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INTERVIEW OF

DR. JOHN KAPPENMAN

October 11, 2013

Conducted by Troy Cline

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

2 MR. CLINE: Well, thanks so much for your
3 time. This is really going to be great. I don't know
4 how much Carolyn told you about the project that we're
5 doing.

6 DR. KAPPENMAN: Well, a little bit. I
7 understand you're talking to various people that are
8 involved in looking at this issue of space weather and
9 how it can all impact us and trying to look at it over
10 its history and timeline.

11 MR. CLINE: That's it, and it's going to be
12 built into an online tool that -- like a timeline, so
13 people are going to be able to go through, and we'll
14 split up these interviews into segments and parts and
15 quotes, along with stories and images and pictures.

16 DR. KAPPENMAN: Sure.

17 MR. CLINE: And then the user's going to be
18 able to go through and just select any thread that
19 they'd like to follow through space weather. I think
20 that's --

21 DR. KAPPENMAN: Right.

22 MR. CLINE: -- the overall vision, so it

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1 should be pretty cool.

2 DR. KAPPENMAN: Okay.

3 MR. CLINE: Well, in this type of interview
4 that -- what I like to do is -- eventually, we edit my
5 voice out as much as possible so it's all the person
6 being interviewed, and so what I'll often do is we'll
7 get things started. I'll ask one of these general
8 questions. And then I won't say much until, you know,
9 you've completed the thought or you've gone through
10 what you'd like to say.

11 And sometimes, if there is a conversation
12 that starts up or if a question just pops up, I'll
13 throw it in there, and if they decide to edit me out
14 later, they can; if not, they'll keep me in.

15 DR. KAPPENMAN: Yeah. Okay. Very good.

16 MR. CLINE: And do you have any questions,
17 though, before I start?

18 DR. KAPPENMAN: No. No, I'm --

19 MR. CLINE: Okay.

20 DR. KAPPENMAN: -- ready to go.

21 MR. CLINE: Awesome. Well, thanks again.

22 DR. KAPPENMAN: Sure.

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1 MR. CLINE: Let's start by you just telling
2 us who you are and what you're doing right now, and
3 then we'll get into the actual questions.

4 DR. KAPPENMAN: All right. My name is John
5 Kappenman. I'm with Storm Analysis Consultants. I've
6 been working on this problem of space weather and how
7 it impacts electric power grids for about 37 years
8 now. The work that I'm involved in now continues to
9 be focused on what is the vulnerability of electric
10 power grids, especially the U.S. electric power grid,
11 and also what things we can do to solve the problem
12 that space weather causes to the electric power grid.

13 MR. CLINE: Okay. That sounds -- that
14 sounds perfect, then. And our first question, I think
15 you've actually already answered, pretty much, your --
16 about what is your primary research interest and --

17 DR. KAPPENMAN: Sure.

18 MR. CLINE: -- what you're doing right now.
19 Do you have more to add to that, or do you think you
20 answered what you want to ...

21 DR. KAPPENMAN: Well, you know, I certainly
22 can talk about some of the specifics of what has

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1 occurred in this area; for example, you know, I
2 started work on this problem in 1977. At that time,
3 we knew about the problem that these storms could
4 cause to electric power grids. We still largely felt
5 at that time that these were nuisance-level problems
6 as far as how they could impact electric power grid
7 operations.

8 The company that I worked with was a power
9 company in northern Minnesota. We were building a
10 long, high-voltage interconnection to Canada, so we
11 felt we had to do a little bit of research at that
12 time to try and understand the problems more fully.
13 Me being the new guy in the Engineering Department, I
14 ended up getting stuck doing that research, and here I
15 am 37 years later, still trying to research this
16 problem.

17 Over that period of time, we have learned
18 through studies as well as through painful experience
19 that these severe geomagnetic storms could perhaps be
20 the largest natural disaster that electric power grids
21 could face, and by extension, perhaps the largest
22 natural disaster that the country could face.

