dropped, voltage dropped? Do you have data?

MR. STONER: We have no recorded data. We have calculated data from Niagara Mohawk.

MR. ROSENTHAL: You have that information.

MR. RIDDLE: I think it has been provided to us.

MR. TERRY: I would like to go back to this time thing. We did some testing on a unit where we dropped power on a quick pulse and we measured it. That was between 100 and 200 milliseconds. That will trip the units. We got all the indications. We got PSF and everything else on that.

MR. CHIU: So you do have test data.

MR. TERRY: We were talking timing. I just wanted to make that clear. With no batteries in there, if you do a quick switch -- granted, that is not the exact pulse; we all understand that -- but I think there was some question on whether it would drop fast enough, 100 or so milliseconds. What our test data tells us is, yes, with degraded batteries that could cause the PSF to be initiated.

MR. ROSENTHAL: But the lights always work, as you would expect.

MR. TERRY: That was the anomaly, right. I'm just talking about the trip signal, the timing.

MR. ROSENTHAL: On the 1C we dropped the 110 v phase input voltage with a VARIAC slowly down and it trips out and K5 never transfers, et cetera. Then we do a test where we bring the voltage back up.

MR. ASHE: You have a crank-down test.

MR. ROSENTHAL: Crank-down test.

MR. ASHE: You crank it down all the way until the

K5 relay drops out. That is one voltage value of 45 volts AC, approximately.

The other thing that was meaningful in the drop-down test, PSB1 and PSB2 have a sharp drop-off following a decrease in voltage from approximately 96 or 95 volts. In other words, they seem to be well regulated as long as the voltage stays above 95 or 96 volts. Once you decrease their input to below that value it tends to drop off very sharply.

MR. ROSENTHAL: That is a quasi-static test.

MR. ASHE: It is not simulating the event at all but it is some actual testing information.

MR. ROSENTHAL: Niagara's calculations are that it would have dropped below that voltage but above the K5. That is 65 volts.

MR. TERRY: That's the best average. We had a range.

MR. ROSENTHAL: Now you turn the VARIAC back up and you are at 110 volts?

MR. ASHE: 120 volts.

MR. ROSENTHAL: There is a little toggle switch on the VARIAC. They flipped it. As I remember the scope traces at the time, that is about 150 milliseconds.

MR. TERRY: I think the quickest we could do it was closer to 100 or around 200. That's right. The nominal value is about 150.

MR. ROSENTHAL: It was dual traced: The power supply goes and you generate the PSF. These lights work and you trip the unit out on the 1C.

On the 1D, you do the VARIAC, drop the voltage. Everything is consistent. Bring it back up, you flip the toggle switch, and as I remember, it didn't trip out.

MR. ASHE: That's correct.

MR. POHIDA: You didn't generate a PSF.

MR. ROSENTHAL: We didn't have a lead on PSF. I'm a lot smarter now than I was two weeks ago.

MR. ASHE: The reason the unit didn't trip on the 1D is believed to be because when that test was repeated on 1D the PSB DC voltage of 20 volts did not decrease below the trip value. How do we know the trip value? The trip value on the 1D was experimentally determined with actual installed equipment. You slowly crank down the VARIAC input to PSB-1, and then at the value that the thing tripped you record it.

MR. ROSENTHAL: That value is what, 16 or 17 volts DC?

MR. ASHE: I don't recall exactly what the value is. We had a range of values of 16.5 to 17.3 for trip values.

On the fast test, after that value had been determined on the 1D experimentally by connecting up

oscilloscopes and digital voltmeters, the fast test was done. The unit did not trip. It was determined with the scope, however, that the DC output never dropped below its experimentally determined trip value.

MR. CHIU: So some capacitor was holding it up.

MR. ASHE: Something was holding it up.

MR. ROSENTHAL: Now I have a postulate here that is cockamamie, and it goes something like this. You degrade the power input to the power supply. The power supply is still putting out some number of amperes. You deplete the stored energy in the capacitor of that power supply. It's all charged up. If you do it fast enough, you never deplete the stored energy in that capacitor and you don't generate the PSF. If it's a cycle or two later into the event, you are still holding up all these loads, you still have 12 volts, you still have 5 volts, but you are draining down the capacitor on the power supply, and then if you do it, it might flip again. So that is why we have asked -- and Exide was staring at us like we were nuts -- for the schematic for the power supply, the little 20 volts, which they buy as piece parts.

MR. ASHE: By the way, we didn't get that.

MR. ROSENTHAL: We don't have it yet?

MR. ASHE: We did not get that.

MR. TERRY: They said they were going to look and

see if they had one. They said they came in a box.

MR. ASHE: Right. It was my understanding they were going to go back to Raleigh. On the box with the power supply, the details of that schematic is there, and they were going to give us one of those off the box.

MR. ROSENTHAL: That may explain the differences between the simulated test on the C and the D.

MR. CHIU: This is crucial data. Carl was mentioning that Exide has one of the simulation channels. Maybe we can go to the simulation channel and measure the transfer function between AC and DC. Once you get that transfer function you will know a lot of things.

MR. ROSENTHAL: But none of that explains the light bulbs.

MR. ASHE: As a point of information it may be helpful. The 1C and 1D units had the most testing in terms of actual recorded data or scope traces. The remaining units have had less extensive testing.

MR. RIDDLE: The B unit was reset and operated and then no testing was done on it before I obtained the card that had this chip on it, right? None of this up and down?

MR. TERRY: Right.

MR. ROSENTHAL: Wait a minute. I thought we quarantined it.

MR. ASHE: No. He's talking about what testing

was done. The transient testing with the switches was terminated after 1D. That's our understanding. If he has a different understanding, then we need to clarify that.

MR. TERRY: That's right.

MR. ASHE: We did the transient testing on 1C; we did it on 1D. After that, the other units weren't subjected to that.

MR. ROSENTHAL: We still dropped the voltage slowly in those games.

MR. ASHE: With the exception of 1G.

MR. ROSENTHAL: We didn't want to kill 1G, and 1A and 1B have such critical loads that we didn't want to put the plant in another transient.

MR. ASHE: Basically, the other units have three tests.

There was verification that power supply was coming in on the B phase; actual verification with instrumentation that's coming in on the B phase.

There was verification of the DC trip value.

MR. RIDDLE: Where is that?

MR. ASHE: The DC trip value. We are talking about plus or minus 20 volts.

MR. RIDDLE: But you measured that in terms of the AC dip.

MR. ASHE: You measured the actual DC at which it

tripped. The way you did that was to crank down on the AC and as the power supply lost its regulation it couldn't hold the DC, so the DC would come down.

MR. ROSENTHAL: You had your digital voltmeter right across the output.

MR. ASHE: Plus or minus 20.

