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BEFORE THE  
NATIONAL TRANSPORTATION SAFETY BOARD  
Washington, D.C.

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In the Matter of the Investigation :  
of the accident involving :  
Trans World Airlines, Inc., :  
Flight 800, B-747-131, N93119, :  
eight miles south of East :  
Moriches, New York, on :  
July 17, 1996. :  
- - - - -x

Baltimore Convention Center  
Halls A and B  
One West Pratt Street  
Baltimore, Maryland 21201-2499

The above-entitled matter came on for hearing  
pursuant to Notice, at 9:00 a.m. on December 10, 1997.

Board of Inquiry:

Honorable Jim Hall, Chairman	Member, NTSB
Dr. Bernard Loeb,	Director, Office of Aviation Safety
Dr. Vernon Ellingstad	Director, Office of Research & Engineering
Mr. Barry Sweedler	Director of Safety Recommendations and Accomplishments
Mr. Dan Campbell	General Counsel

Technical Panel:

Thomas Haueter	Chief, Major Investigating Division
Al Dickinson	Investigator-in-Charge, Operations

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

1  
2 CHAIRMAN HALL: We will reconvene this  
3 hearing of the National Transportation Safety Board  
4 being held in conjunction with the investigation of the  
5 aircraft accident involving Transworld Airline, Inc.,  
6 Flight 800, Boeing 737-131 that occurred eight miles  
7 south of East Moriches, New York, July 17, 1996. We  
8 are now on agenda item number seven, the Ignition  
9 Sources Panel, and I'd ask Mr. Dickinson to please  
10 introduce and swear in the witnesses for this panel.

11 MR. DICKINSON: Good Morning, Mr. Chairman.  
12 Would the two witnesses please rise, and Mr. Bob Swaim  
13 please rise, and raise your right hand.

14 (Thereupon, the witnesses were duly sworn.)

15 MR. DICKINSON: This morning's panel is  
16 divided into two sections, Section A, External Sources,  
17 and Section B, Internal Sources. Section A consists of  
18 Dr. Cassidy and Ed Kittel. Dr. Cassidy is a professor  
19 of geology and planetary science, the University of  
20 Pittsburgh. He has been a professor there for 29  
21 years, and has been in his present position since 1981.

22 Previously, he was a research scientist at  
23 the LaMont Dougherty Geological Observatory of Columbia  
24 University. He has expertise in the origin and the  
25 evolution of planetary and sub-planetary bodies in the

1 solar system, and the origin of cosmic dust.

2 His research activities include the study of  
3 dust condensation in stellar atmospheres, field  
4 recovery of meteorites, and field studies in Antarctica  
5 meteorite stranding services. He has led Antarctic  
6 expeditions 15 times since 1976. He is a member of the  
7 American Geophysical Union and the Meteorological  
8 Society.

9 Dr. Cassidy has been awarded the Antarctic  
10 Service Medal of the United States and the Berringer  
11 Medal of Meteorological Society, and has been honored  
12 with the mineral name, Cassidyite, and the Antarctic  
13 Cassidy Glacier. He also has a minor planet named  
14 after him.

15 He has a bachelor of science in geology from  
16 the University of New Mexico, and a Ph.D. in  
17 geochemistry from Pennsylvania State University.

18 Mr. Ed Kittel is a special agent with the  
19 Federal Aviation Administration. After serving 20  
20 years in the navy as an explosive ordinance disposal  
21 officer, he came to the FAA, and he's been there for  
22 five years. He's a program manager for the Joint  
23 Service EOD Intelligence and Techno-counter Terrorism  
24 at the Defense Intelligence Agency, and he was that  
25 during 1988 through 1992.

1           He has been involved with investigations of  
2           the U.S. Air at Pittsburgh, the ValuJet accident, and  
3           the TWA investigation. His aviation explosive security  
4           projects include 77 airport detonation systems among  
5           the principal designers of the FAA modular bomb set,  
6           and a 21-year member of the International Association  
7           of Bomb Technicians and Investigators.

8           He has a bachelor of science in biological  
9           sciences from Miami, and he has two master's degrees,  
10          one in national and strategic studies, from the U.S.  
11          Naval War College, and the other in international  
12          relations.

13          Mr. Bob Swaim will be giving an opening  
14          presentation, and he is our systems group investigator.  
15          He's been with the Board for nine years, and I've given  
16          a bio on him in a previous panel, so I won't go into  
17          detail there. I'll hand the mike over to Mr. Bob Swaim  
18          at this time.

19                 MR. SWAIM: Thank you, Mr. Dickinson.

20                 CHAIRMAN HALL: Mr. Swaim, before you begin,  
21                 and I will try not to interrupt after this, but I just  
22                 wanted to thank the staff and thank Dr. Cassidy for  
23                 being here and including this as part of the hearing.

24                 I received almost a hundred letters from a  
25                 number of distinguished people, good citizens across

1 the country, asking the question about the possibility  
2 of a meteorite or space junk bringing down and being  
3 responsible for the TWA 800 accident, so I think it's  
4 entirely appropriate that that matter be discussed and  
5 explored this morning, and I appreciate, Dr. Cassidy,  
6 your willingness to come and volunteer your time to be  
7 here this morning with us.

8 So thank you very much.

9 MR. SWAIM: We heard yesterday in the Design  
10 and Certification Panel that a basic tenet of the FAA's  
11 certification for airplanes has been to keep ignition  
12 sources away from the fuel vapors. We heard testimony  
13 regarding how in previous accidents an ignition source,  
14 or numerous possible ignition sources, were identified  
15 and eliminated. We heard discussion that this  
16 philosophy is being strongly questioned.

17 In this panel we will address potential  
18 ignition sources that have been identified during the  
19 investigation. We are going to discuss these potential  
20 ignition sources in two general groups. The first  
21 group will be ignition sources that are external to the  
22 airplane, and include high-speed projectiles, items  
23 entering the atmosphere from space, and small explosive  
24 charges. We'll then have a change of witnesses and  
25 discuss ignition sources that may have developed within

1 the airplane.

2 Mr. Tom Haueter will begin the questions for  
3 Dr. Cassidy, and Mr. Frank Hilldrup will lead the  
4 technical panel's question for Mr. Kittel. Mr.  
5 Haueter.

6 MR. HAUETER: Thank you.

7 Whereupon

8 DR. W. CASSIDY

9 was called as a witness by and on behalf of the NTSB,  
10 and, after having been duly sworn, was examined and  
11 testified on his oath as follows:

12 MR. HAUETER: Good morning, Dr. Cassidy. As  
13 Chairman Hall mentioned, the Board has received over a  
14 hundred letters regarding meteorites and probably an  
15 equal number, if not more, phone calls on the subject.  
16 Can you provide us a short presentation on meteors and  
17 meteorites, and their potential damage being caused on  
18 objects on the ground?

19 DR. CASSIDY: When Bob Benson first contacted  
20 me about this, he and the group of which he's a member  
21 were sincerely trying to respond to the public concern  
22 and interest whether a meteorite might have caused the  
23 crash of Flight 800. The problem between us was that  
24 meteoritics -- and incidentally, it's not meteorology,  
25 it's meteoritics -- meteoritics are so far removed from

1 their field, and aircraft accidents are so far removed  
2 from my field that we weren't sure what we could do  
3 together.

4 One of the things he asked me was: Is there  
5 any way to estimate the frequency with which -- the  
6 expected frequency of the collisions between a falling  
7 meteorite and an aircraft, and my first reaction was  
8 that, first of all, there are no reported incidences of  
9 this having happened, so there would be no data on  
10 which to base such an estimate, so I was rather  
11 pessimistic.

12 But then I remembered that there is a record  
13 of meteorites striking dwellings and cars, so it might  
14 be possible to compare the relative area represented by  
15 dwellings and cars with the relative area represented  
16 by aircraft in the air, and in that way approach some  
17 kind of an estimate of the expected frequency of  
18 penetration of aircraft by a meteorite.

19 There are some uncertainties, of course, in  
20 this estimate, but it did turn out that I could make  
21 such an estimate. It came out to a rather small  
22 expected frequency, very small, as a matter of fact,  
23 but still finite.

24 I'd like to show a few slides to start off.  
25 The first one is a 36-ton meteorite that fell about



1 4,000 years ago in Argentina. Obviously, this would  
2 have an effect on an aircraft if it happened to be in  
3 its path while it was falling, but these objects are  
4 extremely rare, even over the total area of the earth's  
5 surface.

6 The next slide is the most frequent size of  
7 meteorite that falls, as near as we can tell. In the  
8 Antarctic collections this is the most frequent size,  
9 it's about the size of a large olive, and I think that  
10 most of the meteorites that fall are of this size, and  
11 so this is the kind of thing that we are considering,  
12 or possibly slightly larger than this.

13 The next slide -- unfortunately, it's a  
14 little dim, it's okay on the monitor -- it's a house in  
15 Connecticut, Weathersfield, Connecticut, that was  
16 struck by a meteorite in 1982. The meteorite went  
17 through the roof of the house, through the ceiling and  
18 the hallway, bounced on the floor, bounced up, and put  
19 a dent in the ceiling, and rolled into another room.

20 The next slide, I think, is a picture of the  
21 hole in the roof caused by this meteorite. You can see  
22 the shingles there for scale.

23 The next slide is another house, very  
24 coincidentally, also in Weathersfield, Connecticut,  
25 that was struck by a meteorite in 1971. This

1 particular one, you may be able to see some blemish  
2 near the center of the roof, this is a two-family  
3 house, and one family lives on the second floor and the  
4 other family on the first floor.

5 This meteorite went through the roof, through  
6 the crawl space, and embedded itself in the ceiling of  
7 the living room, it did not go through the plaster  
8 ceiling of the living room.

9 The next slide is the ceiling of the living  
10 room after they took the meteorite out. This gives  
11 some feel for the energies involved in a meteorite  
12 striking a structure on the ground.

13 Is there another slide? Oh, yes. These are  
14 the two meteorites, and the length of that scale is  
15 about two inches, the black figure at the bottom is  
16 about two inches long, and the smaller one was the  
17 second one I showed, the 1971 fall, and the larger one  
18 is the one in 1982.

19 So there is a record of these things  
20 happening, and I collected information on this from  
21 three sources. One is an old popular account called --  
22 it will occur to me, it has nomads in the name -- by  
23 LaPas and LaPas.

24 There's another set of records accumulated by  
25 a branch of the Smithsonian called "The Scientific

1 Event Alert Network," and they tabulated meteorite  
2 falls and fire ball observations between 1975 and 1992.

3 Also, a colleague, Dr. Roy Clark, at the  
4 Smithsonian, has a file of meteorites that have landed  
5 near people, and embedded in that file is a subset of  
6 meteorites that have struck houses and cars. So these  
7 were the three sources from which I collected the  
8 record on meteorite falls.

9 Before we get into the calculation I'll say a  
10 little bit about terms so that we know if we use those  
11 terms what we're talking about, and since you may not  
12 be able to read the screen, one term is meteor.

13 Now, meteor is a visual phenomenon caused by  
14 a body plunging through the atmosphere. You don't see  
15 the body itself, you see the glow of compressed air and  
16 ionized gases in front of the meteorite, and that's a  
17 meteor.

18 Now, a shooting star is a popular term. We  
19 all know what we mean when we talk about shooting  
20 stars, and this is a very short-lived meteor, generated  
21 by a dust particle or a bit of cometary ice.

22 A fire ball, or bolide, there may be  
23 different definitions of this, the one that I prefer is  
24 that they're the same thing, it's a longer-lived  
25 meteor, generated by a larger body such as a meteorite.

1           A fire ball, or bolide, is much more  
2           impressive than a shooting star, and it's caused by an  
3           object for which there's a chance that part of it will  
4           survive to reach the surface of the earth.

5           A meteorite is a chunk of silicate rock or  
6           nickel-iron alloy, believed to originate in the  
7           asteroid zone of the solar system, and the asteroid  
8           zone is a region in the solar system between the orbits  
9           of Mars and Jupiter, much farther out from the sun than  
10          Earth.

11          This zone is occupied by thousands of small  
12          bodies, the largest being about 550 miles in diameter  
13          series, and the smallest that we can observe, ranging  
14          down to a few-tenths of miles.

15          Now, we have every expectation, even though  
16          we can't see them there, that the distribution of  
17          fragments goes to much smaller sizes also in the  
18          asteroid zone, and these fragments apparently result  
19          from collisions between the larger bodies. So we think  
20          that that's a source of meteorites.

21          The second view graph is a classification of  
22          meteorites. The only ones that we'll talk about are  
23          irons, stony irons, and stones. Now, this is the kind  
24          of classification that I like, it's simple and it tells  
25          you something.

1           Also, the stones are by far the most  
2 abundant, so if we're talking about meteorites that  
3 penetrate the roofs of buildings or land on the earth,  
4 it's much more likely to be a stone than an iron.  
5 Irons are about seven percent of all meteorites that  
6 fall, stony irons are extremely rare, only one percent,  
7 and stones are about ninety-two percent of the falls.

8           Now, this diagram shows the earth in its  
9 orbit about the sun, and the earth is traveling at 18-  
10 and-a-half miles per second about the sun. The fastest  
11 speed, the fastest velocity, the highest velocity for  
12 any object in the solar system is about 26 miles per  
13 second.

14           So if we want to consider maximum velocities,  
15 then it's easy to see that a head-on collision between  
16 a meteorite going 26 miles per second and the earth  
17 going 18-and-a-half miles per second leads to an  
18 extremely high-velocity collision.

19           If the meteorite overtakes the earth in its  
20 orbit, it's highest velocity can be twenty-six miles  
21 per second, but the earth is moving away at eighteen-  
22 and-a-half, so the greatest velocity of entry for a  
23 meteorite that overtakes the earth is around eight  
24 miles per second, so there's quite a difference there.

25           The overtaking condition ranges from noontime

1 through 6:00 p.m., to midnight, and Flight 800 was  
2 struck, or had its accident I guess just after dusk, so  
3 it would be right around the 6:00 p.m. -- I guess it  
4 was around 8:00 p.m. So it would be a little ways into  
5 the night side of the earth, as it's shown here.

6 Now, if a meteorite comes in at an extremely  
7 high velocity, its chance of surviving for very long is  
8 much lower, because ablation is much more extreme. On  
9 the overtaking side, however, it's easier to slow it  
10 down, and ablation is much less a factor in reducing  
11 the size of the meteorite.

12 This slide essentially contains the remarks  
13 that I just made in describing the previous one.

14 Now, what happens when a meteorite enters the  
15 atmosphere? It has initial contacts with air molecules  
16 which bounce off the front face harmlessly, but as it  
17 gets deeper into the atmosphere, and the air density  
18 increases, the molecules that bounce off the front face  
19 find it harder to get out of the way, because they keep  
20 bouncing into other air molecules and bouncing back  
21 against the meteorite.

22 So the meteorite very quickly then builds up  
23 a cap of compressed air in front of it, and this is  
24 very highly compressed air, and when you compress air  
25 you generate heat, so this cap of compressed air heats

1 up, it heats the front of the meteorite, and as it gets  
2 hotter and hotter it begins to glow, and at that point  
3 it melts the front surface of the meteorite and  
4 vaporizes part of the materials, so this cap of air,  
5 this is the meteor that you see, contains highly  
6 compressed air molecules as well as atoms and ions from  
7 the meteorite. I would describe it probably as a  
8 plasma.

9 The meteorite, however, remains cool in the  
10 center, because the melted material is brushed off as  
11 fast as it forms, and it leaves a trail of droplets  
12 behind it. Also, the passage of the meteorite through  
13 the atmosphere essentially is really so rapid that  
14 conductivity of silicates being what is, the center of  
15 the meteorite does not heat up, it remains at about  
16 zero degrees centigrade.

17 This cap of compressed air is surrounded by a  
18 shock wave, and a meteorite that has reached this stage  
19 will be producing sonic booms. Also, the temperature  
20 of the meteorite is so high that it's glowing extremely  
21 brightly, and this will produce retinal image if an  
22 observer watches a meteorite fall, the same sort of  
23 thing you get if you look at the sun, or if you're in  
24 front of a flashbulb when it goes off, you get a  
25 retinal image.

1           Eventually, the meteorite slows down, because  
2 of its contact with the atmosphere, the drag, and  
3 becomes a freely flowing body, so by the time it  
4 reaches the surface of the earth it's going about 150  
5 miles an hour just as a falling stone.

6           The meteorite decelerates in one of two ways,  
7 either it decelerates because of drag due to the  
8 atmosphere, or if the pressure of this compressed gas  
9 on the front face exceeds the strength of the meteorite  
10 it will break into fragments, and smaller fragments are  
11 easier to decelerate, they decelerate rather rapidly.

12           In either case, it becomes a freely falling  
13 body, unless it is large enough so that part of it can  
14 survive to the surface of the earth still with its  
15 orbital velocity. This is not the kind of case that  
16 we're considering here, I would say.

17           At any rate, for an observer all of these  
18 effects can be confusing, and this is compounded by the  
19 fact that if you're observing a fire ball, you know  
20 neither its distance from you nor its size. Observers  
21 will generally try, however, to estimate the size of  
22 the body, but they don't have a basis for that.

23           If you know the distance of a body you can  
24 estimate its size by its angular displacement, but if  
25 you don't know the distance -- if you know the mass of



1 a body, if you know the size, then you might be able to  
2 estimate its distance from you. But not knowing either  
3 one, any observation that attempts to determine this to  
4 tell you the size of the body or how far away it was is  
5 not reliable.

6 Now, on the problem of estimating the  
7 frequency of damage, damaging impacts to an aircraft,  
8 first of all, no data exists on hits to aircraft, but  
9 there is a body of data on meteorites that have damaged  
10 houses and cars.

11 Now, this is, I think, a quite reliable body  
12 of data, because if a meteorite goes through the roof  
13 of your house, you want to tell someone about it, and  
14 the usual reaction is to call the police, and then  
15 after that call the T.V. stations. So these  
16 occurrences tend to get into the record.

17 Now, in addition to that, if the fall has  
18 been energetic enough to go through the roof of a house  
19 or a car, then you have something that might be  
20 comparable to a fall that would be energetic enough to  
21 penetrate an aircraft. So these are the data points  
22 that I used.

23 If we can estimate the area occupied by  
24 houses and cars, now, I used only data for the  
25 coterminous, United States. Now, coterminous is a word

1       you find in the census tables, and it means the U.S.  
2       without Hawaii and Alaska. The Census began tabulating  
3       Hawaii and Alaska in 1960, but the data from before  
4       that were without those two areas, so I subtracted the  
5       data from 1960, on, for Hawaii and Alaska.

6               So if you can estimate that area then you  
7       have a chance of learning the frequency of roof-  
8       penetrating meteorites per square foot in the United  
9       States. Then if you can estimate the area occupied by  
10      aircraft in the air, then you can compare those two  
11      areas to get an estimate of the expected frequency of  
12      damaging impacts to aircraft.

13              Now, there's a lot of data here. This is the  
14      complete tabulation of roof-penetrating meteorites for  
15      this century. Now, a couple of years have not yet  
16      occurred, but that's an approximation we have to face.  
17      The Census data go in decades.

18              CHAIRMAN HALL: None of those are in  
19      Tennessee, I hope.

20              DR. CASSIDY: Excuse me?

21              CHAIRMAN HALL: I live in Chattanooga,  
22      Tennessee, I just wanted to be sure there weren't any  
23      in there, Dr. Cassidy.

24              DR. CASSIDY: No.

25              CHAIRMAN HALL: Good.

1 DR. CASSIDY: Do you know of one?

2 CHAIRMAN HALL: No.

3 DR. CASSIDY: Okay. Well, if you're from  
4 Chattanooga, I don't know if that means that you're due  
5 or not.

6 Notice that there are some decades in which  
7 no roof-penetrating meteorites are recorded. There's  
8 also one decade in which four happen. Now, this, I  
9 think, is a result of the fact that these are such rare  
10 occurrences that we don't have a long enough time to  
11 get regularity in this record. If instead of ten  
12 decades we were looking at a record from ten centuries,  
13 possibly then the per-century rate would be constant.

14 Now, I was surprised when I -- I thought that  
15 estimating the area of houses and cars would be  
16 relatively simple, just go to the Census tables and  
17 find the number of dwellings in that decade, and arrive  
18 at an average area, an average horizontal cross-  
19 sectional area per dwelling, and throw in a car to that  
20 area, and add it all up.

21 Well, I hadn't thought about it, but our  
22 population has grown tremendously over the century, and  
23 also the number of dwellings has grown tremendously,  
24 going from about 18 million around 1905, to 97 million  
25 dwellings in 1995. So the size of the target has been

1 changing over the period that we're considering here.

2 So I took the mid-points of all the -- I  
3 essentially converted this graph into a bar graph, took  
4 the mid-points of each decade, and used that as the  
5 average number of dwellings for that decade, and then  
6 reduced everything to square feet, to put everything on  
7 an equal basis. So we should be looking at page nine  
8 now.

9 So, again, in this column you have the number  
10 of hits per decade, and then you have the average  
11 number of dwellings, and then you have a question on  
12 what is really the average size of a dwelling, the  
13 average cross-sectional area of a dwelling.

14 I'm not a student of architecture, I guessed  
15 that it was somewhere between 800 and 1,000 square  
16 feet. Now, houses have certainly gotten larger over  
17 this period, but very often it's by adding an extra  
18 story, and that doesn't change necessarily the  
19 horizontal cross-sectional area.

20 So I got estimates of the average target  
21 area, and this is times these numbers for the 800  
22 square feet and 1,000 square feet categories, or times  
23 ten to the tenth, which is a one with ten zeroes after  
24 it.

25 So I could then calculate the hits per decade

1 per year, or decade year, actually, it's per decade,  
2 for a ten-year period. In some decades where there  
3 were no hits at all, that was zero, but you'll see that  
4 there are some numbers there.

5 When we add them up, we get the hits per  
6 decade for the average dwellings and cars area, and  
7 then since we want to average all the decades over a  
8 century, you divide again by ten, so you end up with a  
9 range of target area between 3.5 times  $10^{-12}$  hits per  
10 square foot, and 2.7 times  $10^{-12}$  hits per square foot.  
11 So those numbers are the ones I used.

12 Now, for the aircraft data, the NTSB people  
13 have apparently tremendous resources, and they can  
14 prevail upon the aircraft companies and the airlines to  
15 get this data very rapidly. These list all the models  
16 in the first column that are in general use in the  
17 United States, flying over the U.S., and how many  
18 planes of each model are currently in use.

19 Also, they obtained for me the hours per day  
20 that each model averages over a year, so this is some  
21 fraction of a day, so the number of models, times that  
22 fraction of day that they're in use, times the  
23 horizontal cross-section of the airplane, gives you the  
24 total target area for that type of aircraft per day.

25 Now, this is based on yearly averages. This

1 means that these planes are in the air every day, on  
2 the average, during the year. So if we add up those  
3 total areas for all these models of planes, we get a  
4 number which is the total airplane target at any one  
5 time, over the continental, the coterminous United  
6 States. So that's the other number that I was seeking.

7 Now, in the calculations, we have to assume  
8 there's a constant influx rate of meteorites to the  
9 earth over time, also that any area, any particular  
10 area that you want to designate will receive some  
11 fraction of that influx, which is proportional to that  
12 area.

13 Also, any hit by a meteorite that's capable  
14 of penetrating a roof will cause damage to an aircraft  
15 if it hits the aircraft.

16 Now, there's some question about the  
17 comparability of the dwellings target and the aircraft  
18 target, but I didn't worry about that too much, because  
19 airplanes tend to be in the air with greater density  
20 over highly populated areas, there seems to be some  
21 correspondence there.

22 So the numbers I used were total target area  
23 in square feet that are represented by houses and cars  
24 in the coterminous U.S., and the number of roof-  
25 penetrating meteorites per year, hits per year on

1 dwellings, the total target area of aircraft in the  
2 air, and solved for the number of aircraft-damaging  
3 meteorite hits per year, and that's a simple formula.

4 I apologize for the unites. It's very  
5 awkward, but any units probably would be.

6 I called the total target area dwellings, HC,  
7 for houses and cars. RP is the number of roof-  
8 penetrating meteorites per year, and HC is the total  
9 target area of houses and cars. Was I redundant there?  
10 No. Roof- penetrating meteorites, total target areas  
11 of houses and cars, and "A" is the total target area of  
12 airplanes. So we're comparing hits per year on one  
13 side, and square feet on the other side.

14 So depending on the size of the average house  
15 then, the range can be, when you solve this, it varies  
16 between  $1.7 \times 10^{-5}$  hits per year, and  $1.3 \times 10^{-5}$   
17 hits per year. That's for the total aircraft target.

18 Now, the inverse of that number is years per  
19 hit, so if you divide one by these numbers, you get an  
20 estimate of how frequently you would expect hits to an  
21 aircraft, and that number comes out in these  
22 calculations to one such event between every 59,000 to  
23 77,000 years.

24 Now, there may be disagreement on some of the  
25 values that I used in this calculation, or some of the

1 assumptions I've made. I've tried to lay them out  
2 clearly so that other people can make their own  
3 estimates if they disagree with that.

4 DR. LOEB: Excuse me, Dr. Cassidy. I just  
5 want one clarification, one point for clarification.  
6 That  $1.3 \times 10^{-5}$  or  $1.7 \times 10^{-5}$  is hits per year on  
7 an aircraft.

8 DR. CASSIDY: Yes. To the total aircraft  
9 target, you see, considered as a single area, and that  
10 would have to be one airplane, also.

11 DR. LOEB: Thank you.

12 DR. CASSIDY: But it would not be a specific  
13 airplane.

14 DR. LOEB: Yes, I understand that. But the  
15 way you've done your calculations, that's on a  
16 per-airplane, whatever it is --

17 DR. CASSIDY: Yes.

18 DR. LOEB: -- a generic airplane that would  
19 be some average-type airplane, and not a specific  
20 airplane.

21 DR. CASSIDY: Right. Now, there's one final  
22 point to consider possibly, and that is whether any of  
23 the meteorites that might hit an aircraft actually  
24 would cause damage. As the meteorite gets smaller, the  
25 hits are more frequent, probably, but the energy is



1 less.

2           There is a record of hits to houses that have  
3 caused no damage. There are three meteorites that  
4 weighed up to 92 grams, and would have had an  
5 equivalent diameter between one and two inches that  
6 caused no damage to a house.

7           There's a 50-gram meteorite, we're verging  
8 now on ones that did cause damage, not to a house, this  
9 particular one hit an asphalt street, and created a  
10 dent one inch deep. There are a couple others that are  
11 around two inches in diameter, or between two and three  
12 inches in diameter, that penetrated the roof -- one  
13 penetrated the roof of a warehouse, it wasn't included  
14 in the tabulation, because it's not a dwelling, another  
15 one was one of the Weathersfield ones, that are still  
16 small, but did penetrate the roofs of houses.

17           But there is an overlap in size there around  
18 50, 60, 70 grams in mass, and around diameter of about  
19 an inch to two inches, where it may have caused damage  
20 or may not have, depending on which meteorite it was.

21           I think that about concludes the --

22           DR. LOEB: What were the larger sizes?

23           DR. CASSIDY: The larger size in the  
24 tabulation was the one that struck the car in  
25 Peekskill, New York, that was about 12 pounds.

1 DR. LOEB: About 12 pounds.

2 DR. CASSIDY: Yes. Now, they tell me that in  
3 examining the wreckage, they're fairly certain that  
4 they have not overlooked any penetration hole larger  
5 than about an inch in diameter. If they're very  
6 confident of this finding, then I would say that not  
7 only is there a very low expected frequency for this  
8 kind of occurrence, but also a low expectation, even if  
9 it did occur, that it would be energetic enough to have  
10 caused the damage that we saw.

11 Thank you.

12 MR. HAUETER: Professor Cassidy, I just have  
13 one question. Do you have an estimate of at what  
14 altitude a meteorite becomes a free-falling body?

15 DR. CASSIDY: Yes. That's a very difficult  
16 question for me, and I suppose I should have mentioned  
17 that. It depends a lot on the original mass, how long  
18 it takes to decelerate, and there is, I think, a valid  
19 question on how comparable a roof-penetrating meteorite  
20 is to that same meteorite at, say, 13,000- or 14,000-  
21 feet elevation.

22 It might still have substantially more  
23 energy, it might not be completely decelerated at that  
24 elevation. This is another uncertainty in this  
25 estimate.

1 I think what you're asking is whether it  
2 could be an iron meteorite instead of a stony  
3 meteorite, at least that's what makes sense to me.  
4 Yes, an iron meteorite has twice the density of a stony  
5 meteorite, so it packs twice the energy into the same  
6 volume at the same velocity.

7 So an iron meteorite would be more damaging;  
8 however, remember that the abundance of iron meteorites  
9 falling on the earth is only about seven percent of the  
10 total, and the stony meteorites are ninety-two percent  
11 of the total.

12 In addition to that, the stony meteorites  
13 have less structural integrity, they're weaker, and  
14 they tend to break into fragments, and then each  
15 fragment becomes a possible source of damage.

16 So there's probably a couple of hundred to  
17 one chance that if a meteorite goes through the roof of  
18 your house, it's a stony meteorite.

19 MR. HAUETER: Thank you. I have no further  
20 questions, and I guess I'll turn it over to Mr.  
21 Hilldrup for his questions.

22 MR. HILLDRUP: Thank you. Good morning, Mr.  
23 Kittel.

24 MR. KITTEL: Good morning.

25 MR. HILLDRUP: I wasn't sure if it was

1 covered in your bio from Mr. Dickinson, were you  
2 involved in the Pan Am 103 investigation?

3 MR. KITTEL: I was, but not on-site. I was  
4 involved in more of the intelligence aspects of that  
5 investigation.

6 MR. HILLDRUP: How about the Philippine  
7 Airlines accident in 1990-1991 time frame?

8 MR. KITTEL: Are you referring to the  
9 aircraft bombing?

10 MR. HILLDRUP: No. I'm talking about the  
11 fuel tank explosion in the Philippines.

12 MR. KITTEL: No. I had no involvement in  
13 that.

14 MR. HILLDRUP: Are you familiar with the  
15 details of that accident at all?

16 MR. KITTEL: Yes, I am.

17 MR. HILLDRUP: Okay. Could you review the  
18 role of your office with civil aviation accidents and  
19 with the NTSB?

20 MR. KITTEL: Sure. Our office was created in  
21 the early seventies when terrorists started bombing  
22 airplanes. The FAA felt we should have specialists on  
23 board with knowledge of terrorist bombs, bombing  
24 tactics, countermeasures development, and also  
25 post-blast investigations, as they relate to aircraft

1 accidents, should they have been a criminal act.

2 Since that time, approximately 1972, we've  
3 maintained specialists 100 percent coverage. We have  
4 two full-time headquarters based, explosive  
5 specialists, with backup, from our regional offices in  
6 the field, and our traditional role to the Board has  
7 been when there's an aircraft accident that has no  
8 specific immediate cause, in other words, it doesn't  
9 appear obvious what may have happened, that we've been  
10 asked to participate in the early hours of that  
11 investigation, along with the NTSB co-team, as members  
12 of the investigation to look for possible linkages to  
13 terrorist bombings.

14 In fact, we wind up serving as a linking pin,  
15 as it were, between the Board and the FBI. We're  
16 trained in the same evidence collection techniques,  
17 we're trained to investigate the same way as the  
18 criminal investigators do, but with an aviation  
19 background, and with the knowledge of how aircraft  
20 accident investigations are conducted. So we provide  
21 continuity.

22 As your bomb tech, so to speak, we're able to  
23 transition, from what we've seen and done, should there  
24 be evidence of a criminal act, to the Federal Bureau of  
25 Investigation, who has jurisdiction.

1                   MR. HILLDRUP: With respect to the TWA  
2 investigation, what was your role, and when did you  
3 begin the participation in the investigation?

4                   MR. KITTEL: I was called via the FAA  
5 Operations Center in Washington minutes after the  
6 crash. I initially responded to FAA headquarters,  
7 where we opened up our accident command center, that's  
8 the focal point of coordination between the various  
9 parties that are involved in the initial response, the  
10 emergency responses, as it were, left there that  
11 evening about midnight, and I chose not to take up a  
12 seat on the go-plane, on the initial response aircraft,  
13 but because of the close distance I chose to drive with  
14 more equipment than I would have been able to bring on  
15 the go-aircraft. So I drove and met the go-team at  
16 Islip Airport, and participated immediately from the  
17 first NTSB response, throughout the investigation.

18                   MR. HILLDRUP: Throughout the investigation,  
19 were you involved in the review of all wreckage that  
20 came into Calverton, and was that part of the FBI  
21 review, or was it, in essence, separate from that?

22                   MR. KITTEL: We were involved in all aspects  
23 of records review. In fact, my team, consisting of  
24 either myself or my partner, and two field  
25 investigators, one from Chicago, one from Atlanta,

1 reviewed every single piece of recovered wreckage that  
2 came into the hanger.

3 If I could follow up on that a little bit, we  
4 had a very, very healthy process of how those pieces  
5 were reviewed. We had an interagency bomb tech working  
6 group, as it were, that was put together with members  
7 of the Federal Bureau of Investigation, the Bureau of  
8 Alcohol, Tobacco and Firearms, New York City Police  
9 Department bomb squad, Nassau County Long Island bomb  
10 squad, Suffolk County Long Island bomb and arson unit,  
11 and, of course, ourselves from the FAA explosives unit.

12 Each of the bomb techs on duty reviewed  
13 individually, as well as by group, every single piece  
14 of recovered material coming into the hanger that was  
15 not limited to just aircraft structure, but also  
16 included all the aircraft cabin interior, all the  
17 personal effects, we reviewed literally all of the  
18 evidence in the case.

19 We looked at cargo contents, we looked at  
20 marine life. It was a very efficient system, because  
21 prior to any of the recovered pieces being placed on  
22 the floor or onto a markup, all of the bomb techs on  
23 duty had an opportunity to conduct visual examinations.

24 We would literally get down on our hands and  
25 knees with magnifying glasses and look at the smallest

1 pieces. I might add that we brought in pieces, such as  
2 sand dollars that were the size of your small finger  
3 nail, and the condition and the quantity was fairly  
4 remarkable.

5 We had an opportunity to review all these  
6 items, looking for any potential post-blast effects, or  
7 artifacts, that might become suspicious, and then any  
8 single bomb tech of any of those agencies was able to  
9 isolate a piece and say, we'd like this to be further  
10 examined by metallurgy, or by forensic chemistry.

11 So the somewhat duplicative combination of  
12 all of that expertise brought some of the best  
13 explosive investigators in the country together into a  
14 very effective screening process.

15 MR. HILLDRUP: Okay. Thank you. I'd like to  
16 move into a brief discussion about bombs or small  
17 charges. We've heard a lot this week about explosions.  
18 Could you talk about or differentiate between the  
19 detonation of a bomb and perhaps compare it to a fuel  
20 air type of an explosion event?

21 MR. KITTEL: Sure. A lot of what we've  
22 talked about this week, maybe with the exception of  
23 Richard Bott from China Lake, who talked about high-  
24 speed fragments, a lot of what we've been talking about  
25 are what's termed deflagrations.



1           A deflagration is a fancy term for rapid  
2 burning, a flame front, a combustible material. Go  
3 back to a couple of the presentations yesterday, the  
4 fire triangle, having the three legs of a fuel and  
5 oxidizer, and an ignition source. Those are fairly  
6 slow events, they have comparatively lower peak over  
7 pressures, and longer durations of the event, in other  
8 words, a fast burning, as it were.

9           In the case of high explosives, the types of  
10 things that terrorists make bombs out of, these are  
11 energetic materials that contain both the fuel and the  
12 oxidizer in that chemical compound, requiring only an  
13 ignition source, and for most high explosives, that  
14 ignition source, for it to achieve a detonation, is a  
15 detonator or a blasting cap.

16           So what we have is a tremendous release of  
17 energy, hot gases, shockwave, with a very high peak  
18 over pressure, maybe in the thousands of Psi, for a  
19 very short duration. That provides a very high-speed  
20 reaction, faster than the speed of sound, which is why  
21 you have the bang, it breaks the sound barrier, you  
22 have an explosion, it requires no confinement, and most  
23 of those chemicals in a high explosive are  
24 instantaneously consumed, releasing very high-pressure,  
25 hot gases, as well as a shockwave and a flame print.

1           MR. HILLDRUP: In the event that an explosive  
2 charge is detonated in some close proximity to another  
3 structure, what type of effects would you likely see?

4           MR. KITTEL: The effects are fairly unique  
5 and fairly obvious to the trained investigator. At  
6 very close proximity to the detonation you'll have  
7 complete destruction of the surrounding material or  
8 hole. Along the edges of that hole you'll have very  
9 high temperature, melting type effects. Depending on  
10 the speed of detonation, the type of explosive, and the  
11 distance, they all vary, of course.

12           With an inverse square relationship, you'll  
13 have very hot metal melting of the surrounding  
14 material, or possibly a pedaling of that material.

15           Sometimes you'll have saw-tooth-type  
16 fractures, and then very uniquely to high explosives,  
17 over virtually any other reaction, you'll have the  
18 effects of those hot gases that are involved in the  
19 detonation process. They will either completely  
20 crater, looking almost like the surface of the moon, a  
21 piece of metal, or they'll cause pitting, where they're  
22 forcing pieces of, say, surrounding materials, pieces  
23 of the metal itself into the metal, and leave very,  
24 very distinct patterns.

25           While that's happening, there's also a

1        tremendous release of hot gases, which cause effects  
2        call gas wash, or radial streaking. In some cases  
3        around the hole, as it were, if you had a penetration,  
4        you'll see streaking much like the rays depicted in,  
5        say, a picture or a depiction of the sun, where you'll  
6        have streaks coming out in all directions, 360 degrees,  
7        from the point of detonation.

8                This is happening in very, very high speed.  
9        Detonation velocities, for example, of plastic  
10       explosives, in the vicinity of 26,000 to 27,000 feet  
11       per second, much faster, much more intense physical  
12       effects than you have from, say, fire, or lower  
13       deflagrations, or burning.

14                The other tendency in the radial streaking  
15       and the gas wash effects is that they tend to be  
16       imprinted into the metal, they're not subject to being  
17       washed away, for example, they're permanent, and  
18       depending on the charge size, even for very small  
19       charges, fairly large diameters, where you'll have  
20       splatter and streaking effects, which can be seen with  
21       very, very small quantities, out to three or four feet,  
22       easily.

23                MR. HILLDRUP: You mentioned that a bomb  
24       could produce a hole. What happens to the fragments  
25       that made up that hole?

1           MR. KITTEL: If it's a very close proximity,  
2 say in contact with a piece of aircraft aluminum, for  
3 example, that hole will be just consumed in the  
4 detonation process, it will essentially be vaporized,  
5 but the surrounding metal will have the effects that I  
6 just mentioned.

7           I guess what I'm getting at, would you expect  
8 acceleration of those particles from the targets  
9 referenced, as it were, and is that damage a line of  
10 sight or linear damage that you would expect on  
11 neighboring structure?