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1 So it has taken on a much more focused role,
2 a much more important role in trying to understand
3 these vulnerabilities, and, actually, the role has
4 evolved to try and engineer solutions to reverse some
5 of these vulnerabilities or engineer out some of the
6 vulnerability that we have in the present-day electric
7 power grid.

8 MR. CLINE: Can you describe a little bit
9 further of what you mean by this being one of the
10 largest natural disasters? What types of things would
11 happen if we had a significant solar storm direct
12 impact, an impact on the ground?

13 DR. KAPPENMAN: Sure. Well, we have had
14 some experience with modern-day storms that give us a
15 hint as to what could happen for a more severe storm.
16 For example, there was an important storm back in
17 March of 1989, March 13th and 14th of 1989. At that
18 time, it had only been theoretically proposed by me
19 and other research collaborators that such storms
20 could cause a blackout of the power grid.

21 And this March 1989 storm did, in fact,
22 cause a blackout to a major portion of the North

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1 American power grid, the entire province of Quebec.
2 And it came very close to precipitating a blackout
3 that literally could have extended from the Mid-
4 Atlantic Region of the U.S. all the way across to the
5 Pacific Northwest.

6 In addition, we learned for the first time
7 during that March 1989 storm that large and difficult-
8 to-replace electric equipment, like transformers,
9 could be permanently damaged by the induced currents
10 that these storms closed to flow in the electric grid.

11 Since that March 1989 storm, we've done work
12 to try and estimate more extreme storm scenarios. We
13 had misestimated for many years, even following the
14 March 1989 storm, how much more severe storms could
15 be. And we now have a scientific understanding that
16 tells us that in many -- in some of the most important
17 aspects, that we could see storms that could have
18 intensities ten times larger than the March 1989
19 storm.

20 Now, we already know the March 1989 storms
21 caused some historic impacts to the electric grid.
22 The things that we're concerned about with the

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1 reoccurrence of a very large storm would be that it
2 would not only cause blackouts to major electric
3 grids, like the U.S. power grid, perhaps other
4 economic developed countries around the world, but
5 could also destroy enough equipment on those grids to
6 perhaps greatly extend the blackout beyond just a
7 matter of a few hours or a few days, perhaps into a
8 blackout that could extend into months and perhaps
9 years, across very wide regions that these storms
10 would occur over.

11 In the case of the U.S. -- the analysis that
12 I've done for the U.S., this could have enormous
13 impacts across society. You know, when you think
14 about how electricity is used in our society, it is
15 vital for things like being able to deliver potable
16 water. You know, we would lose supplies of potable
17 water within a matter of a few hours after a blackout
18 occurred. The ability to treat and pump sewage.
19 Perishable foods would be lost after about 12 hours;
20 perishable medications as well.

21 If you think about perishable medications,
22 in the U.S. alone, there's a million patients that

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1 need daily supplies of insulin to stay alive. So loss
2 of that over a wide region could cause enormous risk
3 and loss of life in this country from these sort of
4 scenarios.

5 When you look at everything else that
6 society is dependent upon as far as electricity,
7 within a short period of time, you lose the ability to
8 maintain transportation systems. The ability to pump
9 fuels via pipelines and things like that is lost.
10 Within a short period of time, perhaps a couple of
11 days, the ability to maintain communication systems,
12 telephones and so forth, will also be lost, as they
13 have backup battery and generation supply, but then
14 they become logistically bounded because of loss of
15 electricity and inability to refuel. So it becomes a
16 situation that could place many millions of lives at
17 risk in modern-day society.

18 MR. CLINE: What -- based on what you were
19 just saying, what types of preventative measures over
20 the course of time that -- since people like you have
21 been studying space weather and research and solar
22 storms and the impacts -- what types of preventative

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1 measures can you tell us about that have increased
2 over time to try to protect us from these things?