MR. RIDDLE: This is plus 20 and this is ground.

MR. ROSENTHAL: I'm between ground and plus 20.

MR. RIDDLE: You've got it. Which is the same as right here.

MR. ASHE: We are going to the 20 volt input. The plus and minus DC value was measured and that varied from 19.9 to 21.5 with some variation as you moved from unit to unit.

That is three tests and there was another one on it, too. It was the dropout on K5. That was another one. You verified the actual AC input voltage required for K5 to drop out.

MR. CHIU: In essence, what we have here is PSF could have been generated for all five UPS. We don't have refuting evidence.

MR. ASHE: Not if you say 100 percent.

MR. TERRY: We don't know exactly what was there. We do know if the voltage had dropped off that it would generate that PSF and we were able to demonstrate that you

with a quick, short pulse you could generate the PSF where all the lights were right and all that kind of stuff. That's kind of what we know. That is part of the dilemma here. Exactly what was happening at the event is confusing because of the fact that a couple lights were lit and one light wasn't.

MR. ASHE: My bottom line through all the testing may be helpful to you. The reason we couldn't duplicate the actual tripping in the unit is because we weren't simulating the conditions close enough. That may be helpful; it may not. The testing that was done on the units, in my view, does not simulate physical insight into the event since there is really no recorded data in plant that I'm aware of.

MR. RIDDLE: That was confirmed with our testing. We did DC dropout in a more controlled fashion with square wave pulses, dumping those on the DC, bringing the output down from 20 milliseconds out to a couple seconds. We could never get the card to do what it was reported to have done with this light off and those indications on. We basically did the microscopic version of what you did on the whole system on the card using the test rig that was shown.

MR. ROSENTHAL: When you drop the 20 volts here, what do you get in terms of 12 volts here?

MR. POHIDA: You will still get 12 volts until it comes down to 14 volts or so.

MR. RIDDLE: Correct. You have this capacitor here holding that up.

MR. ROSENTHAL: C1 or C4?

MR. RIDDLE: C1 is holding up the 20 volts.

MR. ROSENTHAL: C4 is holding up the 12?

MR. RIDDLE: Yes. That is after the post-regulator. Your 20 volts comes in here. This is a 5 volt regulator. It goes off to a 5 volt bus. The only thing that drives is the lamps. Then it goes to the 12 volt regulator. It is held up right here, and that drives all the chips.

MR. ROSENTHAL: So I have got good plus 12 to the chips until I get 14 volts here, but I get 17 volts here, which will drive this.

MR. TERRY: You will get a PSF at about 17. A little less, maybe.

MR. RIDDLE: PSF is one of the lines that disturbs me, because it doesn't have the 12; it doesn't have the pull-up to the 12 volts. Floating inputs on CMOS bugged me. There's was another one. This WF knot has the same problem, no pull-up. Why all of the other ones do and these two don't is another lead.

MR. ROSENTHAL: You know that on the board?

MR. RIDDLE: Yes. I measured it. There's no resistor here. I measured the 12 volts to the input here.

On the specific board it has been confirmed that that is the case. My CMOS background says you don't want to float inputs. Depending on what happened backstream on the A20 board, this could cause some problems.

MR. CHIU: What kind of problem could it cause?

MR. RIDDLE: If you float the input, it will invalidate this logic. I am going to bring in another concept here for CMOS, which is tristate. Tristate is a condition when you have -- I will just draw a voltage chart. It won't be exact in terms of numbers.

On tristate, you have a logic thing here, input here, output here. Starting out at zero volts and then, say, for sake of argument, 5 volts here so you can use TTL numbers, you will have a range here and a range here. This is true; this is false; and the same with the output. True and false here. What this does to the output is it makes the output high impedance, i.e., open. If the high impedance goes open and there is no resistor here to pull this PSF up, then this input sees high impedance. This could see whatever it wants to see, but it could see enough to bring it into this region and play games all the way down the circuit.

The way to get that light to go off and have the other ones stay on, I think, since I had lowered the voltage down to about 4.5 volts, I had driven a bunch of these chips

into tristate mode when I lifted the ground. I haven't analyzed exactly what is going on in the movie. I presented that more or less as a clue, previews of coming attractions, so to speak. This tristate region can generate strangeness on the output in terms of this high impedance.

You were following this up as well with Exide. What did they have to say about it?

MR. POHIDA: I brought up the issue of floating inputs to CMOS gates. I wasn't concerned with PSF. It was on some other board where they had designed the unit to possibly be controlled from the controller which they weren't using.

MR. RIDDLE: Not plugged in, right?

MR. POHIDA: It was not plugged in.

MR. RIDDLE: What you need to do is terminate pins that you are not using. You have to tie them off. It is stated in that little write-up on reliability. It says one of the design guidelines for CMOS is "thou shall not float."

MR. POHIDA: You talk about this tristate effect. My experience with CMOS is if you let it float, an input float, the voltage can then float to any voltage. If it floats to a threshold voltage, I thought that the CMOS could start to oscillate.

MR. RIDDLE: That's possible.

MR. POHIDA: Then that can permeate through all

the circuitry through noise, I would think.

MR. RIDDLE: Yes.

MR. POHIDA: Also, the power consumption of that chip goes up.

I just think the fact that they have inputs floating is just asking for trouble.

MR. RIDDLE: Yes.

MR. POHIDA: I don't know about PSF. I don't really know where it comes from. We keep saying A20. We tried to track that yesterday.

MR. ROSENTHAL: Why don't we take a break.

[Recess.]

MR. CHIU: One thing I want to just clarify, and I worked with Jim for a long time. When we go into the circuitry -- and often times Jim will get excited and it we have adjectives that come out. It will be all adjectives. We only look at data impossibilities.

MR. RIDDLE: Nobody designs a perfect circuit. So, every designer will say there's something wrong with everybody else's design.

MR. CHIU: It's very common, and especially being a failure analyst there is a tendency of doing that. We are not criticizing the 1972 design as long as it works. We take all the anomalies, the cause for anomaly -- that's the purpose.

MR. RIDDLE: I think we are looking at possibilities in terms of the tristate mode, the latchup mode, the power imbalance oscillation mode. I think those should be run down. They may occur during this unusual event, and they may give us some clues back to what our lighting scheme is. In general, the circuit works.

MR. CHIU: Do you want to go through that? That's part of our testing later on. Maybe we can go through these three pages.

MR. RIDDLE: Do you want to finish the rest of that?

MR. CHIU: Yes, let's finish that, so you know where we are at this time.

MR. RIDDLE: Where were we, at Page 2. We did the functional testing on A and we were able to do the tests that you had seen on the video there. My feeling is now, although I have to go back and confirm it, that we may be in a tristate mode to make that happen. High speed transient testing is one of the things that we want to follow up on, especially on the power inputs and in reference to ground, to follow up some of the background that Chong is doing in terms of ground loops and those type of problems.