12           MR. KITTEL: I see what you mean. Certainly,  
13 there is a directionality to explosives. If a sphere  
14 of explosives, say a round, circular sphere is  
15 detonated in air, the effects are 360 degrees in all  
16 directions, but when you have contact with a surface,  
17 you tend to have a lot of reflected energy, and then  
18 depending again on the materials and the charge size,  
19 it will transfer through the material, and where you  
20 have penetrations, such as the hole, where you've  
21 penetrated the target material, it will travel in a  
22 linear fashion quite a distance, again, depending on  
23 the charge size, on the order of many feet, if not  
24 yards or meters.

25           MR. HILLDRUP: Okay. Thank you. Are you

1 familiar with the tests that were conducted this past  
2 summer in Brunting Thorpe, England?

3 MR. KITTEL: Yes, I observed them.

4 MR. HILLDRUP: You were present for those  
5 tests.

6 MR. KITTEL: I was.

7 MR. HILLDRUP: Could you briefly review the  
8 results of those tests, basically were they consistent  
9 with the types of damage that you've seen in the past?

10 MR. KITTEL: There were actually two sets of  
11 trials conducted at Brunting Thorpe. Prior to the  
12 NTSB's tests, the FAA and the UK Civil Aviation  
13 Authority conducted some hardening tests of containers  
14 as part of our security R&D program. That occurred in  
15 May, and then in July of this year, we observed and in  
16 some degree participated in the NTSB-sponsored testing.  
17 I believe you're referring to the second series, right?

18 MR. HILLDRUP: That's correct.

19 MR. KITTEL: In the NTSB tests, we took  
20 various charge sizes from -- I'd like to caveat my  
21 questionnaire by saying that for security reasons I  
22 would not like to discuss the actual charge sizes, but  
23 we took very large charges, and then worked our way  
24 down to very, very small -- very small charges, and  
25 shot them through representative aircraft metal similar

1 to the, in fact, identical to the center fuel tank  
2 composition, both upper and lower skin, front and rear  
3 spar, and the span-wise and mid-spar beams.

4 In all of those cases, when we looked at the  
5 results both on the initial plate, which would  
6 represent a point external to the fuel tank, where an  
7 explosive charge might have been placed, and then at a  
8 witness plate, which represented the next adjacent  
9 panel, for example, from rear spar to span-wise beam  
10 one, we were able to see remarkable evidence of the  
11 high explosive effects obviously on the panel that they  
12 were initiated on, but also on the adjacent witness  
13 panel, which was placed at a representative distance of  
14 where that plate would be in the center fuel tank of a  
15 747-100.

16 MR. HILLDRUP: Okay. Thank you. This  
17 damage, all the damage that you described during your  
18 testimony, the pitting, the cratering, gas washing,  
19 high-energy fragmentation, is that unique to a high-  
20 order explosive?

21 MR. KITTEL: It is. It's the signature of  
22 high-order explosives, forensically.

23 MR. HILLDRUP: Okay. Thank you. In summary,  
24 you've seen all the records, or your office, from day  
25 one.

1 DR. LOEB: Excuse me, Frank, I'd like to  
2 interrupt just for one second.

3 MR. HILLDRUP: Okay.

4 DR. LOEB: Did you also witness the tests in  
5 which the explosives were placed on the tank that was  
6 there?

7 MR. KITTEL: I'm sorry, Dr. Loeb, I failed to  
8 mention that.

9 DR. LOEB: Yes.

10 MR. KITTEL: I prefaced my remarks that there  
11 were two series. There were also two series at the  
12 Brunting Thorpe tests, and the other involved  
13 initiation of explosive vapors, using propane air  
14 mixes, and then also the final test, which I believe  
15 Dr. Loeb is referring to, was an actual shot of the  
16 center fuel tank, with a, not a replicative test of  
17 Flight 800, but rather a representation of being able  
18 to initiate a center fuel tank with explosive vapors  
19 inside by high explosives, and I did witness that test,  
20 sir.

21 DR. LOEB: Okay. Prior to that final  
22 ultimate detonation of the tank, there were also test  
23 shots on that tank and that airplane as well, is that  
24 right?

25 MR. KITTEL: Right. The earlier test shots

1 were essentially, and again, without going into the  
2 numbers, we wanted to develop an understanding of how  
3 little explosives could be used to not only breach the  
4 center tank, in this case, on the rear spar, but  
5 penetrate it and be able to initiate a flammable or  
6 explosive mixture.

7 DR. LOEB: And you've seen no such damage  
8 that we've described today in this testimony on the TWA  
9 wreckage components, personal effects.

10 MR. KITTEL: That's correct. To the best of  
11 my knowledge, none of the participating bomb  
12 technicians, nor myself, have seen any indication of  
13 high-explosive effects on any of the wreckage recovered  
14 from Flight 800.

15 DR. LOEB: Mr. Chairman, I have no further  
16 questions.

17 CHAIRMAN HALL: Thank you very much, Mr.  
18 Kittel. Does any of the technical panel have  
19 additional questions of these witnesses? If not, we'll  
20 move to the party tables, and I believe it's the  
21 Airline Pallets Association. Captain.

22 CAPTAIN REKART: Good morning, sir. We have  
23 no questions.

24 CHAIRMAN HALL: Honeywell, Inc., any  
25 questions for these witnesses?



1 MR. THOMAS: Thank you, Mr. Chairman.

2 Honeywell has no questions.

3 CHAIRMAN HALL: Crane Company Hydroair, any  
4 questions?

5 MR. BOUSHIE: Thank you, Mr. Chairman, we  
6 have no questions.

7 CHAIRMAN HALL: The International Association  
8 of Machinists and Aerospace Workers?

9 MR. LIDDELL: Thank you, Mr. Chairman, we  
10 have no questions.

11 CHAIRMAN HALL: Transworld Airlines, Inc.?

12 MR. YOUNG: Thank you, Mr. Chairman, we have  
13 just one question for Dr. Cassidy? I'm just actually  
14 curious, Dr. Cassidy, about how many meteors would you  
15 think strike the earth on a daily basis? I know it's  
16 an estimate, but --

17 DR. CASSIDY: That's a very difficult number  
18 to arrive at. The problem is, the reason I went to the  
19 dwellings and cars record is that it's a solid record  
20 and it's probably much more complete than any estimate  
21 of meteorites striking the total earth surface,  
22 because, first of all, 70 percent of it is ocean, and  
23 an awful lot of the rest of it is pretty much  
24 uninhabited.

25 However, based on the record in houses and

1 cars, it could be possible to make that estimate, it's  
2 something I haven't done yet, because I didn't think it  
3 was important for this hearing, but something which I  
4 may attempt in the future.

5 MR. YOUNG: Thank you, sir. No further  
6 questions.

7 CHAIRMAN HALL: The Federal Aviation  
8 Administration.

9 MR. STEETER: No questions, Mr. Chairman.

10 CHAIRMAN HALL: Very well. We'll move to the  
11 Board of Inquiry. Mr. Sweedler. I'm sorry. I  
12 apologize. The Boeing Commercial Airplane Group.

13 MR. RORIGUES: No questions, Mr. Chairman.

14 CHAIRMAN HALL: I'm sorry, Mr. Rodrigues,  
15 it's too early in the morning. Mr. Sweedler.

16 MR. SWEEDLER: I have no questions, Mr.  
17 Chairman.

18 CHAIRMAN HALL: Dr. Ellingstad.

19 DR. ELLINGSTAD: I have no questions, Mr.  
20 Chairman.

21 CHAIRMAN HALL: Dr. Loeb.

22 DR. LOEB: I have no questions.

23 CHAIRMAN HALL: Mr. Kittel, I want to just  
24 ask again, you have personally yourself looked at all  
25 this wreckage of TWA, as much of it as you could.

1           MR. KITTEL: I would say that I've looked at  
2 probably 95 to 98 percent of it personally. There were  
3 times that I wasn't there that I would try to look at  
4 what I missed while I was gone, but in my absence,  
5 either my partner, and in both cases, our other two  
6 team members, examined 100 percent.

7           CHAIRMAN HALL: You can tell and report to  
8 the American people that you did not see any high-speed  
9 explosive damage, or whatever the appropriate  
10 terminology is, that would indicate that a bomb had  
11 caused this particular event.

12           MR. KITTEL: That is correct, sir.

13           CHAIRMAN HALL: Mr. Kittel, I greatly  
14 appreciate your presence here this morning, and Dr.  
15 Cassidy, we've learned a great deal about meteors. I'm  
16 glad I do live in Tennessee now, not Connecticut, but  
17 that's very informative, and let me stress again that  
18 the Board has tried to be responsive, and we have  
19 received a number of letters from thoughtful people in  
20 this area wanting us to explore the possibility of a  
21 meteor possibly being the cause of this accident, so I  
22 appreciate your contribution to the Hearing. This  
23 panel is dismissed.

24           Why don't we, before we move to the next  
25 panel, take a short break until -- we'll come back

1 promptly at 10:30, and start promptly at 10:30.

2 (Thereupon, a break was taken at this time.)

3 CHAIRMAN HALL: We will reconvene this  
4 hearing of the National Transportation Safety Board.  
5 We now move to our second panel, under agenda number  
6 seven, on ignition sources, and I'd ask Mr. Dickinson  
7 if he would introduce and swear in Panel B.

8 MR. DICKINSON: Thank you, Mr. Chairman. If  
9 the Internal Ignition Sources Panel would please stand  
10 up. Raise your right hand.

11 (Therefore, the witnesses were duly sworn.)

12 MR. DICKINSON: Please be seated. Mr.  
13 Chairman, this panel consists of Mr. Steve Gerken,  
14 George Slenski, Dave Johnson, Chris Hartonas, Mike  
15 Collins, Jerry Hulm, and Ivor Thomas.

16 Steve Gerken is an air force electrostatic  
17 discharge program manager at Wright Labs, Materials  
18 Director at Wright-Patterson Air Force Base in Dayton,  
19 Ohio. He has 14 years' experience, and he's a manager  
20 at the program at Newark Air Force Base in 1983 through  
21 1986, is senior vice president of Electrostatic  
22 Discharge Association, and is a U.S. deputy technical  
23 advisor to the International Electro-Technical  
24 Committee, 101 Electrostatic Problems in Industry.  
25 He has a B.S. in mechanical engineering from the

1 University of Toledo. Steve, if you could identify  
2 yourself. Thank you.

3 George Slenski is a lead engineer, Electronic  
4 Material Evaluation Group, Wright Laboratory, 17 years  
5 with Wright Laboratories, is responsible for planning,  
6 organizing, and conducting electronic failure analysis  
7 on fielded and new systems.

8 He develops and manages new programs, and  
9 improves and enhances aerospace systems, and is  
10 responsible for evaluating state of the air electronic  
11 assemblies, and performing field investigations, mishap  
12 investigations, and assessing the materials and  
13 manufacturing process capabilities of DOD contractor  
14 facilities.

15 His education includes a BS in electrical  
16 engineering and an MS in materials engineering from the  
17 University of Dayton.

18 David Johnson -- please raise your hand --  
19 thank you -- is an engineer at Wright Labs, Wright-  
20 Patterson Air Force Base, in Dayton, Ohio, four years  
21 with the Wright Lab. He performs failure analysis on  
22 complex avionics and aircraft electrical systems  
23 equipment.

24 During the NSTB investigation, he has been  
25 responsible for inspecting fuel probes and

1 compensators, and associated wiring from the accident  
2 aircraft and another Boeing 747 for anomalies that  
3 might contribute to ignition of fuel.

4 His education includes a bachelors degree in  
5 electronics engineering from the University of Dayton,  
6 a bachelors in business management from Kent State, and  
7 a master's degree in industrial education from Miami  
8 University.

9 Chris Hartonas, he's been up here before.  
10 He's an aerospace engineer with the FAA, combined 16  
11 years of experience and design in certification of  
12 electrical systems and equipment for civil and military  
13 aircraft, and his education includes an engineering  
14 degree from Ohio Northern University.

15 Michael Collins is an aerospace engineer with  
16 the FAA for 14 years in the aerospace field, nine years  
17 at the FAA, currently assigned to the responsibility  
18 for propulsion systems on 747 aircraft, certification  
19 and continuing operational safety issues for propulsion  
20 installation on transport category airplanes. His  
21 education includes a BS in mechanical engineering from  
22 the University of Washington, and he's a licensed  
23 professional mechanical engineer.

24 Jerome Hulm is manager of electrical systems  
25 in Boeing, 16 years in the Boeing Company, involved in

1 the design of wiring installations for the air force  
2 AWACs, and tanker and E-6 aircraft. He also  
3 participated in the design analysis and test  
4 certification of FQIS for the Boeing 737, 57, 67, and  
5 77.

6 He is a designated engineering representative  
7 for the FAA, and has been that for ten years. He also  
8 serves in the International Guard, his education  
9 includes a B.S. in electrical and electronic  
10 engineering from North Dakota State University.

11 And last, Ivor Thomas, he's been with us  
12 before on a panel, and he's the chief engineer of fuel  
13 systems and auxiliary power units at Boeing, and has 31  
14 years at Boeing Company, and he has a multiple area of  
15 experience, which we've gone over before.

16 All these people have been entered in our Web  
17 site, in our NSTB Web site. I'll turn the microphone  
18 over to Mr. Bob Swaim.

19 MR. SWAIM: Thank you. The TWA 800  
20 investigation is still an active search for the source  
21 of ignition, and this will be repeated over and over  
22 this week. We started to discuss potential ignition  
23 sources yesterday in the design panel, and yesterday  
24 Boeing said there are no known sources of ignition in  
25 the center wing fuel tank.

1 Under normal operating conditions we haven't  
2 found anything to disagree with that; however, we have  
3 found that certain failure conditions could combine to  
4 become a source of ignition, and I'd like to present a  
5 brief overview of some of the areas that we have looked  
6 into.

7 We looked into these areas as an overview, a  
8 summary, and I'd like to present a slide on each, fuel  
9 pumps, the electrical failures, we looked at the fuel  
10 quantity indication system, we heard some about that  
11 yesterday, hot air fuel tubing and vents, sparks from  
12 static electricity, lightning, and we looked into  
13 problems that might have originated in the main landing  
14 gear well.

15 With respect to fuel pumps, the background  
16 picture shows one of the jettison override pumps from  
17 the center tank of the accident airplane. As you can  
18 see, we thoroughly dissected them in our examinations.

19 We looked at the possibilities and found no  
20 evidence of overheating in the motor cavity, such as  
21 lack of cooling, through inadvertent operation, we  
22 found no evidence of a seized rotor, or worn bearings  
23 that could have caused friction or rotational drag,  
24 short circuiting within the motor cavity, short  
25 circuiting at the electrical connector that would have



1 had to come through the motor cavity, we found no  
2 evidence of a case breach, due to an electrical short  
3 circuit.

4 We looked for heat of an impeller friction on  
5 the housing, due to worn bearings, and we looked for  
6 heating impeller shafts at the worn bearings.

7 With respect to the scavenge pump, which was  
8 never found, we found no evidence of power being able  
9 to reach the pump through a failure of circuitry, we  
10 did recover all of the switches, well, the switch for  
11 this one pump, relay, circuit breakers, and so forth,  
12 everything in the system that provides power to the  
13 pump, and have thoroughly examined those at Wright  
14 Laboratory, in the switch and wire laboratory.

15 We looked for an ignition source in the rotor  
16 cavity or electrical connector in other pumps, and the  
17 capability of the pump to retain some type of ignition,  
18 even with a failure condition, such as a missing  
19 cooling tube, which also acts as a flame arrester.

20 We've been looking at strayed electrical  
21 sources that could have been possible. We found no  
22 evidence of power cables or short circuits that shorted  
23 and burned through the top of the fuel tank to ignite  
24 the ullage. We looked in the area, the dry bay,  
25 between the forward spar and span-wise beam three, and

1 found no evidence of a fire pre-existing in that area,  
2 a short circuit beneath the fuel tank, igniting the  
3 tank, or a leak from the tank.

4 We looked for short circuits of electrical  
5 wires in the dry bay igniting the tank. The reason  
6 there are two dry bays mentioned, one is the air-  
7 conditioning area below, one is in forward between the  
8 span wise three and the forward spar. And we looked  
9 for evidence that we could, of a fuel pump conduit  
10 short circuit in the in-board wing fuel tanks that  
11 could have ignited the ullage, traveled out to the vent  
12 collector, and back into the center tank.

13 We've been examining fuel probes and  
14 compensators. We've looked and found no evidence so  
15 far of a short circuit providing power to the center  
16 tank compensator at or in the re-fueling control unit,  
17 called the volumetric shut-off unit.

18 The wing tip has another dry bay, it's simply  
19 an area without fuel in it, and we've examined that for  
20 a possibility of short circuiting to the wires that go  
21 to a compensator that is further outboard in the search  
22 tank.

23 We examined for short circuits providing  
24 powers to FQIS wires in the flight engineer's fuel  
25 gauge, or at the connector that the gauge attaches to,

1 that was recovered from the wreckage.

2 CHAIRMAN HALL: Did you state what FQIS was?

3 MR. SWAIM: If I didn't, I apologize. It's  
4 Fuel Quantity Indication System, the gas gauge.

5 We looked for the possibility of bleed air  
6 ignition sources. Now, bleed air is very hot air  
7 coming from the engine compressor, it can be over 1,000  
8 degrees at times, and it's used to power the air-  
9 conditioning system, and pressurize the cabin.

10 We looked for the possibility of vapors  
11 igniting from the heat of a pneumatic ducts leak  
12 beneath the center tank, and I've used this photo  
13 before, it shows the large size of the ducts under the  
14 tank.

15 We looked for the possibility of fuel vapors  
16 igniting from heat of smaller ducts that are above the  
17 fuel tank called trim air ducts. We looked for the  
18 possibility of an air cycle machine that has a small  
19 turbine in that equipment, in the background picture,  
20 having exploded and gone up in the bottom of the tank,  
21 and found no evidence.

22 We looked for the possibility of leaking hot  
23 air damaging the Fuel Quantity Indication System, and  
24 the power wire insulation above the tank, melting the  
25 wires together, providing power, and we looked and

1 found no evidence of fuel vapors igniting from the heat  
2 of bleed air after a temperature control failure at the  
3 engine, allowing straight hot air from the engine bleed  
4 to reach these ducts that are in the area of the fuel  
5 tank.

6 The background illustration shows the vent  
7 channels within the wing. Ivor gave a similar slide  
8 yesterday to show how the vents are ported to the wing  
9 tip. We've looked at fuel system tubes, in addition to  
10 the vents. We looked at the possibility of a fire  
11 passing from a fuel line, to the auxiliary power unit,  
12 that would come in through the back spar, through the  
13 landing gear well, and found no evidence.

14 We found no evidence of a fire entering the  
15 center tank through the jettison fuel tube or the  
16 scavenge tubes, and we've reconstructed some of those,  
17 or put some of those into the reconstruction in  
18 Calverton. In the vent system, again, we've looked at  
19 the possibility of fire from a vent system igniting the  
20 center tank from the surge tank before the loss of  
21 electrical power.

22 We looked into the possibilities and did a  
23 lot of testing of electrostatic ignition. The  
24 background photo shows a clamp that is not electrically  
25 bonding to the tube it's mounted on. We looked at the

1 possibility of the fuel flow rate having induced an  
2 electrostatic charge into the tube that you're looking  
3 at, the larger tube, and possibly charging a tube  
4 connector that was not electrically bonded.

5 We looked into the possibility of leakage  
6 onto isolated metals, such as the clamp you're looking  
7 at, that could have discharged to the tube it's mounted  
8 on.

9 Lightning energy may create an arc in the  
10 tank at the clamp similar to how I just described  
11 static from the isolated metal, and we looked into that  
12 possibility, the Board's meteorologists found no  
13 evidence of any type of weather like that within 300  
14 miles.

15 In the landing gear bay, the circular air,  
16 the four circles are body gear retracted, and the line  
17 right below the first bullet, where it says "Wheel  
18 brake fire or heat ignites fuel tank," that's the rear  
19 spar of the airplane, so you can see that they're  
20 fairly close when the gears are retracted.

21 We looked for the possibility of a wheel  
22 brake fire or heat igniting the fuel tank. We looked  
23 at the possibility, and found no evidence of a fuel  
24 fire in that area, from a leaking fuel pump or other  
25 component.

1           We found no evidence of a hydraulic fire in  
2           the rear spar, or a tire explosion from an inadvertent  
3           oxygen fuel. Tires are normally filled with nitrogen.  
4           We looked at the possibility of a tire burst itself  
5           actually breaching that thick rear spar, or one of the  
6           systems, and found no evidence.

7           The area is still under investigation --

8           DR. LOEB: Bob, I'd like to ask you just one  
9           question for clarification before you go on to these,  
10          that we are still under --

11          MR. SWAIM: Okay.

12          DR. LOEB: -- and that is, although -- these  
13          numerous potential sources of ignition, in none of  
14          these have we have found evidence in this specific  
15          accident, many of these, the reason we did look at them  
16          is there is the potential for those to be a source of  
17          ignition for a fuel tank failure, is that correct?

18          MR. SWAIM: That's absolutely correct.

19          DR. LOEB: Okay. Thank you.

20          MR. SWAIM: One of the terms we've been  
21          using, we never close out consideration of any of these  
22          areas, we set them aside. So the areas I've just  
23          presented are areas that right now we've been working  
24          through, and we found evidence against, or found no  
25          evidence of, and for one of those reasons we've set it

1           aside in this accident. That's true.

2                       One of the areas that we are still looking  
3 in, and let me finish on that thought, we do bring  
4 things back from what we have set aside, with no  
5 evidence occasionally. This is an example, the Fuel  
6 Quantity Indication System. We are looking heavily at  
7 it, we have been looking into the possibility of a  
8 short circuit to the fuel quantity system wiring,  
9 outside of the fuel tank, combined with latent  
10 failures, or copper sulfide deposits, chemical  
11 deposits, you'll hear about, in the fuel tank.

12                      The background photos that are two, a left  
13 one and a right one, the one on the left shows two  
14 examples of damage to the wiring, and Mr. Johnson will  
15 be going further into depth, into what was found in the  
16 fuel tank, and explain that photo, it comes out a  
17 little less than clear here, and on the right is some  
18 of the wiring behind the flight engineer's panel in  
19 another airplane, and according to Boeing there is  
20 something like 150 miles of wire in one of these  
21 airplanes.

22                      The second bullet, energy, we've been looking  
23 into, or are currently looking into, is the possibility  
24 of, open investigation, energy being induced into the  
25 fuel quality system, combined again with latent

1 failures, or foreign material, or copper sulfide  
2 deposits in the fuel tank.

3 We're still looking into damage to a fragment  
4 of the wiring that is missing above the forward cargo  
5 compartment, and this idea that we're looking into on a  
6 previous flight, not the accident flight, a cargo  
7 container may have struck the wiring, creating a short  
8 circuit. So we're looking into this possibility.

9 Finally, we're still looking at the  
10 possibility of a short circuit powering the fuel  
11 quantity wires in some unrecovered material. That one  
12 we've got the wiring for parts of it, and not other  
13 parts, and that's a very active open area that I don't  
14 think we can really get too much further into.

15 Those are the areas we've been looking into,  
16 those are the areas we're still looking into. The  
17 Chairman started us into discussing static electricity  
18 yesterday, so I think it will be appropriate to finish  
19 your question with our expert in static, Mr. Steve  
20 Gerken, from Wright Laboratories, now Air Force  
21 Research Laboratory, and he has a few slides to explain  
22 the electrostatic process.

23 MR. GERKEN: Before I get started I'd like to  
24 just give just a brief overview of what electrostatic  
25 charging is, for the benefit of the families and those



1 in the audience that don't understand that. It's a  
2 very simple concept, actually, and we generate charge  
3 through contact and separation between two materials.

4 Most of you are familiar with walking across  
5 a carpeted floor and hitting a metal doorknob, and  
6 drawing a nice arc, that's a pretty good indication of  
7 what electrostatic is, how it's generated, and how it's  
8 discharged.

9 I have some examples here of tape pulling  
10 from a wheel, fuel flow in a pipeline, we have two  
11 different materials, and movement of one against the  
12 other, and finally when fluids exit a pressurized fuel  
13 line, and contact an isolated conductor, that is  
14 another contact and separation mechanism.

15 A lot of things are important to keep in mind  
16 here, that are factors in charged generation, the  
17 materials involved obviously is one intimacy of the  
18 contact, speed of separation, and purity content, and  
19 humidity.

20 As I mentioned we had five test sequences  
21 that were conducted, three at the Naval Research Lab  
22 and two at Wright-Patterson, and you can see here the  
23 dates that we conducted those tests.

24 I give you a photograph of the clamps that  
25 Bob had alluded to, the various types of clamps that

1 might be present in the center wing tank of a 747  
2 aircraft. Particular attention should be paid to the  
3 Teflon clamp, which has very good electrical isolation  
4 from the fuel tube it's around.

5 MR. SWAIM: Excuse me, Steve. Can we go back  
6 to that one a second? I just want to make a point.  
7 Those four clamps, the three to the left were removed  
8 from airplanes, and the one on the right was about to  
9 be put into an airplane. We might be coming back later  
10 to discuss parts being put into airplanes, and I just  
11 wanted to people to note, these are the clamps we'll be  
12 talking about.

13 CHAIRMAN HALL: Let me ask, one of them isn't  
14 titled, does that signify anything, or does that have a  
15 name to it?

16 MR. GERKEN: We believe that to be a form of  
17 nitrile, but we weren't even sure on that one, as a  
18 conductive property, though, and I'll get into that in  
19 a little bit.

20 DR. LOEB: Also, Bob, could you make sure  
21 that we identify anything that may be from the TWA 800  
22 airplane, and please keep those things that are not,  
23 separated out of it, those are just test articles, or  
24 samples, and so forth, and I think we ought to make  
25 that clear.

1                   MR. SWAM: This is true. We looked at a lot  
2 of airplanes in this investigation. I'm six-foot-one,  
3 and 195, I have trouble getting into the center fuel  
4 tank through those little ports, but we did a lot of  
5 them, and none of these are out of the accident  
6 airplane, but they are out of other 747s.

7                   DR. LOEB: Thank you.

8                   MR. GERKEN: The other conductive item we  
9 were concerned with is a Wiggins Coupling, a coupling  
10 used to tie two pieces of fuel pipe together, and the  
11 concern was that that outer male and female shell might  
12 be isolated from the fuel tubing, to the O-rings that  
13 you see here.

14                   Dr. Leonard's initial tests in January, 1997,  
15 were very simple. He took jet A fuel, used an ordinary  
16 syringe, 50 cc, and sprayed it onto an isolated clamp,  
17 such as what you saw in the prior diagrams. For the  
18 most part he got insignificant voltages when he did  
19 that process, but in one case he got 55 volts, which is  
20 not a significant voltage, but it warranted further  
21 investigation into this, so we carried onto phase one  
22 of Wright-Patterson's tests.

23                   Very simply, and I want to make this clear,  
24 our testing at Wright-Patterson was a fuel impingement-  
25 type test, that is, fuel that might be leaking from a

1 cross-feed manifold line onto these conductive items  
2 that are isolated, so the focus of our work was fuel  
3 impingement.

4 We also were very concerned with the  
5 conductors we were working with to ensure that they  
6 were adequately isolated electrically. That's very  
7 critical in their ability to hold the charge, and  
8 obviously critical when we discuss discharge energies.

9 Very quickly, at Leavitt Labs, phase one,  
10 using the clamps that we showed, and the Wiggins  
11 Coupling, the maximum voltage we achieved on the Teflon  
12 clamp, in particular, was 650 volts. The capacitance  
13 of that clamp, with respect to the fuel tube that we  
14 had it around, was just a fraction of a milli-jewel,  
15 .0095 millijewels, which is far below the quarter  
16 milli-jewel that you've heard during these briefings.

17 DR. LOEB: Mr. Gerken, before you go on any  
18 further, can you tell us how that 600 volts was  
19 achieved, what was the mechanism by which you got  
20 voltage on that?

21 MR. GERKEN: Okay. We sprayed fuel, in fact  
22 the test apparatus is up here, too, we pumped fuel  
23 through the system that you see here, the orifice in  
24 question, which varied, was within the test chamber,  
25 fuel was sprayed from the orifice, onto the test

1 specimen, that you can see below, and then a voltage  
2 measurement was taken from the test specimen, external  
3 to the cabinet, by way of a charge plate monitor.

4 CHAIRMAN HALL: This may be -- I'm assuming  
5 you can explain this, I don't know if it's a fair  
6 question or not, but 600 volts sounds like a lot, and  
7 then that translates to what, less than a milli-jewel,  
8 so can you tell us --

9 MR. GERKEN: Yes.

10 CHAIRMAN HALL: -- where that -- when I hear  
11 600 volts, I think, well, that's a lot.

12 MR. GERKEN: That's a fair question. The  
13 equation, if you will, that we use in calculation of  
14 this discharge energy, which you would want it tied to  
15 your minimum ignition energy, is one-half the  
16 capacitance of the item, times the voltage, squared.  
17 So you have two players in here that can drive the  
18 actual energy we might see from the clamps.

19 Capacitance is a huge player, the larger the  
20 capacitance, the less voltage you need to come up with  
21 the energy that would produce a quarter milli-jewel.  
22 Just for reference, to reach the quarter milli-jewel on  
23 a clamp of 45 peakaferrettes, you need in the  
24 neighborhood of 3,500 volts on the clamp.

25 DR. LOEB: I'm also hoping to set this up for

1 the audience. Can you give an estimate of what the  
2 electrostatic discharge is when you walk across the  
3 carpet and put your hand on a metal object, such as a  
4 doorknob, what that may be, relatively, in terms of  
5 jewels?

6 MR. GERKEN: Okay.

7 CHAIRMAN HALL: I want to follow-up on one --  
8 what is capacitance, so I can understand what  
9 capacitance is. You said volt and then capacitance.  
10 What is capacitance?

11 MR. GERKEN: I like to think of it, since I  
12 am a mechanical engineer, also, here, that it's like a  
13 bucket of water. Capacitance is how much charge your  
14 object can hold.

15 CHAIRMAN HALL: Okay.

16 MR. GERKEN: With respect to the other  
17 question, a human body is about 150 peakafferrettes, and  
18 the threshold of sensitivity on the doorknob I spoke of  
19 earlier is about 3,500 volts. So that would be an  
20 energy level in excess of a milli-jewel.

21 DR. LOEB: Thank you.

22 MR. GERKEN: Phase two. We weren't satisfied  
23 with our work in phase one, in terms of fuel  
24 temperatures used, spray distances, target angles, fuel  
25 conductivity, some key players in the generation of

1 charge, so phase two was dedicated to a target plate,  
2 eight-by-twelve inches, that we could easily move in  
3 different directions, and try and categorize all the  
4 different variables that we're looking at here, and, of  
5 course, once again, we were still focused on the  
6 isolation of the object.

7 For the most part we were still working with  
8 the Teflon clamp in phase two.

9 Highlighted here are some of the major  
10 findings from phase two. We had 1,080 volts when we  
11 used a 31 cu fuel. When we got that to 275 peakosemins  
12 per meter, we were able to produce 1,150 bolts, but  
13 it's key to note that as you increase the conductivity  
14 of the fuel, you've also allowed for charge to move  
15 more readily through the volume of the fuel.

16 So even though we get some higher charging  
17 levels, they don't hang around long, especially in the  
18 impingement test, because charge can bleed away through  
19 the fuel to the conductive fuel tube that it was  
20 around.

21 We did some fuel misting tests, and found  
22 very little charge associated with misting, but I do  
23 feel that may be something we'll want to look at a  
24 little bit further in the future.

25 CHAIRMAN HALL: Mr. Gerken, can an anti-

1 static additive have any effect on that?

2 MR. GERKEN: An anti-static additive, and I  
3 have to confess, I'm not a fuel expert, but generally  
4 speaking, you're going to increase the conductivity of  
5 the fuel by adding the additive, whereby giving the  
6 fuel more of an ability to move charge, so if you do  
7 have charge generated, it's easily carried away through  
8 the volume of a fuel to the conductive elements of, in  
9 this case, the center wing tank.

10 In phase one, I mentioned the 1,150 volt  
11 threshold that we achieved using the 45 peakoferrette  
12 value still, and I want to keep referring to the Teflon  
13 clamp, because it had the best isolation, electrically.  
14 We achieved .03 milli-jewels there.

15 Dr. Leonard, he's not with us today,  
16 obviously, he had surgery a couple of weeks ago, but  
17 I'd like to at least summarize his work that he  
18 continued with after our work at Wright-Patterson. We  
19 were concerned with trying to artificially charge the  
20 fuel if there were some means that the fuel might be  
21 charged initially before entering the tank, could we  
22 obviously raise the potential of these clamps and  
23 conductive items, and hence get a greater discharge  
24 energy.

25 This figure shows the apparatus that Dr.



1 Leonard used, the fuel is simply straining from the  
2 reservoir you see onto the isolated clamp, he's used  
3 the filtering system, a filter number ten, which  
4 doesn't mean a lot to me, but I can tell you that it's  
5 --

6 CHAIRMAN HALL: Can we zero in on that,  
7 somebody who is in charge? Can we get any closer to  
8 that? I'm sorry. Please proceed. I'm sorry, sir. I  
9 just thought it would be easier for people to view it  
10 if they could get closer on it.

11 MR. SWAIM: Steve, why don't you at least use  
12 your cursor. You can point out where the --

13 MR. GERKEN: Okay.

14 MR. SWAIM: -- reservoir is and the clamp --

15 MR. GERKEN: Okay. The fuel reservoir is  
16 here, it's strained through the coalescer cell here,  
17 which contained the type ten paper, the charge on the  
18 fuel, as it exited the coalescer, was measured with the  
19 volt meter, the electrostatic volt meter up here, the  
20 fuel impinged on the clamp, and again the voltage on  
21 the clamp was measured with the electrostatic volt  
22 meter.

23 Results were a little bit more exciting when  
24 you artificially charged the fuel. Joe also used  
25 several additives, which had an effect on the amount of

1 charge generated, but the maximum that we were able to  
2 see, with a simple, I guess, Gulf 178 additive, at 333  
3 parts per million, which is no longer available, and  
4 then at 1,000 parts per million we were getting  
5 voltages up in the 4,800-volt range, obviously beyond  
6 the 3,200-, 3,500-volt range that I had mentioned  
7 earlier as being significant.

8 Dr. Leonard also added water to some of the  
9 mixtures that he had there, and that created even more  
10 voltage, 6,500 volts, in particular, using jet A, plus  
11 1,000, with a Gulf 178 additive, and one hour of  
12 saturation in the water, and doing the same test, I  
13 showed 6,500 volts.

14 He replaced the volt meter with a spark gap,  
15 just to verify that we could draw arcs at these  
16 voltages achieved on the clamp, used different  
17 explosive mixtures, as you can see, but he achieved no  
18 ignitions, and he credited that with the fact that he  
19 might have had a lean, or a rich mixture, or did not  
20 get full discharge for the capacitance of the clamp,  
21 both which are possible.

22 MR. SWAIM: I'd like to add here, he was  
23 developing -- let's go back a step. Dr. Joe Leonard is  
24 probably one of the world's experts, he is one of the  
25 world's experts in electrostatic charging with fuels,

1 and he has worked for 30-some years for the Naval  
2 Research Laboratory, and when the Chairman asked us to  
3 find the best, well, we did.

4 So we're very thankful to have Joe with us,  
5 working with us in all of this. He crosses the bridge  
6 between the electrostatics world that is Steve's normal  
7 position, and the fuel's people.

8 So he did some testing down at Naval Research  
9 Laboratory, as Steve has been mentioning, basically,  
10 just to see how much charge we could get on a clamp  
11 from fuel, even though it was fuel not from the  
12 accident airplane, and he was using some additives that  
13 were not in the accident airplane or in service.

14 We simply wanted to see how much charge could  
15 be generated on a clamp, such as we would have gotten  
16 out of another airplane, another 747. That's where  
17 these tests came from.

18 When he was developing arcs, they're  
19 described in his report, they're in exhibit 9b, he was  
20 developing regular arcs, and I asked him about  
21 ignition, and he had a short time, I think it was like  
22 an afternoon, and he did these somewhat informally with  
23 the HEP team, and so forth. So I just wanted to put it  
24 a little bit in context there. I'm sorry, Steve, go  
25 ahead.

1 MR. GERKEN: That's fine. Thanks.

2 Joe also looked at trace elements of diesel  
3 fuel, which was suspected could be present in the JFK  
4 fuel, he did the same electrostatic charging test, but  
5 did not find significant voltages due to the addition  
6 of trace elements of diesel fuel. He also worked with  
7 sulfonates at ten parts per million, and got a maximum  
8 voltage of 4,400 volts in that case.

9 Joe also conducted an experiment very similar  
10 to what we've mentioned, where he collected fuel  
11 samples from Olympic Airways 747 aircraft in June of  
12 1997. The fuel samples taken from this subject  
13 aircraft were from Greece, which was the TWA 800  
14 origination point. He took samples from the center  
15 wing tank, the tank two sump upon arrival and 20  
16 minutes after arrival, and then from the hydrant truck  
17 prior to refueling.

18 Tests were very similar, as I mentioned, to  
19 what was conducted before. The maximum voltage he  
20 achieved was 1,880 volts, with the fuel retrieved from  
21 tank to sump after refueling had started. These values  
22 were, as we've mentioned, well below the 3,200-volt  
23 threshold needed for the quarter milli-jewel. You can  
24 see the range of the conductivity of the fuels as he  
25 measured those.

1           In summary, Joe's initial work certainly  
2 provided enough information that we should and decided  
3 to continue on with testing. Our Wright-Patterson  
4 work, first with direct assets, or clamps that are from  
5 747 airplanes, produced 650 volts, and an energy of  
6 .0095 milli-jewels.

7           Our phase two work, where we increased the  
8 conductivity of the fuel, produced 1,150 volts, and an  
9 energy corresponding to that at .03 milli-jewels.  
10 Finally, when we used charge fuel, we did get a higher  
11 voltage, 6,500 volts, which was well above the .25  
12 milli-jewel threshold. That summarized my tests.

13           MR. SWAIM: Thank you, Steve. I kind of put  
14 Steve on the spot here, since Joe has, like Steve said,  
15 had surgery, and is unable to be with us here today, I  
16 asked Steve to go through Joe's report and try and  
17 summarize it in a slide or two, and I think he's done  
18 that fairly well, and also if Joe is watching, I would  
19 like to say publicly, thank you very much.

20           Steve, in English now, for some of the folks  
21 who don't understand capacitance and peakoferrettes, in  
22 a sentence or two, can you summarize your testing, or  
23 yours and Joe's, ours?

24           MR. GERKEN: Well, the work at Wright-  
25 Patterson, again, was due to direct fuel movement

1       against the test specimen, very similar to what I  
2       mentioned when I started, contact and separation of two  
3       materials generates electrostatic charge, that's tied  
4       into the energy aspect of the investigation by focusing  
5       on the capacitance, the bucket of charge, and the  
6       potential, the voltage that you reach on those clamps  
7       in this case.