3 DR. KAPPENMAN: Well, actually, we don't
4 know of any preventative measures that have increased
5 over time. The story in electric power grid
6 vulnerability has actually been the opposite. We've
7 grown more vulnerable over time, remarkably more
8 vulnerable.

9 You know, for example, when we had the large
10 storm called the Carrington Event in 1859, the only
11 electric technology we had at that time was telegraph
12 systems. The same is largely true for the major storm
13 that occurred in May 1921. We were still very much at
14 the state of infancy as far as electric power grids,
15 communication systems, and that other sort of
16 infrastructure that can couple with these disturbances
17 in the magnetic field that are caused by these storms.

18 Since the late 1950s to today, we have
19 developed a high-voltage network of transmission lines
20 that span continents all over the world. These types
21 of infrastructures are enormously well-coupled to
22 disturbances in the Earth's magnetic field, but we

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1 have been completely unaware that this was a threat
2 environment that we needed to be concerned about.

3 We have had no design code that has ever
4 taken this sort of environmental threat into
5 consideration in the design of electric power grids.
6 And it's only been just this year that the Federal
7 Energy Regulatory Commission finally issued rules or
8 regulations to the electric power industry to tell
9 them to begin developing standards and design codes
10 that take this threat into consideration.

11 So we've got many decades of increased
12 vulnerability that we have to now try and figure out
13 how to undo as we've greatly expanded this modern-day
14 infrastructure.

15 MR. CLINE: That's incredible to think
16 about, especially the impact, and, as you mentioned,
17 the increased vulnerability with the addition of
18 communication satellites and all of the different
19 things that we rely on here on Earth. So I do know
20 and I'm aware that warnings go out from space weather
21 researchers and scientists to just alert various
22 industries that, you know, a potential threat is

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1 underway?

2 DR. KAPPENMAN: Yes.

3 MR. CLINE: Can you tell us what that is?

4 DR. KAPPENMAN: Well, the NOAA and the Space
5 Weather Prediction Center do issue notices, alerts,
6 and warnings for geomagnetic storm activity, space
7 weather activity, and so forth. This information is
8 distributed to the electric power industry. And, as I
9 mentioned before, it's information that's passed along
10 to the industry, but there has been very little done
11 with that information, other than to try and just, you
12 know, heighten awareness, situational awareness that a
13 storm is occurring and it may explain some of the
14 variations and disturbances that occur in the electric
15 power grid.

16 We now have regulations that will require
17 U.S. electric utilities to develop operating standards
18 that take these conditions into consideration. So
19 they will be working to develop more formal operating
20 procedures that they can adopt when these storms
21 occur.

22 The concern that I have, however, is that

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1 these operating procedures may not be at all adequate,
2 especially adequate for the very largest storms that
3 are likely to occur. We know these large storms have
4 occurred before. You know, the physics of the Sun,
5 the physics of the Earth's magnetosphere has not
6 changed. The physics of the electric power grid has
7 changed in a very adverse way, and as a result, we
8 know these large storms have the potential to create
9 enormous widespread damage to the power grids.

10 We really can't -- cannot do anything to
11 prevent storms from occurring or prevent these storms
12 from having these impacts on the power grid, unless we
13 take additional steps to reengineer the power grid and
14 try and block these flows of induced currents into the
15 power grid that create all the problems. And that's a
16 large part of the work that I'm continuing to focus on
17 is methods and devices that we'll be able to use to
18 block these geomagnetically induced currents.

19 MR. CLINE: That's an -- that's an
20 incredible answer to that, because I don't think --
21 you know, I've heard quite a few stories and
22 interviews and talked with people over the years, but

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1 I didn't realize until talking with you today that we
2 are as vulnerable as we really -- as we are. You
3 know, I've heard people talking about how, you know,
4 power grids can be shut down or different components
5 of satellites -- certain things can happen to where
6 they'll try to reduce the amount of static discharge
7 and all of the different things that they try to do.
8 But it sounds like we're still at the infancy of being
9 able to protect ourselves.