I guess the preliminary conclusions from the chip data or the negative voltage on the outputs of the 4049's will invariably cause the chips to latchup. That is clue

number one, the 4049's are susceptible and they are very susceptible from the ground side. Injecting negative voltage into the output is the same thing as raising the ground voltage above the output. Those are identical functions. You are biasing the same diodes.

We know the 4049's are susceptible. We have two blown 4049's to demonstrate that they can be blown in this circuit probably by that means, since that is the simplest and most direct means. We can duplicate the initial failure condition and reported lamp settings but the unlikely conditions have to be initiated to do that, although it does indicate the circuit can be coaxed into misbehaving.

The following samples here have been submitted for lab analysis: the battery pack; the two IC's; the 4049 from B, A and G; and, the relay in the switch from G are going to be extracted. That has been done looking at that, and the G still has a problem in that the latches won't latch. Then it goes to the results.

One of the batteries has been analyzed thoroughly and just determined that it just failed -- died out from old age. We added water to it to recharge it and it wouldn't hold a charge.

MR. CHIU: It's plated out of --

MR. RIDDLE: It's plated out to the point where you can't break it down anymore and reverse the reaction and

turn it back into sulfuric acid. This is typical of old age, where that has been confirmed.

4011 from the A20 is good. The 4049 is bad, catastrophic failure. The damages induced into the power lines VSS or VVD, that hasn't been completely clarified. Circuit analysis is pending on that. The electrical testing, you have seen the pictures of that, of the latchup characteristic coming from the negative side.

We did electrical testing on two other 4049's from the same -- these were from the A and the G board. We opened them up and didn't get any damage. Then we go into the UPSG, has an intermittent open circuit. Normally closed condition to provide continuous signals for 4044's to reset through K1. That is indicated by the fact that I can't set any of the lamps on the G card. We are continuing analysis on that.

The preliminary conclusions are there that of the two damaged 4049's they seem to be more on the ground side, indicative of latchup and possibly transients. Again, from the ground side, a conclusion would be that at least one of the batteries failed due to old age. The UPSG failure seems to have a problem with the push button switch. I know from after I wrote this up now that there are also some other problems on the board. We are on those next week.

That's basically what our situation here is. I

think the thing that we have put off -- we have gone back and done a bunch of this slow voltage dropout testing. It might be useful to do that on this board and a few other boards where people have questions and get some real hard DC values in terms of how long it takes for the 12 volts to dropout and such. What I would like --

MR. TERRY: Which board do you mean, the A21?

MR. RIDDLE: This board here, the A18 and maybe the A21. We are having questions about several boards. At least it plugs some numbers in. What I would really like to do is get back onto the high speed noise transient testing, dumping high frequency garbage in on the power lines and the inputs and outputs and see if I can get something to happen in terms of concept of oscillation or the concept of inducing the latchup downstream on the A21 board.

I see those as immediate actions. It looks like our scope is expanding to look at how some of these other boards are interacting.

MR. CHIU: What it does is, this is in early plant that we have. It is weird. It was asked by Nine Mile Point senior management is to go down to the detail level, subcomponent level, turn every stone. In our early plant we do have this transient as part of our plant and tristate, those are the things we plan to do.

We may look at other boards because we set up a

board cast, and it may be easy to do that with other boards if possible with Nine Mile Point's agreement. The bottom line there is hopefully in about a week or two weeks we can explain the anomaly -- that's the key. The next stage Carl and myself was talking about is -- after we are done with board test we find a scenario which are more feasible than the others, and that scenario will be brought to the simulation channel and turn it on.

MR. RIDDLE: The manufacturer has a system that we can go in and beat up on.

MR. CHIU: Yes, simulation channel.

MR. TERRY: At Raleigh, yes. Something pretty close, I think. At least something that has this control kind of thing. One of the things -- when we talked today we need to look at this thing probably as a system more so than each board at a time. There is a lot going on during these transients. We are just coming up with plausible explanations right now. It's not really the full --

MR. ASHE: Your preliminary analysis on the chip level, what is the key? Is there anything that you have identified that is concrete that would lend itself to the trip not functioning?

MR. RIDDLE: Which trip?

MR. ASHE: The chip, chip level.

MR. RIDDLE: The chip not functioning or the trip

not functioning?

MR. ASHE: The chip itself. In other words, a chip can be degraded but it can still function.

MR. RIDDLE: Yes.

MR. ASHE: In your preliminary analysis, have you come up with one, two, three items in which you feel that a chip itself -- of the ones that you have looked at -- may suggest that there are other chips that may not do their functions?

MR. RIDDLE: The latchup testing could be extreme -- I mean the latching up of a chip can cause various degrees of damage to where it's melted open traces or thinned out traces. There is always a possibility of some damage. However, looking at some of the other chips from the same circuit locations as the failed chips, we didn't see any damage at all.

The chips that do have the damage are catastrophically degraded. I would say the chip was hit and there was enough power available so that the chip is going to be bad. The damage on the two chips that we have analyzed is in sense, enough to make the chip totally non-functional as opposed to degraded. That would come up just during a basic exercise of all functions.

We have talked to Nine Mile about it. You might want to exercise the logic and just walk through it.

MR. ASHE: What I am going to is, there is no real reason to expand the chip investigation at this time; take more chips?

MR. RIDDLE: No, not at random. There is reason to investigate the G Board and find out what's going on, that there might be a chip problem there. I wouldn't want to start pulling boards out and taking chips apart just statistically. There, I don't see any --

MR. ASHE: I was thinking maybe there may have been two points that you saw in the ones that you did do that may suggest something about a lot of the ones that you haven't even looked at. I think what you are saying is that at this point you need to look into the G Board a little bit further. In terms of one or two issues there doesn't seem to be anything at this time identified.

MR. RIDDLE: I don't see anything that I would say wow, we are at big risk here, there may be something wrong with all these chips. I haven't seen any evidence of that to where I would raise a big alarm flag and say wow, we have to take every chip apart and find out what's going on. There are some failure mechanisms and types of damage where you look at it and go yes. For instance, lateral arc overs, inputs and outputs, that type of a problem. Once you see those on a couple of chips you know that they have scurried around the whole circuit.

I haven't seen any of that, so that doesn't scare me right now. We will see what happens.

MR. ASHE: Do you have direct access to Exide?

MR. RIDDLE: No. I guess I need permission from these guys.

MR. TERRY: We will work with them on that.

MR. ASHE: Okay.

MR. RIDDLE: I don't know how much I want to expand my scope. There is probably some pretty hot shot designers over at Exide. My expertise is in the failure analysis side of it. I don't really want to go in there and start beating up on the guys that designed the board. That's not my area of expertise.