8               Based on our testing for fuel impingement, we  
9       did not see voltage levels significant enough to reach  
10      the quarter milli-jewel limit.

11             MR. SWAIM: Okay. Do you believe we should  
12      look a little further, discuss with Dr. Shepherd his  
13      recent results, or his in-progress work?

14             MR. GERKEN: Certainly. The quarter  
15      milli-jewel is a topic for discussion, you know,  
16      whereby temperatures influence that, altitudes and  
17      pressures influence that. That will be something we'll  
18      want to look at further. I believe the fuel misting  
19      issue should be explored a little bit further, whereby  
20      we might atomize the fuel, fill the center tank with  
21      single-plurality atomized fuel particles, and look at  
22      the voltage levels that might be achieved on these  
23      clamps, if you will, through that mechanism of  
24      charging, and not through fuel impingement.

25             MR. SWAIM: Very good. Can static develop in

1 refueling on the ground? I know there were a couple of  
2 accidents in 1970.

3 MR. GERKEN: Yes, it can, and Joe would be an  
4 excellent source for information on those. He worked  
5 very closely with those. I'm not all that familiar  
6 with the actual incidents in those cases.

7 MR. SWAIM: That was actually kind of a  
8 leading question, Steve. Did you know roughly how long  
9 it would take for static charges to dissipate after  
10 refueling?

11 MR. GERKEN: That's very much dependent on  
12 the conductivity of the fuel. If you have a low CU  
13 fuel, it might take quite a while, but when you talk  
14 low CU fuel, as you're talking about minimal  
15 impurities, much more purer fuel, so there's certainly  
16 a tradeoff. The higher CU fuels would certainly bleed  
17 any existing charge much faster than the low CU fuels.

18 MR. SWAIM: Okay. The additive from Athens,  
19 from Europe, does that have this anti-static additive  
20 you're talking about?

21 MR. GERKEN: I believe that's the status 450.  
22 Yes.

23 MR. SWAIM: Okay. So it would be more quick  
24 to bleed off a charge.

25 MR. GERKEN: That's correct.

1 MR. SWAIM: Okay. I believe Dr. Birky had a  
2 question.

3 DR. BIRKY: Yes. In the experimental setup  
4 that you just finished discussing, the clamps were  
5 totally isolated in the system, is that correct?

6 MR. GERKEN: That's correct.

7 DR. BIRKY: Are they isolated in the  
8 aircraft, in use?

9 MR. GERKEN: The clamps themselves, the  
10 isolation in the clamp is dependent solely on the  
11 cushioning material. They didn't touch on that very  
12 much in the presentation, but the four clamps that you  
13 saw at the beginning of the presentation had varying  
14 resistances.

15 DR. BIRKY: Do they have a ground strap on  
16 them, or not?

17 MR. GERKEN: I don't believe so, no.

18 DR. BIRKY: Okay. Okay. You referenced the  
19 Gulf additive that gave the high voltage charge. What  
20 is that additive?

21 MR. GERKEN: I certainly can't speak to that

22 --

23 DR. BIRKY: Okay.

24 MR. GERKEN: -- that would be a Joe Leonard  
25 question.



1 DR. BIRKY: Okay. Okay. Thank you.

2 MR. SWAIM: A question for the Boeing folks,  
3 from the question that was just brought up, we did find  
4 these clamps without bombing straps, separated from the  
5 tubes they were on, separated from structure, or  
6 anything else. We found these in other 747s, and then  
7 we went back with your help and found where they were  
8 in the drawings.

9 Is there some reason that these ungrounded  
10 pieces were in the tank? Why were they there? Mr.  
11 Thomas or Mr. Hulm?

12 MR. THOMAS: Well, let me try and answer  
13 that.

14 DR. LOEB: Before you do that, Mr. Thomas,  
15 could you explain the importance of the bonding straps  
16 and the concept quickly again?

17 MR. THOMAS: This is jumping into electrical  
18 -- maybe Jerry Hulm can answer that. Bonding straps are  
19 used to basically bond between pieces of aluminum in  
20 the airplane pipes or the airplane structure itself, so  
21 that there are no -- generally, we try to avoid  
22 unbonded metal objects inside the fuel tanks.

23 The previous -- excuse me, I don't know the  
24 gentleman's name, Gerken is it, described the concept  
25 of a bucket of water carrying an electric charge, that

1 is the capacitance. If we have a large metal object,  
2 it becomes a large capacitor, and it can pick up large  
3 amounts of charge, and that becomes a hazard to the  
4 airplane.

5 What we have tried to do is to bond all of  
6 those large metal objects to make sure that we do not  
7 have a floating, what we would call a floating metal  
8 object that could acquire charge and become a static  
9 charge point for discharge.

10 In these small couplings, we have not found  
11 the need to bond the couplings, because the capacitor,  
12 again, using the bucket, we're now talking about a very  
13 small cup that can only hold a very, very small charge,  
14 as all the testing we've heard about says those charges  
15 are well below the limit that you would have a spark  
16 that's large enough to ignite the fuel vapor.

17 So on small couplings we tend not to bond  
18 specifically on those small couplings.

19 MR. SWAIM: Jerry, do you have any guidance  
20 on how large a piece of metal can be to be in the fuel  
21 tank unbonded?

22 MR. HULM: The standard that was used in the  
23 development of all of our models is out of MILB 50-87,  
24 which establishes a three-inch rule. If the linear  
25 dimension and direction is less than three inches, the

1 component does not need to be bonded.

2 MR. SWAIM: Okay. What is --

3 CHAIRMAN HALL: Can somebody put that into  
4 English?

5 MR. SWAIM: I was just going to say the same  
6 thing. What is MILB?

7 MR. HULM: It's a MILB 50-87, which is a  
8 military specification that defines specific bonding  
9 and grounding requirements for different types of  
10 components in a fuel tank. One of their guidelines  
11 that they've used that the majority of the industry has  
12 followed, and the military, also, is that if a  
13 particular metallic object is less than three linear  
14 inches in any one dimension, then that particular  
15 object does not have to be bonded as long as it is not  
16 in the primary bond path for some certain, either  
17 electrical device or a static path.

18 CHAIRMAN HALL: Does the FAA have a  
19 requirement, or is this just the air force?

20 MR. HARTONAS: The Federal Aviation  
21 Administration, the regulations of the FAA, provide  
22 ground rules. They do not specifically -- they do not  
23 specify how grounding and bonding is to be accomplished  
24 in the airplane. The equipment must meet its intended  
25 function as installed on the airplane, and it must be

1 safe.

2 MR. SWAIM: So if something is less than  
3 three inches in any dimension, I guess that would  
4 include these clamps width-wise, is that correct,  
5 across the width of the clamp?

6 MR. HULM: Correct.

7 MR. SWAIM: Okay. I know we haven't prefaced  
8 this with other accidents, or building that up, but  
9 similar clamps, Teflon-lined clamps, were involved in  
10 two refueling incidents where 727s were being refueled  
11 in Minneapolis in 1970. It was a higher flow rate, but  
12 then we've also discussed a breached fuel tube spraying  
13 fuel onto an insulated metal.

14 Do you have any thoughts as far as the  
15 validity, or as far as what's been seen in service  
16 since there were two airplanes lost?

17 MR. THOMAS: Let me try and answer that. We  
18 can maybe tie in the previous presentation again. We  
19 had two successive 727 fires due to electrostatic  
20 charge at Minneapolis at exactly the same pier at the  
21 airport, separated by two months, or three months,  
22 approximately that time length. We investigated that  
23 at length, Joe Leonard was involved in a lot of that.

24 What we found in that, those incidents, there  
25 was some minor damage to the airplanes, they weren't

1 major fires, what we found was the amount of static  
2 charge being developed by the fueling system, the  
3 trucks, if you will, that are fueling the airplane, was  
4 significantly higher than we'd ever experienced, and  
5 the data eventually pointed to this number ten paper  
6 that Joe Leonard was using in the prior investigation.

7 It turned out that that was a new paper that  
8 was going into the filter system at the airport, and  
9 that filter paper had a significantly higher charging  
10 capability than previously known, and that was deduced  
11 to be the cause of those two incidents, and that paper  
12 was removed from service immediately, and the problem  
13 has gone away since.

14 So we're looking at an airport problem, the  
15 filter truck. I'm surprised Joe has some number ten  
16 paper that he could use for this particular test, and,  
17 again, it shows when he's testing, that he got much  
18 higher charges using that paper, even on a small scale.

19 MR. SWAIM: Okay. Thank you, Ivor. This  
20 year in the Safety Board's lab we opened a -- I'm  
21 changing off the static subject -- this year we opened  
22 a fuel quality compensator from the TWA 800 wreckage,  
23 and we found a black spot on a crimped wiring islet.  
24 After examining the spot under magnification, research,  
25 not surprisingly, for the number of airplanes they

1 have, led us to the air force laboratory at  
2 Wright-Patterson again for a second subject. The air  
3 force has a specialized laboratory that examines wires  
4 and switches, and it turns out they had extensive  
5 experience with probes, and similar black markings.

6 With that I'd like to introduce Mr. Slenski,  
7 who is the team lead for the wire and switch lab, the  
8 electronics lab, and ask him to tell us about some of  
9 the air force's experience with fuel probes, and I'd  
10 like to emphasize the couple of slides I know he has.

11 I don't know too well where he's going, but  
12 the couple of slides he does have relate to air force  
13 probes, and that's leading into what was found in the  
14 800 probes.

15 CHAIRMAN HALL: Well, let's cover that  
16 material in your 1990 paper as well.

17 MR. SLENSKI: Yes, Mr. Chairman.

18 CHAIRMAN HALL: Good.

19 MR. SLENSKI: Good morning, Mr. Chairman. My  
20 name is George Slenski, and this presentation will  
21 discuss the analysis of fuel probes removed from U.S.  
22 Air Force aircraft over about a seven-year period. I  
23 believe this may have been covered previously, but I  
24 just wanted to again go over fuel probe description.

25 Again, the fuel probes are basically large

1 capacitors, tubular construction, you're measuring the  
2 capacitance between an inner and outer electrode. What  
3 we have to remember is that capacitance is a function  
4 of the applied signal wiring, probe construction, and  
5 the ratio of the fuel to air between the electrodes,  
6 and any resistance changes can obviously affect this  
7 performance.

8 Just again to point out, the probe systems  
9 are designed to limit current on an aircraft, and then  
10 if you did have a short in a probe there should be  
11 insufficient energy to ignite the fuel in the aircraft  
12 fuel tank.

13 These are examples of a fuel probe, and this  
14 is when it was first reported to us. On the bottom of  
15 the left there is an intact fuel probe, and I also want  
16 to point out that none of these probes that we will be  
17 presenting are from TWA 800, and the probes in the 747  
18 are similar to these designs, but they're different  
19 types of probes.

20 What we're illustrating here is the buildup  
21 of this material, copper sulfite, over a long-term  
22 period of time.

23 Again, in the lower left-hand corner, the way  
24 this became apparent is that our maintenance personnel  
25 were experiencing measurement problems on the fuel

1 quantity systems of several types of aircraft, they  
2 also noticed black marks on the fuel probes, and in  
3 that situation they obviously were concerned, could  
4 this be an arc that occurred in the fuel probe, and  
5 that's how we became involved in this analysis.

6 Now, this is a closeup, and this is actually  
7 the bottom of that probe, we're looking at the actual  
8 compensator end, and what we're looking at here, the  
9 three arrows are pointing to a black streak on the  
10 metalized portion of the outer electrode, the top part  
11 is a piece of nylon in the blackened area there, and  
12 the other area is referring to one of the wires, and  
13 basically we have a low-resistance path between that  
14 wire and ground, and that was the source of the  
15 measurement problems.

16 Now, we look at these materials, they're  
17 actually conductive, and when we mention conductive  
18 it's relative. These types of probes typically should  
19 have around 40 megohms of resistance between any two  
20 points in this system in order for it to work properly.

21 In the cases we're looking at here, if you  
22 measure these resistances, or probe the resistances,  
23 we're looking at from one to a hundred kilo-ohms, and  
24 that's significantly low enough to actually affect the  
25 operation, and that will give you inaccurate readings



1 of the fuel probes.

2 First of all we can talk about the upper left  
3 photo of the compensator, and, again, this is the  
4 compensator end of the fuel probe, and, again, showing  
5 you the blackened residues we're finding there, and  
6 this is the wire that's actually inside the piece of  
7 Teflon tubing.

8 CHAIRMAN HALL: Where's the blackened  
9 residue, would you point it out?

10 MR. SLENSKI: There's a square there, it's a  
11 blue square, just inside that square is the residue  
12 area. What we'll look at next is, if we go over to the  
13 right, is inside that Teflon tube, and this is the  
14 inner part of that tube now, we've actually taken it  
15 apart and dissected, that's showing you the black  
16 residue actually on the surface, and this material, if  
17 you probe this, basically, if you had two meter probes,  
18 and you put those down on the surface, you'd finally  
19 have a, well, what I would call a semi-conducting  
20 material, it's not a highly conductive material like a  
21 piece of copper, and that's why we're referring to it  
22 as semi-conducting, and it's around one, to maybe a  
23 hundred kilohms, typically. But, again, that's enough  
24 to affect operation of these probes.

25 Now, if we go directly to the lower one on

1 this quadrant, what we looked at previously was an  
2 optical version of that coating. What we're looking at  
3 here is an scan electrode micrograph of that same  
4 residue, and the SEM, or scan electrode microscope, is  
5 beneficial to us, because you get great depth of field.

6 If you notice, you can actually see this  
7 coating lifting off the surface, and what we're looking  
8 at here is a very thin film buildup of material, and  
9 that's basically the phenomenon that we're dealing with  
10 here.

11 In the next chart I'm going to show you some  
12 analysis of that material. I'm going to move over now  
13 to the left lower quadrant. This is the wire that was  
14 next to that Teflon material. This wire was silver-  
15 plated copper wire.

16 Now, maybe I can explain this in maybe easier  
17 terms here, there's a considerable amount of sulphur in  
18 our fuels that we use in our aircraft, and I think if  
19 you're familiar with -- silver tarnishes fairly easily,  
20 a lot of times that tarnish turns black, in many cases  
21 that's sulfur that's in the atmosphere. So sulfur and  
22 silver react readily together, and you form silver  
23 sulphite.

24 In addition, the sulfur will also react with  
25 copper that may be exposed, and you form copper

1 sulfite, and these are these semi-conductive compounds  
2 that appear to be black or gray on these probe  
3 surfaces.

4 If we can first go up to the lower left  
5 quadrant, I'll just focus on this example again.  
6 Residues on the wires, most of these probes, in some  
7 cases, have been on the aircraft over 25 years, and,  
8 again, we need to point out this is an aging phenomena,  
9 a degradation of materials over many years in fuel.

10 And, again, what we're looking at here is a  
11 low resistance between the wire and actually one of the  
12 probe elements, and you can see it there. At one time  
13 it was actually touching in there, which caused a low-  
14 resistance path, and, again, affected the operation.

15 What I want to point out here, too, is that  
16 we look at these films, we're not finding a buildup of  
17 carbon. If we found a large buildup of carbon, and we  
18 saw ruptured surfaces in here, then we would be  
19 concerned about arcing that had occurred in here.

20 So this is not an arcing phenomena, this is a  
21 low resistance or leakage current that is basically  
22 affecting the operation of the probe, but is not  
23 causing arcs between surfaces.

24 Now, if we go over to the lower right, I  
25 don't know if this is going to show up too well, maybe

1 we can zoom in on that area there. That's better.

2 This is just how we prove whether or not what we're

3 looking at is actually there on the surface.

4 This is a spectrum showing silver sulphur,  
5 and "S" is silver, "AG" is silver, and "CU" is copper,  
6 that these elements truly exist on the surface, and the  
7 analysis technique is energy disperses spectroscopy,  
8 basically, what we're doing here, and this is while  
9 it's in a scan electrode microscope, you bombard the  
10 surface with the energy, and you get X-rays released,  
11 and each element has a characteristic X-ray, and so  
12 that's how we identify the elemental makeup here.

13 This has an accuracy of about one percent, so  
14 if you have one percent of material on there, you will  
15 detect the element.

16 If we could go to the upper left quadrant  
17 first. This is actually a good example of the fuel  
18 problem we were having. This is on the wires now,  
19 instead of on the probes.

20 In this case here, if we look at that red  
21 square or rectangle we have here, the problem in this  
22 case is our maintenance is reporting a fuel quantity  
23 problem on the probe system, and what they found with  
24 isolation once we removed these wires is that there was  
25 low resistance between that terminal in that lower blue

1 splice, which is ground, basically, and in this case  
2 we're getting resistances in the high kilo-ohms range,  
3 100 K, 100 kilo-ohms, and again, that was affecting  
4 probe operation.

5 DR. LOEB: Mr. Slenski, may I interrupt for  
6 just a minute?

7 MR. SLENSKI: Sure.

8 DR. LOEB: Are those ohmic values you're  
9 giving done at the operating bulge of the equipment, or  
10 are those test voltages, high voltages?

11 MR. SLENSKI: When we're making these  
12 measurements we're typically using an ohm meter, which  
13 is 1.5 volts, so it's very current limited low voltage,  
14 and we'll talk about it later on. In some cases we  
15 applied higher voltages to see how these films  
16 behave --

17 DR. LOEB: Okay. Thanks.

18 MR. SLENSKI: -- at higher voltages and  
19 currents. If we move to the upper right quadrant, this  
20 is a closeup of this connection, and, again, showing  
21 you this black-gray residue that does form, and you can  
22 see it's actually formed between these two wires, and  
23 that conductor path caused the malfunction of the fuel  
24 quantity system.

25 MR. SWAIM: Mr. Slenski, I have a question

1 for you. You were showing us the film, it kind of  
2 looks like flaking paint, or something --

3 MR. SLENSKI: That's correct.

4 MR. SWAIM: -- in the closeup, and here  
5 you're showing us two wires that are next to each  
6 other. If you flex the wires, or remove the wires from  
7 whatever, how easy is it to break that film?

8 MR. SLENSKI: Well, if you noticed in the  
9 previous slide, you can almost what I would call mud  
10 cracking of this film. Again, it's a very thin film,  
11 any type of stresses will crack that film, and  
12 typically, this is the problem we ran into in  
13 maintenance, if anyone hit that probe, you would  
14 actually interrupt that conductive path, because it's  
15 very sensitive.

16 Any flexing, any movement, you can break that  
17 surface up and over time it will grow back, so it was  
18 an intermittent problem, and that's one reason why we  
19 became involved, because it was very difficult to  
20 isolate this and understand the phenomena.

21 MR. SWAIM: Excuse me. Just for  
22 clarification purposes, could you be more specific in  
23 talking about that film, whether that is on the -- you  
24 referred to wires, is that on the insulation or on the  
25 conductor?

1                   MR. SLENSKI: It's actually on the  
2 insulation. The conductor is not exposed here. This  
3 is, I believe, a Teflon insulation, and the material is  
4 actually forming on the surface, as you can see between  
5 those two wires.

6                   MR. SWAIM: Thank you.

7                   MR. SLENSKI: Now, if we could go down and --  
8 first of all, note that yellow rectangle again, because  
9 the next two slides are going to show you again our  
10 chemical analyses of those areas, so we can go to the  
11 lower left quadrant.

12                   This is a variation on the earlier analysis I  
13 had mentioned, energy dispersive spectroscopy. This is  
14 what we call an X-ray map, and what we do, and, again,  
15 this is using a scan electrode microscope, we actually  
16 scanned the surface very carefully, and what we're  
17 detecting out of the elemental distribution, in this  
18 case, copper and sulphur across the surface, so the  
19 lower image there, the black line image is what we  
20 scanned, and what we're seeing is the deposition of  
21 copper and sulphur.

22                   Again, this technique shows you elemental  
23 makeup, it does not tell you that you have a compound  
24 there, copper sulphite, it just says you have copper  
25 and sulfur present, but as you can see, it follows a

1 similar pattern.

2 Now, if we move over to the lower right  
3 quadrant, this a simulated -- presented a little bit  
4 differently. Now, we can see this material actually  
5 forming the path. Again, red is copper, yellow is  
6 sulfur, and this is foaming on the insulated material  
7 as a thin film.

8 Again, they are very unstable materials, they  
9 are very moisture sensitive. If you would breathe on  
10 this, or have higher moisture content, you'll  
11 definitely change your resistance. I should also point  
12 out the -- it was interesting in the case of Mr.  
13 Johnson's presentation, copper sulfite and silver  
14 sulfite are not soluble in water, so these will be  
15 still present, even if they're immersed in water over  
16 time.

17 Mr. Swaim had asked us to specifically  
18 discuss this probe. This is an interesting case, and  
19 again, this probe design is not what we're looking at  
20 in this 747 aircraft, it's an older design. This  
21 particular probe actually ignited fuel vapors while it  
22 was outside of an aircraft, under testing, and the  
23 intact probe is shown in the upper right corner there.

24 The center is a section, and I think if we  
25 can zoom in on that center there, I think it's the most



1 interesting. There's actually black residues on this,  
2 and in this case this is carbon build-up, and so we  
3 have a sooting inside the tube, and what our  
4 maintenance personnel have reported is the fuel probing  
5 malfunction, they removed it off the aircraft, they  
6 were testing the probe, and when they applied their  
7 test voltages, there was basically a small explosion  
8 inside the fuel probe.

9 I should point out the test system did not  
10 have limited current voltage, so in this case if there  
11 was a short in that probe, they could apply higher  
12 voltages to it, and thereby ignite fuel vapors.

13 The lower left-hand quadrant there shows you  
14 the internal structure of a new probe, and the bottom  
15 one, the blackened one was the one that was taken off  
16 the probe that actually ignited the vapors, and, again,  
17 you can see how it's discolored, and it just shows you  
18 the evidence that there had been an ignition inside  
19 this probe.

20 The source of the ignition is what we'll be  
21 discussing of that previous probe, and then, again,  
22 this occurred actually in the compensator area, and if  
23 you'll look at the upper left corner, where we've  
24 dissected the probe there, the red rectangle shows you  
25 the actual short area, and the nylon piece there, that

1 little spot right there, is the actual arc site, so we  
2 actually had arcing between that red wire and that  
3 green wire.

4 Again, this is where we did find buildup of  
5 the copper sulfite residue. In this case here, we were  
6 looking at the possibility of that residue developing a  
7 conducted path, when they applied the voltage, which  
8 again, was not limited like on a normal conventional  
9 fuel system, there was an arcing that occurred in that  
10 film, and that ignited residual fuel vapors that were  
11 still left in that probe.

12 Now, if we go to the lower right quadrant,  
13 again, that shows you again the ignition between the  
14 two terminals, and there's deposits on either surface,  
15 or carbon residues, again, evidence of an ignition.

16 Now, if we move to the lower left, this is  
17 the actual arc site which was found on the piece of  
18 nylon. We've got melted material here, and transfer of  
19 metal. Typically, in our analysis, when we're making a  
20 determination, if we've had an arc occur, we look for  
21 metal transfer, and in this case, we, indeed, had metal  
22 deposited on the surface of the nylon.

23 This is an experiment we ran in the log, and  
24 I think if we just look at the lower left quadrant,  
25 again, this is a buildup of the copper sulfite residue

1 and silver sulfite residue, and they're typically  
2 combined, you'll find them both together. This was on  
3 a terminal in -- again, I just want to show that this  
4 is a different type of probe system.

5 This is actually a Fiberglas interprobe  
6 element that has been plated with silver, and where  
7 that termination occurs there is an exposed terminal,  
8 and that streak you see there is the buildup of the  
9 conductive residue.

10 In this case here, that residue was around 13  
11 kilo ohms, which is fairly low resistance. Again, most  
12 of our probes need around 30 to 40 mega ohms, so this  
13 was several orders of magnitude higher resistance we  
14 normally need in here, and what we had done in this  
15 case was we took two probes down to the surface, and if  
16 we go over now to the lower right, this is an example  
17 where we actually inject a current on that film, and I  
18 wish I had a video of this, I did not video this  
19 several years ago, we did get a settling small arc  
20 foaming on the surface here, and over time it actually  
21 ruptured this film, and that's what you see, these  
22 little molten balls on the surface there, is from the  
23 actual failure.

24 This was done in a laboratory experiment, and  
25 in this case, how much energy we were using, I can go

1 over that. This was a DC power source in this case, it  
2 was 10 milliamps and 13 volts, and in this case, first  
3 of all we have to convert that to power, so we're  
4 talking about 13 milliwatts, and then to get the  
5 energy, you have to consider the amount of time that  
6 you apply that power, so for the sake of here we'll say  
7 one second, if it's one second you're looking at 13  
8 milli-jewels of energy, and obviously that's a function  
9 of time.

10 This is just an example that these films can  
11 sustain enough current and voltage to obviously exceed  
12 the quarter milli-jewel of energy under certain  
13 conditions.

14 The last chart is just a summary of what  
15 we've discussed. Again, the copper sulfur and silver  
16 sulfur residues are semi-conductive. What we're  
17 dealing with is more of an aging problem here of film  
18 probe components and wiring. The process here is, it's  
19 a time-dependent degradation corrosion process.

20 Sulfur nor fuel reacts with the silver and  
21 the copper, and I think one question you might ask, and  
22 I'll answer that now, well, how do you solve the  
23 problem. One is if you have nickel plating, you don't  
24 seem to see this reaction, so many of our newer probe  
25 systems use nickel-plated wiring, and nickel surfaces.

1           Just to follow-up on the additional summary  
2 here, the resistance was -- really, for the air force  
3 it was an issue with resistance, it was a reliability  
4 issue, and fuel failure problem. Our maintenance  
5 people were concerned that they were getting arcing and  
6 fuel probes, and in the cases of in the tank, that was  
7 not an issue.

8           We did have the example of arc or ignition  
9 for the probe outside the tank. And, again, the point  
10 is that these residues can only sustain low current  
11 voltage levels, although the levels would be sufficient  
12 to exceed the quarter milli-jewel of energy, most  
13 likely, in the case an event did occur. That concludes  
14 my presentation.

15           MR. SWAIM: Thank you very much. I know Dr.  
16 Birky is itching with a question, so I'll let him --

17           DR. BIRKY: Well, I'd like to pursue, if I  
18 could, the probe that you had the ignition on. Do you  
19 have any idea what the maximum voltage and current  
20 could have been from that instrument used for testing?

21           MR. SLENSKI: I know Mr. Swaim had asked me  
22 that question, and that was a very old system, and  
23 quite a few years ago, and my understanding, and maybe  
24 I need to explain what I do in the air force, where  
25 I've researched that, and we do investigate fuel

1 failures, and we provide that information to our  
2 program offices and fuel personnel, and they will take  
3 that information, and usually fix the problems that  
4 we're finding.

5 I handed that information off to the  
6 maintenance personnel, and I really didn't get further  
7 involved in that. In this case when I had some  
8 discussions with them early on, the system was not  
9 limiting the voltage and current sufficiently, and we  
10 have not seen further probes like this in our lab, so  
11 I'm assuming they fixed that problem, but I don't know  
12 those actual levels.

13 That's why I did run that test in a lab, it really  
14 didn't take that much energy, so to speak, to actually  
15 cause arcing to occur on the surface.

16 DR. BIRKY: May I follow with another  
17 question, as more general, but related to the same  
18 subject as a result of yesterday's discussion on  
19 ignition and the program the industry has to look at  
20 the probes inside the tanks of the aircraft.

21 I guess my question is generally a couple of  
22 questions, one, probably directed at Mr. Hulm or Mr.  
23 Thomas, when you got data back from I think 52 aircraft  
24 of inspection, have you seen or are you looking for  
25 this type of evidence, of deterioration, or production

1 of these problems?

2 MR. HULM: Currently, the inspection bulletin  
3 does not provide specific instructions to look for  
4 these deposits of copper or silver sulfite. The next  
5 revision of the bulletin that we're preparing for  
6 release in January will add a test to basically do a  
7 low-level insulation test of the wiring in the tank to  
8 detect any sort of contamination of this sort. So it's  
9 currently not in there, and the bulletin doesn't have  
10 any specific instructions, but the revision that's  
11 coming up will.

12 DR. BIRKY: I think you reported yesterday  
13 that you didn't see anything evident of a potential  
14 ignition source. Is that a correct summary of my  
15 interpretation of your testimony yesterday?

16 MR. SLENSKI: It's based on the bonding and  
17 grounding values that we're getting back from the  
18 airlines. The data we're getting back is the  
19 quantitative data, the actual measurement data when  
20 they go in and measure the bonds and ground, so when  
21 we're looking at those specific components, there's not  
22 been any condition source identified.

23 MR. SWAIM: We're getting a little bit ahead.

24 MR. SLENSKI: I beg your pardon.

25 CHAIRMAN HALL: Dr. Birky, can I -- I'd like

1 to get into -- we've got Mr. Slenski up here right now.

2 MR. SLENSKI: Yes. Yes.

3 CHAIRMAN HALL: Mr. Slenski, I read your  
4 papers on the causes of aircraft electrical failure  
5 that you did, dated December 20, 1990, and the you had  
6 a second paper here --

7 MR. SLENSKI: Yes.

8 CHAIRMAN HALL: -- that you did with a  
9 gentleman with McDonnell-Douglas Aircraft Corporation.  
10 Who pays your salary, Mr. Slenski?

11 MR. SLENSKI: Who pays my salary? I'm a U.S.  
12 Air Force employee.

13 CHAIRMAN HALL: So the taxpayers pay your --

14 MR. SLENSKI: That's correct.

15 CHAIRMAN HALL: So you've done some work  
16 here, and you point to 652 mishaps in air force or  
17 military aircraft that were caused by electrical  
18 failures.

19 MR. SLENSKI: Let me explain maybe where that  
20 paper came from. Again, in our Web we do conduct  
21 mishap investigations for the air force. There was  
22 concern that -- when electrical failures occur in a  
23 system, and there is an accident, most of the  
24 electrical components are fairly low temperature,  
25 organic materials that can be easily destroyed in the



1 accident and ensuing fire.

2 What we attempted to do was first of all to  
3 help the accident investigators develop what types of  
4 parts they should be looking at when there is an  
5 accident that does occur, and this was an attempt of  
6 our safety office to look at the components that seemed  
7 to contribute to failures.

8 So those are numbered mishaps over a several-  
9 year period that the air force had recorded, and when  
10 we say mishaps, in the air force terms, we categorize  
11 those three ways.

12 There's a class A, which is death or serious  
13 injury, loss of the aircraft is a class B, which are  
14 injuries and a certain dollar value aircraft, a class  
15 C, which is a potential class A or B. So not all those  
16 were serious accidents, many of those cases, those were  
17 all class C mishaps, which were potential class A or B.

18 It was an attempt to look at where our  
19 concerns would be, and since you've read the paper,  
20 interconnections were one of our concerns, around 34 to  
21 36 percent of our mishaps for electrical related  
22 failures were in that area.

23 CHAIRMAN HALL: I think you said the three  
24 causes of failure were switches, connectors, and  
25 conductors, right?

1 MR. SLENSKI: That's correct.

2 CHAIRMAN HALL: Now, what was done with this  
3 information? I know you used it to be helpful to the  
4 people that are investigating accidents, but did you-  
5 all come up with any recommendations to prevent  
6 accidents? I guess my question is: Has the air force  
7 taken any action in regard to these two papers that you  
8 did?

9 The other one was a development and analysis  
10 of insulation constructions for aerospace wiring  
11 applications that you did. Was that funded with  
12 McDonnell-Douglas as well?

13 MR. SLENSKI: McDonnell-Douglas was the  
14 principal contractor, I was the program manager.

15 CHAIRMAN HALL: I guess this one pertains  
16 mainly to wiring --

17 MR. SLENSKI: That's correct.

18 CHAIRMAN HALL: -- and said basically  
19 identifies some things that should be done in the  
20 future with wiring. My question is: Did you come up  
21 with any recommendations -- has the air force taken any  
22 action in regard to any of this work you've done?

23 MR. SLENSKI: We can address first in the  
24 mishap handbook. As an example, what we published was  
25 a handbook for investigators and people who conduct the

1 investigations to use as guidance, and I think we've  
2 actually published around 350 to 400 copies of that,  
3 and distributed that actually throughout the world, to  
4 get that information out. I briefed the World Air  
5 Force on our results, other countries, and the U.S., so  
6 we've tried to get this --

7 CHAIRMAN HALL: The FAA?

8 MR. SLENSKI: I actually gave a presentation  
9 to the FAA at some of the fire safety conferences. I  
10 briefed the results of the wire and the mishap  
11 investigation. So the attempt was to --

12 CHAIRMAN HALL: Mr. Slenski, so you know  
13 where the Chairman is coming from, the Chairman is a  
14 taxpayer, pays both for the salaries of the FAA and the  
15 United States Air Force --

16 MR. SLENSKI: That's correct.

17 CHAIRMAN HALL: -- and so he's very  
18 interested if there's important information that's  
19 generated through those tax dollars, through research,  
20 that affects aviation safety, that that information get  
21 out.

22 It looks to me like that you might tell me if  
23 there are other people at Volpe, or Oklahoma City, or  
24 Atlantic City have done work in this area as well, but  
25 what I wanted to know, it seems to me you've done a

1 substantial amount of work in this area, we've got a  
2 lot to learn from you, and is there anything we can  
3 learn or understand, because we happen to be in that  
4 business ourselves of investigating accidents, but our  
5 main interest is then using that information to prevent  
6 accidents, so that's where I'm coming from.

7 MR. SLENSKI: To respond to that, as an  
8 example, we discussed wiring issues. We're running a  
9 program now to find ways to inspect wires using  
10 non-destructive techniques, and I'll discuss that in  
11 the aging aircraft panel.

12 The other issue, you mentioned the other  
13 paper or presentation was on the development of a new  
14 wire. We had issues several years ago with arc  
15 tracking of certain types of insulation, polyimid  
16 81381, it's a particular insulation used on many of our  
17 aircraft.

18 We initiated a program to eliminate that  
19 particular mechanism of arc tracking, or carbon arc  
20 tracking, and we came up with a product that does not  
21 exhibit these properties, and that's today what we're  
22 using in most of our mainline aircraft, and we convert  
23 all of our maintenance on our current aircraft to also  
24 use that insulation in most cases.

25 CHAIRMAN HALL: But in your studies you

1 didn't come up with any recommendations, the Air Force  
2 has not made changes in terms of inspection techniques,  
3 regulations, in regard to the work you did, and do you  
4 feel comfortable with unbonded metal in the center fuel  
5 tank of air force aircraft that is less than three  
6 linear inches, and is there an inspection program in  
7 that area?

8 MR. SLENSKI: That's tough to answer in that  
9 particular question. Given the philosophy of the air  
10 force typically, and I think it might be somewhat of  
11 the FAA, when someone builds a system, they're  
12 qualifying that, they go through that process, and the  
13 contractor and our program offices develop all the  
14 requirements for the aircraft, risk assessments, how  
15 we're going to maintain the aircraft, so in many cases  
16 each aircraft has its own requirements, and I think  
17 over here, to my left side, the MILSPEC, from bonding,  
18 and the air force had quite a bit of input in  
19 developing that specification several years ago.

20 So we've been involved and concerned about  
21 this, and as we're mentioning, to highlight these  
22 areas, there are aging aircraft programs dealing with  
23 some of these issues we're talking about, connectors,  
24 and wiring.

25 CHAIRMAN HALL: In the air force?

1 MR. SLENSKI: In the air force. Correct.

2 CHAIRMAN HALL: And we're going to get our  
3 nose in the aging aircraft.

4 MR. SLENSKI: That's correct.

5 CHAIRMAN HALL: Mr. Johnson.

6 MR. JOHNSON: I have a comment to maybe add  
7 some additional information. Prior to my going to work  
8 in the lab I worked in the acquisition engineering  
9 function at Wright-Patterson, and I worked in an office  
10 called the Avionic Integrity Program Office.

11 Our function was to look for methods of  
12 improving design practice, and as one example of  
13 George's impact, we used him as a key input source for  
14 developing best practice design approaches, and to  
15 evaluate contractor best practice design methodologies,  
16 so his work has a very direct impact on new design  
17 practice, through the implementation of that program  
18 and through his consultation work that I've seen him  
19 perform on programs I've been involved with throughout  
20 the air force acquisition community.

21 MR. SLENSKI: I can add that as an example,  
22 what I did with the handbook is we went to our safety  
23 center down in Albuquerque and brief all the  
24 investigators of our findings. We've gone to our  
25 depots, maintained aircraft to get those results out to

1           them for their information.  So we tried to disseminate  
2           the information.  Again, we're a research lab, we're  
3           not --

4                   CHAIRMAN HALL:  Are you aware of any research  
5           underway at the FAA in this area?

6                   MR. SLENSKI:  As far as reference to which --

7                   CHAIRMAN HALL:  Where are you working?  Who  
8           would you interface with, with the Federal Aviation  
9           Administration?  Are they doing any work in that area  
10          as far as developing techniques to understand the  
11          failure mechanisms?

12                   MR. SLENSKI:  Yes.  I have worked in the past  
13          with some of the personnel in Atlantic City in the fire  
14          protection area, and I have had discussions with FAA --

15                   CHAIRMAN HALL:  Maybe Chris or Michael can  
16          tell us, because I know we've got a big fire safety  
17          center up at Atlantic City, I've had the pleasure of  
18          visiting up there, and it's an impressive facility.

19                   MR. HARTONAS:  Yes, Mr. Chairman.  Is your  
20          question specific on the findings of copper sulfur?

21                   CHAIRMAN HALL:  Yes.  Now, are you familiar  
22          with the work that Mr. Slenski has done, and is there  
23          anything that the FAA is doing in this particular area?

24                   MR. HARTONAS:  We have recently become  
25          familiar with the findings with copper sulfur in

1 probes. We have issued a proposed rule that will  
2 provide for protection from copper sulfur. We're  
3 considering additional action in the future that will  
4 have to do perhaps with replacement of probes once we  
5 have concluded that it's necessary.

6 MR. SLENSKI: You used the word you have  
7 recently become familiar with that. During the course  
8 of this accident investigation?

9 MR. HARTONAS: During the course of this  
10 investigation.

11 MR. SLENSKI: Thank you.

12 CHAIRMAN HALL: You haven't made any  
13 recommendations, Mr. Slenski, have you, on how often  
14 these probes should be replaced, or be inspected, or  
15 how long a wire should last, or be inspected?

16 MR. SLENSKI: Oh, that's an interesting  
17 question. I have had discussions on various program  
18 offices, and we discussed that, since obviously the air  
19 force has fairly old aircraft in some areas, and we  
20 have discussed that area. So I have provided some  
21 guidance, technical guidance, I should say, again, in  
22 our area we work in.

23 CHAIRMAN HALL: Can you share that with us,  
24 or would that get you in trouble?

25 MR. SLENSKI: Well, again, that's one of the



1 problems I've run into. Some of this is -- I've given  
2 the information to the organizations. I sometimes  
3 don't know if they've followed-up or implemented those  
4 recommendations. We'd have to get back with you on  
5 that to see a specific inspection.