10 DR. KAPPENMAN: Well, that's true. You
11 know, in fact, we've raised these questions with the
12 White House taskforce looking at geomagnetic storms
13 and pointed out to them that, you know, if we knew
14 that a very large storm were to occur, like, next
15 week, what is it that we could reasonably do to
16 safeguard the country?

17 You know, one of the scenarios would be to
18 have the president issue an order to shut down the
19 electric power grid. Well, that's not something we
20 want to take lightly either, because even the shutdown
21 of the electric power grid is a disaster for the
22 country. You know, if you'll look at the blackout

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1 that occurred in August of 2003, that affected 60
2 million people in the country. That cost the economy
3 about \$10 billion in lost gross domestic product.

4 Fortunately, we recovered from that in a
5 matter of a couple of days. Shutting down the entire
6 U.S. electric power grid would probably take, you
7 know, longer to recover from, perhaps a week or so,
8 but at least we would have a power grid that we could
9 bring back into service.

10 If we allow the storm to occur and it causes
11 the widespread damage that we think is possible, we
12 know we do not have any of this equipment as spares
13 that could be readily replaced. It could be as much
14 as a decade to try and recover from that sort of
15 scenario. And then, of course, you become concerned
16 about the issues of what impact would that have to
17 society, you know, a widespread loss of water, foods,
18 medications, you know, ability to keep people warm and
19 sheltered, transport, emergency provisions, things
20 like that?

21 You know, we predicate all of our disaster
22 recovery methods on being able to provide assistance

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1 from nearby unaffected regions. In the case of these
2 space weather events, these are things that can have
3 literally a continental laydown, a planetary laydown.
4 We may not have nearby unaffected regions for some of
5 the worst-case scenarios that one could face.

6 MR. CLINE: So even on the -- this may be a
7 very simple question, but it does -- the daytime side
8 of Earth, or the side that's impacted most directly by
9 a storm, is that actually -- which side of the Earth
10 is facing the Sun, does that actually have an impact
11 on how people are affected on Earth, if there is an
12 incredible storm like that?

13 DR. KAPPENMAN: Well, actually, for the
14 processes that we're concerned about, these are
15 geomagnetic storm processes, and they usually tend to
16 be more severe on the side away from the Sun, the
17 nighttime side of the Earth, although we have seen
18 some of these magnetic storm processes produce large,
19 impulsive disturbances into the day side regions as
20 well.

21 Typically, for a storm of the class that
22 we're concerned about, this is something that's

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1 probably going to last a day or more, is going to have
2 a large number of intense sub-storm events that will
3 occur over the course of that several-day period, and
4 it therefore has the potential to sweep across to most
5 of the planet and produce impulsive disturbances that
6 could be quite regionally intense for many, many areas
7 of the country over the course of that storm.

8 MR. CLINE: And over the course of space
9 weather research, and, really, pretty much the more
10 intense study has been, what, the last 50, 60 years?

11 DR. KAPPENMAN: Well, yes, right.

12 MR. CLINE: And so based on that, I would
13 assume at the beginning and for the first probably
14 several decades we didn't have much warning time. We
15 knew a storm was happening back then. But now how
16 much warning time would we have for a significant
17 event like that?

18 DR. KAPPENMAN: Well, you know, I was one of
19 the people that helped to champion the current space
20 weather warning satellite that we use, the ACE
21 satellite. And with that satellite, it's positioned
22 out at the L1 position in space, so it sees the

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1 incoming coronal mass ejection before it encounters
2 the Earth's magnetic field. And, you know, for the
3 fastest-moving events, it could probably give us at
4 least a ten-minute warning before the CME first
5 encountered the Earth's magnetic field.

6 And then, of course, it would continue to
7 provide status data on that CME over the course of its
8 entire transit to Earth. And, you know, it becomes an
9 important input to, you know, simulation models that
10 we have a capability to run to try and tell us what
11 that CME means as far as the potential for storm
12 severity.