MR. ASHE: Some of the things in terms of just information might be helpful.

MR. RIDDLE: Yes.

MR. ASHE: Not in a critical sense, but just obtain information. That's the kind of light I was using that in, not so much that you are going to go in there and criticize somebody's design. It may be helpful if you got one or two pieces of information about it. I was just curious that you have direct access.

MR. RIDDLE: I guess I can get that. My mission is still from John, is to look at the lights to go on and off and all the possibilities to follow that up on, which is

-- I am doing that in a diligent manner.

MR. CHIU: That is our mission. If it requires to go to Exide to review their data sheet or expand the study a little bit more another board, that would be part of the mission. Our job is to turn every stone, to make sure we don't leave anything out. That mission is still on. We don't discount possibilities at all. Don't mistake my earlier statement about we try to -- it just from our point of view we are failure analysts, we are not designers.

I want to make sure that everybody understands where is our limit. Knowing that limit, we can do our mission in a more effective way.

MR. ROSENTHAL: I am very glad that you are working the problem out. I feel if you weren't working the problem we would have to find somebody to assist us to work the problem. It may be appropriate for me over time for me to fly some people out to you. We would always -- we will work through Niagra Mohawk just to keep the communications going. I have no problem with that. As time goes by, that may be very appropriate. Similarly, if you go down to Raleigh to Exide doing some, testing, I think I would like to accompany that.

Can you give me just a couple of minutes again on tristate and latchup.

MR. CHIU: There's a blackboard if you want to use

it.

MR. ROSENTHAL: I understood the C-MOS logic, if you ride around the point you could oscillate on the input. I always thought that meant the output we go hard one, hard zero, and oscillate back and forth. What you are telling me is that there is another mode.

MR. RIDDLE: Let me see if they have a work estimation here that I can derive. I am not a designer, so I don't want to explain this in an incorrect way.

MR. ROSENTHAL: If that's public literature, maybe all you do is xerox it and share it with us.

MR. RIDDLE: I already sent a fax of this to you that talks to you in technical -- it basically goes through all of the parameters here. Let's see if there's a section here on the tristate. There's a section here, 119, on the SCR latchup mode.

MR. TERRY: Jack, if I understand your question, just looking at this input here, let's say this was switching back and forth. Your question is, does that mean that this keeps switching back and forth and that keeps switching back and forth, and on and on down?

MR. ROSENTHAL: Right. I thought that this would --If this sits right around the transition point, I was under the impression that this would go hard high, hard low but oscillate. Now what I think I am hearing is, no there

is still another mode where there is nothing.

MR. CHIU: Which board is that?

MR. RIDDLE: A18.

MR. TERRY: I am just taking that as a starting point. I think there was a question, maybe this was changing. So what does that mean -- I am just taking that as an example on downstream.

MR. ROSENTHAL: It seems to me the only way that you can explain it is to say that a PSF was not generated --

MR. CHIU: We have three scenarios.

MR. RIDDLE: There are three possible scenarios.

MR. CHIU: We will write it down for you.

MR. ROSENTHAL: He's going to use the board. The professor, go ahead.

MR. CHIU: If you have any more scenarios, let us know and we will discuss it. One, the PSF not be generated. In 4049 you can latchup. That's what the problem was. The second one is PSF generated, lamp on the PS light reset by K1. MR. ROSENTHAL: By K1 on the A21 board.

MR. CHIU: A21 board, yes. That can also cause the situation we see. The third one is the board characteristic, which is dual transient. I hear you talk about oscillating -- OPS oscillating -- tristate. There is only three possibilities that we talk about.

MR. ROSENTHAL: On the third one with the board

doing its funny thing, PSF would not be generated again or may or may not have been?

MR. CHIU: Maybe the board do funny things. PSF may generate it but the DS light doesn't get generated. You oscillate and signals the PSF, but didn't trigger everything else. So, only one signal goes through PSF, turn on all the lights. All the rest of it does not turn up because they are just not reaching that state.

MR. ROSENTHAL: SSTR, the output of the A21 board, was generated. Do we all think that occurred and stated its switch position long enough to pick up K1, 2, 3 on the A27 module. Is there any doubt over that?

MR. CHIU: We did review that, but it looks for one reason it's illogical.

MR. TERRY: We know the breakers change, we know that.

MR. CHIU: That one I think is based on what data you have. That leaves the from our study and your study, there is no reason to doubt it right now. There is no reason to doubt that, we didn't have none.

MR. POHIDA: Number three includes ground transients.

MR. CHIU: Actually, this one and this one, both.

MR. POHIDA: Number two, DS light. I am sorry, I don't know --

MR. CHIU: DS light is all those lights that are the light right here.

MR. POHIDA: On the card?

MR. CHIU: On the card.

MR. TERRY: They are directly connected to that 4044 latch through --

MR. POHIDA: How do you explain what is reset by K1. I guess I don't understand that.

MR. CHIU: What we can do is, we can -- Jim, you did some test on reset. Can you mention that? The test was reset of K1.

MR. RIDDLE: K1, when you drop a voltage down below a certain -- I have some inconsistencies there -- essentially you have a K1 relay here that is powered. You drop the DC down. When it's powered up this is held open. Then, when you drop the power this closes and that goes in and resets all of the latches. This goes to the set.

MR. POHIDA: K1 is just the reset.

MR. RIDDLE: It's just a reset button. It also uses it for a lamp test, so it has been wired up. On the newer version you have two push buttons and one is a lamp test and one is a reset. On the older version here you have a mod -- the older version, this is the switch one and K1 relay here. On the older version they have done this jumper mod where they have cut this trace and wired into the

switch.

MR. ASHE: Why did they do that wire mod in the back, do you know?

MR. RIDDLE: Because they wanted to be able to do a lamp test and reset at the same time.

MR. ASHE: Got it.

MR. RIDDLE: On the newer version on the universal board, there is two of these buttons next to each other.

MR. POHIDA: You are saying that K1 may have been affected by voltage drop?

MR. RIDDLE: K1 drops out at 12 or something volts. It will drop out and reset all this stuff.

MR. ROSENTHAL: Just so that we have our notes, on the 21 board?

MR. TERRY: Right.

MR. RIDDLE: When I lower the voltage down below 12 volts on the new card and blow ten volts on the old cards these all reset. Unfortunately, that resets everything downstream there. In terms of a voltage dropout, strictly a voltage dropout down at ten or eight volts, if it can be sustained at these 12 volts past these regulators it will reset all of these.