6 Again, our program offices are aware of these  
7 issues, they've taken some actions, I can't say  
8 actually what those are.

9 CHAIRMAN HALL: I understand. Anything else  
10 that you ought to contribute, Mr. Slenski, that you  
11 think is important, because you seem to be the  
12 individual, if you looked at -- you-all looked at 652  
13 different air force incidents, am I correct --

14 MR. SLENSKI: That's correct.

15 CHAIRMAN HALL: -- in some detail. Is there  
16 anything, other than the presentation you had here that  
17 you think would be useful for us?

18 MR. SLENSKI: Well, I think some of the  
19 issues will probably be discussed in the aging aircraft  
20 panel. I have a presentation there on failure  
21 mechanisms of wiring, which I'll be getting into.

22 CHAIRMAN HALL: Mr. Swaim, I have a note  
23 here, and I don't know whether it came from you or from  
24 someone else, it says "Recommendation is to break for  
25 lunch, because the next panelists will be long."

1 MR. SWAIM: Well, I didn't send it.

2 CHAIRMAN HALL: I don't mean to offend the  
3 next panelists, and I don't know who gave me the note.

4 MR. SWAIM: No, no. I --

5 CHAIRMAN HALL: I just had somebody call me  
6 on the telephone up here that was an electrical  
7 engineer in Texas that had an idea on another ignition  
8 source, so I don't know how these things are working,  
9 but do we want to break or do you want to continue?

10 MR. SWAIM: Well, the way we've set this up  
11 is talking about static, and move that up, because of  
12 your question of yesterday, and then have Mr. Slenski  
13 discuss the previous air force experience to introduce  
14 us to probes, and what's been found, and go on to Mr.  
15 Johnson talking about the findings of the probes from  
16 the accident airplane, and another airplane, the  
17 derelict that we've got probes out of.

18 CHAIRMAN HALL: Well, why don't we then --  
19 what I want to do is set a ground rule here. Why don't  
20 we go to Mr. Johnson, and then would that be a time to  
21 break for lunch? Should that be at 12:30, or should  
22 that be at 1:00 o'clock?

23 MR. SWAIM: I've got a feeling it's probably  
24 going to be closer to 1:00.

25 CHAIRMAN HALL: Well, let's just say that we

1 will -- if some people need to move in and out, excuse  
2 themselves, we understand, but we will continue then to  
3 1:00 o'clock, and break again, as we did for lunch,  
4 between 1:00 and 2:00, so that people can make some  
5 plans for lunch, and know what the schedule is. So  
6 we'll now continue until 1:00 o'clock, with Mr.  
7 Johnson.

8 MR. SWAIM: And we'll come back to wiring  
9 again later, I have no doubt. Mr. Johnson.

10 MR. JOHNSON: Good morning, Mr. Chairman, my  
11 name is David Johnson, and my purpose here today is to  
12 provide some factual data relative to evaluation of  
13 fuel probes and fuel compensators that were provided to  
14 us by the NTSB for evaluation for anomalies that might  
15 contribute to an ignition.

16 The two sets of probes came from -- one set  
17 came from November-93105, that was the derelict  
18 aircraft Mr. Swam just alluded to. We had several  
19 probes, I believe we had -- well, now I'm drawing a  
20 mental blank -- we had a total of 11 specimens from  
21 that aircraft, the combination of probes and  
22 compensators.

23 I believe the breakout was five probes, and -  
24 no, I'm sorry, six probes and five compensators, and  
25 the other set of material we evaluated was from

1 November-93119, which was the TWA Flight 800 mishap  
2 aircraft.

3 We evaluated the fragments and wreckage that  
4 were left from the -- or recovered parts from that  
5 mishap.

6 I thought I'd start with just a short listing  
7 of the analytic techniques that we used in doing this  
8 analysis. We used optical microscopy, scanning  
9 electron microscopy to evaluate physical anomalies. We  
10 used energy dispersive spectroscopy to evaluate surface  
11 chemistry, and we also used microscope equipped Fourier  
12 transform infrared spectrometer for the same purpose,  
13 to evaluate the elemental content of surface materials.

14 We also used those two bottom techniques to  
15 verify the structural elements, the materials that were  
16 used, we got a report of what the materials should have  
17 been, and we verified that that, in fact, is what they  
18 were, and we did determine that all materials involved  
19 with the construction of the probes, wiring,  
20 insulation, all materials matched what was purported  
21 they should be.

22 I'm going to start with some images from the  
23 derelict aircraft equipment, N93105, if you could pull  
24 up on the upper left-hand image there. This is an  
25 example of --

1                   CHAIRMAN HALL:  What is a derelict airplane,  
2                   so we'll know?

3                   MR. SWAIM:  It was an airplane that was in  
4                   the junkyard, sir.  Well, that one hadn't gotten to the  
5                   junkyard, but it was an airplane that had been taken  
6                   out of service for economic reasons, and --

7                   CHAIRMAN HALL:  It doesn't have a bad  
8                   reputation, or anything, it just --

9                   MR. SWAIM:  No, no.  The point is, as Mr.  
10                  Slenski mentioned, it's easy to break the film for the  
11                  copper sulfite, so we cut the wiring, the fuel tank  
12                  wiring out with the probe.

13                  DR. LOEB:  The airplane was a retired  
14                  airplane, is that maybe a good way to refer to it?

15                  MR. SWAIM:  That's appropriate.

16                  DR. LOEB:  If we could be very clear, again,  
17                  from which airplanes these various probes, and blocks,  
18                  and so forth that were looked at.

19                  CHAIRMAN HALL:  If this is a retired  
20                  airplane, obviously, it was not under anybody's  
21                  responsibility at the time, sitting out in the desert  
22                  somewhere, or something.

23                  MR. SWAIM:  This one was in Kansas City, and  
24                  it had been parked almost two years before we took  
25                  these probes out.

1                   CHAIRMAN HALL: Let's just be sure we're  
2 careful o that. Okay.

3                   MR. JOHNSON: Yes. The -- I have to regain  
4 my point --

5                   CHAIRMAN HALL: I'm sorry, Mr. Johnson, but  
6 when you said derelict airplane, that just got the  
7 Chairman's attention.

8                   MR. JOHNSON: It was reported to us that the  
9 plane was being sent to be broken up for scrap, and  
10 they recovered the probes, and some probes and  
11 compensators from it prior to that happening. The  
12 picture that we're focused on is a typical combination  
13 of wiring and the terminal block assembly.

14                   We started by doing an overall inspection,  
15 using an optical microscopy X-ray of the probes to  
16 determine the general condition and to verify that  
17 there were no sources for a short circuit in the  
18 overall construction of the entire capacitor assembly.

19                   We found nothing remarkable in that analysis,  
20 so we very quickly then focused on the terminal block  
21 and wiring that was attached, and so this report, in  
22 the interest of brevity, contains only our analysis of  
23 the terminal block and wiring.

24                   The points of interest in this image are the  
25 strain relief plant that is in the image there, to

1       restrain the ship's wiring. The wiring, I think it's  
2       of interest to mention, is ship's wiring, and the probe  
3       is brought into, and I guess attached to the wiring  
4       inside the tank.

5               So the strain relief plant and the way the  
6       wires are dressed is a function of an operation done  
7       inside the tank, as it's reported to us, and we found  
8       quite a bit of variation in the lay up, or the way the  
9       wires were dressed and clamped down under the strain  
10      relief plant.

11             Other details of interest, you can see  
12      labeled there the high and the low "Z" wires, those are  
13      nomenclature that come from the electrical system  
14      designers, I suppose, that we used to identify the  
15      signal wires that are passed from fuel probe to fuel  
16      probe, and then eventually exit the tank and progress  
17      to the other part of the quantity indication system.

18             The white wires that you see on the right-  
19      hand side there pass under the clamp, and you can see  
20      toward the left side, upper edge of the image, two  
21      areas where there's been heat shrink, too, applied.

22             In that area the Hi-Z wiring are shielded  
23      wires, and what that means is that there's a poor  
24      conductor with a layer of Teflon insulation, and around  
25      that insulation is a fine weave of silver-plated copper

1 braid, and that silver-plated copper braid, well,  
2 actually, that's, I think, Fiberglas, but that's a good  
3 sort of similar kind of construction there.

4 The shielding is then also covered with a  
5 layer of Teflon, and in this area where we see this  
6 heat shrink, the outer Teflon insulation has been  
7 stripped back to expose the shielding, and to that  
8 shielding then is attached those black wires that you  
9 see there, which I refer to as the Hi-Z pigtail leads.

10 Those leads are soldered or attached to the  
11 braid by means of a soldered joint, which is then  
12 insulated and protected by means of the heat shrink,  
13 and at either end of the heat shrink there's some  
14 material to seal the joint.

15 DR. LOEB: Mr. Johnson, would you please  
16 explain Hi-Z and Lo-Z for the audience?

17 MR. JOHNSON: Well, we -- I guess I'd have to  
18 defer to a Boeing or Honeywell rep on that. We looked  
19 specifically at the physical properties and didn't get  
20 a whole lot into the electrical --

21 CHAIRMAN HALL: Mr. Hulm, can you do that?  
22 Is there anybody on the panel that can explain --

23 MR. HULM: Yes. I can address that.

24 CHAIRMAN HALL: Okay. Thanks.

25 MR. HULM: The Hi-Z and Lo-Z refers to low



1 impedance, high impedance, as related to the way the  
2 indicator works, whether it's a low impedance circuit  
3 inside or a high impedance, it's got a lot of  
4 resistance, or low resistance.

5 The Lo-Z lines are the lines where the signal  
6 comes out to the probe itself, and the Hi-Z line is the  
7 pickup side, to pick up the signal on the other side  
8 and turn that back to the indicator.

9 MR. SWAIM: In real simple terms, Mr.  
10 Chairman, what we found is that red wire, the Lo-Z wire  
11 is attached to the outer tube, and the Hi-Z is attached  
12 to the inner tube.

13 MR. JOHNSON: I guess if we move over to the  
14 other top image there, that's a little better image of  
15 the heat shrink that we've been referencing. You'll  
16 note that there's a length of insulated core conductor,  
17 center conductor of the coaxial wire here, which  
18 extends from the area where the braid joint is, to a  
19 crimp-on ring connector, which is used to attach, make  
20 the electrical and mechanical interconnect to the  
21 terminal block for the Hi-Z wires.

22 Mr. Slenski was mentioning copper sulfite  
23 deposits, copper and silver sulfite deposits. You'll  
24 note in this image just adjacent to the red insulator  
25 on the crimp-on connector, between the crimp-on

1 connector and the heat shrink, there's a rather dark  
2 stain that is present on the Teflon insulation. That  
3 was determined to be copper, and -- well, let me back  
4 up.

5 MR. SLENSKI: That's right near the green  
6 thing, or --

7 MR. JOHNSON: Right there at the --

8 MR. SLENSKI: Okay.

9 MR. JOHNSON: Between the tip of the pen and  
10 where that red insulation is on the left, right along  
11 through there.

12 CHAIRMAN HALL: That's the same construction  
13 I mentioned before we had the low resistance, it's a  
14 pigtail in there, so you've got ground, and in the  
15 terminal, that red terminal, is your active lead, and  
16 that's where we had the buildup of that low resistance.  
17 That's the same area, and he did say he did find the  
18 presence of copper sulfite there, like we found.

19 MR. JOHNSON: Yes. Okay.

20 CHAIRMAN HALL: Now, that's copper sulfite?

21 MR. JOHNSON: Yes. Yes, sir.

22 MR. SWAIM: That material is similar to what  
23 Mr. Slenski was showing us on the air force probes.

24 MR. JOHNSON: Okay. On the right-hand side  
25 of that image you'll notice a -- well, first of all,

1 the steel clamp has been rotated almost 180 degrees out  
2 of its normal position, to allow the movement of the  
3 wires from beneath it to show -- I wanted to show you  
4 the surface, the opposing surface right beneath the  
5 steel clamp. That surface is neuraled, or serrated,  
6 and the shape of those protrusions is a very sharply  
7 pointed combs, that's a field of very sharply pointed  
8 conical structures.

9 If we can move to the lower left-hand image.  
10 This is a newer design, apparently. It was reported to  
11 us that this was a post-series three, and I suppose a  
12 series four construction. We found examples of this  
13 construction in both the two sets of hardware that we  
14 evaluated.

15 The wiring is now much more heavily guarded  
16 with heat shrink, and I think that's a Fiberglas braid  
17 material that you see exiting off the edge of the image  
18 on the left-hand side. The clamp is a nylon P-clamp  
19 design that the wire passes through, and the surface  
20 beneath, that you can see in the other bottom image  
21 there, we moved that same structure -- we moved the  
22 P-clamp to allow viewing the surface of the terminal  
23 block directly below, and that shows that the neuraling  
24 of the conical structures have been removed from the  
25 terminal block. Those were the primary design changes

1 that we observed in our inspection.

2 This page contains some images of -- and this  
3 is strictly a sampling, this is by no means all-  
4 inclusive, I just wanted to portray a sample of what we  
5 found in our inspections here. The image -- well,  
6 first, a general comment is the note indicates these  
7 were damaged sites that we found that were apparently  
8 caused by contact of the PTFE, or Teflon insulation,  
9 with an adjacent surface, a form of compression damage.

10 If we could look at the upper left-hand image  
11 a little more closely, that image shows two things of  
12 interest. One is, at the top of the picture, that's  
13 the edge of the terminal block, the terminal block is  
14 upside-down here, if you will, relative to the picture,  
15 and the conical shapes that I was referencing in the  
16 previous picture can be seen looking like teeth, I  
17 guess, in profile, along the edge of -- that's the side  
18 of the terminal block, we're looking at -- this was not  
19 cut or anything, and so the outermost row of cones is  
20 present there, and we found directly adjacent to that  
21 some damage to a Hi-Z outer insulation layer.

22 I might also point out there that the black  
23 residue present, we determined that that also had high  
24 concentrations of silver, and copper, and sulfur,  
25 indicating to us that the fuel had reached the braid,

1 the shielding braid of that Hi-Z wire, and we had  
2 gotten the flow of these deposits out onto the surface.

3 MR. SWAIM: And that's the time phenomena, it  
4 takes time to do that.

5 MR. JOHNSON: Yes, that's correct. By the  
6 way, all these images we're looking at here are from  
7 aircraft November-93105, which is the non-mishap  
8 aircraft.

9 MR. SWAIM: Thank you.

10 MR. JOHNSON: Moving on to the right-hand top  
11 image, this point was found without touching or moving  
12 the wires. Well, first of all, the black wire that you  
13 see looped over that has all the blue arrows pointed at  
14 it was in tight contact, intimate contact with the  
15 white Hi-Z lead that is passing through the middle of  
16 the picture, and I noted that there was a slight bulged  
17 appearance as I rotated this terminal block assembly  
18 under the microscope, and so I moved the black wire  
19 aside to get a better look at what might be underlying  
20 that bulge, and found this damage, and I photographed  
21 it in-situ here, to make it clear there's been no  
22 disassembly, just a slight movement of that black  
23 wire.

24 I think you may also be able to see a  
25 difference in skin tone, if you will, along that wire.

1 Close to the damage that you can see there, the surface  
2 looks dull or grayish in color, whereas when you move  
3 further away it's more shiny. That, again, is a  
4 concentration, a film deposit consisting of copper,  
5 sulfur, and silver material.

6 If we go down to the image directly below  
7 that, the lower right-hand image, this is what I found  
8 when I disassembled the wiring from the terminal  
9 blocks, where I could gain access to that surface being  
10 shown, or pointed to in the image we just looked at.  
11 When I did that, I could clearly visualize the core  
12 conductor exposed through the Teflon, or PTFE  
13 insulation.

14 If we could move to the lower left image,  
15 this is another very similar in appearance, but  
16 different wire, different assembly, different probe.  
17 This wire happened to be in contact with the smooth  
18 surface of the terminal block, and I found that the  
19 core conductor had been exposed at that point.

20 MR. SWAIM: This was not at that saw tooth.

21 MR. JOHNSON: No. The only damage that I  
22 have images here to present that was caused by the  
23 neural surface on the terminal block is the one in the  
24 upper left-hand quadrant there. The other three  
25 images, the other two sites represented by those three

1 images were caused by, I guess, compression with  
2 adjacent surfaces, and in both cases, those turned out  
3 to be smooth surfaces.

4 MR. SWAIM: Dave, I don't want to get you too  
5 far off track here, you're doing a great job, but I  
6 wanted to ask you, this is a series three probe, a  
7 series three terminal block shown in the upper left  
8 corner with the serrations, did you find any damage to  
9 wiring on the series four probes that did not have  
10 that?

11 MR. JOHNSON: We found just one site that was  
12 contained within the clamp itself, where when the clamp  
13 was tightened down, it -- well, let me back up a page  
14 here. Yes, if we could back up to the previous page  
15 and look at the lower right-hand image, you can see --  
16 it was on this particular assembly, as a matter of  
17 fact, you can see there's a pinched area there in the  
18 heat shrink, and when I removed that heat shrink and  
19 looked at the Hi-Z pigtail lead that was directly  
20 beneath that pinch mark, there was a indentation in the  
21 Hi-Z pigtail wire at that point, and when I was looking  
22 at that under high magnification, I was able to  
23 visualize the poor conductor through the insulation,  
24 the insulation had thinned to the point where it was  
25 possible to actually -- the insulation was still

1 intact, however, it was apparently thinned enough to  
2 allow light to pass and reflect back for me to be able  
3 to observe the core wire, or core conductor.

4 DR. LOEB: You indicated you found that on  
5 only one of the series four probes. How many did you  
6 look at, series four?

7 MR. JOHNSON: In preparation, it's been a  
8 long time since we did these inspections. I'd have to  
9 get back to you with that answer. Bob, do you have any  
10 idea how many series four that we looked at?

11 MR. SWAIM: That we looked at? No, I don't.  
12 I know that I looked at the record of what we got from  
13 the 800 airplane this morning, and talked to Dave last  
14 night, he had six of the terminal blocks of the series  
15 three style, and he had identified most of the fuel  
16 probes that we recovered from that accident airplane.  
17 It had the wiring stripped off, the terminal blocks  
18 were missing, we did have a combination in the  
19 airplane, though.

20 DR. LOEB: Well, what I'm referring to is  
21 105, the retired airplane, or others. I mean have we  
22 looked at that many of the series four blocks?

23 MR. SWAIM: At this point, I'd say no.

24 DR. LOEB: Okay. Thank you.

25 MR. JOHNSON: I would estimate that I looked



1 at least four of this style in my 105 evaluation.

2 DR. LOEB: Okay. Thank you.

3 MR. JOHNSON: This is another example of some  
4 degradation we found, too, in this case, a Lo-Z wire.  
5 What you see in the image on the upper left is a black  
6 stain that we -- this one was large enough you could  
7 see, and because of the contrast with the red wire, the  
8 background you could very plainly see with the naked  
9 eye, the presence of this black residue, and, again, it  
10 was found to contain high concentrations of silver  
11 sulphur and copper.

12 I think it's also interesting to note that  
13 you can see some striations, some lines in the  
14 blackened area there, which, when you look at this  
15 under the microscope, well, we can't do it any longer  
16 since it's now been encapsulated for cross-sectioning,  
17 but at that point, using a stereo microscope, you could  
18 see a definite pattern of the wire strands embossed up  
19 through the surface of the insulation.

20 That was of great interest when we had a  
21 group of -- Mr. Swaim and a group of interested  
22 individuals came to our laboratory. They requested  
23 that we do cross-sectional inspections, which we did,  
24 and you can see in the lower left-hand corner the  
25 result of that. In the area about the middle of the

1 image above is where this cross-section was taken, and  
2 --

3 DR. LOEB: Let me interrupt just for -- what  
4 airplane was this from?

5 MR. JOHNSON: This is still of the --

6 DR. LOEB: This is still 105, the --

7 MR. JOHNSON: Yes.

8 DR. LOEB: -- retired airplane. Okay. If we  
9 could just continue to periodically make that clear.

10 MR. JOHNSON: Yes, sir.

11 DR. LOEB: Thanks.

12 MR. JOHNSON: This was what we observed.

13 Each of the wire strands there, for reference, is about  
14 eight-thousandths of an inch in diameter, 32-gauge  
15 strands, and you can see that the insulation has been  
16 thin there at the top portion, plus it's been thinned  
17 to less than eight-thousandths of an inch, and you can  
18 also see the significant deformation that's taken place  
19 and sort of creating an egg shape in the overall  
20 appearance of the cross-section.

21 Looking at the image on the lower right-hand  
22 side, you can see a more highly magnified image. The  
23 area that's magnified is roughly where the orange arrow  
24 pointing down from above is pointing, over to the image  
25 we just looked at.

1                   MR. SWAIM: Is that the outside or the inside  
2 where the orange arrow comes down to?

3                   MR. JOHNSON: It's coming down from the  
4 spectrum from above. I'm sorry.

5                   MR. SWAIM: Very good. Thank you.

6                   MR. JOHNSON: Okay. The two arrows that come  
7 down from above are pointing to physically the same  
8 place, at different magnifications.

9                   We used a metallograph, another form of  
10 optical microscope, to take a 500X image of that area,  
11 and what we found was, in cross-section, we could see  
12 the deposit on the surface of that PTFE insulation, and  
13 we did an EDS inspection similar to what Mr. Slenski  
14 was describing to determine the elemental composition  
15 of that film, and we found that it was -- we found a  
16 very high concentration of silver in this particular  
17 area, and, in fact, we can see that fairly clearly in  
18 this image.

19                   If we move up to the spectrum above, you can  
20 see peaks present on this for silver. Unfortunately,  
21 this image was not very well focused when I included it  
22 in the presentation. Right above the number three on  
23 the "X" axis there's a peak, which is silver.

24                   The one just to the left of it, the tall  
25 peak, is sulfur, and then the peak, the shorter peak

1 just above the number one on the "X" axis is a copper  
2 peak, there's another one out at about the number eight  
3 on the "X" axis there.

4 So, again, we found concentrations of silver,  
5 sulfur, and copper in that film. The point that was  
6 looked at was on that film, approximately where that  
7 orange arrow is pointing, from the spectrum, down to  
8 the image on the bottom right.

9 That's, I guess, all the material I brought  
10 along to present, relative to the non-mishap, the  
11 derelict equipment.

12 CHAIRMAN HALL: I think that it's very  
13 important that we state that all the slides and  
14 material you've been over are not from the TWA-800  
15 accident aircraft, is that correct, Mr. Swaim?

16 MR. SWAIM: Everything that he has shown us  
17 so far is from another 747 that was parked almost two  
18 years before, it's not the accident --

19 CHAIRMAN HALL: Can you tell us a little more  
20 about that airplane? Do you have any more information  
21 on that airplane, or could we get that for the record?  
22 I'd like to know who --

23 MR. SWAIM: I believe we have it in the  
24 exhibits already.

25 CHAIRMAN HALL: Okay. Fine. I just want to

1 be sure that it's clear that this is not from the  
2 accident aircraft.

3 MR. SWAIM: It is, and we made sure that all  
4 of the slides were titled with the N93105 at the top.  
5 I'll take action, if it's not in the record, to get it  
6 into there.

7 CHAIRMAN HALL: Thank you.

8 MR. JOHNSON: In addition to the inspections  
9 that we did that I've shown, we also performed some  
10 electrical measurements on the probes, which I left the  
11 wire attached to the terminal block when I made the  
12 measurements using a high resistance ohm meter, and we  
13 checked, starting at very low levels, and all 11  
14 specimens went up to 200 volts.

15 The reason I chose 200 volts was, if a 120-  
16 volt ship's power had impressed on one of these probes,  
17 the ACC signal has peaks that reach approximately 200  
18 volts, not quite, but almost, so I wanted to  
19 characterize to see if any of these showed any sort of  
20 short circuit, or a low resistance at that sort of a  
21 level, and it turned out that all of these were in very  
22 good shape. I'm presuming they were all functioning  
23 when the aircraft was removed from services, they were  
24 supposed to.

25 MR. SWAIM: Was this a high amperage, what

1 type of amperage were you running at this point, a very  
2 low amperage?

3 MR. JOHNSON: Very, very low. I think the  
4 current limit, because of the danger involved when you  
5 run up to this particular instrument, will go to a  
6 thousand volts, and I did characterize some of them at  
7 that level, and, again, found no problems, but the  
8 current is a pretty stiff current, and a micro amp  
9 level of current clamp, I believe, on that instrument,  
10 so the current levels were very low.

11 The next series of images are from the mishap  
12 aircraft, and the next three slides will all contain  
13 images that are exclusively from that airplane.

14 I wanted to present some top-level images  
15 that would give you some feel for what it was that we  
16 were working with when we evaluated the materials that  
17 came from the mishap aircraft. We received some  
18 material that, as you can see in the upper left-hand  
19 images, there were a few examples of thermal damage  
20 that we found on just a very few number of pieces of  
21 the wreckage.

22 It turns out that when we did elemental  
23 analysis of the material that's shown as a dark stain  
24 on the upper left-hand image, most very closely matched  
25 that for polyurethane, and the folks that did the

1 analysis for us felt very strongly that that was  
2 thermally damaged polyurethane coating.

3 It turns out that the coating material used,  
4 this is a center tube out of fuel probe, and the  
5 finished material on that nickel tube is polyurethane,  
6 so it closely follows, that's what we'd expect to find.

7 On the image in the lower left-hand quadrant  
8 there, there was a dark stain that we evaluated, and  
9 that stain very closely matched what one would expect  
10 with respect to references for burnt fuel. So we found  
11 some minor thermal damage that might be attributed to  
12 actual combustion of materials, as a result of the  
13 mishap.

14 The images on the right-hand side are just  
15 some examples of some of the overall initial condition  
16 shots that we took when we first received the  
17 equipment.

18 MR. SWAIM: Dave, excuse me.

19 MR. JOHNSON: Yes.

20 MR. SWAIM: Going back to the left side of  
21 the page there, I believe that specimen 59 that he has  
22 been just showing us, fragment 59, is from the center  
23 tank. It might have been from the burnt tank in the  
24 right wing, but I'm pretty sure it was from the center  
25 tank.

1           We found, like I said earlier, few fragments  
2           from the center tank, I think that's one.

3           MR. JOHNSON: Okay. I have to rely on the  
4           cataloging that was done by others, so I'll --

5           MR. SWAIM: I'm sure that's correct.

6           MR. JOHNSON: Moving on to the next page,  
7           these are a combination -- I wanted to show an example  
8           of Lo-Z, Hi-Z, and Hi-Z pigtail wire damage that we  
9           found. So if we look at the top left-most image, that  
10          is a picture of Hi-Z sense wire that has a split, it's  
11          been opened up in it. That is most likely mishap-  
12          induced damage.

13          The braid that I was referencing earlier, the  
14          silver-plated copper braid material is clearly visible  
15          through that slit.

16          The next middle image on the top row there is  
17          an example of the kind of very typical damage that we  
18          found to the Lo-Z wire. This wire is, again, a  
19          20-gauge copper, the core conductor is copper, and it  
20          had silver plating.

21          The insulation is Teflon, PTFE-type material,  
22          and there are broken strands of the wire visible there,  
23          and the wire looks -- gave the appearance of having  
24          been pulled probably back through a clamp, it was  
25          heavily skinned, and the damage was of the nature that



1 would imply the insulation was skinned off due to a  
2 more tensile load having been applied.

3 DR. LOEB: So you would assume that that was  
4 part of the breakup damage as well.

5 MR. JOHNSON: Yes, sir. The next image is a  
6 split we found in a Hi-Z pigtail lead. The two images,  
7 the two right-most images are the same area on the same  
8 wire. The top image is an optical image, the bottom is  
9 one that was done using scanning electron microscopy.

10 We looked at a few of the damage sites that  
11 appeared to have something in common with the damage we  
12 saw on the non-mishap wires, wire that appeared to have  
13 some compression damage that was different from what  
14 we're seeing, that looked very obviously to the eye to  
15 be mishap-induced, and when we look at this particular  
16 site, again, there were -- I excerpted this.

17 In the report there were three separate  
18 spectra that are listed. I lifted one for purposes of  
19 explanation.

20 Where the red number two is, in the lower  
21 portion of the right lower image, is the approximate  
22 spot where the spectrum was taken that's at the lower  
23 left-hand side of the view. Once again, we found high  
24 concentrations of silver and copper, and this case a  
25 slightly smaller amount than usual of sulfur, based on

1 the number of counts that we used here.

2 So based on the presence of that film, we  
3 would presume that there was some damage at this site,  
4 a violation of the wire insulation prior to the mishap.

5 MR. LOEB: And, again, that is from the  
6 accident airplane.

7 MR. JOHNSON: Yes, that's correct, that one  
8 is. The last of my image slides here contains, on the  
9 left side is an optical photograph of just an example  
10 of Hi-Z wiring. What you see is the piece of  
11 insulation that resides between the stripped wiring,  
12 where the ring clamp that we looked at, some of the  
13 earlier images, is crimped on.

14 In this case, the wire was apparently snapped  
15 loose during the mishap from that ring connector.

16 On the left side, the blue area just above  
17 the ruler is heat shrink material, and there are some  
18 remnants of the elastomeric sealant that was used. The  
19 white material that appears to be embossed with a braid  
20 pattern is, in fact, the Teflon, or PTFE insulation,  
21 around the core conductor.

22 I wanted to show this image, because it has  
23 two points of interest. One is the heavy embossing  
24 that the pressure from the braid material left behind  
25 on the wiring, and the second is the residue, again,

1 silver, copper, and sulfur-rich residue that we found  
2 there.

3 Now, the concentration here, and, in fact,  
4 all of this Hi-Z wire construction that we found in the  
5 mishap materials showed a very low, relative to the  
6 non-mishap aircraft, the November-93105 aircraft. This  
7 contained much less of the residue.

8 I think that could be most likely  
9 attributable to the fact that this is Teflon, it's  
10 material that is difficult from others to adhere to.  
11 The material was submerged in ocean water, and there  
12 was some washing action, I'm sure, while it was  
13 submerged, and during recovery, that would have removed  
14 this thin film, but nevertheless, we did find evidence,  
15 and the lower right-hand portion of the page is a  
16 series of elemental maps that show the disposition of  
17 several elements.

18 The upper right one is the presence of  
19 sulfur, the one in the middle, on top, is chlorine, the  
20 one on the top right is copper distribution, going  
21 across the bottom there's silver, and some zinc, and  
22 then the lower right-hand-most image is the scanning  
23 electron microscope normal image of what was being  
24 mapped in the other frames.

25 DR. LOEB: Could you make it very clear where

1       you found the copper, and silver, and sulfur deposits?  
2       Specifically, where was it on this wire insulation, on  
3       the silver braiding, or --

4               MR. JOHNSON:  The residues were deposited on  
5       the insulation, between the strip wiring end and the  
6       shield solder joint region I was alluding to a little  
7       bit earlier in the presentation.

8               DR. LOEB:  Right.  Thanks.

9               MR. SWEEDLER:  Did you do a reference  
10       spectrum away from a damaged area to see if there was  
11       any contamination?

12              MR. JOHNSON:  Yes.  Yes, we did.  In our  
13       report there is an example of a wire that showed  
14       similar damage to the one that had the little red  
15       number two on the previous slide, and that ship, we  
16       found examples where we had the same sort of a split  
17       type of damage, but without the presence of the  
18       residue, so we did some reference.

19              We found lots of locations where we just saw  
20       background materials, or in the case of the mishap  
21       equipment we saw residues that would be consistent with  
22       having been immersed in seawater.

23              DR. BIRKY:  Does that mean you did not find  
24       the copper, silver, and sulfur away from any damage  
25       area, is that correct?

1           MR. JOHNSON: Yes. In summary, we did find  
2 the mechanical damage to wiring immediately attached to  
3 the terminal blocks of fuel probes and fuel  
4 compensators. We, however, found no evidence of  
5 electrical short or arcing in any of these locations,  
6 and we did also find semi-conductive residues, the  
7 silver, copper, sulfur residues that Mr. Slenski spoke  
8 of in his studies, and we found evidence in our work on  
9 both the mishap and non-mishap probes. That's the end  
10 of my presentation.

11           MR. SWAIM: Thank you very much. That was  
12 quite a presentation, it took a good a while, I know,  
13 Mr. Johnson.

14           Did you find that the shrink wrap you were  
15 just talking about in the second-to-last shot prevented  
16 copper sulfite accumulations from bridging, or was it  
17 able to pass under the shrink wrap?

18           MR. JOHNSON: I can't really address that.  
19 We didn't look specifically for bridging beneath the  
20 end of the heat shrink. What we have seen in the past  
21 is cases of poor adhesion, where that sort of sealing  
22 was done around a joint like this, and where the  
23 deposit did progress beneath the seal, and provide a  
24 low current path.

25           Mr. Slenski's work has demonstrated that. We

1 didn't have time to really get into that sort of detail  
2 on this particular study, that's, I guess, work we  
3 still have to do.

4 MR. SWAIM: Mr. Slenski, I pass the same  
5 question to you.

6 MR. SLENSKI: Well, what I'll comment on is,  
7 when I have shown examples of that problem on that one  
8 connection where we had residues between the crimped  
9 joint and the termination, the recommendation we made  
10 is to use shrink wrap around there and protect the  
11 exposed conductor, which they had done, and that solved  
12 the problem.

13 MR. SWAIM: It did solve it.

14 MR. SLENSKI: But let me point out, we had to  
15 go to great lengths to develop a process to completely  
16 seal around the crimp joint and the splice area, and  
17 they had to actually work on that for some time.

18 MR. SWAIM: Simply putting shrink wrap on --

19 MR. SLENSKI: It sometimes doesn't do it.  
20 You have to control your processes extremely carefully,  
21 and understand what you're trying to protect against,  
22 but it is possible.

23 DR. LOEB: Mr. Johnson and Mr. Swaim, I think  
24 we need to pursue that, though, and have those tests  
25 done to see if we do see it beneath the shrink wrap.

1           MR. JOHNSON: One additional point of  
2 interest relative to these joints, there were a couple  
3 of compensators out of the non-mishap aircraft that we  
4 reviewed that had a different kind of interconnect  
5 between the shielding and the pigtail. We found a  
6 couple of examples where the interconnect was made by  
7 means of a barrel crimp-on connector.

8           There was no solder that I could see involved  
9 in the joint, and in those cases where we saw that  
10 there was no heat shrink around those particular type  
11 of connectors, so there was a path there definitely  
12 between that construction that could be established  
13 between the ring connector at one end of the path and  
14 ground, with the braid on the other side.

15           MR. SWAIM: Okay. If the copper sulfite, or  
16 we're calling it copper sulfite, the copper and silver  
17 with the sulfur combination, is a product of time, do  
18 you have any idea of how much time it takes to start  
19 really building this material?

20           MR. JOHNSON: No. I couldn't answer that.  
21 Maybe Mr. Slenski could, based on his experience.

22           MR. SLENSKI: What I can recall is we have  
23 found the residue form in as short a period as ten  
24 years, and it possibly could be shorter, so it will be  
25 a function of the amount of sulfur in your fuel, the

1 amount of exposed area, and temperature, most likely,  
2 because what we're looking at here is, again, a  
3 degradation mechanism, it is somewhat of a corrosion  
4 reaction, which will be driven by a heat, obviously,  
5 service area.

6 MR. SWAIM: Okay. I take it that it's also a  
7 function for the sulfur, from which probes, or which  
8 wiring is most in the fuel, if something towards the  
9 bottom of the tank --

10 MR. SLENSKI: It's a longer immersion time.  
11 I should point out, too, and it's something we really  
12 never have gotten into, that we would suspect is, the  
13 potential applied to the wire could also help  
14 accelerate this process.

15 MR. SWAIM: Okay. Very good. One more  
16 observation from sort of the overall pool of things  
17 that we looked at. The deposits we saw on the non-  
18 mishap, these same deposits that we saw in the non-  
19 mishap equipment appeared to be much more dense and  
20 more completely covering this Hi-Z area, this Hi-Z lead  
21 area, on the compensators. They are more consistent,  
22 more dense on those than on the probes. I'm led to  
23 believe that the compensators were located low in the  
24 tank, and might therefore be submersed for greater  
25 periods of time at a stretch, beneath the level of the



1 fuel. I did not get an opportunity to review the  
2 positioning of these equipments in the tank, but that's  
3 a possibility.

4 MR. SWAIM: Okay. Since this provided, as  
5 Mr. Slenski put it, a high-resistance path between  
6 electrical conductors, would you call that a latent  
7 failure, or something that was there that would not be  
8 detected by normal inspection?

9 MR. JOHNSON: You would have to have a test,  
10 it's a potential for inducing latent failure, that's, I  
11 think, for sure, and you would have to have, I think,  
12 some fairly specialized tests to detect it. I think in  
13 operation you might be able to develop a finger print  
14 for the presence of this by understanding the  
15 electrical performance of the sense system, the fuel  
16 quantity sensing system, and understand if you had a  
17 leakage path present, you know, what sort of impact  
18 that might have on your fuel quantity measurements, and  
19 when seeing erroneous measurements that probably would  
20 be indicative or could be used as an indicator for this  
21 sort of a problem.

22 MR. SWAIM: Okay. I'm going to give you a  
23 leading question, basically, for the general public  
24 here. Mr. Slenski, are we done with our work on copper  
25 sulfide, and this type of research? Is this something

1           that's still open?

2                       MR. SLENSKI: In reference to being open, I  
3 think there are still some concerns that we have  
4 malfunctioning fuel systems, that this product could be  
5 a source of the problem, and as I was saying, it's  
6 difficult sometimes to detect it, because of its  
7 intermittent nature.

8                       So I don't think we're done with this, and I  
9 think the question had been asked, have you done  
10 anything to solve this problem, and we have met with  
11 manufacturers, and informed them of the issue, and with  
12 users of probes, and there are ways to get around the  
13 problem.

14                      As I said, the nickel-plated conductor, you  
15 won't have this problem. So there are ways to get  
16 around the copper sulfite issue -- the silver --

17                      MR. SWAIM: I'm more concerned for  
18 determining whether we have a real threat here, or it's  
19 something that we're just looking at, and we happen to  
20 be experiencing while we're looking for the causes of  
21 ignition.

22                      I know Mr. Hulm has been looking into this  
23 from the Boeing standpoint. Mr. Hulm, do you want to  
24 mention what Boeing has been finding, or your position?

25                      MR. HULM: Well, we've had the opportunity to

1       examine -- well, first of all, you're going to have to  
2       kind of highlight the differences between the probes  
3       that the air force is looking at, and the fuel probes  
4       in the Honeywell system installed on the 747 airplane.

5               The probes themselves are made of aluminum  
6       and nickel, the terminal block is plastic, the bolts  
7       and the screws are stainless steel.

8               The only place there was copper on those  
9       terminal blocks is there was some braising used to join  
10      two of the blocks together, it's a very thin and minor  
11      nature. I don't believe that during the investigation  
12      that that particular area showed any significant  
13      concentrations and any sulfite deposits.