13 MR. CLINE: So even in that worst-case
14 scenario, with something moving that quickly, that's
15 hardly enough time, I would think, to really shut down
16 a power grid system across the country.

17 DR. KAPPENMAN: No, that's right. We'll
18 certainly see, typically a day in advance, something
19 big that has happened on the surface of the Sun, be
20 able to see that it is something that looks like it's
21 very well-directed towards the Earth. But, you know,
22 that's still, you know, not the same resolution of

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1 clarity of data as we would get from actually
2 measuring the CME itself as it passes by the ACE
3 satellite.

4 MR. CLINE: Now, in some of the questions
5 that we have, one of the questions we'd like to ask --
6 and I believe you've actually already touched on this
7 somewhat through this interview -- that are what are
8 some of the key events or turning points in your space
9 weather research?

10 DR. KAPPENMAN: Yeah. Okay. Well, you
11 know, like I said, we originally started this work in
12 1977, thinking it would be a rather small and simple
13 problem to solve. Once we started getting into the
14 research, though, we -- you know, it continued to be
15 an ever-mushrooming set of problems that these storms
16 presented.

17 For example, I published a paper back in
18 1980 where we made the very meek, one-sentence
19 statement in that paper that we think there's a non-
20 zero probability of future geomagnetic storms causing
21 blackouts to power grids. Well, that did become a
22 reality in the March 1989 storm, when the Quebec grid

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1 blacked out. We also didn't realize or didn't expect
2 that large transformers could be damaged by this. So
3 we were enormously surprised by the large power
4 transformer that was damaged also during that March
5 1989 storm.

6 So we continue to have a situation, even in
7 modern storms, where we often get greatly and
8 unpleasantly surprised about how geomagnetic storms
9 can impact electric power grids; you know, for
10 example, we didn't realize that these storms could
11 produce that same sort of damage, even at very low-
12 latitude locations. The October 2003 storm ended up
13 destroying 15 large transformers in the South Africa
14 grid there at very low latitudes geomagnetically.

15 So it revealed to us that these sort of
16 storms, especially if they were very large-sized,
17 could truly have planet-wide impacts to modern-day
18 power grids and, therefore, modern-day society.

19 MR. CLINE: And my understanding of the
20 storm that you just described from October, that
21 actually was -- it just sort of glanced us. Instead
22 of a full impact, that could have been absolutely

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1 devastating.

2 DR. KAPPENMAN: Well, that's right. You
3 know, we -- I think we've gotten -- we've been blessed
4 to have some wake-up calls provided to us without
5 having to experience firsthand the full consequences
6 of one of these really large storms. And that's what
7 I -- that's the message I try to carry to people in my
8 industry, in that, you know, we cannot afford to learn
9 our lessons firsthand on this type of disaster,
10 because its consequences could be so large that we may
11 not, as a society, be able to easily recover from it.

12 You know, we learn, unfortunately, from
13 natural disasters that occur in one region. You know,
14 for example, most recent event I can think of or point
15 to would be Hurricane Katrina. And then we work
16 harder to prevent that sort of disaster from occurring
17 in many other regions.

18 This sort of disaster literally could cause
19 unacceptable consequences over very, very large
20 regions of our planet, and, you know, as a result, we
21 -- you know, we wouldn't have the ability to
22 understand the full potential of these consequences

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1 without suffering all of the consequences themselves
2 or the full potential of these storms without
3 suffering the consequences firsthand.

4 MR. CLINE: That's amazing. That is
5 amazing, and it really brings home the importance of
6 not only understanding space weather, as we have
7 started to do in just the past five or six decades
8 intensely, as you've been describing, but into the
9 near future, especially with the growing
10 vulnerabilities that you've described.

11 DR. KAPPENMAN: Well, that's right, and we
12 know that, you know, these storms have occurred
13 before. They are certain to occur again. The only
14 thing we don't know is exactly when they will occur.