The numbers I got on this board about 10.2, 10.3 volts on the DC. Basically the way you test that is, you lower the DC voltage and you move the wire over to set the

light. You take the wire off and the light goes back out. You put the wire back in and the light comes back on. If the voltage were -- if you put the wire over and the light comes on, you take it out and move it back and the light stays on, that means that the latches are now free to set. That's how I made that measurement.

Yes, you can in the dropout -- voltage dropout across the K1 relay, that will reset this business. The problem is that it doesn't explain what is going on. I can't keep this stuff on.

MR. ROSENTHAL: You can't keep this on without keeping this on.

MR. RIDDLE: Right, by just using a DC dropout.

MR. TERRY: Jim, I think all three of the scenarios that were outlined there require some form of latchup or hangup or something.

MR. RIDDLE: Yes, right.

MR. TERRY: On that down --

MR. RIDDLE: That's why we are chasing it so hard.

MR. TERRY: There really isn't any scenario that --

MR. RIDDLE: There is no static or now power supply dropout by itself failure that can make this -- can explain this whole thing.

MR. TERRY: Right.

MR. CHIU: That's very --

MR. RIDDLE: We are throwing out possibilities as to what that --

MR. TERRY: There are three ways which you could -- with some kind of a latchup -- explain the light inconsistency. That's all we have been able to come up with.

MR. RIDDLE: We came up with another today, which is an unbalanced power supply driving --

MR. TERRY: True, but still --

MR. ROSENTHAL: Let me get back to the unbalanced power supply. Let's just say that by 1991 standards this 1970-ish --

MR. RIDDLE: Late 1970's.

MR. ROSENTHAL: May not have been --

MR. RIDDLE: 7851 --

MR. ROSENTHAL: May not have been -- the drawings are -- the design goes back to --

MR. TERRY: The first one is 1972. That's the vintage design. I think Exide indicated they developed it between 1968 and 1972, that timeframe.

MR. ROSENTHAL: Without arguing whether it could have been better done or worse done -- this thing sits there for five years, right?

MR. TERRY: Right. It sits there in operation --

MR. ROSENTHAL: It sits there in operation. If there was under at least normal operation a problem with watching the output of the 20 volt power supplies by the electronics on the 18 board, that would have been generating or could have been generating, then PSF signals which would have been tripping those units out.

MR. TERRY: Yes, unless they were associated with --

MR. ROSENTHAL: You have to find something to associate with this specific transient. Of course, all that does is generate a PSF which does not explain why. One reason my blood pressure either goes up or down is when I first told my management my initial findings they said it's the batteries. They said whoa, and I have not been able to explain there were other things. There was a press brief.

I said I thought that this was a contributing factor, and people again -- light off on the batteries, because that's something that people can understand. Unfortunately, we are still in a mode where, if problems with these others things and PSF was not generated, then we haven't fixed the problem.

MR. CHIU: You have to understand, Nine Mile Point's modification, could the power into the inverter power which supplied constant power -- next time we have a transient we don't have voltage dropout. That is a big job.

MR. ROSENTHAL: It will make it far less susceptible, except for my grounding issues.

MR. CHIU: Except which we are tracing very hard.

MR. TERRY: I guess I would like to clarify for you maybe where we are coming from. It is one of those situations where I guess it's impossible to rule out almost anything because we have this darn anomaly. Looking at the circuit design and the voltages that we looked at and what we have done in terms of the power supply, everything tells us that PSF should have been generated. Granted, we don't know that it was not, but everything tells us that it should have been.

MR. ROSENTHAL: Yes.

MR. TERRY: On that kind of a voltage dip. That's not impossible but in my own mind at least, a very low probability. The other things are very conceivable. The idea of getting a PSF and eliminating it, to me, is very viable.

MR. ROSENTHAL: Yes.

MR. TERRY: It's the downstream lights that remain a mystery. Having that happen, that K1, we are in a range where it's possible if all it takes is a momentary latching --

MR. RIDDLE: Latching --

MR. ROSENTHAL: But that delatches the 4044's.

MR. TERRY: That's what I say. So, that --

MR. ROSENTHAL: That doesn't account for the higher level --

MR. RIDDLE: It's a good explanation for half the answer, but it doesn't go back and address the other lights.

MR. CHIU: What we do here is first in our subcomponent review is, we try to make sure all those low probability things can be all identified and ruled out, and all the things we cannot explain downstream and we will recommence everything that may prevent it from happening if we really go the route. Later on we will have an even higher reliability.

The first thing we done is put a better power supply in, change the battery at least from the designer's point of view, Exide's point of view we return that back to design. There is other glitches maybe to stall us there, lights worked. We tried to see whether there's any one of them can later on generate not UPS and not trip off, some glitches. We want to make sure the reliability can even be higher. That's why the study is doing.

We not try to refute -- okay, we didn't review so far -- we don't have a data review of the root causes being done together which we would have review that root cause analysis. We will add on more.

MR. ROSENTHAL: By the way, it is conceivable to

me that on different time scales -- what we discussed this morning --later on or two milliseconds later, you do pick up the PSF. Those are distributing factors.

MR. RIDDLE: That makes our analysis complicated. To expand on what Chong is saying, we looked at the power supply dropout thing, we looked at the mods, we seemed to be covering that as far as protection of the DC side. We want to follow up on the ground side if there is already recommendations out of the text as part of protecting the ground surge suppression, zener diodes and stuff like that, take care of something that comes in from the ground side, from the transient side.

I think we want to finish our testing on the transient noise injection, et cetera situation, and make sure we knock that out. We haven't -- like I say, we haven't come up with anything inconsistent with their root cause and their corrective action. We haven't really found anything that is way out in left field. A lot of this is speculation about the latchup and about the operating and high impedance mode.

That is worth tracing. We don't have any hard evidence -- we have hard evidence that this chip went into latchup, but like I say, that may have happened during subsequent testing. We are still pretty speculative about everything that we are coming up with. We are not saying it

has to be a transient, it came in through the ground line. We are not trying to sell that line.

MR. TERRY: We have hard evidence on one chip, right?

MR. TERRY: Right.

MR. TERRY: Went into latchup and then --

MR. RIDDLE: We have hard evidence that went into latchup.

MR. TERRY: C-MOS latchup.

MR. ROSENTHAL: C-MOS latchup -- where the output is indeterminate, this high impedance.

MR. RIDDLE: No.

MR. TERRY: That's a different --

MR. RIDDLE: C-MOS latchup is when the power supplies short circuit and cause the whole device to short circuit. That's going to make it so that, depending on which direction it is, whether it's on the high side or low side, everything is going to be high. Every inverter has high input and a low input or a low input and high output.

We get into a situation where you have a high input and a high output or low input and low output, depending on which direction it latches, towards the ground or toward the high side or both.