14              The only place we do have on those probes  
15      exposure to sulfite again is on the compensation, and  
16      that's the in the interior side, where there's a copper  
17      stud mounted to some -- that's silver-plated copper  
18      soldered to -- which, again, normally, Teflon-  
19      insulated, and attached to the terminal block,  
20      connecting the two inter-probes, or inter-cylinders in  
21      the compensator.

22              So the exposure on the probe itself is a lot  
23      less, and I think that's a little bit indicative by  
24      what Mr. Johnson noted when he performed the insulation  
25      resistance test on the probes removed out of 93109, the

1 derelict airplane, or the other service airplane. Even  
2 with the sulfite deposits he did see there, there was  
3 no indication that there was breaching of the  
4 insulating capabilities of the probe.

5 Our own work we've done, you know, we've seen  
6 silver and copper sulfite, but our service history,  
7 from what we've been able to tell, and gather data at  
8 this point in time, indicates that we haven't had a  
9 problem with it.

10 CHAIRMAN HALL: Do you-all manufacture for  
11 the air force as well?

12 MR. HULM: We produce some airplanes for the  
13 air force, yes.

14 CHAIRMAN HALL: Do you share information?

15 MR. HULM: I would have to say we do. In  
16 this particular area, we've got a whole group of fire  
17 specialists, but I'm sure that these people are  
18 communicating with not only the air force, but the  
19 entire industry.

20 DR. LOEB: Is the service bulletin revision  
21 or upgrade that you're working on, is it going to call  
22 into attention the copper sulfite, and have it  
23 specifically looked at to see whether there's evidence  
24 of it in these tanks?

25 MR. HULM: Again, the inspection service

1       bulletin currently does not have it, but we are putting  
2       that revision into conduct that type of test so we can  
3       detect this type of deposit.

4               DR. LOEB:   That's my point.  You are putting  
5       that in, you are going to be looking at that --

6               MR. HULM:   Yes, sir.

7               DR. LOEB:   -- is that correct?  Mr. Swaim  
8       might can answer that question that you raised earlier,  
9       we are going to continue to look at this, this is not a  
10      closed issue, it's an open issue, and we'll remain  
11      under investigation until we learn all we need to know  
12      about it.

13              MR. SWAIM:   Very much so.  This hearing is  
14      essentially in the midst of our work, so that's why I  
15      was kind of leading Mr. Slenski with that question.

16              MR. SLENSKI:  I think, I would like to make  
17      the comment, now that I've had time to think about this  
18      a little bit, but maybe the point I should make is the  
19      copper sulfite, silver sulfite has been a reliability  
20      problem for most of our aircraft systems, it's been an  
21      issue with malfunctioning probes.

22              I think the issue here, which was a new  
23      finding, was the is exposed conductors, which once  
24      those are exposed, now these residues can build up in  
25      areas where you hadn't planned for them to be there.

1 I think the point I heard from Boeing is, we  
2 know probes have very limited sources of copper and  
3 silver exposed to have this problem, but when Mr.  
4 Johnson found damaged insulation, now we've opened up a  
5 new avenue for the residue to form, and I think the  
6 question we're getting to is, do we need to study this  
7 further? I think now with that combination, now it  
8 does become more of an issue.

9 DR. LOEB: You have copper, and you have  
10 silver in the wiring to the probes, to the block, to  
11 the terminal block, is that correct?

12 MR. SLENSKI: It's a silver-plated wiring.

13 DR. LOEB: That's right. So you have sources  
14 of copper, you have sources of silver, and you have  
15 sources of sulfur.

16 MR. SLENSKI: That's correct.

17 DR. LOEB: We have wires that we've seen in  
18 some of these retired airplanes, or other sources of  
19 other airplanes that we've pulled probes off of, not  
20 the TWA 800, which we have seen the wires open, and the  
21 conductors exposed.

22 MR. SLENSKI: I should say that we have a  
23 whole group of probes, and Mr. Swaim would probably  
24 have to tell me where they came from again, but we  
25 haven't even looked at yet in our lab.

1 DR. LOEB: Yes. You have a bunch of probes  
2 from the Bunting Thorpe airplane.

3 MR. SWAIM: That's correct. Before the  
4 Bunting Thorpe, England, airplane was destroyed by the  
5 explosive tests, we removed the probes so that we would  
6 have them available for this type of lab testing. It's  
7 hard to get probes that have the wiring still attached,  
8 and not moved around to breach or break this film. It  
9 seems to be so easy to break, that we did remove those  
10 before we lost that airplane, that asset.

11 MR. HULM: I wonder if I could address the  
12 comment by Mr. Gerken, you know, the fact that the  
13 damaged wiring is really --

14 CHAIRMAN HALL: Yes. And this would be the  
15 last comment before the lunch break, so please proceed.

16 MR. HULM: I didn't mean to imply that we  
17 were trying to ignore that issue at all, I think we do  
18 realize it's there, and we are trying to address it.

19 We do have a service bulletin that we are  
20 preparing, to go in the center tank, and to take a look  
21 to find any of these terminal blocks that are in the  
22 airplane, that we're seeing the majority of the damage  
23 on, and if those blocks are present, to remove them out  
24 of the airplane, put in probes with the series four and  
25 later terminal blocks, and either wiring that was

1 attached to those terminal blocks will be, either that  
2 entire harness in the center tank will be removed and  
3 replaced, and the wiring to that terminal block will be  
4 re-terminated, to eliminate any possible damage.

5 One important point in the analysis that the  
6 air force did is that a lot of these points, I believe  
7 a majority of them, you can't hardly see with your bare  
8 eye. I mean some of this stuff we looked at was under  
9 extreme magnification, you know, it blows things up to  
10 life-size proportions, and the damage points are very  
11 small, and the concentrations of the sulfides around  
12 those areas is very small.

13 So we are taking the steps to eliminate those  
14 types of terminal blocks from the center tank of the  
15 airplane, and the perfect opportunity to do that is  
16 because we have the corresponding inspection bulletin,  
17 and those tanks will be open, and I want take the  
18 opportunity to go into those tanks and replace those  
19 probes.

20 And also a part of that bulletin, we are  
21 going to be asking for those parts back from the  
22 airlines when they pull them out, so we'll get an  
23 enormous amount of data to add to the data base that  
24 the air force has built up, and if the NTSB is  
25 formulating here for us.



1                   CHAIRMAN HALL: Thank you very much, and on  
2                   that positive note we will break for lunch, and  
3                   reconvene promptly at 2:00 o'clock.

4                   (Whereupon, at 12:58 p.m. a luncheon recess  
5                   was taken.)

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1 tests.

2 I want to, again, as we close, thank Boeing  
3 for their commitment in this regard as well. I think  
4 this is good news for the traveling public. Mr. Swaim,  
5 would you please continue?

6 MR. SWAIM: Yes, sir. Thank you. I have a  
7 couple of follow-up questions that were handed to me  
8 over the lunch period.

9 First off, for clarification, Mr. Slenski,  
10 why did the air force begin to look at fuel probes, and  
11 how did you come to find copper sulfide deposits in the  
12 first place?

13 MR. SLENSKI: The initial discussion on the  
14 fuel probes came about around 1990, and I believe, and  
15 it's been a few years now, but the maintenance  
16 personnel noted black streaks and residues on fuel  
17 probes, and they were concerned that these could be  
18 evidence of arcing in the tank, and at the same time  
19 they were having problems with fuel measurement  
20 inconsistencies in several of our aircraft.

21 It was in that situation there how we became  
22 involved being a materials lab, we routinely, again,  
23 conducted failure analysis investigations, and we were  
24 selected to look at the probe, because they were trying  
25 to understand what had really occurred, was it an

1        arcing event that occurred in the fuel probe, if not,  
2        what is its residue?

3                MR. SWAIM: Okay. You say 1990. Were these  
4        new airplanes with a new problem, had the airplane  
5        suddenly reached a certain age, or was it just that it  
6        came to light in 1990?

7                MR. SLENSKI: These were fairly old aircraft,  
8        so they had been in service for quite a few years, and  
9        I believe they referenced them as trainer-type aircraft  
10       and tanker-type aircraft, so they have been in service.

11               I believe the situation is removal for cause,  
12       which they had assumed the problem was the fuel probes,  
13       they had noted these residues, and they just wanted to  
14       find out the source.

15               DR. LOEB: Through the maintenance process,  
16       you're saying, as opposed to the crews squawking the  
17       fuel indicating system.

18               MR. SLENSKI: Well, I think the situation  
19       here is the crew obviously was having a problem with  
20       the fuel system. In the process of determining the  
21       cause, they looked at all possibilities. Fuel probes  
22       is not always the first system we're going to look at,  
23       just because of access.

24               DR. LOEB: That's right.

25               MR. SLENSKI: So they probably looked at

1 other components, and then they looked at the fuel  
2 probes finally, and said, if we replace these, the  
3 problem goes away, and the air force does have certain  
4 refurbishment on probes, and when they saw these  
5 residues, I think they said we need to get these  
6 analyzed to find out what's going on.

7 DR. LOEB: But do you believe that most of  
8 these came to light as a result of the operating crew  
9 squawking the system --

10 MR. SLENSKI: I can't say for sure --

11 DR. LOEB: -- or do you know?

12 MR. SLENSKI: -- on that. I really can't  
13 say. I don't know if a maintenance personnel just  
14 noted it during maintenance of the system, or whether  
15 it was a write-up against the system.

16 CHAIRMAN HALL: Mr. Slenski, if you could  
17 find that information out and provide it for the  
18 record, we would appreciate it.

19 MR. SLENSKI: Okay. I'll see if we can get  
20 that information.

21 CHAIRMAN HALL: That is specifically what the  
22 question was when we first became involved.

23 DR. LOEB: Well, the real question is: How  
24 did we learn, how did you learn about this continuous  
25 problem, and was it primarily through the operating

1 crews, the pilots squawking the system, or was it --

2 MR. SLENSKI: Sure.

3 DR. LOEB: -- through the maintenance folks,  
4 or --

5 MR. SLENSKI: Okay. I think -- we'll attempt  
6 to get that answer.

7 DR. LOEB: Okay. Thank you.

8 CHAIRMAN HALL: Something must have led  
9 somebody in 1990 to put out your contract  
10 F-33615-89-C-5647 that was a survey of data on failures  
11 of aircraft electronic and electrical components.

12 MR. SLENSKI: I don't think that these were  
13 related in that that particular investigation is,  
14 again, something we started in our lab, being a failure  
15 analysis lab, and working mishaps for the air force.

16 We were concerned that as we went to more  
17 electric aircraft, we needed to address electrically  
18 related failures and mishaps, and we just so happened  
19 -- that program was actually initiated in 1989 through  
20 the Small Business, and it was to collect data to help  
21 us understand how to do analysis and collect  
22 components, and really, in that particular study, fuel  
23 probes were not, although I think they are mentioned in  
24 there when we looked at the large body of data, which  
25 you had mentioned before, fuel probes really did not

1           come out as a major problem, although we did surveys in  
2           those areas, we had reviewed data on fuel probes.

3                   MR. SWAIM: Mr. Slenski, in about 1988 or so,  
4           the air force began a more enhanced quality program.  
5           Do you have any familiarity with that? Could this have  
6           come out of that more intense research, and the quality  
7           of the airplanes, and such?

8                   MR. SLENSKI: When you're referring to a  
9           particular quality program, or just in general?

10                   MR. SWAIM: It was fairly general, where they  
11           started reviewing data on airplanes, and incidents, and  
12           failures, and --

13                   MR. SLENSKI: I'm not sure if that's related  
14           or not. It might have had some bearing on that.

15                   MR. SWAIM: Again, when we read a report, our  
16           safety center gets that information, and then they  
17           would review these reports and decide what action has  
18           to be taken.

19                   CHAIRMAN HALL: Whatever background  
20           information you can provide for the record on that,  
21           we'd appreciate.

22                   MR. SLENSKI: Okay. Thank you.

23                   MR. SWAIM: Mr. Hulm, the testing that Boeing  
24           did on the 23-year-old probes in September of 1996, I  
25           believe, were those removed from the airplane with the

1 wiring still attached, or was the wiring removed,  
2 probes taken out, and then put into whatever your test  
3 rig was?

4 MR. HULM: The probes were removed from the  
5 airplane without the wiring attached, so it was  
6 completely disassembled before we put it back together  
7 in our lab. In other words, the probes came out  
8 separately from the wiring.

9 MR. SWAIM: Okay. Thank you. Do you know,  
10 Mr. Hulm, on the part of Boeing, what prior knowledge,  
11 what data base of knowledge, or collection of knowledge  
12 Boeing has on copper sulfite, and this subject?

13 MR. HULM: The knowledge I have of it is that  
14 we've seen it on probes and wiring in very small  
15 amounts. We understood it could be there where the  
16 mechanism was, but we've never had an issue where it  
17 affected, that we've been able to identify, that was  
18 awarded to us, that affected the reliability of the  
19 airplane, or it was such a problem to cause us to look  
20 any further.

21 We knew it was a semi-conductive material,  
22 but we hadn't seen any bridging of the individual  
23 components either in the probes or in the wiring that  
24 would indicate that we had a problem on the airplane.

25 CHAIRMAN HALL: Was that something they were



1 looking for in the inspections then?

2 MR. HULM: This particular issue with the  
3 sulfites, this would not be part of the inspection  
4 right now, no.

5 CHAIRMAN HALL: So how would you know about  
6 it then?

7 MR. HULM: Well, this would be kind of like  
8 what the air force experienced, if we got massive  
9 reports from the airlines that they were having  
10 problems with the system, and the wiring, and --

11 CHAIRMAN HALL: Okay.

12 MR. HULM: -- repeated failures, and stuff,  
13 and they couldn't resolve it, then we would have  
14 reacted in the same way, similar to the way the air  
15 force did, and we didn't have any indication that  
16 people were noting the same thing that the air force  
17 did.

18 Again, when you look at the way the air force  
19 found the problem, they saw the residue on their probes  
20 themselves, and since our probes are nickel and  
21 aluminum, with very little of the silver or copper on  
22 the probe itself, you wouldn't see any residue on the  
23 probe, the probes would be very clean. So the only  
24 place you'd really have to concentrate is on the  
25 terminal blocks and the wiring itself.

1 DR. LOEB: In fact, that's one of the reasons  
2 why we think it's so important to get in there and take  
3 a real close look at these things, because you won't  
4 see them necessarily if you're not specifically looking  
5 for that.

6 MR. HULM: Exactly. In fact, I think even  
7 one step further, it's better even to get, like,  
8 similar to what the NTSB is, get some airplanes where  
9 you can actually cut them up and bring them to a lab  
10 and analyze them, so you can get the exact amount of  
11 what the contamination is, and test it appropriately,  
12 where you won't be able to do that in an airplane.

13 CHAIRMAN HALL: But this is a phenomena, if I  
14 understand, of age, or not.

15 MR. HULM: Yes, sir. It's a component of  
16 age, and then the amount of time that the probe  
17 actually spends in the fuel, because the fuel is the  
18 component that contains the sulfur, and that's what  
19 initiates the corrosion.

20 MR. SWAIM: Since the air force is using  
21 airplanes of equivalent or slightly older years than  
22 the commercial flight, and the air force is using a  
23 slightly more sulfur-rich fuel in JP-4, or at least  
24 used to before JP-8, Mr. Slenski, do you think that  
25 could have a bearing on the air force having found a

1 problem with this in 1990?

2 Now, I'm not saying we found a specific  
3 problem with it at this point, but if we have, could  
4 that be a bearing in the difference of seven years or  
5 so here?

6 MR. SLENSKI: I think that's a reasonable  
7 assumption, in that we used to use JP-4. I think I've  
8 heard the same statement made before, it might have  
9 more sulfur compounds in it, and then we have maybe  
10 older aircraft, too, possibly.

11 CHAIRMAN HALL: Do you have fuel experts in  
12 the air force, do you know the composition of your  
13 fuel?

14 MR. SLENSKI: I believe we do. We don't have  
15 any on this panel, but we do have experts on the fuel.  
16 We have a fuels lab actually dedicated to that area.

17 CHAIRMAN HALL: So somebody would know what  
18 the composition of the fuel is you use, and wouldn't  
19 that be important to you in doing your work?

20 MR. SLENSKI: For our analysis, if you go  
21 back and look at some reports, we did have the fuel  
22 analyzed, the JP-4 analyzed in one of our reports, and  
23 as I think Mr. Swaim had mentioned, we changed over to  
24 JP-8 pretty much anyway in our aircraft several years  
25 ago.

1                   CHAIRMAN HALL: Do you know why that decision  
2 was made?

3                   MR. SLENSKI: I can't really. I'm not,  
4 again, a fuels person, and unless someone else here --  
5 I don't know if Steve has any comments on it.

6                   CHAIRMAN HALL: No. I don't want any  
7 speculation. If somebody knew, that would be fine.

8                   MR. SWAIM: Very good. For the record, Mr.  
9 Chairman, you'd asked about the parked airplane that we  
10 got these other probes out of. The good folks from TWA  
11 made a call back to Kansas City, I understand the  
12 airplane came in for a de-check, actually I found this  
13 through -- the airplane came in for a de-check, a heavy  
14 maintenance check, and the maintenance check had not  
15 been completed when they decided to cease using the  
16 airplane. It was parked in Kansas City on September  
17 26, 1994. The total time was 95,004 hours, so it was a  
18 couple thousand ahead of the accident airplane. The  
19 total landings were 17,941.

20                   CHAIRMAN HALL: When did you climb in it,  
21 into the tank, or get the stuff out of there, do you-  
22 all remember the date on that?

23                   MR. HULM: If not, I'll get it for the  
24 record.

25                   CHAIRMAN HALL: I want to be sure we're very

1 clear that it's not -- that presentation did not come  
2 from TWA 800, and what we were looking at was from an  
3 airplane that had been sitting for some period of time,  
4 so be sure that's clear on the record.

5 Is this a good time, I'm just going to ask  
6 this question, because it's been on my mind, and I'm  
7 trying to understand. As you-all know, on the cockpit  
8 voice recorder, at 20:29:15, there's a voice that says  
9 "Look at that crazy fuel flow indicator there on number  
10 four."

11 Mr. Hulm, do you-all know what -- can you  
12 tell me what that fuel flow indicator, where that --  
13 the wiring on that, and that probe, and what you might  
14 know about that, or what -- what is your-all's opinion  
15 on that comment?

16 MR. HULM: The fuel flow indicator itself is  
17 totally separate from the fuel quantity indication  
18 system, it's not related in any way, it doesn't monitor  
19 or measure fuel in the tank with fuel probes, or  
20 anything like that.

21 CHAIRMAN HALL: It's not in any way  
22 connected.

23 MR. HULM: No. It's two totally separate  
24 systems, they don't share any sort of data between  
25 them, or anything. It's an independent system, just a

1 measure of the fuel going into the engine, and it's  
2 kind of a backup to the quantity system, to provide a  
3 check between the two.

4 CHAIRMAN HALL: So it's not attached to any  
5 of the probes or anything?

6 MR. HULM: No, it's not. There's a separate  
7 -- I guess maybe Mr. Thomas might be better to address  
8 --

9 CHAIRMAN HALL: Well, it was widely reported,  
10 of course, when we released the cockpit voice recorder,  
11 Monday, and I thought it would be appropriate. I'm  
12 sure you-all have been aware of that since the  
13 beginning of the investigation as to whether you had  
14 any thoughts on that, or what had been done in that  
15 area, because it is so, what is it, a minute -- within  
16 a minute before we lose contact with the -- the  
17 electricity ceases.

18 MR. THOMAS: Mr. Chairman, if I can -- the  
19 fuel flow meters are installed on the engine, they  
20 provide a signal of how much fuel -- they obviously  
21 provide a signal of how much fuel the engines are  
22 using, it's a simple turbine device that puts out a  
23 pulse.

24 Normally, if the engine fuel flow meter  
25 starts misbehaving, it may be there's ice, or whatever,

1 that may be affecting that turbine performance for a  
2 short time, it will just wriggle and it will go away.  
3 It has absolutely nothing to do with the gauging system  
4 for the tanks. We use it as a completely separate  
5 backup. If one of the gauging systems on a given tank  
6 was to fail, you could continue to use the flow meter  
7 to track how much fuel was coming from that tank. It's  
8 a backup system.

9 CHAIRMAN HALL: Okay. Please proceed, Mr.  
10 Swaim, I just wanted to clarify that at this point.

11 MR. SWAIM: Okay. We had an illustration,  
12 I'd be hoping this would all come up later. In the  
13 wing center section there are seven small vertical  
14 lines connected by lighter lines that are red. The  
15 pencil point is right now indicating the left aft fuel  
16 probe.

17 The heavy red line that comes out of the rear  
18 spar of the tank comes down along a wiring run, with  
19 other wiring, it comes up the side wall of the  
20 airplane, into the overhead, it would be over the left-  
21 most passengers, and then forward under the upper deck  
22 windows on the left side of the airplane, and then  
23 crosses over the roof of the airplane, and goes into  
24 the flight engineer station. So that's the routing for  
25 the center wing tank wire harness.

1           The blue routing that comes in from the right  
2 wing is the routing for the fuel flow that we were able  
3 to find. It comes into where the pencil point just  
4 was, right there, and that's in the electronics  
5 compartment behind the nose gear.

6           The only place that the group has been able  
7 to find a common run of wiring is, as Ivor said, not  
8 between the fuel flow and the fuel quantity, but from  
9 that electronics compartment, up to the flight  
10 engineer's panel, through the wiring that goes to the  
11 volumetric shut-off box, part of the ground re-fueling  
12 equipment, and there is a common routing in that. I  
13 think that's a pretty good graphic answer.

14           CHAIRMAN HALL: Well, and I guess didn't we  
15 have a problem with fuel in the airplane on the ground?

16           MR. HULM: Well, that's more where I was  
17 going with the --

18           CHAIRMAN HALL: Okay.

19           MR. HULM: -- other questioning.

20           CHAIRMAN HALL: Well, then I'll shut up and  
21 you-all go on, as long as we're going to cover all  
22 that, Mr. Swaim, because all that is on the record, and  
23 people would want to be -- we need to be sure it's  
24 covered.

25           MR. SWAIM: I'm trying to. The center tank,



1 to go back to my train of thought here, the airplane,  
2 the accident airplane, Mr. Hulm, it had an increase  
3 over the last several months of its existence of  
4 writeups, maintenance actions against the ground  
5 refueling equipment.

6 Does the ground refueling equipment rely on  
7 the compensator from the center tank, for that tank,  
8 obviously?

9 MR. HULM: Could you please re-state the  
10 question? Sorry.

11 MR. SWAIM: Sir, the ground refueling, the  
12 volumetric shut-off box, does it take signals from the  
13 compensator from the center tank, for refueling that  
14 tank?

15 MR. HULM: I'm drawing a blank here.

16 MR. SWAIM: Okay. It's a detailed question.  
17 I apologize. It's a detailed question. Obviously,  
18 there's no preparation for this kind of thing, so okay.  
19 Let's try --

20 DR. LOEB: Do you want that provided for the  
21 record?

22 MR. HULM: I can definitely get that for you.

23 DR. LOEB: I mean I think we need to do that,  
24 at least, and/or if you have any information that does  
25 speak to that, you might want to bring that up.

1           MR. SWAIM: Well, I think the proper person,  
2 I think, for that would have been Mr. Taylor, from  
3 Honeywell, yesterday.

4           CHAIRMAN HALL: Is he still here? He has  
5 left. Very well.

6           MR. SWAIM: Okay. We will be investigating  
7 that further. As I've mentioned, and will keep  
8 mentioning, this is an open part of the investigation,  
9 it really is.

10          CHAIRMAN HALL: Let me just say, Mr. Swaim,  
11 so it's clear to anyone who is watching these  
12 proceedings, that we are in the process of an  
13 investigation, and we have an obligation to explore  
14 these issues. That does not mean that any of these  
15 issues are going to lead us to conclusions, and at  
16 present, we do not have any, and there will not be a  
17 probable cause that will come as a result of this  
18 hearing, but the things that are identified in the  
19 maintenance records, and identified in the cockpit  
20 voice recorder, flight data recorder, need to be  
21 covered, and the public view, as part of this  
22 investigation, so if you're doing that, proceed ahead.

23          MR. SWAIM: Thank you, sir.

24          MR. RODRIGUES: Excuse me, Mr. Chairman --

25          CHAIRMAN HALL: Yes?

1 MR. RODRIGUES: -- the answer to your  
2 question, Bob, is yes, it does use a volumetric shutoff  
3 in the center tank.

4 CHAIRMAN HALL: Thank you.

5 MR. SWAIM: Okay. We will be following-up,  
6 obviously, as the Chairman mentioned. I had a question  
7 to the FAA. Mr. Hartonas, before this investigation  
8 what awareness had the FAA had into sulfide deposits  
9 such as copper silver sulfide?

10 MR. HARTONAS: Yes. As I stated earlier, Mr.  
11 Swaim, is that the FAA had no previous knowledge of  
12 copper sulfur deposits. We became aware of it during  
13 this investigation.

14 MR. SWAIM: Okay. Thank you.

15 MR. HARTONAS: However, in the course of this  
16 investigation, as we identify here today, and it was  
17 presented during this hearing, the copper sulfur  
18 deposits, including damaged wiring insulation off the  
19 FIQS system, drew some safety concerns as potential  
20 ignition locations. I recently introduced AD to  
21 provide protection for the wiring of the FIQS, we'll  
22 address both of those.

23 MR. SWAIM: AD or NPRM?

24 MR. HARTONAS: It's an AD, it's a proposed  
25 rule under the umbrella of airworthiness directives.

1                   MR. SWAIM: Okay. Very good. Question from  
2 that comment for Mr. Hulm. Is there a reason that the  
3 fuel quality system wiring was protected only at the  
4 gauge, when we have the fuel quality system wiring tied  
5 to other wires and routed with other wires between the  
6 tank, the flight engineer station, down to the  
7 electronics compartment, and so forth, as we saw in  
8 that graphic?

9                   MR. HULM: So when you say protected at the  
10 gate here, you're referring to the current limiting  
11 circuitry within the gauge itself --

12                   MR. SWAIM: Correct.

13                   MR. HULM: -- correct? I think that was just  
14 the normal course of the design itself. The majority  
15 of the wiring from --

16                   CHAIRMAN HALL: That design didn't change on  
17 any subsequent models, or is that consistent on all  
18 your models?

19                   MR. HULM: Correct. It's basically the same  
20 we use on all of our models. The wiring from the  
21 flight engineer's disconnect, down to the center tank  
22 disconnect, and to all the main tanks, really, I mean  
23 to all the tanks, from all the indicators is basically  
24 the Teflon wiring, with the nylon over blade across it,  
25 and that protects some abrasion.

1           There is some of the normal ship's wiring  
2           between the flight engineer's, the actual indicator,  
3           about three feet of wiring that goes to the disconnect,  
4           and then down to the all-shutoff unit, and we use our  
5           standard wire routing practices within the airplane to  
6           make sure that we have any separation from structure  
7           for the wire bundles.

8           Within the pressurized vessel itself, the  
9           wire bundles are clamped with either a circular clamp  
10          every 24 inches, or else there's another clamping  
11          arrangement used, where it's like a channel clamp that  
12          will hold bundles, and there's a foam bar that will go  
13          across the top to keep that in place, to make sure that  
14          it was secure.

15          There are tie wraps around the bundles to  
16          hold them and make sure they're not moving around a  
17          lot, and things aren't flopping around, to make sure  
18          there's no interference with structure, and any time  
19          there's a penetration through a sharp edge or anything,  
20          you'll have plastic grommets to protect the wiring,  
21          also.

22          Within the tank itself, when you look at the  
23          wire routing within the tank, again, we use stand-offs  
24          to keep the wire away from structure. We utilized the  
25          Teflon wiring within the tank, also. Again, there's

1 grommets wherever there's a penetration through  
2 structure to make sure that there would be no chance to  
3 nick or abrade the wire itself.

4 We used good practices in routing the bundle,  
5 and I don't think that the main reason for any physical  
6 separation of the harness from any other wiring would  
7 be mostly a concern with interference from other  
8 electrical systems causing an inaccuracy in the gauging  
9 system, so with these particular systems, at the time  
10 they were designed, it was not determined to be  
11 necessary.

12 So the view then is, if you do get an outside  
13 electrical short on the FIQS wiring itself, nothing  
14 will happen, because the components and the cells in  
15 the tank are designed to withstand the 115 volts AC  
16 that you may get into the wiring.

17 MR. SWAIM: Because of the quarter-inch gap  
18 in the fuel probe components that Mr. Taylor was  
19 talking about, that's the --

20 MR. HULM: Correct. We do the 1,500-volt AC  
21 insulation resistance test, I mean the dielectric  
22 withstanding test and the 500 DC insulation resistance  
23 test.

24 So those components can withstand that, and  
25 the minute you get the short, you're going to cause a

1 malfunction of your indicator, and it would be noticed  
2 by either the flight crew or ground maintenance, and  
3 that particular section would be corrected and  
4 repaired.

5 DR. LOEB: Let me just see if I understand.  
6 You're saying the protection from the possibility of a  
7 second failure, a short circuit, is that you would get  
8 an erratic gauge indicator, and that's the protection  
9 from that.

10 MR. HULM: Well, the real protection is the  
11 fact that the components in the tank can withstand the  
12 150-volts AC.

13 DR. LOEB: Well, they can withstand that,  
14 providing there's no additional failure, there's no  
15 short circuit, or something of that nature that would  
16 give you a short across it that you would not want.

17 MR. HULM: Correct.

18 DR. LOEB: So if that is the case, then the  
19 only protection we have right now is some sort of an  
20 erratic gauge indicator that may alert the crew that  
21 something is happening.

22 Is there any downside to a surge protection  
23 system --

24 MR. HULM: That we --

25 DR. LOEB: -- is there any downside to it?

1 MR. HULM: To a surge protection system?

2 DR. LOEB: Yes. For the wiring going into  
3 the tank.

4 MR. HULM: One of the issues we've looked at,  
5 I think as a result of what the FAA has released, and  
6 the end paper that they put out, one of the  
7 recommendations was to add surge protection at the spar  
8 disconnect going into the tank, and some of the issues  
9 there that need to be addressed is the fact that a lot  
10 of time these components are passive in nature, and if  
11 they do fail, you'll never know until --

12 DR. LOEB: You mean you have a latent  
13 failure.

14 MR. HULM: It depends on how the unit would  
15 be designed. If you have some sort of surge protector,  
16 you've got to design the proper enclosure to ensure  
17 that it's going to be there at the time that you need  
18 it.

19 DR. LOEB: Well, I would agree with that, but  
20 the point that you just made is that some of these  
21 failures could be latent, you don't know that they're  
22 there --

23 MR. HULM: Correct.

24 DR. LOEB: -- that's exactly what is of  
25 concern, and I recognize that originally the system was



1 designed that way. I guess my question is going to be  
2 you now, did anyone think about this kind of added  
3 protection following the Philippine Airlines' 737  
4 explosion?

5 MR. HULM: Not to my knowledge, I think,  
6 again, because the exact cause of that particular  
7 accident was unknown, and nobody really addressed the  
8 issue of --

9 DR. LOEB: Well, what was ruled out was the  
10 possibility of any external cause for that explosion,  
11 meaning that it had to be something internal,  
12 therefore, somehow in that accident, energy got into  
13 that tank from the system, and there was no  
14 consideration of adding some additional protection such  
15 as a surge protection system.

16 MR. HULM: I'm probably stepping a little bit  
17 outside of my area of knowledge as far as the  
18 Philippines accident, and everything that's associated  
19 with that, but I'm not aware of any study they did in  
20 that regard.

21 DR. LOEB: Okay.

22 CHAIRMAN HALL: Well, if there is any, you  
23 can provide it for the record.

24 MR. HULM: Yes, sir.

25 MR. SWAIM: Mr. Hulm, Boeing released the

1 service bulletin for the center tank inspections, 2205,  
2 which is nearly a hundred pages of instructions. Would  
3 it, in its present form, address the problems, the  
4 breaks in the insulation, or the copper sulfide that  
5 we've been seeing here today?

6 MR. HULM: No, it would not.

7 MR. SWAIM: Okay. But the revised service  
8 bulletin would, is that right?

9 MR. HULM: That's correct.

10 MR. SWAIM: Okay. Are all the airplanes  
11 already inspected, the 52 that you mentioned yesterday,  
12 going to have to be reinspected for the new service  
13 bulletin?

14 MR. HULM: I think that's a determination  
15 that needs yet to be made. We haven't made a decision  
16 on that yet.

17 MR. SWAIM: Okay. Mr. Hartonas, I understood  
18 from Mr. Cheney yesterday that the FAA is waiting for  
19 the revision to come out with an NPRM or an AD  
20 airworthiness directive on that, is that right?

21 MR. HARTONAS: The FAA is closely viewing the  
22 impact of multiple tank entrances, with the fact that  
23 there's already been discovered, damaged wiring  
24 insulation or damaged probes. We want to minimize tank  
25 entrance, when we go in there we want to make it

1 worthwhile with meaningful inspections.

2 MR. SWAIM: Is that a yes or a no? Are we  
3 going to AD it or not?

4 MR. HARTONAS: The FAA is going to most  
5 likely move with an NPRM or AD action for tank  
6 inspections.

7 MR. SWAIM: Most likely is safe, that's fine.

8 MR. HULM: Mr. Swaim, I wonder if I could  
9 make a correction to --

10 MR. SWAIM: Please.

11 MR. HULM: -- what I just said earlier? The  
12 real fix for the nick wiring and stuff that you  
13 referred to on the previous question, the real fix for  
14 that is the surface bulletin, the re-work service  
15 bulletin that we'll be generating from the series three  
16 terminal block, not the inspection bulletin.

17 We're really trying to keep any re-work  
18 instructions out of that inspection bulletin, and keep  
19 that purely just to inspect and determine the condition  
20 of the aircraft. If any corrective action is required,  
21 then we'll go back and release the appropriate service  
22 bulletin to address that specific situation.

23 So the inspection bulletin will not address  
24 the issues as far as the nick wiring and the things you  
25 see, that's where the series three terminal block

1 service bulletin, that one will address those issues.

2 MR. SWAIM: Okay. I guess I'm coming down to  
3 the kind of question that the Chairman has been asking,  
4 how long is all this going to take, first, for the  
5 service bulletin, then for the NPRM, or AD, and then I  
6 guess back for another service bulletin? How long are  
7 we talking?

8 MR. HARTONAS: Mr. Swaim, I want to clarify  
9 the statement I made previously. Once we have a  
10 comprehensive inspection plan, the FAA will definitely  
11 do that. We're in the midst of preparing that  
12 comprehensive inspection plan with Boeing.

13 MR. SWAIM: It has to be worked out, we  
14 understand that. Mr. Hulm, I believe you may even had  
15 said yesterday, January, next month, the inspection  
16 service bulletin --

17 MR. HULM: January of next month for the  
18 inspection bulletin revision, and we're looking at late  
19 January, early February for the bulletin for the series  
20 three terminal block.

21 MR. SWAIM: And then, Mr. Hartonas, how long  
22 will it take to make that mandatory through an AD, if  
23 it comes through, I understand, in a typical -- we're  
24 not trying to pin you down, I'm just trying to get a  
25 general idea of how long we're talking for this

1 process.

2 MR. HARTONAS: Well, seeing that this is a  
3 priority right now, to this tragic accident, it will be  
4 just a matter of a few days before the FAA has the AD  
5 ready.

6 MR. SWAIM: Would this be the kind of  
7 inspection, Mr. Hulm, or Mr. Hartonas, I'm sorry, that  
8 would be go out and inspect all the airplanes within  
9 six months, or would this be within the next de-check,  
10 or four years?

11 MR. HARTONAS: We haven't gone that far in  
12 the development of it. We're still looking -- we're  
13 still trying to make sure all the parts are there, and  
14 try to assure that once we do go out with it, the  
15 airlines have the materials and the instructions they  
16 need in order to accomplish the service bulletin  
17 itself. It doesn't do us any good releasing it,  
18 telling them to do it in three months, and then we  
19 can't supply the parts for them to do the re-work.

20 So that issue is still being worked through  
21 Boeing, we're still talking to our suppliers, making  
22 sure the appropriate wiring is there, the wiring  
23 bundles, and all the terminal blocks that they need to  
24 upgrade these probes are available.

25 MR. SWAIM: I think that's a good point.

1 It's not just Boeing, and the FAA, and the airlines,  
2 there's a lead into this, isn't there? There's some  
3 kind of logistics before you release a service  
4 bulletin, correct?

5 MR. HULM: Correct. There's a lot of  
6 coordination to go on, even with the FAA and everything  
7 that we've been doing here, all of our suppliers that  
8 -- we have a different supplier for the tank harnesses,  
9 it's quite difficult to make long-lead items,  
10 especially with the connectors themselves, and the  
11 terminal blocks, we have another supplier for those at  
12 this present time, and then the logistics of making  
13 sure that if probes are returned, that the facilities  
14 are there to re-work them in time, and turn them  
15 around, and get them back to the airline, so there's  
16 quite a lot of work to do in order to get one of these  
17 service bulletins out, and particularly this one,  
18 because the components involved and the age of the  
19 airplane.

20 MR. HARTONAS: Mr. Swaim --

21 MR. SWAIM: Please.

22 MR. HARTONAS: -- the FAA agrees with that  
23 statement. We recognize that these inspections are  
24 going to be very meaningful and important; however, we  
25 constitute a lot of maintenance activity, and perhaps

1 this maintenance activity may be repeatable. That is  
2 the reason why the FAA proposed additional protection  
3 to the airplane's wiring, so that additional  
4 maintenance activity, or the burden to the airlines is  
5 minimized.

6 DR. LOEB: The additional protection being  
7 the surge protection, or --

8 MR. HARTONAS: The airworthiness directive at  
9 this time provides for surge suppression or shielding  
10 separation, it doesn't pin down a specific method.

11 DR. LOEB: Now, that is an NPRM at this  
12 point. The is not an AD. It has 90 days on it, is  
13 that correct?

14 MR. HARTONAS: Yes, it does.

15 Dr. LOEB: After that, an AD, when it is  
16 issued, will provide about how long, do you know,  
17 for --

18 MR. HARTONAS: One year.

19 DR. LOEB: One year. So that this additional  
20 protection that you're talking about is out in the  
21 future, just like the inspections would be.

22 CHAIRMAN HALL: He answered the question.  
23 Let's move on.

24 MR. SWAIM: Great. Thank you. Since all  
25 this has to be done for the center tank, and the

1 different Boeing representatives illustrated and  
2 demonstrated how similar the center tank and the other  
3 tanks in the airplanes are, why hasn't the FAA called  
4 for these same inspections in the other fuel tanks?

5 MR. COLLINS: The center tank is the most  
6 flammable environment, as the NTSB flight test has  
7 shown, so that's our first priority. We are evaluating  
8 the other tanks, though, as follow-on action, and a lot  
9 of that action will be based on what we learn out of  
10 inspections and the program with the center tank.

11 We have plans for a comprehensive program on  
12 all airplanes, not just the 747, and that would cover  
13 all tanks, also.