15 MR. CLINE: Do you have any other types of
16 impact stories or personal stories or anything else
17 you would like to add to the interview?

18 DR. KAPPENMAN: No, I think we've pretty
19 much covered ...

20 MR. CLINE: We really have. This has --

21 DR. KAPPENMAN: Yeah.

22 MR. CLINE: -- been an incredible interview.

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1 DR. KAPPENMAN: Well, good.

2 MR. CLINE: I'm like, "Wow."

3 DR. KAPPENMAN: I'm glad it was worth your
4 while.

5 MR. CLINE: It really was. I mean, you're
6 the first one, I think, we've interviewed who's talked
7 about direct impacts to that extent because of, of
8 course, what you do.

9 DR. KAPPENMAN: Right.

10 MR. CLINE: And I think it's going to be a
11 real great addition to this. This is the one that the
12 people are going to listen to and be like, "Oh, wow.
13 We need to listen to that more. That's really
14 important. It's not as abstract."

15 DR. KAPPENMAN: No, that's right.

16 MR. CLINE: But thank you so much --

17 DR. KAPPENMAN: Yeah.

18 MR. CLINE: -- for your time. And our
19 next --

20 DR. KAPPENMAN: You know, and if you think
21 about electricity --

22 MR. CLINE: Uh-huh.

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1 DR. KAPPENMAN: -- let me give you a little
2 statistic. You know, we've expended an enormous
3 amount of geopolitical capital to preserve the
4 security of oil supplies to the country and to the
5 world. Electricity in the U.S. is about 40 percent of
6 all of the energy that we use. It's more than double
7 the amount of energy we use due to oil. So it's more
8 than twice as important as oil in terms of the type of
9 energy that we use.

10 MR. CLINE: That's amazing.

11 DR. KAPPENMAN: Yeah.

12 MR. CLINE: Wow.

13 DR. KAPPENMAN: And we've been very
14 fortunate that -- you know, up until now, you know,
15 our electric supply has not been threatened. It's
16 been incredibly reliable, stable, not subject to
17 political hostilities and things like that. But, you
18 know, the Sun could change that equation in an
19 instant.

20 MR. CLINE: In just a flash, I mean,
21 literally.

22 DR. KAPPENMAN: Yeah. It really ...

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1 MR. CLINE: You know, what we'll do with the
2 -- everything that we've just talked about is Carolyn
3 will have this translated.

4 DR. KAPPENMAN: Yeah.

5 MR. CLINE: Or -- and then --

6 DR. KAPPENMAN: Transcribed, yeah.

7 MR. CLINE: Not -- transcribed, excuse me --
8 yeah, into English. She'll have it transcribed for
9 us. And then what she'll do is go through, do some
10 minor edits, and then send you a copy that you can go
11 through and actually read through the entire interview
12 and add to, strike, move anything around you'd like.

13 DR. KAPPENMAN: Yeah. Very good.

14 MR. CLINE: And then we'll send that off to
15 the audio engineer to come up with the actual final
16 copy of what we do.

17 DR. KAPPENMAN: Very good.

18 MR. CLINE: So -- all right?

19 DR. KAPPENMAN: All right. Thank you.

20 MR. CLINE: Thanks so much for your time.

21 Again, it was --

22 DR. KAPPENMAN: Yeah.

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1 MR. CLINE: -- just great.

2 DR. KAPPENMAN: Have a good day.

3 MR. CLINE: You too. Bye.

4 (Whereupon, the interview of Dr. John

5 Kappenman was concluded.)

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CERTIFICATE OF TRANSCRIPTION

I, MARY E. YOUNG, hereby certify that I am not the Court Reporter who reported the following proceeding and that I have typed the transcript of this proceeding using the Court Reporter's notes and recordings. The foregoing/attached transcript is a true, correct, and complete transcription of said proceeding.

Date

Mary E. Young

Transcriptionist