MR. ROSENTHAL: On the one that delatched, what was--

MR. RIDDLE: On the ground side, so it pulled

everything towards ground. On the determinate mode, that depending on what sort of noise -- you saw that. Remember where I did that demonstration where I touched my baby finger on that input pin, floating input, the thing latched straight up. Then I shorted -- there was enough current that I could pick up from scuffing my feet on the floor to put this chip into a latchup mode.

MR. TERRY: This was on the 4049?

MR. RIDDLE: Yes, stock 4049 from the store. If it turns out to be a noise problem, just go through and make sure that all the inputs are terminated. I don't see any major -- what I am saying is that major design flaws or major rebuilds and fixes and exhaustive circuit analysis is going to be necessary at this point. We are all in agreement that we had a transient problem and a power dropout problem. The power dropout problem has already been corrected several different ways in terms of the batteries and switching it over.

Running down the transient thing, I think, is going to be straightforward as well.

MR. ROSENTHAL: Boeing does sneak circuit analysis; are you familiar with their work?

MR. RIDDLE: Boeing?

MR. ROSENTHAL: Boeing --

MR. CHIU: Circuit board modeling; that's what you

are talking about?

MR. ROSENTHAL: Whatever they fixed up, bar doors were flying open and they chased that down. I think a rocket went off and they chased it down to the umbilical cord on the rocket separating but all the pins didn't quite make and break at the right time. Clearly, they have heavy-weights too. Are you familiar with their work.

MR. CHIU: Last year I was hired by NASA to do the--

MR. ROSENTHAL: Yes, I understand that.

MR. CHIU: I deal with some of the heavy duty simulation, try to simulate how all those can occur. That's probably what you are talking about. Here, I think we -- the way they do it is board, they give us drawing. They really simulate through computer. It doesn't have a board, but simulate the whole thing in computer. You can have various input left and right and to see how performance occurs.

We think that's probably not warranted at this time because we have a board.

MR. RIDDLE: I am familiar with the Boeing product there, Patterson and Charlie and some of the reliability people up at Seattle. They also have a lab that does essentially what we do; take chips apart and find out what the damage is, do a physical analysis first, analyze failed

components, lay everything out to find out which way the damage points in terms of the failure mechanism is and then go after corrective action on those.

We are pretty much down the road as far as damaged chips. I would like to look at the other boards that I haven't looked at. If we have anymore bad chips, ferret them out, get them analyzed, get pictures of everything and see if there is a common trend on the damage. And then start basic corrective action, this and this and this could cause that damage, and just knock all three of those out. Putting transient suppressors here didn't take care of the noise problem, we will beef up the battery replacement schedule, take care of the DC dropout problem, terminate the inputs in order to take care of the noise problem and you are done.

Whether or not a combination of those two or three, we may never be able to simulate exactly which order -- like your point about it may have happened at different times during the vent work, it was a power thing and then a transient thing and a latchup thing -- a latchup thing and a transient, that can turn into a real complicated thing.

If we identify the key contributing factors and just do something about all three of those, we have enhanced the reliability of the system immensely.

MR. ASHE: Just a couple of things. Are you

planning to look at the 4049 chip on the A21 board on the other UPS's?

MR. RIDDLE: I would like to. I have requested that, yes.

MR. TERRY: I think --

MR. ROSENTHAL: We better find something that goes times five.

MR. TERRY: That's sort of been our -- we know we had the 4049 failed but it doesn't go times that.

MR. RIDDLE: There's one that's good and one that's bad.

MR. ROSENTHAL: That's an answer.

MR. TERRY: I think that's true. I guess I don't know the status of that, probably a better answer.

MR. ROSENTHAL: You are going up to Nine Mile again, I take it. Let us know when, and we may want to accompany you. I would appreciate it if you looked literally at the ground -- I think it was Mr. Lewis but I'm not sure and Frank may remember -- who I think was working for Exide at the time, a sub-sub. He just commented that he was surprised not to see a nice big braided copper strap across the hinge on the card cage and just screw to screw on the hinge.

Instead, it may be possible that the sheet metal ferreted cage -- whatever you want to call it -- is in fact

just got a number 16, number 20 wire to another spot on it, and that the grounding -- at least that is grounded through the hinge and the paint on the hinge. It sounds flaky, but --

MR. RIDDLE: There's another possibility is what you and I talked about, on the interlock channel. All these boards are tied together through an interlock. If that happens to go to ground and you get noise transients on the ground, the interlock comes back in through here, bypasses all this circuitry and comes back in through here and comes out here.

If you have a noise blast through your interlock it would come in, and if it caused latchup of this 4049 or this 4049 here, it's going to turn these three lights on independent of whether or not that fits into the PSF never generated. It comes back in through the outside here.

MR. CHIU: There's a scenario --

MR. RIDDLE: That's another scenario that is a possibility. Now, the interlock does have a pull up resister that's going to help with its noise immunity. But if it gets a significant enough spike through the input that might be possible. Unfortunately, that requires putting a transient in the input which has caused permanent physical damage on at least the low speed stuff. That is something also to follow up there. That will help -- that's a

possibility as well.

We don't know where the interlock goes. Either it ties them in together or does it go to ground, does it go high. We need to look at that. There are some things in the cabinet that I think Chong is going to run down for us next week. We will be able to knock those down one by one.

MR. ROSENTHAL: Jim Stoner was saying that at start up they had measurable -- pre-start up. The whole ground plane was two-tenths of a gnome.

MR. STONER: Right, two-tenths of a gnome. I don't think that it had been checked recently, at least I didn't get an indication they had. That might be something that you might want to have tested, impedance of the entire grounding system.

MR. RIDDLE: We do have some conflicting or at least incomplete information about where all the ground wires go. I think that was your number one action as far as when you go out there.

MR. CHIU: Yes, we transmitted a request, I think to Nine Mile Point. I think they are looking at that data.

MR. STONER: Just as a clarification, two-tenths of a gnome at ground is a good reading.

MR. RIDDLE: Yes, a very good reading.

MR. CHIU: Very good reading.

MR. STONER: The only question in my mind is, is

it still at that low value or has it changed.

MR. RIDDLE: Is that between the UPS cabinet and the center of the switchyard.

MR. CHIU: I think that we have -- as you guys already know -- we have a professor, T.C. Chen from University of Southern California. He's well known internationally. I feel that he is on our team, so we are not taking that loosely. MR. IBARRA: Chong, if you were to go and find some anomalies in the grounding tomorrow within the UPS units, is that going to help you in linking up what happened; this common mode to the trip?

MR. RIDDLE: That would support the ground transients coming in and disrupting the chips, failure mode.

MR. CHIU: That would support one and two volts, because you see the second mechanism, PSF generated -- we don't have a light on DS light. That can cause a ground transient and latchup a PSF right there. K1 reset everybody else.