14 MR. SWAIM: Okay. Can you expand on that  
15 comprehensive program for all airplanes?

16 MR. COLLINS: Yes. That was outlined in  
17 Administrative Garvey's letter to Chairman Hall, in  
18 response to your recommendations, and it said, we're  
19 going to propose action applicable to the fleet of  
20 large transport airplanes, and one of the requirements  
21 is to have each type certificate holder develop a fuel  
22 tank maintenance and inspection program, and require  
23 each operator to have an FAA-approved fuel tank system  
24 maintenance program, and require review of the original  
25 certification compliance findings to the fuel system



1 requirements, to re-validate that failures within the  
2 fuel tank system and fuel system will not result in  
3 ignition, and also, interim required procedural changes  
4 to prevent operation of any electrically driven fuel  
5 pump and fuel tanks, with adjacent heat sources, unless  
6 that pump's inlet is fully submerged in liquid.

7 One alternative to that would be if they had  
8 a flame arrester installed on the pump inlet, as  
9 interim action.

10 MR. SWAIM: Good. I'd like to come back to  
11 that thought in a couple of minutes, and I would like  
12 to talk about pumps in a couple minutes. Before we get  
13 off wiring, Mr. Slenski, we've been looking at  
14 pictures, a couple of pictures of the various wiring  
15 bundles.

16 There's a document in one of the exhibits,  
17 it's exhibit 9c, page 197, it's an OSHA document that  
18 -- I'm sorry, 9c, 49 -- that says electrical arcs can  
19 be 35,000 degrees Fahrenheit, and expand wire, the  
20 copper, 65,000 times, and that's what that big flash  
21 and spark are.

22 My question is: Can nylon or Teflon  
23 insulation withstand those kinds of temperatures, Mr.  
24 Slenski?

25 MR. SLENSKI: In reference to an arc?

1                   MR. SWAIM: Yes, in reference to an arc in a  
2 tightly wrapped bundle, if you get two of the chafe  
3 together, or however short.

4                   MR. SLENSKI: In that situation, the Teflon  
5 would probably sublime, vaporize instantly, and melt  
6 away from that area very quickly.

7                   MR. SWAIM: So there is a possibility of  
8 putting power onto the wrong wire, if there's an arc in  
9 a bundle?

10                  MR. SLENSKI: The question is what the arc  
11 would do to the bundle, adjacent wires, is that what  
12 you're asking?

13                  MR. SWAIM: Yes.

14                  MR. SLENSKI: I'm sure there's going to be  
15 damage to surrounding wires, to some extent, and,  
16 again, Teflon melting is way below that temperature,  
17 and so as you mentioned, arcs are very hot, but they're  
18 also very isolated and limited in the area, that you  
19 probably would cause some damage in the surrounding  
20 insulation.

21                  MR. SWAIM: Question for you. You examined  
22 some other wiring when you were looking at the  
23 scavenged pump relay, and I know you found something of  
24 interest on that, a crack in the insulation. Do you  
25 have anything that you can speak to, as far as that, in

1           this flow?

2                       MR. SLENSKI: I've got two charts that can  
3 discuss some of our findings, if you'd like.

4                       MR. SWAIM: If we could do that fairly quick,  
5 yes.

6                       MR. SLENSKI: Basically, the first chart here  
7 will hopefully set up -- if we could look at the right  
8 top corner there, quadrant, what we're looking at there  
9 is the actual scavenge pump relay, and the wiring that  
10 was attached to that relay that was submitted to us for  
11 analysis, and in this case, we requested a look at the  
12 electrical context for evidence of anomalies such as  
13 melting, pitting at the context, and just briefly we  
14 really -- we found no evidence of that in these  
15 contacts.

16                      However, in the inspection of the exhibit,  
17 when we examined a wiring, we noted that this  
18 particular insulation, which has been referred to in  
19 the past as Poly-X, was marked with a process called  
20 hot stamp marking, and with this process here, the wire  
21 is marked basically for purposes of maintenance, and  
22 also so you can track and identify the wire. So if we  
23 zero in on the lower right quadrant, this is the actual  
24 marking process.

25                      And, again, this is the actual process, it

1 comes down on the wire and penetrates the insulation,  
2 normally, slightly, to emboss the wire with the  
3 nomenclature.

4 In this case here, it has been a fairly deep  
5 penetration, as we're seeing in these photos here. The  
6 seven-four, as you can see, has been rotated, in the  
7 middle photo, you can see where it's penetrated the  
8 insulation, and the top shows a close-up of that  
9 particular seven, and we felt that was excessive  
10 penetration of the insulation.

11 Now, if you look over to the left lower  
12 corner, this is off another mark, basically, a dash of  
13 some type, and there was actually a crack emanating  
14 from that particular hot stamp mark, and actually  
15 exposed a conductor.

16 Now, we did not see any evidence of arc  
17 tracking or arcing from that event, and I think we need  
18 to recognize this type of cracking could have occurred  
19 during the actual breakup of the aircraft.

20 MR. SWAIM: This is from the accident  
21 airplane, right?

22 MR. SLENSKI: This is from the mishap  
23 aircraft. That's the wiring off the scavenge pump.

24 The next chart has a little more detail here,  
25 if we go to the upper left quadrant. This is a cross-

1 section now of one of these wires, and now you can see  
2 the actual penetration of this hot stamp process into  
3 the insulation.

4 This insulation consists of three layers.  
5 There's an outer white layer, an inner amber-colored  
6 layer, and a middle amber-colored layer, and an inner  
7 white layer. As you can see here, it penetrated all  
8 three layers.

9 If we go over to the right side, you might  
10 want to back off on that a little bit so they can see.  
11 Let's look at the lower right corner cross-section  
12 there. That's a longitudinal cross-section, showing  
13 several marks of wire, and you can see how it's  
14 penetrating the insulation, but also note that from the  
15 lower right, to the top left, you can see a marked  
16 increase in the depth of penetration there. This is  
17 just showing you that this mark is inconsistent.

18 If we go up further, just to the top of that,  
19 that's a close-up of one of those penetration areas,  
20 and we can see that, in this case here, looking at my  
21 notes here, that there's 1.1 mils of insulation left,  
22 or 20 microns of insulation left.

23 This is normally, I believe I've looked at  
24 numbers here around 8 mil of insulation, or eight-  
25 thousands of an inch of insulation.

1           So our concern here, this is just an  
2 observation, that you might want to go look at the hot  
3 stamp process and other parts of the aircraft that was  
4 used on this wire.

5           MR. SWAIM: Mr. Chairman, the point here is,  
6 and the reason I asked Mr. Slenski to bring that up is,  
7 we will be back in the hanger shortly, up in Calverton,  
8 looking for more wiring, especially of that combined  
9 routing between the flight engineer station and the  
10 electronics bay, but that is the most shredded portion  
11 of the airplane. In the center photo behind us, Boeing  
12 said there is 150 miles of wire.

13           CHAIRMAN HALL: But you'll be able to know  
14 where the wiring came from, is my question.

15           MR. SWAIM: Yes, sir. Every six inches the  
16 wire is marked with a unique mark --

17           CHAIRMAN HALL: The hot stamp.

18           MR. SWAIM: -- as Mr. Slenski just showed  
19 you, and the marking tells us right where that wire  
20 came from, or at least the routing that wire came from.

21           CHAIRMAN HALL: And you said that hot stamp  
22 might be a problem, Mr. Slenski, is that --

23           MR. SLENSKI: I think it's recognized in the  
24 industry.

25           CHAIRMAN HALL: Gauging it down to the

1 Chairman's level here, is that something we should be  
2 concerned about?

3 MR. SLENSKI: Anytime you have a process that  
4 penetrates insulation, you need to be concerned. Now,  
5 this is a standard technique for marking, controllable,  
6 it's not a problem. We've used it in industry for  
7 quite a few years. It's being used today. I think  
8 back then -- I think we have better controls today, but  
9 I think, you seem to recognize that if you're going to  
10 mark wire by this process, you have to be very careful  
11 on the controls.

12 CHAIRMAN HALL: Do we know how much of the  
13 wiring we have already, Mr. Swaim?

14 MR. SWAIM: Well, from previous trips to  
15 Calverton, having lived up there for a little now, we  
16 have parts of that harness in at least three general  
17 areas of that six-acre hanger that I'm aware of. It is  
18 a fairly hefty wire bundle, it's -- Larry is working to  
19 put a picture up that's just a small portion of that  
20 bundle. There we go. This is the photo I used  
21 yesterday. There are two fingers sticking through the  
22 hole in the right side, where his finger just showed.  
23 The bundle is about three, three-and-a-quarter inches  
24 in diameter, where it goes off to the left of the  
25 photo.

1                   Right now it's a lot of shredded individual  
2 wires, and different piles of wires that are around the  
3 hanger. This is what I've said over and over, it's an  
4 active investigation, we keep going back, we keep  
5 spending weeks up there looking at just this type of  
6 thing.

7                   CHAIRMAN HALL: But if it arced, we might be  
8 able to find out within --

9                   MR. SWAIM: It's a needle in a haystack, but  
10 we will be looking.

11                  CHAIRMAN HALL: Thank you.

12                  MR. SWAIM: Mr. Hartonas, the surge  
13 suppression the FAA is considering, there were some  
14 press reports regarding induced energy tests --  
15 actually, before I speak to you, Mr. Hartonas, let me  
16 ask Mr. Hulm about the induced energy tests that were  
17 picked up by the press. We've done a lot of testing  
18 with Boeing. Can you elaborate on those induced energy  
19 tests, tell us something about those?

20                  MR. HULM: Yes, sir. As part of the  
21 investigation, we were asked to look into a number of  
22 different things, and this is just one area we wanted  
23 to gather some more information on. We did this in  
24 concert with the NTSB and the FAA.

25                  The question was posed, how much energy can



1 we induce from wiring that's adjacent to the FIQS wires  
2 -- let me start over again. The question was, the FIQS  
3 wiring from the flight engineers panel, down to the EA  
4 bay, how much coupling do we get from adjacent wires,  
5 and can that energy from that adjacent wiring get into  
6 the FIQS wiring, and then into the tank?

7 The technical term is induced electromagnetic  
8 interference. They're like electrical transients, and  
9 the nearest way to put that, I think maybe in real-  
10 world terms so people can understand it, it's like a  
11 magnet.

12 If you take a magnet, the closer you move it  
13 to like a paper clip, the stronger the field becomes,  
14 and all of a sudden you pick up, and if you move it  
15 away you can kind of feel the pull and the lessening of  
16 the strength, and if you go really fast, you kind of  
17 get a transient, that's what it would look like, you  
18 kind of feel a pull on your finger, and it will go  
19 away, and that's what these wires do as they generate  
20 electrical and magnetic fields, when an electrical  
21 pulse goes through them, and that pulse then gets  
22 transferred over to adjacent wiring, and that's the  
23 kind of thing -- we were asked to look at that and  
24 determine exactly what it would take to cause any sort  
25 of problem with the equipment in the tank.

1           So what we did was we got a full ship's head  
2 of center tank probes and the compensator, we got the  
3 wiring, the actual airplane wiring, and these stuff,  
4 and we got the wiring all the way from the spar, up the  
5 flight engineer's panel, we mocked up a little flight  
6 engineer's panel, with the national indicator that's  
7 used on the airplane, so that we have a relatively  
8 simulated environment, we thought, as close as we could  
9 get it to a laboratory, which is to simulate an  
10 airplane.

11           There's multiple phases to the testing, and  
12 it's a rather long test that we have in progress, and  
13 we're right in the middle of the fourth phase right  
14 now, but the first phase is to just check out the  
15 system to make sure we're correct, and we did, and it  
16 was okay.

17           The second phase was to induce these type of  
18 transients on the power wires going into the indicator  
19 and see if anything could get through the indicator,  
20 and into the wiring, and into the tank, and that looked  
21 okay, there were no problems there.

22           The third phase of that testing was what I  
23 would term as a severe stress test, and it did not  
24 necessarily represent anything we knew could be on the  
25 airplane at the time, but it represented to us an

1 environment that we should examine.

2 So what we did was we took 75 feet of wiring,  
3 and basically wrapped it around the FTS wiring that we  
4 had in the lab, and this was the ship's portion of it,  
5 and we attached that to a transient generating device.

6 In this case it's a giant relay coil. What  
7 happens with relays is that when you turn them on and  
8 off, they'll degenerate a nice voltage transient for  
9 you that can get coupled onto your wiring.

10 So when we did that under normal airplane  
11 conditions without any faults induced into the tank,  
12 there were no problems. We didn't see any arcing or  
13 any breakdown within the tank units themselves, or in  
14 the tank wiring.

15 The next part of that testing was to insert a  
16 piece of debris between the inner tube on the probe,  
17 and the inner surface of the outer probe, and what we  
18 did was we actually shorted that piece of debris  
19 directly to that inner tube, and then laid it up  
20 against the outer tube, so there was not a direct short  
21 circuit there, but it was laying up against it.

22 When we did the transient testing under those  
23 conditions, there was a small arc between the inner  
24 surface of the probe, or that outer tube, to that piece  
25 of debris we had, and that debris was either -- we used

1 two different kinds when we were doing this testing --  
2 either a thin piece of strand of steel wool, or a piece  
3 of lock wire, and in both instances we had little arcs  
4 that we could see at a curve right at that junction,  
5 where those two met each other.

6 CHAIRMAN HALL: They were arcs.

7 MR. HULM: Yes, sir, visible arcs. The next  
8 part of that is we had to determine how much energy is  
9 in those arcs then. There was a tremendous amount of  
10 time and a tremendous amount of effort put into that,  
11 because this is basically new stuff, and nobody has  
12 done this type of testing before, and it was a very  
13 difficult procedure to go through, and it took probably  
14 almost a month-and-a-half of steady testing in order to  
15 get to a method that we had some relative confidence  
16 in, even though right now we still need some way to  
17 collaborate some of the information we did get.

18 What we did find out is that we did have one  
19 instance during the testing, out of 70 different  
20 measurements that we took, or 70 different transients  
21 that we generated, where we exceeded the .2 milli-jewel  
22 limit that is the industry standard as far as our  
23 ignition energies.

24 At that point in time, the NTSB and the FAA  
25 have been participating totally with us on this, and

1 they've been witnessing all of our testing and  
2 everything. We had to make a decision whether this  
3 represented a real airplane environment, and we're  
4 basically conducting an experiment at this time, and we  
5 had to determine if there was an actual threat on the  
6 airplane, so what we did is we conducted the test on a  
7 747 at the same era that the TWA 800 airplane was  
8 built, and it was configured very similar to the TWA  
9 800 airplane.

10 We were able to use that airplane, it was an  
11 in-service airplane, so it wasn't like it wasn't in  
12 salvaged condition or anything. We were able to use  
13 the power system on that airplane for the testing, so  
14 we got as much of a real environment as totally  
15 possible, and what we did was we took our own set of  
16 probes down with us, and basically disconnected those  
17 from the tank, so we would not induce anything into the  
18 tank that we did not want to, because we wanted to make  
19 sure we didn't cause a hazard or anything, since that  
20 was an in-service airplane, and we connected it up to  
21 our own little ships at -- to our probes outside of the  
22 tank, so we reconstructed basically what we had in the  
23 lab, using a real airplane, and were able then to hook  
24 up our test equipment to these probes to determine and  
25 measure the voltage specs that we were getting on the

1 wiring, going into the tank.

2 There was a lot of work that went into this  
3 test. We did a lot of analysis, looking at all the  
4 airplane wiring, relative to the FIQS wiring, making  
5 sure that when we were doing a test that we exercised  
6 every component we knew that could be a possible  
7 inductive source for energy into that tank.

8 That testing showed that the voltages that  
9 were being induced in the wiring, as part of the real  
10 airplane itself, were extremely lower than what we were  
11 getting in the lab, and there was no indication from  
12 that test that any arc could be generated from the  
13 voltage transients that we saw from the airplane.

14 So that's kind of like where we're at with  
15 the testing right now. What we're going to be doing is  
16 taking that information and moving that into a  
17 laboratory environment, so we can do some additional  
18 investigation now on some of the information that we  
19 got from the airplane itself, and try some different  
20 failure modes that we weren't able to do on the  
21 airplane, because it was an in-service airplane, and we  
22 could not damage it in any way. So we're still just --  
23 that's kind of like we are at in the investigation  
24 right now.

25 MR. SWAIM: Very good. I'd like to mention

1 at this point that this has been a very long, drawn-out  
2 process, Mr. Chairman, it is not something that can be  
3 done quickly, and we've been getting a lot of support  
4 out of Mr. Hartonas and the FAA, and Mike Stockhill,  
5 out of our Seattle office, staying with Boeing on this  
6 program.

7 Mr. Hulm --

8 CHAIRMAN HALL: Before you get off that, let  
9 me ask --

10 MR. SWAIM: No, I'm not getting off it.

11 CHAIRMAN HALL: Okay. Well, go ahead.

12 MR. SWAIM: Okay.

13 CHAIRMAN HALL: I've got a question before  
14 you get away from it.

15 MR. SWAIM: Yes, sir. You mentioned you'd  
16 wrapped in the previous lab test the 75 feet around the  
17 harness, was that tightly wrapped like a coil, or was  
18 that a slow, just general spiral type of wrap?

19 MR. HULM: From what I understand, it was a  
20 slow, general spiral, maybe like a circle every foot or  
21 every two feet, but it was secured around the bundle  
22 itself, it wasn't laying loosely up against it.

23 MR. SWAIM: Okay. Now, what was the highest  
24 voltage you saw in those tests?

25 MR. HULM: In those tests it was

1 approximately 1,600 volts.

2 MR. SWAIM: Okay. What was your primary  
3 voltage, the voltage induced into the 75 foot, was it  
4 1,600 volts that you put into that original 75 foot?

5 MR. HULM: I don't recall that offhand, what  
6 the induced side was. I'd have to check, look at the  
7 lab tests.

8 MR. SWAIM: Mr. Hartonas, you were there, do  
9 you remember?

10 MR. HARTONAS: I believe it was 28 volts.

11 MR. HULM: No, that's the power that was  
12 supplied to the coil itself. What sort of transient  
13 the coil was generating, that I don't know. That's  
14 what you're asking, right?

15 MR. SWAIM: Very good. Mr. Chairman?

16 CHAIRMAN HALL: Well, my question is, you are  
17 familiar with the systems group report --

18 MR. SWAIM: Yes, sir.

19 CHAIRMAN HALL: -- which I've read, along  
20 with a little bit of other information, and on page ten  
21 of that there's a footnote down at 13 that says "The  
22 fuel quantity indication system and the number four  
23 engine fuel flow wires pass fluorescent cabin white  
24 wires of up to 350 volts AC in the shear grouting."

25 If you read all of this together, then you



1 know that there was the crazy fuel indicator we talked  
2 about, we know that they had a problem with the plane  
3 accepting fuel at loading, that was -- if I'm incorrect  
4 on any of this, correct me, but I'm taking this, that  
5 they had to pull the circuit breaker to fuel the plane,  
6 and that there had been some electrical problems with  
7 the lights.

8 Now, is the model you are recreating going to  
9 kind of explore, to be sure that, what's that word you  
10 used, where it jumps, or transfers, or --

11 MR. HULM: The electrical transient --

12 CHAIRMAN HALL: Yes.

13 MR. HULM: -- induced electrical transient.

14 CHAIRMAN HALL: Are you going to address  
15 that, is that being addressed?

16 MR. HULM: I don't know if the testing we'll  
17 do will specifically address the issue you're talking  
18 about. I think -- I don't -- as part of the  
19 investigation, this testing is basically rated to what  
20 we could induce. I think that will cover any sort of  
21 transient that may have been induced by the lighting  
22 wiring itself.

23 The specific wiring that you're talking  
24 about, the highest voltage that we have routing with  
25 the FIQS wiring that we have identified, was some cabin

1 lighting was back by the sidewall of the airplane, and  
2 that was only 200 volts.

3 CHAIRMAN HALL: Is that footnote correct, Mr.  
4 Swaim, is there 350 volts there, or is that not  
5 correct?

6 MR. SWAIM: I believe from the wiring diagrams  
7 we've looked at, it's correct. The primary input might  
8 be a little under 200 volts, as I remember. I'm doing  
9 this off the top of my head, sitting here. We'll go  
10 back and we'll explore that, and make sure.

11 CHAIRMAN HALL: Well, you just read all this  
12 and those things kind of jump out at me. They may not  
13 jump out at anybody else, but they --

14 MR. HULM: The analysis that we did showed  
15 that the highest voltage we had routing with the FIQS  
16 wiring was 200 volts. There is 300 volts in the  
17 airplane, and it may be this particular lighting  
18 circuit you're talking about, but that did not show up  
19 in our review as routing with the fuel quantity wiring,  
20 although it may be --

21 CHAIRMAN HALL: And you've gone through all  
22 the maintenance writeups on this airplane and the  
23 maintenance history, which we're going to get into in a  
24 later panel, as part of this --

25 MR. HULM: I personally have --

1                   CHAIRMAN HALL:  You personally -- you have  
2                   not.

3                   MR. HULM:  No, I have not.

4                   CHAIRMAN HALL:  Is there somebody with Boeing  
5                   that has that responsibility?

6                   MR. HULM:  Yes, sir.

7                   CHAIRMAN HALL:  Okay.  I want to ask that  
8                   question, because that's what I get when I read all  
9                   this information, I would like to know whether that is  
10                  a problem or not a problem.

11                  DR. BIRKY:  I have a couple of questions I  
12                  would like to pursue about that, if I could.  I assume  
13                  from  your discussions that --

14                  CHAIRMAN HALL:  Wait just one minute now,  
15                  here we go, and then I'll be quiet, and you-all have  
16                  the floor again.  This is in exhibit 9A of your docket  
17                  SA-516, and I'm on -- and this is on page 112, where it  
18                  says that "The raw bundle 1360 has a fuel flow number  
19                  four sigma wires, routed partially with bundle W350 on  
20                  the right side of the forward fuselage, close proximity  
21                  of fuel flow wires to 350 volts, AC power, and that  
22                  wire is 1306-L1892-22, of the cabin fluorescent  
23                  lighting transformer T-63, at station 360."  If you  
24                  could look into that, Mr. Hulm, I would appreciate it.

25                  MR. HULM:  I just think we were

1 miscommunicating a little bit. You're talking fuel  
2 flow again and I was talking fuel quantity, so that's  
3 the difference, but we'll look into that for you then.  
4 Thank you, sir.

5 CHAIRMAN HALL: According to his footnote it  
6 all comes together, it's bundled together.

7 MR. HULM: We'll look into that.

8 CHAIRMAN HALL: Okay. Go ahead, Dr. Birky.

9 DR. BIRKY: I assume that when you're doing  
10 these inductants tests, which I will call them that, if  
11 that's appropriate, you're not using the shielded wire  
12 to the tank, is that correct?

13 MR. HULM: We're using the configuration that  
14 was on the TWA 800 aircraft. That does contain a Hi-Z  
15 wire that is shielded, yes, but not the overall shield,  
16 as on some of the later 747s.

17 DR. BIRKY: So you're wrapping both wires  
18 together around the bundle, is that correct?

19 MR. HULM: We're wrapping the wire that's  
20 inducing the energy onto the FIQS wiring around all  
21 three wires that are going into the tank.

22 DR. BIRKY: Okay. When was that change made  
23 to all the wires that go into the center tank?

24 MR. HULM: At line number 244, there was some  
25 manufacturing instructions released at that time to add

1 additional shielding from the flight engineer's panel  
2 disconnect, down to the spar on all the FIQS wiring in  
3 the airplane.

4 DR. BIRKY: And the voltage you get is  
5 dependent on what factors when you do that test?

6 MR. HULM: The transfer voltage?

7 DR. BIRKY: Yes.

8 MR. HULM: It depends on the proximity of the  
9 source to the wire.

10 DR. BIRKY: And the number of turns per the  
11 length?

12 MR. HULM: Yes. The number of turns is more  
13 to make sure that you've got a really tight connection  
14 between the bundles, as opposed to adding additional  
15 energy into the -- you know, the more you would do  
16 that, it would induce more energy, but for the purposes  
17 of this test, it was almost negligible, that wasn't  
18 really taken into account.

19 If you took a piece of wire and you wrapped  
20 it, you know, within every quarter inch you had a turn,  
21 that's going to induce more energy than if you had it  
22 spread out over a longer distance, but the number of  
23 wraps we had, like one or two per foot, would not make  
24 a significant difference in the results. The idea  
25 there is that the wires couple tightly close to the

1 FIQS wiring.

2 DR. BIRKY: And was that designed to  
3 approximate the way the wires might be run in the  
4 aircraft?

5 MR. HULM: No, that was not designed to  
6 approximate any sort of installation that would be in  
7 the airplane. The test is basically a stress test on  
8 the system to see if we could get some sort of energy  
9 into the tank.

10 CHAIRMAN HALL: Well, I think it would be  
11 helpful if the results of that test could be made  
12 available for the public record, is that a problem?

13 MR. HULM: I don't know that to be a problem.

14 CHAIRMAN HALL: Good.

15 MR. SWAIM: We have some mention of that in  
16 the systems group report, as it is. It's an ongoing,  
17 open test. We've gotten to the third --

18 CHAIRMAN HALL: Well, Mr. Swaim, as you know,  
19 the American people rely on us to be their independent  
20 person on these investigations --

21 MR. SWAIM: We will put it in there, sir.

22 CHAIRMAN HALL: -- and Boeing is an  
23 outstanding corporation, and they've got 200,000  
24 employees, and build excellent aircraft, but we're  
25 testing something here, and it might possibly -- it may

1 or may not have anything to do with what caused this  
2 accident to occur, and we need to ensure that the test  
3 protocol and what's being done is understood and  
4 available for everybody, or you and Dr. Birky need to  
5 go and do your own tests for us.

6 MR. SWAIM: Yes, sir.

7 CHAIRMAN HALL: Okay?

8 DR. BIRKY: Can I come back and ask Mr. Hulm  
9 another question at least on this test. You indicated  
10 that the shielding was on both wires has been changed  
11 on subsequent aircraft. Do you know why that was done?

12 MR. HULM: What's written in the  
13 manufacturing paper, because it was released to do  
14 that, was that they were having problems with the  
15 accuracy of the system at the low end, when the gauge  
16 was reading near zero, and they were attributing that  
17 to interference from different systems in the airplane,  
18 so they added the additional shieldings and removed  
19 that interference so that they could calibrate the  
20 indicators correctly.

21 DR. BIRKY: So the shielding does percent RF  
22 pickup, is that correct?

23 MR. HULM: That's correct. Yes.

24 DR. BIRKY: That's all for right now.

25 Thanks.

1                   MR. SWAIM: I have one last question in this  
2 area. You've not had a chance to go back, and you  
3 don't know what my question is going to be anyway,  
4 so --. Two months before the accident the number four  
5 fuel flow indicator, quote, "Pegged high and  
6 inoperative," unquote.

7                   According to Ms. Eckrodes (ph.) factual  
8 report on maintenance, factual report, exhibit 11A,  
9 page 24, "The writeup said that the maintenance  
10 personnel suspected wiring, but that the system passed  
11 all tests." Is this the kind of thing that, you know,  
12 transient like this, that you're talking about with  
13 your EMI problems, your interference type of problems?

14                  MR. HULM: Well, without speculating too far,  
15 these transients are very short in nature, you're  
16 talking milliseconds --

17                  MR. SWAIM: Milliseconds.

18                  MR. HULM: Yes. -- if not microseconds in  
19 some instances, so I don't think any -- anything that  
20 could be observed, like a fuel flow meter problem,  
21 would not be as a result of these type of transients.

22                  MR. SWAIM: Mr. Hartonas, is an electrical  
23 engineer with the FAA, and looking at it from your  
24 standpoint, I mean there's the Boeing standpoint, and  
25 you've been doing your testing, and we've been doing



1 testing with the parties, which includes you, that the  
2 FAA has got its own expertise, what do you see as far  
3 as latent failures, or single-level failures that could  
4 affect this fuel quality system? Do you see anything?

5 Is there anything the FAA is doing that we're  
6 unaware of?

7 MR. HARTONAS: The FAA has participated in  
8 this investigation from the start, and we diligently  
9 have gone out looking for possible ignition sources of  
10 a latent nature. We could include failures of a latent  
11 nature, such as conductive debris in the tank, that  
12 could bridge probes. We could say that the copper  
13 sulfur may be of a latent nature, bridging probes.

14 MR. SWAIM: But if you have conductive debris  
15 in the tank, and I know in our systems factual we  
16 mention --

17 CHAIRMAN HALL: What is conductive debris,  
18 so, again, I'll understand?

19 MR. SWAIM: Okay. If we have bits of metal  
20 from the sump or the bottom of the fuel tank that gets  
21 picked up, and we found documented in the factual  
22 reports, the nine exhibits, that some, say, steel wool,  
23 and some other metal were found in the fuel pumps, so  
24 I'm saying now, without the background, if some of that  
25 safety wire, steel wool type of debris -- what kind of

1 problems could that create for the fuel probe, let me  
2 put it that way.

3 MR. HARTONAS: I didn't quite finish. I  
4 mentioned the copper sulfur perhaps being a dormant  
5 developing type failure, a latent failure, conductive  
6 debris, in the same category. Damaged wire insulation  
7 also falls under the category, but you also need two  
8 conductors to fail, or the insulation of two conductors  
9 to fail.

10 Those in themselves, those in themselves  
11 could not be an ignition source, could not spark an  
12 ignition. You would have to have some type of energy  
13 getting into the tank, a hot short, perhaps, or an  
14 induced transient, which could be -- lightening  
15 produces such transients.

16 Those voltage sources, in combination with  
17 conductive debris, copper sulfur, the damaged wire  
18 insulation, or damaged probes, are the ones that could  
19 present the combination for a possible ignition source.  
20 That is why the FAA has taken the prudent action, as we  
21 have with the NPRM.

22 CHAIRMAN HALL: Does that answer your  
23 question?

24 MR. SWAIM: I think it does. It does.

25 MR. HULM: I wonder if I could clarify one

1 thing, though.

2 MR. SWAIM: Please.

3 MR. HULM: Mr. Hartonas referred to  
4 lightening as being a possible source like this. I  
5 think people must understand that these airplanes are  
6 protected against lightening strikes. The proper  
7 shielding exists on the wiring along the leading edge  
8 of the wing itself, and the structural design of the  
9 airplane, which Mr. Thomas could speak of more fluently  
10 than I could, is designed to protect against lightening  
11 strikes, so in that instance I guess I'd like to  
12 clarify that. Our systems are protected against that  
13 source of energy in the tank.

14 MR. HARTONAS: I agree with that statement,  
15 Mr. Hulm. I was referring to the broken shield that  
16 was discovered in the exhibits, certain shields tend to  
17 deteriorate with time on the airplane. I just don't  
18 like to speculate on scenarios.

19 The NPRM, in fact, is out for the comment  
20 period, 90 days, and we'll review all the data and  
21 findings in the conclusion of those 90 days.

22 MR. SWAIM: But let me go to Mr. Slenski for  
23 a moment. Is this a way that, I know I'm jumping into  
24 the aging panel, but is this the way that shielded  
25 wiring brakes down, where the shielding can penetrate

1 or somewhat penetrate to the inner conductor?

2 MR. SLENSKI: Well, actually, that's an  
3 interesting question, because you might ask, why do we  
4 put silver on copper anyway. We put it on there to  
5 make it conductive, because copper oxidizes fairly  
6 quickly, normally, silver stays fairly surface  
7 conductive, and part of the shield integrity is to  
8 maintain very low conductivity, it all interfaces in  
9 connections.

10 So if you degraded that silver interface, you  
11 could actually increase resistance of your shield, and  
12 that would lower your shielding capability, basically.

13 MR. SWAIM: Okay. But one aspect of Mr.  
14 Hartonas's answer, could that provide us with a small  
15 spark gap, essentially, if the inner insulation is  
16 breached by degrading shielding?

17 MR. HARTONAS: We recommended the testing for  
18 different scenarios in failing a shield. I think it's  
19 part of the continuing investigation.

20 MR. SWAIM: Okay. Very good.

21 MR. SLENSKI: What you're saying is possible,  
22 no doubt about it.

23 MR. SWAIM: Has it been seen as a breakdown,  
24 an aging mechanism of shielded-type wiring?

25 MR. SLENSKI: The shielded wire, what I was

1 referring to, there had been issues where loss of  
2 conductivity, if you're talking about breakage of the  
3 shield, and somehow getting arcing, I --

4 MR. SWAIM: Or to puncture the inner  
5 insulator with the broken shielding.

6 MR. SLENSKI: Now, what you're talking about  
7 is the primary conductor shorting to the shield.

8 MR. SWAIM: Yes.

9 MR. SLENSKI: That's definitely -- that has  
10 been a problem.

11 MR. SWAIM: That has been. Thank you.

12 MR. SLENSKI: I have seen failures associated  
13 with that.

14 CHAIRMAN HALL: Do we have a picture of that,  
15 with the shield, and a --

16 MR. SWAIM: Mr. Johnson had a picture where  
17 he had looked at the shielding, and they might be able  
18 to flip that up. There is the shielding inside the  
19 outer layer of insulation, inside that shielding is  
20 another layer of insulation, and I should probably let  
21 Mr. Slenski explain it, and Mr. Johnson, rather than  
22 myself.

23 MR. JOHNSON: I think what you're pointing  
24 out here is obviously the --

25 MR. SWAIM: The shield is something on the

1 wire, it's not something separate.

2 MR. JOHNSON: The shield is there to protect,  
3 obviously from electrical shielding, but underneath  
4 that shield is another primary conductor that's also  
5 insulated, and the scenario you're dealing with here is  
6 if you penetrate that primary insulation, you could  
7 actually have a short between the shield, which is  
8 ground, and your primary wire, which may have a  
9 potential on it, and I have seen that in the field, as  
10 a failure.

11 CHAIRMAN HALL: Thank you.

12 MR. SWAIM: As a matter of clarification, a  
13 question from the tech panel here, the Madrid 1976 747  
14 that was involved in an accident, was that a similarly  
15 manufactured airplane to the TWA 800 airplane, was that  
16 of the same vintage, do you know?

17 MR. THOMAS: As far as I know, yes, it was a  
18 very similar vintage airplane.

19 MR. SWAIM: Very similar along the  
20 production, that they would have been wired  
21 approximately similar?

22 MR. THOMAS: Yes.

23 MR. SWAIM: Okay. In that one, do you  
24 remember, Mr. Thomas, what the cause of that accident  
25 was, or Mr. Hartonas?

1                   MR. HARTONAS: I did not investigate that  
2 accident; however, it was stated that it was due to  
3 lightening strike. How exactly it happened, I have not  
4 read the report.

5                   MR. SWAIM: Very good. Thank you. Mr.  
6 Thomas, do you have anything to add to that?

7                   MR. THOMAS: No. As far as I remember, it  
8 was attributed to a lightening strike. I don't believe  
9 any definitive ignition inside the tank was identified  
10 from the lightening strike.

11                   MR. SWAIM: Very good. Since we have Mr.  
12 Thomas again, we've been dealing very heavily with --  
13 well, let me ask one last question regarding the fuel  
14 probes. We have two of the fuel probes that Mr.  
15 Johnson showed us before we were removed them from the  
16 airplane, these are still in the airplane, and with the  
17 wiring coming up beneath those fuel probes, there is  
18 apparently little commonality to how the wiring is  
19 routed to the fuel probe, up through the clamping, into  
20 the terminal block.

21                   Is there a Boeing specification back in the  
22 seventies that would have said, this is how you route  
23 these wires into this field probe?

24                   MR. COLLINS: The way that's usually  
25 controlled is that there are drawings, a three-

1 dimensional drawing of the probe itself, and it shows  
2 the wiring going to it, and it should have been  
3 standardized at that point in time.

4 I'm not familiar exactly with what those  
5 show, but as part of the series three terminal block,  
6 when we go in and look at these probes, we'll ensure  
7 that we standardized the wiring to each probe so that  
8 it's non-interference will not cause any more damage to  
9 the wiring itself.

10 MR. SWAIM: In the service bulletin?

11 MR. COLLINS: Correct.

12 MR. SWAIM: Okay. Could you please provide  
13 us some kind of a description to how it was done, after  
14 the hearing, as a follow-up action, provide us some  
15 kind of a record as to how it was done back then, would  
16 that be possible?

17 MR. COLLINS: Yes, sir, I'll try to find that  
18 for you.

19 MR. SWAIM: Okay. Thank you. Mr. Thomas, in  
20 theory, or in actual history, actually, Mr. Collins,  
21 I'm sorry, what kind of pump failures could or in the  
22 past have led to ignition of fuel tanks, that you're  
23 aware of?

24 MR. COLLINS: I'm not personally aware of any  
25 fuel tank explosions that were caused by fuel pumps.



1 The things I've investigated or dealt with --

2 MR. SWAIM: But in the literature?

3 MR. COLLINS: You talked about some failures  
4 earlier that the group had looked at under this  
5 investigation, and that listed some areas where we have  
6 concerns that types of failures may create ignition  
7 sources inside the pump, and things like that, which is  
8 why the pumps are explosion proof.

9 I mentioned earlier a reevaluation of fuel  
10 systems and part of that is to look at the possible  
11 mechanical failures, contamination being brought into  
12 the inlet of a pump, and we will be requiring that the  
13 sections of pumps and heated tanks, or tanks near  
14 heated equipment, that those pumps stay covered with  
15 liquid, or have a flame arrester to preclude any flame  
16 that may, or spark that may be in the inlet of the pump  
17 from igniting vapors. But I don't know of any from the  
18 stuff I've looked at, that have actually occurred.

19 MR. SWAIM: Okay. Larry is working on  
20 bringing up a photo of material, foreign material found  
21 in some fuel pumps, and I believe this is in the  
22 exhibits.

23 Most of it is tank sealant, sealant from the  
24 bottom corners of the tank, and it is mentioned, I know  
25 in the factuals were mentioned pieces of metal found in

1 some of the pumps or pump housings. What can this do  
2 to the pump internally? Is this something that is not  
3 a problem, Mr. Collins?

4 MR. COLLINS: Sufficient contamination may  
5 lock the rotor, so the motor is trying to turn the  
6 pump, and it can't turn. That's one of the basis of a  
7 qualification test run, before the system is  
8 certificated to show that that doesn't create  
9 temperatures, and that they create auto-ignition.

10 MR. SWAIM: Okay.

11 MR. COLLINS: We did look at some pumps in  
12 this investigation that had contamination in there, but  
13 I don't recall any signs of damage to the pump, or  
14 heard any reports of it causing ignition-type damage.

15 There were some that were reviewed, and the  
16 maintenance records where they had been removed, and  
17 there were foreign objects in the inlet, but I don't  
18 recall the specifics of the removal causes.

19 MR. SWAIM: Okay. We have a picture up there  
20 of tank sealant, I used that term without explaining  
21 what it was. It's the rubberized sealant that the  
22 finger is pointing to.

23 Mr. Thomas, in fuel pumps, how coarse of a  
24 piece could get through -- well, is there a screen  
25 between flakes of paint sealant from places like this,

1 and the pump itself?