MR. IBARRA: Your analysis has centered only on one board, right?

MR. CHIU: Right.

MR. IBARRA: You still have to trace out and make sure that --

MR. RIDDLE: How that leaves that board --

MR. IBARRA: Right. There is still a link there

that would have to be made.

MR. CHIU: Right. That schematic will help us and compare with what they really have.

MR. IBARRA: It would go a long way in trying to explain the --

MR. CHIU: Yes, go a long way.

MR. TERRY: I should comment here that from Niagra's overall look at this thing, frankly, we have eliminated elevation of the ground voltage.

MR. ROSENTHAL: Good.

MR. TERRY: Based on a few things. First off, we looked at the ground current. It is fairly low. We have the data on that, around 1,200 amps I think, which is a relatively low thing. We also have indications within the plant in terms of the generator relaying and things of that nature that give us pretty positive indication that the ground fault did not go outside of the yard.

I think the third thing, while all of us agree that the grounding elevation can cause all kinds of weird things including damage to these chips, it would not just go in and selectively pick out U10, CD4049. Rather, we would see extensive damage. You will be getting our root cause I think today.

MR. ROSENTHAL: It came, and that was that little yellow slip that came.

MR. TERRY: We talked with Dr. Chiu and reviewed it. That's not to say that something could have been going on inside of the cabinet.

MR. IBARRA: Internally, yes.

MR. TERRY: Internally. So, I am not trying to tell you that. What I am talking about here is -- and we will certainly take a look at this impedance to make sure. There are all kinds of real good indication that the ground mat is fine and that there was not a general elevation of the ground mat during this fault. I think we have good evidence on that.

Fortunately, we have measurements and other data that would tell us otherwise if that were not the case.

MR. CHIU: I support that on my calculation. What the professor from USC looked at is the ground scheme, things that are more than outside cabinet. That's his analysis.

MR. TERRY: We know during a trip inside of these cabinets there could be certain circuits or circulating currents or other ground currents being generated.

MR. STONER: Based primarily on internal wiring --

MR. TERRY: Internal wiring and localized elevations of grounding is really where we are in terms of that. Because the other side of that is so far during

testing really it takes this either elevation of ground voltage or the output voltage or power supply voltage going negative or something like that to create this inverted differential between the ground voltage and the voltage to the chip. That has been pretty well established also during testing.

Frankly, we use that as part of our rationale as to why it couldn't have been a general elevation of ground levels. Consistently you won't just pick one 4049 or something, you will burn out a lot of C-MOS and other things if you have a general elevation of ground voltage.

MR. CHIU: You also have --

MR. TERRY: We are convinced of that.

MR. CHIU: -- feedwater control system and other system. You could probably talk roughly about 10 voltage system. We will see some rather large glitches if we have general ground elevation.

Let me ask a question now. You guys are ahead in terms of circuitry, elementary ahead of me at least. What do you think about direction. Is there anything that you see obviously incorrect or we are down a wrong path, or chasing a ghost, or we are not chasing deep enough. I want to get your feedback, because I work with Carl and his people and we try to think about a lot of things to make sure we uncover all stones.

But it is always good to see some great minds telling us what work --

[Laughter.]

Let us know, so we can correct ourselves or make it better, go deeper, go shallower, ghost.

MR. IBARRA: We had Exide come here with all of their drawings and there were several of their people. We did trace out the logic. We ran through it, and it does make sense of how it should work.

MR. CHIU: How it supposed to work.

MR. ROSENTHAL: I guess if you go back, I am very convinced that the SSTR signal was in fact generated times five. That pretty much goes to a power transistor and on, and that it would have had to be generated for at least a couple of cycles in order to have fit the shunt core. What they were talking, at least multiple -- 1630 milliseconds.

You are right on the A21 board, and it makes sense to me. It makes a lot of sense. I guess I was talking to your licensing guy and he thought that actually these people might know some of the response times. Do you have any idea what the response time of this K1, 2, 3 on the A21, A1 board would be?

MR. TERRY: I think you asked that earlier, and I don't think we --

MR. ASHE: Probably a more important one is K5.

MR. ROSENTHAL: At least it starts establishing time.

MR. ASHE: The K5.

MR. RIDDLE: Is that the big relay.

MR. ASHE: Yes. We know that these units have been switching back and forth. What we don't know -- successfully, with dead batteries.

MR. TERRY: Total loss.

MR. ASHE: That's right. What we don't know is a time. We are trying to get a fixed -- how long --

MR. RIDDLE: Is that a big old --

MR. ASHE: No.

MR. RIDDLE: We will run some numbers on them.

MR. ROSENTHAL: It's bigger than this and smaller than that. It's half the size of this cup.

MR. RIDDLE: You could probably just get that information from the data sheet from the relay itself. Read the manufacturers name on it, call the manufacturer.

MR. TERRY: We have looked at that, and I just don't know what it is right now.

MR. CHIU: If you know the data sheet or model number and we can try to find the time constant for you.

MR. TERRY: Bob Crandall has all of that.

MR. CHIU: Otherwise, we could do --

MR. ROSENTHAL: I think we are talking about -- I

forgot what it was -- 100 millisecond, 200 millisecond. That sort of range, that sort of number.

MR. CHIU: You already did a test or something.

MR. ROSENTHAL: Remember that the other thing is, we do have -- if you go to change analysis and you say wait a minute these units are always running, there have been other trips where there were clean transfers --

MR. ASHE: Transfer.

MR. ROSENTHAL: Transfer and they have ridden out, don't lose site of that.

MR. ASHE: For clarification, do you --

MR. ROSENTHAL: Does that mean that if you lose the turbine -- the units are sitting on the unit auxillary transformer and will switch to the reserve auxillary transformer, there will be some perhaps very small perturbation and that's seen down at the UPS level that they would be riding those out.

MR. TERRY: This is the first thing we can come up with where we have had this like 100 or 200 milliseconds, kind of a dip. We have had a fast reduction and know they work there. This is obviously the first time they have all five gone off.

MR. CHIU: Maybe that's another thing because the Nine Mile Point test -- if you have a really deep, steep transient, they all work. Only this gray area -- that may

be less --

MR. RIDDLE: That's right.

MR. IBARRA: In fact, that is what we have come to conclude, that if it was loading the K, that cause the problem not being there or being there. There not being there wouldn't have caused the problem.

MR. CHIU: I tend to agree with that, based on what I know about it.

MR. TERRY: Also, I think based on -- there is some question I agree, on exactly what did that voltage look like at the boards. None of us really know for sure. We just have calculation.

MR. RIDDLE: Exactly.

MR. TERRY: It sure looks like even in the ranges of the voltages that we have looked at from a minimum of around 50 up to I think like 65 volts, that whole entire band based on testing of the relays that we had out there, none of that, either 50 volts or 65 volts is still enough to keep K5 sealed in.