2 MR. THOMAS: Yes, there is.

3 MR. SWAIM: How fine or how coarse, actually,  
4 of a piece could get through that screen?

5 MR. THOMAS: The screens on the larger pumps  
6 are full mesh, which means if you look at the  
7 microphone, you're looking at a mesh. If you could  
8 have four of those wires per inch --

9 MR. SWAIM: A quarter-inch, essentially.

10 MR. THOMAS: Basically, it's slightly smaller  
11 than a quarter-inch length of the wire sizes, yes.

12 MR. SWAIM: Okay. So slightly less than a  
13 quarter-inch.

14 MR. THOMAS: Yes. On the scavenge pump,  
15 there are 12-mesh, so a tenth-of-an-inch on the very  
16 bottom of the scavenge pump, and then a quarter-inch  
17 mesh, one inch up.

18 MR. SWAIM: Is it conceivable that a piece of  
19 conductive debris could get through there, or metal, a  
20 piece of metal could get through there and caught in  
21 the impeller, and through being rubbed against the pump  
22 housing, create a hot point, and that point, just going  
23 somewhere, is that conceivable?

24 MR. THOMAS: It's hard to conceive of that.  
25 Let me walk through that process.

1 MR. SWAIM: Okay. Please.

2 MR. THOMAS: You have the -- the pump is  
3 running 99.99 percent of its time pumping, doing what  
4 it's supposed to do, pumping fuel. Most of that debris  
5 is probably washed into the pump, if you can imagine  
6 small pieces going through a fine-mesh screen, being  
7 sucked by the fuel, being carried along by the fuel  
8 into the pump.

9 In the case where the pump is -- so a jam at  
10 that point, as Mr. Collins said, if you got into the  
11 pump and jammed, the pump would stop, and the circuit  
12 breaker would lull, and the pump would stop working, or  
13 alternatively, small pieces would flow through the pump  
14 impeller, the impeller has fairly large passageways  
15 anyway, would flow on, and would eventually get caught  
16 in the engine filters themselves. So that's the normal  
17 process that would take place.

18 If you look at the case where the pump is  
19 dry, in other words, the tank is empty, and the pump is  
20 left running, which is maybe a few minutes until the  
21 flight engineer turns the pump off, the pump has a very  
22 low suction capability to pull air through the pump.

23 We have a check valve on the discharge side  
24 of the pump, which is specifically designed to make  
25 sure the pump can't force air into the engine features,

1 because the engine itself doesn't like air, it tends to  
2 cough and burp.

3 So we make sure that when the override pump  
4 runs out of fuel, that check valve goes closed, so it  
5 tends to be a natural protection against the override  
6 pump, in this particular case, forcing air into the  
7 engine, so that really makes the pump work as a very  
8 poor air pump, it doesn't want to suck things up when  
9 it's running on air. So you kind of have this mixed  
10 match.

11 If I have a piece of debris being flushed  
12 along by the fuel, it jams the pump, or the pump is in  
13 the fuel. If you have a piece of debris when the pump  
14 is running dry, then the pump can't suck the piece of  
15 debris up into the inlet, so it tends to be self-  
16 protecting.

17 I could imagine an extremely remote case,  
18 something happening in the last two seconds, where the  
19 pump runs out of fuel, but it's an extremely remote  
20 case, I can't even imagine it happening, in reality.

21 CHAIRMAN HALL: Could we find out and  
22 establish how many pumps there are, what we referring  
23 to, in the center tank?

24 MR. SWAIM: In the center tank? Go ahead,  
25 Mr. Thomas.

1                   CHAIRMAN HALL: No. How many pumps there are  
2                   in the whole thing.

3                   MR. THOMAS: Okay. As I explained yesterday,  
4                   was it yesterday --

5                   CHAIRMAN HALL: I think it was, yes.

6                   MR. THOMAS: -- or the day before yesterday,  
7                   they have two override pumps in the center wing tank,  
8                   and a scavenge pump, there's three. Two are relatively  
9                   large pumps that are designed to supply fuel to the  
10                  engines, and a very small pump, this size, which is the  
11                  scavenge pump, that is designed to pick up the remnants  
12                  of the fuel in the bottom of the tank, where the big  
13                  pumps can't pick up themselves.

14                 CHAIRMAN HALL: So all this conversation  
15                 we just went through, does that apply to all three  
16                 pumps --

17                 MR. THOMAS: Yes.

18                 CHAIRMAN HALL: -- or just to the scavenge  
19                 pump?

20                 MR. THOMAS: It will apply to all three  
21                 pumps.

22                 CHAIRMAN HALL: Okay.

23                 MR. SWAIM: The point I'm going to here,  
24                 though, is we did find material in the pumps, but  
25                 metal, and this rubbery tank sealant, and it has been

1 found to not be beneficial for the pump. Why isn't  
2 there more of a screening put in there? Would it be  
3 possible to put in some type of a flame arrester, such  
4 as we have for the vents out at the wing tips?

5 MR. THOMAS: The short answer, where we  
6 designed the systems, the interest was keeping large  
7 pieces of debris out of the pump, so the pump wouldn't  
8 get jammed by a large piece of the debris.

9 In looking at this whole accident, and trying  
10 to say what else could we do, there was the question  
11 that the Chairman asked on Monday, what else could we  
12 do to the airplane to help improve it, we have started  
13 looking at putting a kind of flame arrester  
14 installation in the scavenge pump.

15 We're testing that right now even as we speak  
16 to try and determine the right configuration for that,  
17 a flame arrester in the scavenge pump inlet.

18 That would provide protection against some  
19 strange ignition source that may occur in the scavenge  
20 pump itself, even though we have no data in history  
21 that says it happens. We're, again, extending  
22 ourselves over and above what we've done. We're  
23 looking at that very hard at this point.

24 The concern we have is, now, do we start  
25 picking up lots of little pieces of debris on that

1 flame arrester, which is a very small hole, it's fifty-  
2 or sixty-thousandth of an inch in diameter, a series of  
3 them in almost a honeycomb design. Whether or not we  
4 now start accumulating more --

5 CHAIRMAN HALL: Is this a phenomena, also,  
6 Mr. Thomas of aging, that the tank flakes, or does a  
7 new tank flake, or have you ever looked at all that?

8 MR. THOMAS: I'm not a sealant expert, so I  
9 really don't know. I can certainly inquire of our  
10 people.

11 CHAIRMAN HALL: Yes. We're going to get into  
12 the aging aircraft panel again, and I just didn't know,  
13 is that something that's --

14 MR. THOMAS: I don't know whether it's an  
15 aging problem, or small pieces of sealant. As the  
16 photograph showed earlier, you kind of put the sealant  
17 around the bolts and along all the interfaces, whether  
18 or not a small piece at the end will come loose, be  
19 jarred loose, I don't know if that's an aging problem  
20 or not. I will certainly happily take an action item  
21 to have it looked into.

22 CHAIRMAN HALL: Thank you.

23 MR. SWAIM: We found a photo here of what  
24 we're talking about. There is the inlet and the screen  
25 for the scavenge pump anyway. Now, I believe that one



1 has a finer filler, does it not?

2 MR. THOMAS: Yes. That's the 12-mesh. The  
3 screen itself is approximately two inches high. The  
4 bottom inch is a 12-mesh screen, and the  
5 tenth-of-an-inch hole diameter at top is, I believe is  
6 a quarter-of-an-inch mesh, the top one inch of the  
7 screen.

8 MR. SWAIM: Are there any potential problems  
9 with putting a flame arrester in this inlet? I'm not  
10 trying to appear beneficial to you, it's just that I'd  
11 hate to go through this accident investigation and do  
12 my next one, because the flame arrester created a  
13 problem.

14 MR. THOMAS: As far as the scavenge pump is  
15 concerned, the biggest question is how quickly would  
16 the screen plug up. In other words, you're changing  
17 from this normal kind of screen to a finer diameter  
18 screen, would it plug up and cause additional  
19 maintenance problems. I don't see that there'd be a  
20 safety issue.

21 MR. SWAIM: But this is the exterior of the  
22 tank, right?

23 MR. THOMAS: This is the inside of the tank.  
24 No, sir. This is the inside of the tank.

25 CHAIRMAN HALL: So this part is inside,

1 because that scavenge pump, part of it's outside the  
2 tank, right --

3 MR. THOMAS: Yes.

4 CHAIRMAN HALL: -- but this is inside.

5 MR. THOMAS: Yes. This is, basically, you  
6 can leave the picture there, this tube that you see in  
7 the picture, this thing is almost immediately in the  
8 middle of the tank, centered in the tank. The tube  
9 itself runs aft to the rear spar, so it's about six- or  
10 eight-foot run of tubing to the pump itself, and what  
11 we're looking at is, can we put a flame arrester in  
12 that tube that will provide additional protection and  
13 enhancement to the design.

14 CHAIRMAN HALL: So it wouldn't be where you  
15 could clean it out, really.

16 MR. THOMAS: You would have to go into the  
17 tank to clean it, and that's the issue I was  
18 addressing.

19 CHAIRMAN HALL: Did I keep hearing you-all  
20 say that it's bad to go into the tank? Can someone  
21 explain in the simplest terms possible why it's bad to  
22 go into the tank --

23 MR. THOMAS: I think that --

24 CHAIRMAN HALL: -- other than I understand  
25 you have to take the plane down, and empty the tank,

1 and do a lot of things. Is there a safety reason?

2 MR. COLLINS: The main concern we have is  
3 causing damage, due to the tank entrance, to systems  
4 that could later cause failures, damaging wires, or  
5 components probes.

6 CHAIRMAN HALL: So whoever is in the tank is  
7 an unguided missile, or something, and damaging things  
8 that --

9 MR. COLLINS: No, I didn't say that, but  
10 there is a risk any time you open a system for  
11 maintenance.

12 CHAIRMAN HALL: Okay. That's why -- I just  
13 didn't know whether it was something else. I thought I  
14 understood that, but I wanted to be sure.

15 MR. THOMAS: All of the mechanics who are  
16 allowed tank entry have to go through very specific  
17 training for tank entry, it's a very confined tank.  
18 Try and crawl into a fuel tank -- the 747 is a big  
19 airplane, fairly short guys like myself can stand up in  
20 the center wing tank.

21 The wing tanks are very small, they're very  
22 difficult to crawl into, and there's just a general  
23 philosophical concern of people just banging things as  
24 they're trying to get out, and those kinds of issues.  
25 The mechanics are trained to be very careful in doing

1 so, but it is that finite risk of something happening.

2 CHAIRMAN HALL: Maybe the IM can tell us the  
3 size of the person that goes in the tank. Go ahead,  
4 Bob.

5 MR. SWAIM: Okay. We found that this is a  
6 compensator in the bottom of the fuel probe in the  
7 center tank of that derelict airplane we were  
8 discussing before, 105, and the wires hanging down to  
9 the compensator, and the tube that's under, is to the  
10 right side of the picture, it's a greyish, silver tube,  
11 has got a number of dents pointed out with the arrows,  
12 so you can see, there is some kind of possible damage  
13 that we've seen in our investigation, which is  
14 essential to what Mr. Thomas was saying.

15 Mr. Collins, what are the requirements for  
16 protection of fuel pumps from foreign objects?

17 MR. COLLINS: It's a basic requirement that  
18 to perform their function between maintenance  
19 intervals, and for the pumps, there are no scheduled  
20 maintenance intervals, and if they don't create  
21 failures, an adverse failure, stopping the function  
22 safely would be an acceptable failure, for instance.

23 The cause of an ignition source is definitely  
24 not an acceptable failure, so they have to be installed  
25 to protect against any kind of adverse failures.

1           MR. SWAIM: Okay. A point of clarification  
2           for Mr. Thomas. Yesterday, somebody had mentioned the  
3           vent system having a flame arrester in the 747, the way  
4           it was said, it was generic. Did the accident airplane  
5           have a flame arrester system?

6           MR. THOMAS: No, it did not. It had the  
7           equivalent of a flame arrester system known as a surge  
8           tank suppression system. This consists of a  
9           photoelectric cell looking at the tube from the  
10          outboard, outside of the airplane, into the search  
11          tank.

12          That photoelectric cell is looking for a fire  
13          coming in from the outside of the tank, out from the  
14          atmosphere, outside the airplane, into the fuel tank.  
15          The photoelectric cell is wired to, I believe it's  
16          three Freon canisters that act as fire extinguishers,  
17          so the intent of the system is if it detects a fire  
18          coming in from the outside, say in a ground fire  
19          condition, it would fire those freon bottles and flood  
20          the search tank with a freon fire extinguishing agent  
21          and stop the fire from progressing into the rest of the  
22          airplane.

23          The flame arrester was, in effect, a no  
24          moving parts replacement for that system. The surge  
25          tank suppression system had several problems of people

1 shining flashlights up and saying, is this where the  
2 system is, and the photoelectric cell reacting to the  
3 flashlight, and firing the system, and the mechanic  
4 than has to go in there and replace the freon bottles.

5 So those kinds of issues encouraged us and a  
6 lot of the operators to switch to a flame arrester  
7 system.

8 MR. SWAIM: Mr. Collins, building on that,  
9 what are the regulatory requirements the FAA has to  
10 prevent ignition from coming in through the vent  
11 system, or from going tank to tank through the vent  
12 system.

13 MR. COLLINS: The regulations requiring  
14 flames coming in the vent system are really a  
15 lightening protection issue. There's a rule-making  
16 project to require flame arresters at the vent entrance  
17 on the airplane, and that's to protect against ground  
18 fire effects coming in the vent system. Again, that's  
19 a rule-making project, it's not a regulation at this  
20 time.

21 MR. SWAIM: Okay. Tank to tank.

22 MR. COLLINS: Tank to tank, the method of  
23 preventing flames from going to tank to tank is to  
24 prevent a flame in a tank in the first place. There is  
25 no requirement to have any sort of tank-to-tank flame

1           arresters, or anything like that.

2                       The problems inherent with that is when you  
3           install a flame arrester in the vent outlet, you also  
4           have to protect against clogging or freezing over with  
5           ice of that vent flame arrester, so you need to have  
6           relief valves during climb and during descent, to  
7           protect against over pressure in the tanks, or under  
8           pressure during flight. So there is no regulation  
9           requirement for flame arresters between tanks.

10                   MR. SWAIM: Very good. Mr. Chairman, it's  
11           been a long time coming, I'm coming down to the end of  
12           that list of questions.

13                   CHAIRMAN HALL: All right.

14                   MR. SWAIM: I'd like to ask my fellow members  
15           of the technical panel.

16                   CHAIRMAN HALL: All right. Dr. Birky, do you  
17           have any additional questions?

18                   DR. BIRKY: I have a couple, if I might.

19                   CHAIRMAN HALL: All right.

20                   DR. BIRKY: The first one is, I'd like to go  
21           back to Mr. Hulm a little bit, and I guess I'm missing  
22           something in this RF induced voltage experiment you  
23           were doing with 75 feet of wire. What were you trying  
24           to simulate with that experiment?

25                   MR. HULM: We were just stressing the system

1 to a very high level to see what would happen in the  
2 tank under normal operating conditions and under  
3 failure conditions. We weren't necessarily trying to  
4 simulate any known airplane environment. We were  
5 taking a past, what we know today, and trying to find  
6 out if there's something else we don't know about.

7 DR. BIRKY: And that wire bundle that you --  
8 you had this FIQS wire running in, do you have  
9 something that turns off at a high enough rate that you  
10 used as -- relate to do, switching on and off?

11 MR. HULM: The wire that induced the voltage  
12 onto the FIQS wiring itself, that wire is hooked up to  
13 a switch, which is hooked up to a relay, so we could  
14 turn on that relay and turn off that relay, and every  
15 time we did that, that induced a very short voltage --

16 DR. BIRKY: I understand that.

17 MR. HULM: I'm sorry. Maybe I'm missing your  
18 question then.

19 DR. BIRKY: Well, I guess, isn't that induced  
20 voltage dependent upon the rate at which you turn the  
21 power on and off, the voltage?

22 MR. HULM: Well, the switch time is what's --  
23 we used the standard switch, and that's really what  
24 controlled the rate of change between --

25 DR. BIRKY: So you manually used the switch,



1 you didn't use the re-power relay for that.

2 MR. HULM: Well, yes, it was just a normal  
3 switch, with a spring contact on it, and that had a  
4 certain transition time, and that's the what then  
5 controlled the length of the transient that was being  
6 induced onto the wiring.

7 DR. BIRKY: And you were able to get 1,600  
8 volts in the experiment, is that correct?

9 MR. HULM: We had a very large power  
10 contactor-type relay, that's the kind we were using, I  
11 mean a very large relay coil attached to that wiring,  
12 yes. We were able to generate up to 1,600 volts.

13 DR. BIRKY: What was the primary voltage  
14 again, I've forgotten, 32 or 28 volts, is that correct?

15 MR. HULM: It was a 28-volt relay coil, yes.  
16 It was a 600 milliamp coil. That's the rating of the  
17 cross electric current that it took to actuate the  
18 coils, which is a very large relay.

19 DR. BIRKY: Well, the size of the relay  
20 doesn't determine how much voltage you get induced in  
21 that, does it?

22 MR. HULM: Well, it will determine the actual  
23 length of it, because it will store a lot more energy,  
24 right? So that particular coil itself was generating  
25 very large, very long transients.

1 DR. BIRKY: Okay. Well, we can pursue that  
2 later --

3 MR. HULM: Okay.

4 DR. BIRKY: -- privately, I think.

5 MR. HULM: Yes, sir.

6 DR. BIRKY: The second question I had was  
7 dealing with, yesterday we talked about this inspection  
8 system, I don't think we asked you what were the  
9 primary findings, what you did find from those aircraft  
10 you inspected, the 52 aircraft you inspected to date.  
11 You gave us a conclusion from that, but you didn't tell  
12 us what you found in those 52 aircraft.

13 MR. HULM: What we did find was that a large  
14 majority of the airplanes met the original  
15 manufacturing specification, and of those that didn't,  
16 there were none that exceeded a hazard level for the  
17 airplane that would result in some sort of an ignition  
18 source in the tank that we were concerned with.

19 What we're finding from the airlines, in  
20 their report back, and what we have in our information  
21 is that as they do these measurements, and they record  
22 the data for us, if it doesn't meet the original  
23 manufacturing specification, which allows a certain  
24 amount of degradation before you hit any sort of hazard  
25 level, is that they re-work the bond or the ground back

1 to the original manufacturing specification, and that's  
2 the kind of data we're getting back.

3 DR. BIRKY: So some of the wires you  
4 inspected did not have proper grounding on components,  
5 is that what I'm hearing you say?

6 MR. HULM: It's mostly a matter of degraded  
7 bonds or grounds, is that they've kind of slid over  
8 time, which is kind of to be expected. Most of them  
9 had stayed within, but over time they've just slightly  
10 drifted out of tolerance.

11 DR. BIRKY: How would you decide if they're  
12 out of tolerance that they would not be a risk or an  
13 increased hazard to an ignition?

14 MR. HULM: That's a detailed analysis. We  
15 have an entire group working on the data itself, and  
16 reviewing all of the information coming back from the  
17 airlines, and we look at each installation  
18 individually, and determine exactly what the particular  
19 bond or ground was there for, and based on what's  
20 there, whether it's static, then we evaluate if it's  
21 still within acceptable limits or not, and we've found  
22 everything so far within acceptable limits.

23 DR. BIRKY: I thought you said some of them  
24 were outside the --

25 MR. HULM: They were outside the original

1 manufacturing specification. I mean there's still a  
2 buffer between that and something then that would  
3 result in an ignition -- if it goes slightly out of the  
4 manufacturing spec, it's not a hazard to the airplane.

5 DR. BIRKY: Do you have a criteria by which  
6 you make those decisions, whether they are a risk or  
7 not, or when you go back and re-do it, the bonding?

8 MR. HULM: Well, we make them -- the  
9 instructions in the service bulletins themselves say  
10 that, because the original manufacturing specification  
11 says to go ahead and re-work it, so we don't say, well,  
12 if it's this much above the original manufacturing,  
13 then you can leave it alone, we just say bring it back  
14 down to the original condition, when it was as the  
15 airplane was delivered.

16 CHAIRMAN HALL: Now, that's over time.  
17 What's over time? Can you put a definition on that?

18 MR. HULM: Well, we're inspecting the entire  
19 747 fleet, so it's -- right now it's 30 --

20 CHAIRMAN HALL: When would have been the last  
21 time they checked? Were they checked on C-checks?

22 MR. HULM: These particular bonds and grounds  
23 are never checked in the tank.

24 CHAIRMAN HALL: Never checked.

25 MR. HULM: That's correct, sir.

1 DR. BIRKY: I have no further questions.

2 CHAIRMAN HALL: Thanks. Let me understand  
3 this, you mean the things inside the tank that are  
4 supposed to be grounded are never checked.

5 MR. HULM: If a component is removed for any  
6 sort of maintenance --

7 CHAIRMAN HALL: Then it's checked.

8 MR. HULM: -- and it has a bond and ground,  
9 once that's installed back in, it has to be installed  
10 per the manufacturing drawing, and all the other bonds  
11 and grounds are not checked on it, as far as I know.

12 CHAIRMAN HALL: What's the air force policy  
13 on that, do you-all know?

14 MR. SLENSKI: I'm not aware of the air force  
15 policy on that.

16 CHAIRMAN HALL: Could you find out for me,  
17 Mr. Slenski?

18 MR. SLENSKI: The question is: Do we check  
19 bonding inside of tanks?

20 CHAIRMAN HALL: Yes.

21 MR. SLENSKI: We'll try to get the  
22 information.

23 CHAIRMAN HALL: If you could, I would  
24 appreciate it.

25 DR. LOEB: What he means is other than on

1 condition, I mean is there some periodic --

2 CHAIRMAN HALL: Schedule of maintenance.

3 DR. LOEB: -- or scheduled maintenance that  
4 looks at those issue.

5 MR. SLENSKI: The question then is concerning  
6 scheduled maintenance.

7 DR. LOEB: Yes. I mean he understands that  
8 obviously if there is a problem, then it's looked at,  
9 but other than on condition, is there any kind of  
10 scheduled or periodic --

11 MR. SLENSKI: I'll see if we can get the  
12 information.

13 CHAIRMAN HALL: Thank you.

14 MR. SWAIM: I had a question from some of our  
15 colleagues here. Mr. Thomas, do you have any history  
16 that you know of, of a cracked pump body? I'm going to  
17 come to Mr. Collins next.

18 MR. THOMAS: No, I do not. No.

19 MR. SWAIM: No. Okay. Mr. Collins, can you  
20 think of any actual cracks in the pump housing that  
21 breaches the pump housing?

22 MR. COLLINS: No, but you've reminded me that  
23 there was a condition on another airplane, it's not one  
24 that I work, but there was a part of the inlet that was  
25 separating, and that's the subject of an airworthiness

1 directive.

2 MR. SWAIM: Of the diffuser?

3 MR. COLLINS: Yes, I believe so.

4 CHAIRMAN HALL: Mr. Swaim, where are you on  
5 questions now?

6 MR. SWAIM: I'm reading one from the back  
7 row, I'm about done.

8 CHAIRMAN HALL: Okay. Because I'd like to  
9 finish up, and let's give the parties a chance, and I'd  
10 like to take a break before we do that.

11 MR. SWAIM: Absolutely.

12 MR. COLLINS: The diffuser, as I recall, we  
13 have an AD out that requires carrying a certain amount  
14 of fuel, to, again, keep that inlet covered --

15 MR. SWAIM: Okay. Thank you.

16 MR. COLLINS: -- so it's never dry, and that  
17 way if there is any sort of degeneration or spark in  
18 there, it would not cause fire.

19 MR. SWAIM: Okay. Thank you. That's it.

20 CHAIRMAN HALL: All right. Well, we want to  
21 be sure we give the parties ample time to question this  
22 panel, but we'll take a break until 4:15, and  
23 reassemble back here at 4:15, promptly. Stand in  
24 recess.

25

1                   (Thereupon, a short break was taken, after  
2                   which the following proceedings were had:)

3                   CHAIRMAN HALL: We will reconvene this  
4                   hearing of the National Transportation Safety Board.  
5                   We are in the middle of a discussion of our second  
6                   panel, on ignition sources. We have just completed  
7                   questions by the technical panel, and the Chairman has  
8                   one clarification that he'd like to get with Mr. Thomas  
9                   before we proceed to the parties for questioning.

10                  Mr. Thomas, as you know, there was a 747 that  
11                  was in a fatal accident on May 9, 1976, in Madrid, that  
12                  I think was one serial number off of the TWA 800, or a  
13                  sister ship on the line at about the same time, if  
14                  that's correct, or --

15                  MR. THOMAS: I don't know the exact spacing,  
16                  but they were very close.

17                  CHAIRMAN HALL: They were close together.

18                  MR. THOMAS: Yes, sir.

19                  CHAIRMAN HALL: That was a fuel air explosion  
20                  that was -- the Board did not do the investigation, but  
21                  we were, if I understand, a party to the investigation,  
22                  and the cause was lightening, and you mentioned that  
23                  Boeing had taken some steps, and I think because  
24                  there's been so much conversation about that particular  
25                  accident, it might be good for you to just briefly



1 mention that, and what Boeing has done since that time  
2 on lightening protection on the 747 --

3 MR. THOMAS: Okay. Certainly.

4 CHAIRMAN HALL: -- so we don't leave any  
5 doubt in the public's mind in that area.

6 MR. THOMAS: Okay. I'll try and do that.  
7 Yes, the airplane, the Madrid airplane was struck by  
8 lightening, the probable cause was an ignition, or some  
9 kind of ignition, I believe in the outboard main tank.  
10 I don't remember the exact details.

11 Subsequent to that accident, although it was  
12 established where exactly the ignition source was  
13 inside the fuel tank, we went through the design very  
14 carefully to look at possible ways we could get energy  
15 from a lightening strike into the fuel tank.

16 The fuel tank itself is a big aluminum box,  
17 which acts as a Faraday cage to keep -- basically to  
18 carry the lightening currents down the outside of the  
19 tank, rather than allowing currents to go into the tank  
20 and cause any kind of problem.

21 We also had, if you will, a failure in that  
22 mechanism to keep the lightening strike currents on the  
23 outside of the Faraday box, so when we went through, we  
24 shielded the FIQS wiring, there's some short run of  
25 wiring in the leading edge, we shielded that wiring,

1           there was a question over whether there were some  
2           leakage of induced current, as we've been talking about  
3           in the last session, propagating through the plastic  
4           access doors. We changed those access doors.

5                        I believe there was a question on one of the  
6           valves in the rear spar, as to how it was bonded, and  
7           we corrected that. All of those actions were AD'd on  
8           the airplanes, and I presume, I don't have the data,  
9           but I presume that the TWA airplane was covered by  
10          those Ads.

11                      CHAIRMAN HALL: You have not had any  
12          difficulty with that problem since then, since you made  
13          those changes, that you're aware of --

14                      MR. THOMAS: No, no.

15                      CHAIRMAN HALL: -- through your current  
16          system that you-all described the other day --

17                      MR. THOMAS: That's correct.

18                      CHAIRMAN HALL: -- where you-all were  
19          notified of problems. Very well.

20                      MR. THOMAS: Mr. Chairman, while I have the  
21          microphone, can I --

22                      CHAIRMAN HALL: Sure.

23                      MR. THOMAS: I realized as I got off the  
24          podium here, I had not finished my answer to Mr.  
25          Swain's question on flame arresters.

1           CHAIRMAN HALL:  If you would reacquaint us  
2 with the question then, so we can --

3           MR. THOMAS:  The question was to do with  
4 putting flame arresters in inlets of pumps.

5           CHAIRMAN HALL:  Right.

6           MR. THOMAS:  We went in length describing the  
7 scavenge pump and its function, and where it was in the  
8 tank, and putting a flame arrester in the scavenge pump  
9 inlet, and the question was, were there any problems  
10 associated with putting a flame arrester in the inlet  
11 of a pump to provide additional protection to that  
12 pump, and I answered the question that the scavenge  
13 pump, the only question would be plugging that flame  
14 arrester with debris, and the need to go into the tank  
15 to clean out the flame arrester on a regular basis.

16           If you apply that same argument to the main  
17 boost pumps that supply the engine, you now have a  
18 very, very different consideration, because now you  
19 have the potential for plugging the boost pumps that  
20 feed the engine with debris, you also have the  
21 potential of plugging that flame arrester with ice.

22           A normal way of getting rid of water that  
23 comes -- we bring water on board when you fill the  
24 airplane, some amount of water comes in, a lot of  
25 water condenses from the airplane descending.  The

1 normal process for us removing that water is to use a  
2 scavenge system that picks up water from the bottom of  
3 the tank, and actually throws it into the engine, into  
4 the pumped inlets, so that water goes at a very fine  
5 mist into the engine, it gets consumed by the engine,  
6 but at a slow enough rate that the engine doesn't know  
7 it's happening.

8 If you put a flame arrester in that pump  
9 inlet, you now have a very high probability of plugging  
10 that flame arrester with ice, and then the pumps would  
11 choke, and we basically would have an airplane without  
12 boost pumps running. So it's a very different  
13 situation between a scavenge pump, which is, in effect,  
14 a secondary feature of the airplane, and the main  
15 engine feed systems, it's a very different question.  
16 I want to make sure the record reflected that.

17 CHAIRMAN HALL: And I think it's very, very  
18 appropriate.

19 MR. SWAIM: Thank you.

20 CHAIRMAN HALL: Thank you, Mr. Thomas.

21 MR. COLLINS: Mr. Chairman --

22 CHAIRMAN HALL: Yes, Mr. Collins.

23 MR. COLLINS: -- if I may correct a statement  
24 I made earlier, too, when Mr. Swaim asked me about the  
25 requirements for installation of fuel pumps in

1 transport airplanes, I meant to mention the requirement  
2 for -- there is a requirement for inlet screens on  
3 boost bumps, and we talked about the screens, but there  
4 is a federal requirement for that, also.

5 CHAIRMAN HALL: Okay. Very good. Thank you.  
6 Now, I'm trying to remember where we left off. It is  
7 Honeywell, Inc.'s time up at bat. Honeywell, Inc., do  
8 you have any questions for this panel?

9 MR. THOMAS: Thank you, Mr. Chairman. No, we  
10 have no questions.

11 CHAIRMAN HALL: Crane Company Hydroair, do  
12 you have any questions?

13 MR. BOUSHIRE: Thank you, Mr. Chairman.  
14 Crane Hydroair has no questions.

15 CHAIRMAN HALL: The International Association  
16 of Machinists and Aerospace workers, and I assume that  
17 you-all represent some of the machinists --

18 MR. LIDDELL: Yes, sir.

19 CHAIRMAN HALL: -- the mechanical people who  
20 get inside the tanks.

21 MR. LIDDELL: Yes, Mr. Chairman.

22 CHAIRMAN HALL: Do you have any of those  
23 folks at the table that actually do that work?

24 MR. LIDDELL: Speaking to you.

25 CHAIRMAN HALL: Very good. Well then I'm

1       sure you must have some questions, or maybe you can  
2       help us and clarify anything you hear that we've been  
3       discussing today, that may or may not be correct,  
4       because you have actually been inside a center tank.

5               MR. LIDDELL: Yes, sir, numerous times.

6               CHAIRMAN HALL: Well, please, proceed.

7               MR. LIDDELL: Yes, sir. My first question is  
8       for Mr. Swaim. Do you happen to know if the aircraft  
9       93105 was in an airworthy condition?

10              MR. SWAIM: No. As I had mentioned  
11       repeatedly, but I'll be happy to say it again, to our  
12       best knowledge, that airplane came in -- the  
13       information, as a matter of fact, you provided me, was  
14       that the airplane had come in for a de-check, that's a  
15       very heavy maintenance check, and I'm sure you know the  
16       interval better than I do, Mr. Liddell, the airplane  
17       had come in for a heavy maintenance check, and while it  
18       was in for maintenance, they decided it was no longer  
19       economically viable to keep operating it, and it had  
20       been parked almost two years before we examined it, and  
21       I don't think you were there when I was in it, but you  
22       had one of your associates with me.

23              MR. LIDDELL: Yes. Do you know how long it  
24       was sitting open, and what condition it was in? Was it  
25       in a preserved condition?

1 MR. SWAIM: No. It was not in a preserved  
2 condition. I was told when I was there that it had  
3 been opened up in the -- as a matter of fact, when we  
4 were looking at probes and testing the previous  
5 September, September or October, I believe it was  
6 September, and that was, I believe, and this is in  
7 answer to the Chairman's question, in April.

8 MR. LIDDELL: Could you give us a short  
9 description, or tell us what is the purpose of the  
10 volumetric shut-off valve? Or maybe Mr. Hulm could  
11 tell us.

12 MR. SWAIM: I think that's a more appropriate  
13 question for the manufacturer. Mr. Hulm.

14 CHAIRMAN HALL: Did you hear Mr. --

15 MR. THOMAS: Let me make sure I heard the  
16 question. What is the purpose of the volumetric top --

17 MR. LIDDELL: Yes, its purpose and operation.

18 MR. THOMAS: The purpose of the volumetric  
19 top-off system is to shut off the fuel flow into the  
20 tank when you're fueling the airplane. The gauging  
21 system is, in effect, reading pounds. At some point,  
22 when you're trying to put in, and I can exaggerate  
23 here, if you're trying to put in 100,000 pounds of fuel  
24 into a tank that only holds 80,000 pounds, you can't do  
25 that, because you're going to basically dial in that

1 amount.

2 If it's a very light fuel, like JP-4, you try  
3 and put in 80,000 of fuel into a 80,000 tank, it may  
4 not go, there may not be enough volume in that tank for  
5 light fuel, to actually take on board that much fuel.  
6 The volumetric top-off is really intended to protect  
7 the tank from overfilling, when you deliberately try  
8 and put a lightweight fuel into the tank, and try and  
9 actually put too much fuel into the tank.

10 MR. LIDDELL: So would it be fair to say that  
11 this device would shut off periodically to prevent that  
12 condition from happening?

13 MR. THOMAS: It would normally shut off, as  
14 far as I know, when the fuel is very close to the top  
15 of the tank.

16 MR. LIDDELL: Mr. Chairman, if you want to  
17 know the procedure for entering a fuel tank, we'll go  
18 through that now.

19 CHAIRMAN HALL: Please.

20 MR. LIDDELL: Okay. Before an entry into a  
21 fuel tank, it has to be open and vented, and purged of  
22 all fuel fumes. In some cases, you do enter it with  
23 fuel in it, but most cases in a de-check, and in the  
24 discussion we had --

25 CHAIRMAN HALL: Well, tell us what -- do you



1 know what de-check, how often that is?

2 MR. LIDDELL: De-check is usually three to  
3 four years, depending upon the operational hours of the  
4 carrier.

5 CHAIRMAN HALL: Somebody can answer that.  
6 How many hours is a de-check? Does it depend on --  
7 does TWA know how often you do de-checks?

8 MR. YOUNG: We do it on calendar time, Mr.  
9 Chairman.

10 CHAIRMAN HALL: On calendar time. Okay.  
11 Thank you.

12 MR. LIDDELL: After this is done, entry is  
13 made into the tank. It's not so much how tall you are,  
14 the entry is about two-by-three feet, semi-circular.  
15 Once you get in, you have no light. The pictures  
16 I've seen around here show the center tank lit up to  
17 where you could see everything. All you can see is  
18 what's in front of your face with a flashlight.

19 If you have people that get claustrophobic,  
20 they have a condition. In a closed environment it  
21 takes two people to go in and do this task, plus one on  
22 the outside to help anybody who gets sick inside, out.

23 Then once you go in, you can't see. The  
24 reason the FAA and Boeing have an adversity of people  
25 going in and out of center tanks is, if you can't see

1 anything, you can damage it, you can hit it with your  
2 feet, and then you may not even know that you've  
3 damaged it. It usually takes, for a center tank, eight  
4 hours work for two men to inspect, not fix, just to  
5 find out what's wrong.

6 CHAIRMAN HALL: Well, that's very helpful,  
7 Mr. Liddell. That gives us a good understanding of  
8 what's required there. So the whole thing is dark.

9 MR. LIDDELL: Yes. Completely dark. There's  
10 no light at all. It's void of light.

11 CHAIRMAN HALL: You've got your flashlight,  
12 and that's it.

13 MR. LIDDELL: Right in front of your face  
14 only, as far as you can see.

15 CHAIRMAN HALL: Okay.

16 MR. LIDDELL: I have no further questions,  
17 after that.

18 CHAIRMAN HALL: Anything else that you-all  
19 that work on these tanks, you know, that need to be  
20 added or asked of this panel?

21 MR. LIDDELL: Not at this time.

22 CHAIRMAN HALL: The rest of the information  
23 that's been told is fairly accurate.

24 MR. LIDDELL: Yes. Thank you.

25 CHAIRMAN HALL: This whole panel -- has

1 anyone on the panel been in a tank? All right. Trans  
2 World Airlines. Captain?

3 MR. YOUNG: Thank you, Mr. Chairman, TWA has  
4 no questions at this time, and I have not been in a  
5 tank.

6 CHAIRMAN HALL: Okay. Neither have I, sir,  
7 and although I think we have, several of our folks now  
8 have been. Mr. Steeter, with the Federal Aviation  
9 Administration.

10 MR. STEETER: Yes, Mr. Chairman. I'd like to  
11 start off with some items here for Mr. Johnson. You  
12 showed a picture up there of a wire with an exposed  
13 conductor, and discussed the residue that you had  
14 picked off of that wire. I wasn't clear on that, I  
15 knew that that was a wire from the accident aircraft,  
16 but was it from the center wing tank?

17 MR. JOHNSON: I can't answer that right at  
18 the moment. I didn't pull all the captioning from the  
19 report. The image is in the docket with the report  
20 that we submitted, you may be able to tell from the  
21 information included there, but I don't have it with  
22 me, in front of me right now.

23 MR. STEETER: Okay. But it was from the  
24 accident aircraft.

25 MR. JOHNSON: Yes. It was from the mishap

1 aircraft.

2 MR. STEETER: All right. Now, again, for Mr.  
3 Johnson, and this now goes to the fuel probes that came  
4 off of the out-of-service aircraft, where you showed us  
5 the pictures of the deposits that had been discovered  
6 on there. With this aircraft out of service, I'm  
7 presuming that it was defueled and the tanks were opened  
8 up, do you know that to be the case, or not?

9 MR. JOHNSON: No. That wasn't information  
10 that was provided to us.

11 MR. STEETER: Okay. Can Mr. Swaim answer  
12 that one? Was the aircraft in a defueled condition,  
13 Bob?

14 MR. SWAIM: Essentially. There were puddles  
15 in the tank, and the tank still had a pretty good  
16 smell. It wasn't as bad as going into a tank that had  
17 just been taken out of service. Essentially, defueled,  
18 yes.

19 MR. STEETER: So it did still have vapors in  
20 it then, correct? I mean you said you could smell it.

21 MR. SWAIM: It had a smell to it, a strong  
22 smell.

23 MR. STEETER: The reason I'm asking is, I'm  
24 wondering, Mr. Johnson, if you have any idea whether or  
25 not -- I'm trying to understand -- the sulfur comes

1 from the fuel, is that correct?