MR. ROSENTHAL: When you said slowing decaying, we are talking about the output of these power supplies slowly coming down, while Jim is telling me that the AC almost step changed from --

MR. STONER: From rated --

MR. ROSENTHAL: From rated to that degraded.

MR. TERRY: That would follow pretty much --

MR. ROSENTHAL: Based on the oscillograms and what not.

MR. TERRY: Right.

MR. CHIU: You guys think -- my question is, do you think we are on the right track?

MR. ROSENTHAL: Yes.

MR. IBARRA: You are saying system-wide where we are more further along than you are. We can also say from minute point of view, you are further along than we are.

MR. CHIU: Yes.

MR. IBARRA: Whatever work you are doing, it seems to be good work. We still have to make the link if that's possible.

MR. ROSENTHAL: Times five.

MR. IBARRA: Yes, times five.

MR. CHIU: We have to do a link pretty soon. All those things that we talk about, the future tests, transient generation, noise going to the input, the grounding tracing, the board characteristic analysis hopefully, we will make a link closer and closer. Hopefully, at a certain point we can all say we have a link. You move toward our direction and we will move toward your direction.

MR. ROSENTHAL: Jim was saying that -- I quizzed him at length about RF on the AC or a higher harmonics. You

thought that was unlikely.

MR. STONER: No, I said there could be a signal riding on the wave -- as far as the ground loop, I didn't see a ground.

MR. TERRY: By the way, we also --

MR. ROSENTHAL: Every transformer is good for so many -- ten DB or more.

MR. STONER: But there is no positive indication that that occurred, but just because of the nature of the arcing in the transformer the potential is there.

MR. TERRY: We would expect the RF was generated at the transformer.

MR. IBARRA: At the source.

MR. TERRY: At the source. The spark and generating a wide spectrum of RF, we all know that. We also looked at that and really, the path has some just tremendous attenuation on it. So, in terms of getting any meaningful signal there through the power feed, that really isn't viable. We concluded there just isn't any way to get it there. We have a number of people --

MR. ROSENTHAL: Because, you are saying it's 1020 DB across every transformer.

MR. ROSENTHAL: Right.

MR. ROSENTHAL: Five, or --

MR. TERRY: That's right.

MR. ROSENTHAL: Is that the logic?

MR. TERRY: That, plus the cables themselves frankly have a lot of attenuation also. Just the transformers alone going through three or four transformers, it's at least 1,000 times attenuation at each transformer. It's really very, very -- it's a good suppressor of RF signals. It's just not designed for that. It is for other things.

MR. CHIU: We will look at RF from two point of views. One is your sparking that goes through air, goes through what we will call radiative interference, pickup by pigtail. Lan going to the signal. What we did is, we get a simplified calculation of how much voltage you can generate into the RF in terms of voltage you can use. Lan going to antenna, the maximum we can get, just micro volt. So, it couldn't cause all this phenomena, latchup. We need like ten volt to get this thing going.

So, the magnitude -- not all magnitude -- times difference in terms of what it can do, we eliminate that. Another one we look at is, if high frequency transients shoot a spark that go through the roof and go through the ground -- go over input signal line and come in, that wouldn't because the high impedance -- inductance. Inductance just keep occurring constant.

MR. RIDDLE: It's already a noisy environment in there anyway with all these SCR's firing, as far as --

MR. ROSENTHAL: Apparently, they had also done some pre-OPS and keying of --

MR. TERRY: They tried transmitters in front of it, right. That's where he was saying if you open the doors and set off a walkie talkie, they could get the unit to trip that way. But you close the doors and there's immunity.

MR. RIDDLE: That could be the case, and it's grounded fairly well. At least it is grounded fairly well.

MR. ROSENTHAL: If I go down today -- in fact I remember mentioning it to somebody that we didn't do it -- to key his portable radio you would expect nothing to happen and if you would open the doors and repeat that, it would probably trip.

MR. TERRY: I think Crandall indicated that that was the experience. That's a good question; was it repeatable or was it sometimes. That, I don't know.

MR. RIDDLE: It would be nice to do that down at the manufacturer.

MR. CHIU: My experience, I chase noise quite a bit before RF. What it does is, RF when you radio -- for example mega hertz you are talking micro volt. When you go into a cabinet, even though you have what we call the perfect antenna goes restless, they have effect of 1,000

amplify. You are talking about mini volt maximum.

Only mini volt can activate things. In the past experience I have chasing ground chicken noise, you have like a module. The signals is mini volt. You give a little mini volt and activate -- fact of 100 change. Nuclear, NIS system. Those are mini volt systems to begin with. You interject one mini volt. This system you look at circuitry there are ten voltage.

One thing this guy is susceptible, based on just my --

MR. TERRY: Not the 4049.

MR. CHIU: Not 4049.

MR. TERRY: All we are saying is that the unit is susceptible if you leave the door open and if you stand in front of it with a walkie talkie. That's not unique, by the way at Exide. We have done that other places.

MR. CHIU: Some other system.

MR. RIDDLE: Turbine control system.

MR. CHIU: Yes, turbine control system.

MR. TERRY: Turbine control guys doing it and hit it. MR. CHIU: Mini volt.

MR. TERRY: It can cause it, and it is certainly a plausible thing to look at, and that's why we looked at it as a way of possibly tripping the unit. We had to look at it.

MR. ASHE: Are you familiar with the DTL's of the transmitter, when that was actually done?

MR. TERRY: I am not.

MR. ASHE: Power level, higher frequency, carry waves, side band -- you are not familiar with any of these?

MR. TERRY: No, I am not.

MR. ROSENTHAL: Of course, that's totally the wrong frequency also here. Here, we are talking higher harmonics of 60 cycles --

MR. ASHE: Not any arcing, no.

MR. TERRY: The arcing could be any part of the spectrum.

MR. RIDDLE: Broad spectrum.

MR. CHIU: The arcing you have a wide band spectrum up to 2.5 mega hertz. It's between zero and 2.5, you always have noises.

MR. RIDDLE: You would have to sweep it.

MR. ROSENTHAL: Except that, as I go through the transformers the attenuation of the higher is even more.

MR. TERRY: Right.

MR. ROSENTHAL: Ten, 20 DB is like an average number.

MR. TERRY: As a common all five thing, that is what we are --

MR. ROSENTHAL: Right. Does anybody have anything

else to say?

[No response.]

MR. ROSENTHAL: Okay, we are concluded.

[Whereupon, at 12:25 p.m., the meeting concluded.]

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission

in the matter of:

NAME OF PROCEEDING: Nine Mile Point Nuclear Power Plant Information Exchange Meeting

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