2 MR. JOHNSON: Yes.

3 MR. STEETER: Okay. So if you had sulfur  
4 deposits on there, and then the probe ended up for two  
5 years not being immersed in fuel, does that have any  
6 effect on the buildup that you were seeing there, does  
7 it continue to grow, or does it become static, does it  
8 recede, or what effect does the dry air have on it?

9 MR. JOHNSON: I'm not sure. I don't know  
10 whether Mr. Slenski might have some --

11 MR. SLENSKI: Well, I think you have to have  
12 the continuous source of the sulfur to continue to grow  
13 the film on there, so I think it would depend on the  
14 concentration of the vapors, of the fuel in the tank,  
15 and the residuals that may be left in there.

16 But I would think pretty much you'd have to  
17 almost have immersion to continue to build up this  
18 film, and I think you alluded to this previously, it's  
19 also, from what we've seen, and this is something that  
20 probably has to be studied more, the potentials being  
21 applied to these circuits may accelerate this whole  
22 process.

23 You set up fields, and, again, we mention  
24 this as a corrosion process, and whenever you apply  
25 voltage in there, you can accelerate those types of

1 processes.

2 MR. STEETER: Okay. So you would expect  
3 then, if I understand you right, that once the  
4 immersion is no longer occurring, whatever buildup you  
5 had on there would be static, at least, it would not  
6 grow.

7 MR. SLENSKI: It would definitely --

8 MR. STEETER: Okay.

9 MR. SLENSKI: -- I would think.

10 MR. STEETER: Okay. Understood. Thank you,  
11 sir. Mr. Hulm, there was a little bit of discussion  
12 earlier on the MILSPEC, and you referred to the three-  
13 inch rule when we were talking about whether or not you  
14 needed to ground or bond a clamp. My question is: I  
15 think you describe that as any dimension less than  
16 three inches requires no bonding. Could you clarify  
17 that? For example, if I had a clamp that had a total  
18 of a six-inch circumference, but it was only half-an-  
19 inch wide, would I have to bond that?

20 MR. HULM: I guess to answer your question  
21 what I'd like to do is, we've got bonding and grounding  
22 experts within the company that do this kind of thing,  
23 rather than trying to me answer it here, I'd rather get  
24 the answer to you --

25 MR. STEETER: That would be fine, sir.

1 MR. HULM: -- if that's okay.

2 MR. STEETER: Yes. That would be fine.

3 Thank you.

4 MR. SWAIM: Of course, we'll be getting a  
5 copy of that, right?

6 MR. HULM: Yes, sir.

7 MR. SWAIM: Okay.

8 MR. STEETER: I'm sorry. That's what I  
9 meant. I was hoping it would go to the right --

10 CHAIRMAN HALL: Well, if you'd supply that  
11 for the record, we'd certainly appreciate it.

12 MR. HULM: Yes.

13 MR. STEETER: And that's where we need it,  
14 sir. Now, either from Mr. Hulm or Mr. Thomas, and I  
15 believe it was Mr. Hulm who said that there was no  
16 specific requirement to inspect any of the bonding  
17 points, or anything like that, in the tank.

18 However, when you do have a situation where  
19 you know you're going to go into the tank for some type  
20 of maintenance, such as that of a de-check, does Boeing  
21 have any policy in there, in maintenance guidelines,  
22 regarding zonal inspections, and things like that?

23 MR. HULM: Maybe Ivor can answer that  
24 question better than I could.

25 MR. THOMAS: To the best of my knowledge

1       there are requirements when you do a de-check, when  
2       you're doing a heavy maintenance check. As I said  
3       earlier, you're in the tank, looking at the structure,  
4       looking for deep cracks, those kinds of things. There  
5       is a requirement to do a zonal check on the system, to  
6       look around to see if everything is in working order.

7               There are other requirements that probably  
8       others can probably get into better than I can, in  
9       terms of checking things like the behavior of check  
10      valves on the pumps, make sure they're working, which  
11      requires breaking into the system, and restoring it.  
12      So there's a regular maintenance program going on.

13             The specific bonds, like a grounding slab, is  
14      the area where we've said, you know -- they're designed  
15      to be a good ground for the life of the airplane, and  
16      so the question that we're trying to answer in these  
17      inspections is really, does the data in the fleet  
18      confirm that those grounds work for the life of the  
19      airplane.

20             MR. STEETER: All right. Thank you, sir.

21             MR. JOHNSON: I have a bit of additional  
22      information relative to your question about whether  
23      that image we showed was from the center tank. We  
24      still don't know that, but possibly someone present  
25      may.



1           That was taken from sample number 29, out of  
2           the sample bag, or from a probe marked by someone  
3           previous to us, with an identification number 29. So I  
4           see some digging going on, we may be able to come up  
5           with an answer for that for you.

6           MR. STEETER: Well, while they're checking  
7           the data base over there, sir, if I could refer again  
8           back to Mr. Johnson for one other item. The picture  
9           that's right behind Mr. Hartonas there, of the damaged  
10          wire, I believe when you showed the full diagram up on  
11          the overhead, that there was a graph of the -- a  
12          spectrographic analysis that was done on that.

13          MR. JOHNSON: Yes.

14          MR. STEETER: I'm not sure, but I believe  
15          there was a peak off to the left side of that graph.  
16          Was that a carbon peak?

17          MR. JOHNSON: Yes. I think that's what it  
18          was. The real tall peak off on the left.

19          MR. STEETER: Yes. That's correct.

20          MR. JOHNSON: Yes, it was.

21          MR. STEETER: Now, what's the significance,  
22          if any, of the carbon peak, and my concern is, does  
23          that indicate any signs of any arcing of any type?

24          MR. SLENSKI: No, that doesn't. I don't  
25          believe so. First of all, the analysis here, as we've

1 mentioned before, is EDS, you talked a little bit about  
2 this.

3 What that does is analyze the surface and a  
4 small bowl underneath the subsurface, and the full  
5 polymer is made out of a carbon chain. So what we're  
6 looking at is the carbon makeup of the Teflon.

7 MR. STEETER: I see.

8 MR. SLENSKI: We did not do surface analysis,  
9 which there are techniques available, that would be in  
10 the first couple atomic layers, but I don't believe --  
11 I think what we're looking at there is just a Teflon --

12 MR. STEETER: So that's something that came  
13 out of the insulation then, in effect.

14 MR. SLENSKI: That's correct.

15 MR. STEETER: Okay.

16 MR. JOHNSON: And in looking at that  
17 particular damage site very carefully, under fairly  
18 high magnification, there was no evidence of melting,  
19 or beading, or anything that you might associate with  
20 an arc having been present at that site.

21 MR. STEETER: Okay. I understand. Thank  
22 you, sir. Chairman Hall raised some obvious points of  
23 concern about whether or not the FAA and the air force  
24 were sharing information, and you did mention that you  
25 had been to a meeting with the FAA, so I'm trying not

1 to leave an impression that that was one meeting.

2 Do you work fairly regularly with the people  
3 at our Fire Safety branch at Atlantic City?

4 MR. SLENSKI: I've had considerable contact  
5 with a Mr. Hill and a Pat Cahill. When we've had  
6 issues, we've discussed it over the phone. Of course,  
7 with the NTSB investigators, this is not the first NTSB  
8 investigation we've done, so we've worked in other  
9 projects, and there has been a cross-flow of  
10 information.

11 MR. STEETER: Okay. Have you ever had any  
12 difficulty that you are aware of between the air force  
13 and the FAA, as far as sharing of information in safety  
14 matters?

15 MR. SLENSKI: In my personal experience,  
16 absolutely not. We've had a fairly good relationship.

17 MR. STEETER: All right. Thank you, sir.  
18 Mr. Collins, there have been numerous times,  
19 discussions about the agency's concerns, and Boeing  
20 made it obvious, too, about their concerns about  
21 getting into the fuel tanks too often, and you  
22 discussed the problems of potential damage to  
23 components in the tank, and I think we had some photos  
24 up there that showed that. Is there also an issue  
25 regarding the introduction of debris into the tank, in

1           those cases?

2                   MR. JOHNSON:  Yes, there is, and here has  
3           been evidence of that found in the tank, of debris  
4           brought in.

5                   MR. STEETER:  Is there concern there, again,  
6           because that could be the type of debris that sets up  
7           these potential failure scenarios?

8                   MR. JOHNSON:  Yes.  There could be block  
9           wire, for instance, that gets stuck on a piece of  
10          clothing, or something.

11                  MR. STEETER:  Okay.  That's all I have, Mr.  
12          Chairman.  Thank you.

13                  CHAIRMAN HALL:  Thank you, Mr. Steeter.  Is  
14          that the only way to get in that tank, is just with a  
15          flashlight, I mean with lighting and video cameras, and  
16          all the things that are available these days, is that  
17          how it's done, Mr. Liddell?

18                  MR. LIDDELL:  Yes, sir, it has to be  
19          physically done by people.

20                  CHAIRMAN HALL:  Well, I'm not trying to get  
21          rid of your job now, I'm just saying, it would seem to  
22          me if you went in there with more lights, and a video  
23          camera, or something, then you'd have some record, I  
24          don't know, I was just --

25                  MR. LIDDELL:  Well, you would have the

1 problem of flammability, you'd have the fumes --

2 CHAIRMAN HALL: Flammability, and lights.

3 Okay. Well, that's explainable.

4 MR. THOMAS: Could you put that view up  
5 again, it's particularly --

6 CHAIRMAN HALL: Yes.

7 MR. THOMAS: If you look at it, there's a  
8 person on the right-hand side of the screen, there's a  
9 pencil pointing at the hole, that is the hole you have  
10 to crawl through, right there, to get into the tank,  
11 and that's typical of any of our fuel tanks.

12 MR. SWAIM: And, of course, you're doing this  
13 on top of a ladder, hanging above the ground, probably  
14 what, ten feet over, and you basically have to do the  
15 Fosberry Flip in there. It's not an easy hole to climb  
16 through.

17 CHAIRMAN HALL: Are people specifically  
18 trying to do this, Mr. Liddell?

19 MR. LIDDELL: Well, specifically trying, if  
20 you get the job, and you're given training on how to  
21 get in, somebody shows you how, yes, sir.

22 CHAIRMAN HALL: And what to look for.

23 MR. LIDDELL: What to look for, and what not  
24 to do.

25 CHAIRMAN HALL: Good. All right. The Boeing

1 Commercial Airplane Group.

2 MR. RODRIGUES: No questions from Boeing, Mr.  
3 Chairman.

4 CHAIRMAN HALL: Okay. The Airline Pilots  
5 Association, Captain?

6 CAPTAIN REKART: Thank you, Mr. Chairman.  
7 Mr. Gerken, many hours ago you described the static  
8 electricity generating tests and their results, and  
9 just a few questions concerning how representative your  
10 setups were of the actual aircraft configuration and  
11 operation. Was there any attempt to replicate the  
12 conditions of TWA 800, specifically the fuel pressures  
13 that you were leaving, versus the pump pressures that  
14 were generated by the fuel pumps in the airplane, and  
15 the test sprays versus the tank geometry? I've got a  
16 couple more, but if you take those two first, I'll come  
17 back.

18 MR. GERKEN: It has been several hours ago.  
19 Pressure, we varied that through a whole realm of  
20 different pressures, from my understanding, 25 psi was  
21 used, which is very similar to pressure in the fuel  
22 lines, the orifices, we used eight to ten different  
23 types of orifices, from regular whole orifices, slots,  
24 there's a whole host of them, I don't know those right  
25 now, but to try and duplicate different types of leaks.

1           The jet fuel that we used to start the whole  
2 experiment on phase one was Jet A, from JFK, and we did  
3 vary the fuels throughout the experiment.

4           CAPTAIN REKART: You talked there momentarily  
5 about the filter paper. There was also screening used  
6 across the orifice face, I believe. What was the  
7 purpose for the screening?

8           MR. GERKEN: The screening in the orifice  
9 itself was used to stabilize the flow somewhat. When  
10 we used the slotted orifice, we got no control over the  
11 flow, whatsoever, and it's within the report, but as we  
12 saw variances in the flow, contacting our plate or test  
13 specimen, we saw differences in charging current and  
14 voltage, and we'd try to stabilize it a bit.

15          CAPTAIN REKART: You said you added water to  
16 the fuel to get a different result. In the 30-odd  
17 years that I've been flying, the only water that we've  
18 ever added to fuel was for takeoff on some of the  
19 military airplanes. What did that do to the fuel that  
20 you were using, specifically changing it from what was  
21 being used on TWA Flight 800?

22          MR. GERKEN: The use of the water in the fuel  
23 for the electrostatic testing was done by Dr. Leonard.  
24 We did none of that at Wright-Patterson, so I can't  
25 address it fully, but there had been numerous studies

1 that show that water cumulation in the fuel does,  
2 indeed, increase static charging.

3 MR. SWAIM: Maybe I can ask Mr. Thomas, do we  
4 get water into the fuel of these airplanes in-service,  
5 and what kind of extents do you go, as far as the small  
6 jet pickups and such to mix the water? Can you help  
7 this?

8 MR. THOMAS: Yes, I tried to address that a  
9 little bit in the pump discussion. Certainly, there's  
10 no free water in the fuel, as it comes on board the  
11 airplane. You have filters in the trucks, and  
12 coalescers, all designed to make sure you absolutely  
13 minimize whatever -- that there is no water in the fuel  
14 on the way to the airplane. However, there is some  
15 dissolved water in the fuel.

16 As the fuel cools, that water will condense  
17 out and settle on the bottom of the tank. Also, when  
18 you breathe -- as the tank is descending, you'll  
19 breathe in air, and dif that air has obviously got some  
20 kind of relative humidity, you'll bring water into the  
21 tanks that way.

22 So the normal approach that the Boeing  
23 Company uses, we'll provide a number of jet pumps, very  
24 simple -- no moving parts pumps, go to the bottom of  
25 the tank, with the intent of picking up the water as it



1 drifts down to the bottom of the tank.

2 The discharge from those pumps, which is  
3 basically a mixture of fuel, and whatever water is  
4 picked up, is returned to the tank very close to the  
5 inlets of the main boost pumps, so the main boost pumps  
6 basically pick up that water, to gather all the fuel  
7 it's picking up to send to the engines.

8 You have a very, very fine, very low  
9 percentage of water mixed with the fuel on the way to  
10 the engine, and so it's basically a continuous  
11 scavenging system to pick up the water, and send it to  
12 the engine, and that's pretty standard on most of our  
13 airplanes. If you go back to the 707s, we didn't have  
14 it. All the airplanes come with a sump drain system,  
15 so you can drain the water off on a regular basis.

16 MR. SWAIM: Thank you, sir.

17 DR. LOEB: Captain Rekart, I think it's fair  
18 to say we did those tests just to see what would happen  
19 if, I mean it was a matter of trying to explore the  
20 various possibilities, and learn and understand, is  
21 that correct, Bob?

22 MR. SWAIM: Absolutely. Water is present in  
23 the system, we're just trying to be -- you're  
24 absolutely right, Dr. Loeb.

25 CAPTAIN REKART: I understand that, Dr. Loeb,

1 I realize why you did the tests, but the rig itself was  
2 not dimensionally the same as the tank, nor was it  
3 modeled on the tank in any way.

4 MR. GERKEN: No, it was not.

5 CAPTAIN REKART: Okay. Thank you. That was  
6 the question.

7 Mr. Slenski, you showed some photographs of a  
8 military non-747 fuel probe, which had arcing damage,  
9 and I believe there's some metal transfer associated  
10 with that. What was the value of the electrical power,  
11 the energy necessary for that sparking? Was that  
12 laboratory induced, or was it service induced? Do you  
13 know how much energy that part was subjected to?

14 MR. SLENSKI: Are you referring to the fuel  
15 probe that ignited the residual vapors, or the test we  
16 did in our lab?

17 CAPTAIN REKART: I don't believe it was a  
18 test you did in the lab, I think it was a piece that  
19 you brought in from the field.

20 MR. SLENSKI: A field failure?

21 CAPTAIN REKART: Yes, sir.

22 MR. SLENSKI: I really don't have that  
23 information, as far as what -- it was the tester that's  
24 typically used with that particular probe system, and I  
25 know that's been asked several times. If we need to

1 get that information, I can see if we can track that  
2 down.

3 MR. SWAIM: We've been searching for that  
4 piece of information. It was an obsolete tester, it's  
5 called a capacitance fuel probe tester, MD2A, and it's  
6 an obsolete piece of equipment, and we've been  
7 searching for that ourselves, I think just a few days  
8 before the hearing here. We're probably going to get a  
9 copy out of an archive.

10 CAPTAIN REKART: Okay. Thank you. Mr.  
11 Slenski, your statement that copper sulfide deposits  
12 are a result of many years of exposure to fuel, have  
13 you seen any difference between the military problems  
14 and the civilian problems regarding exposure?

15 For example, a DC-9 may be fueled eight times  
16 a day, and in the process its fuel washed by the high-  
17 pressure fuel coming in. An airplane that sits on  
18 alert, or something like that, may not be fueled for  
19 three weeks. Do you see any difference in the  
20 operational use of the aircraft versus the buildup of  
21 the sulfur compounds?

22 MR. SLENSKI: Well, if you're asking the  
23 question, to speculate on that, I mean I don't have the  
24 data, because I haven't looked at enough commercial  
25 aircraft probes to make that determination.

1 I think the situation here we're dealing  
2 with, keeping it immersed in the fuel is probably going  
3 to accelerate the process, and the types of fuels you  
4 use have an impact on that, also.

5 If there's more sulfur in the fuels, then I  
6 think this reaction will occur faster.

7 As I said before, I even think it's a  
8 function of the potential that's supplied to the  
9 system, so there are many factors in that. You're  
10 right, the use of the tanks may have impact.

11 CAPTAIN REKART: Okay. Mr. Chairman, the FAA  
12 just asked a question a little while ago, and I may be  
13 repeating their question, if you feel it is, I'll  
14 withdraw it, but when the FIQS discrepancies are  
15 discovered during the air force depot maintenance, that  
16 warrant corrective or preventive actions, how are these  
17 actions communicated to the other users of both that  
18 airplane and similar airplanes, if it happens to be  
19 like a Casey-135, or -- how does the civilian world get  
20 that information? Perhaps that's the similarity in the  
21 question that I was referring to, sir.

22 CHAIRMAN HALL: Well, I'd like to hear it  
23 answered again.

24 MR. SLENSKI: The question here again is, how  
25 do we transfer this information to the commercial?

1 CAPTAIN REKART: Yes, please.

2 MR. SLENSKI: I don't personally know that  
3 mechanism. Again, obviously, our contractors are  
4 similar for Casey-135, and Boeing airplane. There's  
5 going to be some cross feeder information there, I  
6 expect, but I don't know if there is a formal  
7 mechanism. Again, if that's the question --

8 CHAIRMAN HALL: Well, do you think you could  
9 find out before tomorrow, Mr. Slenski, if there's any  
10 difference between the way the air force performs  
11 maintenance on these center fuel tank systems and the  
12 FAA rules and regs?

13 MR. SLENSKI: I can try to get that  
14 information, by tomorrow, I'm not sure, we'll have to  
15 make some phone calls.

16 CHAIRMAN HALL: That would be very helpful,  
17 if you could, because all we're trying to do is be sure  
18 that if there's knowledge that impacts the safety of  
19 the operation, whether it's gathered or collected in  
20 the military service, of course, the vast majority of  
21 the military aircraft are Boeing, or McDonnell-Douglas,  
22 or Lockheed, and a lot of those are the same, you know,  
23 they've got a different name to them, it's essentially  
24 the same plane.

25 MR. SLENSKI: The question you're really

1 asking, do we inspect fuel probes, and do we have some  
2 process for inspecting fuel probes, is that what you're  
3 asking?

4 CAPTAIN REKART: If you find a discrepancy in  
5 the fuel probes, or if you find a defect, how do you  
6 get this information to similar users in the civilian  
7 arena?

8 MR. SLENSKI: Well, that's a different  
9 question, so that's what really we're asking now, is  
10 how do we disseminate the information.

11 CAPTAIN REKART: Yes, sir.

12 MR. SLENSKI: Okay. Mr. Chairman, is that --

13 CHAIRMAN HALL: Well, it's two different  
14 questions, one is how you disseminate it, and secondly,  
15 what is it.

16 CAPTAIN REKART: That's right.

17 CHAIRMAN HALL: I was mislead here by Mr.  
18 Swaim, I thought you-all were going to come equipped  
19 with all that information, I apologize to you-all, but  
20 I'm very interested in, is there anything different  
21 that the air force does in regard to these tanks, or is  
22 it all done the same, you know, the things we've heard  
23 about, the bonding, we heard this three-inch linear, it  
24 can be ungrounded.

25 I'm not a highly technical person, but I do

1 know the difference between grounded and ungrounded,  
2 and if there are ungrounded things in the tank, is that  
3 the same thing in the air force as it is in the --  
4 they're never inspected per FAA regulations, is it  
5 different in the air force?

6 Now, I understand, given all that, it's a  
7 different operation, it's a military service, the fuel  
8 may be different, but if you could get that information  
9 either tomorrow, or for the record, we would appreciate  
10 it, also as well, the Captain's question of, if you  
11 come up with important information regarding, say, the  
12 737 equivalent, or the 747 equivalent, in the military,  
13 how is that information transferred between the FAA and  
14 the military?

15 MR. SLENSKI: For the record, I think we can  
16 get the information by tomorrow, but as far as our  
17 preparation here, it was primarily to discuss the  
18 testing we had done for the NTSB, so we really had not  
19 been prepared --

20 CHAIRMAN HALL: Well, I understand. Well,  
21 that's my misunderstanding, that's not your fault. I  
22 appreciate you-all being here, and you've made a real  
23 contribution, I'm not being critical, I'm just -- I'd  
24 just like to know that information.

25 MR. SLENSKI: Thank you.

1           CAPTAIN REKART: I apologize. Also, I'm a  
2 pilot, and my questions tend to be operational, and I  
3 realize that your expertise isn't in the operational  
4 side, and I certainly don't ask the questions to  
5 embarrass you, it's just that I was hoping to get an  
6 answer.

7           MR. SLENSKI: That's fine. If we don't have  
8 the information, we'll attempt to get it --

9           CAPTAIN REKART: Okay.

10          MR. SLENSKI: -- we just may not be able to  
11 answer it here.

12          CAPTAIN REKART: For Mr. Johnson, much of  
13 your presentation focused on the various degrees of  
14 pre-existing discrepancies in the FIQS wiring. Could  
15 you please comment on the difficulty in detecting these  
16 irregularities on in-service airplanes, without having  
17 to do any destructive testing? It seems like  
18 everything that you did was destructive testing, and  
19 needless to say, in line operations, you can't go out  
20 and cut the wires and examine them. Is there a quick  
21 and easy on how you can do it with non-destructive  
22 testing?

23          MR. JOHNSON: Relative to the exposed  
24 conductor, the compression damage --

25          CAPTAIN REKART: Relative to the sulfide



1 compound presentation on the wiring, and so on, and so  
2 forth.

3 MR. JOHNSON: Well, we've talked about  
4 indications coming from the fuel system itself as  
5 leakage currents begin to climb, not getting accurate  
6 fuel measurements, so that would be one indicator that  
7 you've got a degrading fuel system problem. But I'm  
8 not aware of anything in place today.

9 I'm sure a test could be devised to go after  
10 measuring those leakage currents. You'd have to do  
11 some characterization of known good systems, new  
12 systems, and then some further characterization of some  
13 that were known to have some residues present, and  
14 develop a fingerprint for the problem, and then you can  
15 carry out some testing that would, I think, give you  
16 the information about the condition relative to the  
17 amount of residues present, but I don't know of  
18 anything firsthand that's available. I can't tell you  
19 a test method readily available today for doing that.

20 CAPTAIN REKART: Okay. Thank you. I guess,  
21 Mr. Hartonas, can you discuss the design requirements  
22 and standards concerning the routing and the bundling  
23 of FQIS wiring with other wires carrying higher  
24 currents, is there a standard there that --

25 MR. HARTONAS: You're asking what the FARs

1 are, pertaining to wiring, routing, and separation?

2 CAPTAIN REKART: Well, I'm asking if there is  
3 a standard that is dedicated to delineating the  
4 electrical potential between two wires that are bundled  
5 together, and so on, and so forth, and what kind of  
6 standard that is, and give us an idea of the  
7 requirement.

8 MR. HARTONAS: I believe that each  
9 manufacturer has developed their own standards and  
10 requirements for wiring separation and protection of  
11 one system from another. I cannot discuss each one of  
12 those. I have some personal knowledge of some  
13 manufacturers, but that information is proprietary.

14 I can tell you, however, that there are FARs  
15 that do require separation and routing, but there is a  
16 ground rule, and they will not tell you exactly how to  
17 do it. Is that helpful?

18 CAPTAIN REKART: Yes. Thank you. Just one  
19 more comment, Mr. Chairman, if I could, Mr. Liddell  
20 brought up a comment earlier about 105, aircraft 105,  
21 and we've called it a derelict, and we've called it  
22 several other things today, I would be very pleased if  
23 it were just referred to as a non-airworthy airplane,  
24 because that's basically what it is. Every other term  
25 that we've used so far to describe that aircraft, to my

1 knowledge, is not an FAA-recognized term, being non-  
2 airworthy is, and that says what the airplane was.

3 In being non-airworthy, so were its  
4 components, and it pretty well describes the airplane  
5 and the components. If we could go with the term  
6 similar to that, I'd appreciate it.

7 CHAIRMAN HALL: Well, I'll refer that to my  
8 general counsel, and get back to you on that, because I  
9 don't know whether that's a legal matter or not. I  
10 know I don't like the word derelict, because that gives  
11 me a different picture than what I think we're talking  
12 about here.

13 CAPTAIN REKART: I don't know if it's legal,  
14 sir, but I don't want to get into that side of it.

15 CHAIRMAN HALL: I'll check on that. Is that  
16 the terminology the FAA would use, a non-airworthy  
17 airplane? Is there anything that covers those that are  
18 parked and taken out of service, sit out in the desert?

19 MR. COLLINS: I personally refer to flight  
20 standards to give us the correct terminology.

21 CHAIRMAN HALL: Maybe Mr. Donner can find out  
22 the answer for us, and make some contribution to this  
23 effort.

24 MR. DONNER: It's fairly simple, it's either  
25 airworthy or it's not airworthy.

1 CHAIRMAN HALL: Well, Mr. McSweeney, is there  
2 an answer from the FAA table? We don't want to be  
3 abusing the airplane?

4 MR. McSWEENEY: First, let me give you the  
5 FAR, to be airworthy means you are in compliance with  
6 the type certificate, and the condition for safe  
7 operation. There has to be a determination of that in  
8 each and every aircraft.

9 I would kind of disagree with the statement  
10 about unairworthy parts. You could have an airworthy  
11 part on an unairworthy aircraft, because the aircraft,  
12 as a whole, might not conform to its type certificate.  
13 Airworthy is a well-used term, and that's what it  
14 means.

15 CHAIRMAN HALL: Well, I appreciate that  
16 clarification. Other questions, Captain?

17 CAPTAIN REKART: No more questions, sir.  
18 Thank you.

19 CHAIRMAN HALL: Well, that completes the  
20 round. Does anyone have anything else, from any of the  
21 parties? Mr. Steeter --

22 MR. STEETER: Yes.

23 CHAIRMAN HALL: -- the Federal Aviation  
24 Administration.

25 MR. STEETER: Thank you, sir, I just wanted

1 to check before we finished here, and see if Mr. Swaim  
2 found that part number 29, and if we can answer that  
3 question while we're here.

4 MR. SWAIM: Certainly, I got a couple of  
5 things that we've found while we've been up here. Part  
6 number 29, in direct answer to your question, according  
7 to what we have, was out of either tank two or three,  
8 it's a similar part used in either inboard wing fuel  
9 tank. Part number 59 that Mr. Johnson was showing you  
10 in his photos, fragment 59, indeed, we have out of the  
11 center tank, it was Honeywell FG-420A12, for those with  
12 the exhibits.

13 In response to Mr. Liddell, I said that I  
14 believed that was in the tank in April, and I was off  
15 by a few weeks, it was May 20th of this year. I think  
16 that was all that I came up with.

17 CHAIRMAN HALL: Okay. Thank you. Other  
18 questions from the parties? Mr. Liddell, are you sure  
19 now -- you represent the people that actually do this  
20 work, are there any other questions, are you satisfied  
21 with all the questions that we've asked here?

22 MR. LIDDELL: Yes, Mr. Chairman, I am.

23 CHAIRMAN HALL: Very well. Does the  
24 technical panel have any additional questions? If not,  
25 Mr. Sweedler.

1                   MR. SWEEDLER: Yes, Mr. Chairman, I have a  
2                   few. Mr. Thomas, is there a recommended inspection  
3                   interval for 747 center fuel tanks?

4                   MR. THOMAS: As far as I know -- well, let me  
5                   -- there is a recommended interval, I do not know what  
6                   it is. It's basically tied to the structural  
7                   inspections of the tank. In other words, you go into  
8                   the tank on a regular basis, and I can't confirm  
9                   whether it's a de-check, or somewhere in that region,  
10                  to go into that tank to do structural inspections, and  
11                  at the same time do zonal inspections of the systems in  
12                  the tank.

13                  MR. SWEEDLER: So there is some --

14                  MR. THOMAS: There is a requirement. In  
15                  fact, we'll probably get into that in the aging  
16                  airplane discussion tomorrow.

17                  MR. SWEEDLER: Okay. Well, I can wait until  
18                  tomorrow. I have a couple of questions concerning the  
19                  Philippine Airline accident in 1991. There was some  
20                  discussion yesterday from, I'm not sure which of the  
21                  FAA witnesses, but there was some indication that the  
22                  recommendations that the Board had made -- the Board  
23                  made four recommendations after that accident, three of  
24                  those were not accepted by the FAA, but the implication  
25                  of the statement yesterday was that some of those

1 recommendations were not going to be reconsidered,  
2 based on new evidence that was coming to light.

3           Could I ask you if either of the two FAA  
4 witnesses know which of those recommendations are now  
5 being reconsidered?

6           MR. HARTONAS: Mr. Chairman, I'm coming up to  
7 speed on the Phillippines accident rather quickly. I  
8 don't have all the information yet. I know that we'll  
9 be taking a look at the data that was generated as a  
10 result of that investigation. Perhaps I could take an  
11 action item.

12           CHAIRMAN HALL: If you could just let us  
13 know, and provide that for the record.

14           MR. SWEEDLER: Thank you. That's all the  
15 questions I have, Mr. Chairman.

16           CHAIRMAN HALL: Dr. Ellingstad.

17           DR. ELLINGSTAD: Thank you, Mr. Chairman. I  
18 have just a couple of clarifying questions for Mr.  
19 Hulm.

20           First of all, revisiting the induced voltage  
21 tests that you did, let me just see if I understand,  
22 the voltage that was induced into the FIQS system was a  
23 function of the relay coil, and the 75 feet of wire  
24 that you had wrapped around it was essentially an  
25 extension of the coil, is that correct? It was a

1 function of the coil being there that --

2 MR. HULM: That's correct.

3 DR. ELLINGSTAD: Okay. Thank you. Just one  
4 additional one. With respect to your new procedures,  
5 with respect to inspecting components in the tank,  
6 could you comment just very briefly about the  
7 comprehensiveness of this? Are you examining the  
8 probes and internal components, or are you examining  
9 wire outside the tank as well?

10 MR. HULM: The inspection bulletin that we do  
11 have just concerns the components within the center  
12 tank itself, and we will be putting together a  
13 comprehensive list of different inspection items for  
14 the airlines to look at, and it will be based on the  
15 information that has come to light as a result of all  
16 the work that we've done with the NTSB and the FAA on  
17 this issue.

18 So we're going to make sure we hit all the  
19 discrepancies we see in the different airplanes we've  
20 looked at, but right now we haven't extended it past  
21 the center tank.

22 DR. ELLINGSTAD: Thank you, Mr. Chairman.

23 CHAIRMAN HALL: Dr. Loeb?

24 DR. LOEB: I have no questions.

25 CHAIRMAN HALL: I just have a few quick



1 questions. Mr. Slenski, your study that I referred to  
2 earlier, where you had the 652 mishaps which were  
3 caused by electrical failures related to instruments,  
4 wiring, and electronic components, do you know if any  
5 of those, or how many of those ended up in fuel air  
6 explosions?

7 MR. SLENSKI: I don't have that information.  
8 In that particular study, the intent was just to  
9 collect the components that were involved, and we  
10 really didn't have -- at this point we don't have the  
11 data to correlate that actual number to the event on  
12 the aircraft. We can't reconstruct that at this time.

13 CHAIRMAN HALL: Well, I'll ask Mr. Thomas and  
14 Mr. Hulm, do you know how many so-called fuel air  
15 explosions of Boeing -- do you keep a record of those,  
16 and how many there would have been, either during  
17 maintenance on the ground, in-service? We were aware,  
18 of course, of the Iranian airliner that we discussed,  
19 the Phillippines, La Bianca, which was brought down  
20 because of a small explosive charge, it was a criminal  
21 act. Are there any others? And if you don't know, I'm  
22 not trying to put you on the spot, I just -- I know  
23 these are very rare events --

24 MR. SWAIM: Yes.

25 CHAIRMAN HALL: -- but I'd like to be sure

1 for the record we have what we do know about them.

2 MR. SLENSKI: We do keep records of these  
3 events, obviously. I don't have it off the top of my  
4 head to run through them. I think the FAA, in their  
5 April 3rd publication, requesting comments, against the  
6 NTSB recommendations, had a pretty complete list of  
7 those commercial and military aircraft.

8 CHAIRMAN HALL: That's where I've seen that.  
9 Is that part of our record?

10 MR. SLENSKI: Yes. I believe that's in the  
11 flammability reduction -- we'll have to correct that,  
12 if it needs it, with Mr. Anderson, when we do that  
13 panel.

14 CHAIRMAN HALL: All right. Well, let's do  
15 that, if we can. Well, good. Well, let's -- none of  
16 the parties have anything else, the technical panel,  
17 board of inquiry. Well, I'd like to go to each one of  
18 you gentlemen and see if you have anything else you --  
19 I know some of you will be appearing again in another  
20 forum, right, tomorrow, but if you have anything that  
21 you think we should be aware of, looking at, anything  
22 the Board should be doing that would help us find the  
23 probable cause of TWA Flight 800's tragedy. Mr.  
24 Gerken?

25 MR. GERKEN: Well, as I mentioned earlier,

1 Mr. Chairman, I think there may be a need for  
2 additional work in fuel misting and electrostatic  
3 charges that might be generated through atomization of  
4 fuel, and the possibility of filling that space with  
5 single polarity electrostatic charge, which could then  
6 charge up some of these conductors we're concerned  
7 about, and basically give us a different charge  
8 generation avenue, if you will, other than fuel  
9 impingement that I discussed earlier. I think that  
10 would be something we'd want to work on in the future.

11 CHAIRMAN HALL: Thank you very much. Mr.  
12 Slenski.

13 MR. SLENSKI: Well, Mr. Chairman, I think  
14 based on what we've heard, we'll probably be still  
15 studying some of these phenomena we've just discussed  
16 on the fuel probes, and I'm not sure where that's going  
17 to take us yet, but we'll be continuing to investigate  
18 that.

19 CHAIRMAN HALL: Thank you. Mr. Johnson.

20 MR. JOHNSON: I don't have any  
21 recommendations at this time for improving the effort.  
22 I would like to take the opportunity to thank you, Mr.  
23 Chairman, for the opportunity of participating in such  
24 an important effort. This is a real team effort for  
25 the air force.

1           There are several individuals I'd like to  
2 mention. Mary Ann Ramsey, Rick Rybolt, J. Edward  
3 Porter, Abigail Cooley, and Tom Dues were of particular  
4 assistance to me. We all hope that our contributions  
5 here will aid in furthering the investigation, and aid  
6 in helping the families deal with this tragedy.

7           CHAIRMAN HALL: Thank you very much, sir.  
8 Mr. Collins.

9           MR. COLLINS: No, Mr. Chairman, I don't have  
10 any specific recommendations. I've been working with  
11 the investigation of this accident, this tragic  
12 accident, since last July, 1996, and I know the Board  
13 has a lot of other things they're looking at, and I'm  
14 sure in the flammability reduction panel tomorrow,  
15 there will be other issues that will come up.

16           CHAIRMAN HALL: Mr. Hartonas.

17           MR. HARTONAS: We will continue supporting  
18 this investigation, Mr. Chairman. Thank you.

19           CHAIRMAN HALL: Well, thank you very much.  
20 Mr. Hulm.

21           MR. HULM: This is the last panel I have the  
22 opportunity and the pleasure to be on, and I want to  
23 express my appreciation to you for letting me be here.  
24 I hope I answered your questions adequately, and I  
25 really appreciate the support the NTSB is giving,

1 especially in Seattle, we're working really closely  
2 with Mike Stockhill, I want to make sure he gets proper  
3 recognition, too.

4 Thank you, Mr. Chairman.

5 CHAIRMAN HALL: Well, good, and thank you,  
6 you did an excellent job of representing your company.  
7 Mr. Thomas.

8 MR. THOMAS: Since I'll be here tomorrow, I  
9 think, serving on the next two panels, I really want to  
10 second some of the comments down the table here, where  
11 obviously this investigation is leading to new  
12 research.

13 There's a large amount of information being  
14 put on the table today, also a lot of questions have  
15 been raised by that information, and we need as a team  
16 to go forward and work to understand those things, and  
17 I think that's a very important thing we all have to  
18 do, work together.

19 CHAIRMAN HALL: Well, I appreciate it. As  
20 you know, the foundation of the National Transportation  
21 Safety Board's investigations for 30 years has been the  
22 party system, in which we cooperate together with the  
23 single aim of finding what caused the accident, and  
24 making recommendations to prevent it from happening  
25 again.

1           We've been able to work with the parties in  
2 this investigation, as we have in past investigations,  
3 in a very constructive fashion, and I hope that we'll  
4 continue in the future.

5           I appreciate all of the resources that have  
6 been committed to this investigation by the various  
7 parties that are represented here in front of me today.  
8 This is, as you pointed out, a very important  
9 investigation, as all the investigations are that the  
10 Board undertakes, and we really appreciate the party  
11 system, we appreciate all of you-all's willingness to  
12 assist us in such a fine fashion, with this  
13 investigation. This panel is excused.

14           We will reconvene in the morning at 9:00  
15 a.m., at which time we will begin which panel, Mr.  
16 Campbell?

17           MR. CAMPBELL: The Aging Aircraft

18           CHAIRMAN HALL: The Aging Aircraft panel, and  
19 we will stand in recess until 9:00 a.m.

20           (Whereupon, at 5:15 p.m., the hearing in the  
21 above-entitled matter was adjourned, to be reconvened  
22 at 9:00 a.m., on Thursday, December 11, 1997.)  
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