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. :

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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

P RO C E E D I NG S

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

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

(Thereupon, the witnesses were duly sworn.)

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

Previously, he was a research scientist at the LaMont Dougherty Geological Observatory of Columbia University. He has expertise in the origin and the evolution of planetary and sub–planetary bodies in the solar system, and the origin of cosmic dust.

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

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

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

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

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

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

Mr. Bob Swaim will be giving an opening presentation, and he is our systems group investigator. He's been with the Board for nine years, and I've given a bio on him in a previous panel, so I won't go into detail there. 1'11 hand the mike over to Mr. Bob Swaim at this time.

MR. SWAIM: Thank you, Mr. Dickinson.

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

I received almost a hundred letters from a number of distinguished people, good citizens across the country, asking the question about the possibility of a meteorite or space junk bringing down and being responsible for the TWA 800 accident, so I think it's entirely appropriate that that matter be discussed and explored this morning, and I appreciate, Dr. Cassidy, your willingness to come and volunteer your time to be here this morning with us.

So thank you very much.

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

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

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

MR. HAUETER: Thank you.

Whereupon

DR. W. CASSIDY

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

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

DR. CASSIDY: When Bob Benson first contacted me about this, he and the group of which he's a member were sincerely trying to respond to the public concern and interest whether a meteorite might have caused the crash of Flight 800. The problem between us was that meteoritic -- and incidentally, it's not meteorology, it's meteoritic -- meteoritic are so far removed from their field, and aircraft accidents are so far removed from my field that we weren't sure what we could do together.

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

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

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

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

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

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

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

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

The next slide is another house, very coincidentally, also in Weathersfield, Connecticut, that was struck by a meteorite in 1971. This particular one, you may be able to see some blemish near the center of the roof, this is a two–family house, and one family lives on the second floor and the other family on the first floor.

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

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

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

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

There’s another set of records accumulated by a branch of the Smithsonian called “The Scientific

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

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

Before we get into the calculation 1'11 say a little bit about terms so that we know if we use those terms what we're talking about, and since you may not be able to read the screen, one term is meteor.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

So the meteorite very quickly then builds up a cap of compressed air in front of it, and this is very highly compressed air, and when you compress air you generate heat, so this cap of compressed air heats up, it heats the front of the meteorite, and as it gets hotter and hotter it begins to glow, and at that point it melts the front surface of the meteorite and vaporizes part of the materials, so this cap of air, this is the meteor that you see, contains highly compressed air molecules as well as atoms and ions from the meteorite. I would describe it probably as a plasma.

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

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

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

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

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

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

If you know the distance of a body you can estimate its size by its angular displacement, but if you don't know the distance -- if you know the mass of a body, if you know the size, then you might be able to estimate its distance from you. But not knowing either one, any observation that attempts to determine this to tell you the size of the body or how far away it was is not reliable.

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

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

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

If we can estimate the area occupied by houses and cars, now, I used only data for the coterminous, United States. Now, coterminous is a word you find in the census tables, and it means the U.S. without Hawaii and Alaska. The Census began tabulating Hawaii and Alaska in 1960, but the data from before that were without those two areas, so I subtracted the data from 1960, on, for Hawaii and Alaska.

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

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

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

DR. CASSIDY: Excuse me?

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

DR. CASSIDY: No.

CHAIRMAN HALL: Good.

DR. CASSIDY: Do you know of one?

CHAIRMAN HALL: No.

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

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

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

Well, I hadn't thought about it, but our population has grown tremendously over the century, and also the number of dwellings has grown tremendously, going from about 18 million around 1905, to 97 million dwellings in 1995. So the size of the target has been changing over the period that we're considering here.

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

so, again, in this column you have the number of hits per decade, and then you have the average number of dwellings, and then you have a question on what is really the average size of a dwelling, the average cross–sectional area of a dwelling.

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

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

So I could then calculate the hits per decade per year, or decade year, actually, it's per decade, for a ten-year period. In some decades where there were no hits at all, that was zero, but you'll see that there are some numbers there.

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

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

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

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

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

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

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

So the numbers I used were total target area in square feet that are represented by houses and cars in the coterminous U.S., and the number of roof-penetrating meteorites per year, hits per year on dwellings, the total target area of aircraft in the air, and solved for the number of aircraft–damaging meteorite hits per year, and that's a simple formula.

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

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

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

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

Now, there may be disagreement on some of the values that I used in this calculation, or some of the assumptions I've made. I've tried to lay them out clearly so that other people can make their own estimates if they disagree with that.

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

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

DR. LOEB: Thank you.

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

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

DR. CASSIDY: Yes.

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

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

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

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

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

I think that about concludes the --

DR. LOEB: What were the larger sizes?

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

DR. LOEB: About 12 pounds.

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

Thank you.

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

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

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

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

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

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

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

MR. HAUETER: Thank you. I have no further questions, and I guess 1'11 turn it over to Mr. Hilldrup for his questions.

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

MR. KITTEL: Good morning.

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

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

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

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

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

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

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

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

MR. KITTEL: Yes, I am.

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

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

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

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

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

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

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

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

MR. KITTEL: We were involved in all aspects of records review. In fact, my team, consisting of either myself or my partner, and two field investigators, one from Chicago, one from Atlanta, reviewed every single piece of recovered wreckage that came into the hanger.

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

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

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

We would literally get down on our hands and knees with magnifying glasses and look at the smallest pieces . I might add that we brought in pieces, such as sand dollars that were the size of your small finger nail, and the condition and the quantity was fairly remarkable.

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

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

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

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

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

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

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

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

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

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

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

While that's happening, there's also a

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

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

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

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

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

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

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

MR. HILLDRUP: Okay. Thank you. Are you

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

MR. KITTEL: Yes, I observed them.

MR. HILLDRUP: You were present for those tests.

MR. KITTEL: I was.

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

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

MR. HILLDRUP: That's correct.

MR. KITTEL: In the NTSB tests, we took various charge sizes from -- I'd like to caveat my questionnaire by saying that for security reasons I would not like to discuss the actual charge sizes, but we took very large charges, and then worked our way down to very, very small -- very small charges, and shot them through representative aircraft metal similar to the, in fact, identical to the center fuel tank composition, both upper and lower skin, front and rear spar, and the span–wise and mid–spar beams.

In all of those cases, when we looked at the results both on the initial plate, which would represent a point external to the fuel tank, where an explosive charge might have been placed, and then at a witness plate, which represented the next adjacent panel, for example, from rear spar to span-wise beam one, we were able to see remarkable evidence of the high explosive effects obviously on the panel that they were initiated on, but also on the adjacent witness panel, which was placed at a representative distance of where that plate would be in the center fuel tank of a 747-1oo.

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

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

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

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

MR. HILLDRUP: Okay.

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

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

DR. LOEB: Yes.

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

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

MR. KITTEL: Right . The earlier test shots were essentially, and again, without going into the numbers, we wanted to develop an understanding of how little explosives could be used to not only breach the center tank, in this case, on the rear spar, but penetrate it and be able to initiate a flammable or explosive mixture.

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

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

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

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

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

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

MR. THOMAS: Thank you, Mr. Chairman. Honeywell has no questions.

CHAIRMAN HALL: Crane Company Hydroair, any questions?

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

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

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

CHAIRMAN HALL: Transworld Airlines, Inc.?

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

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

However, based on the record in houses and cars, it could be possible to make that estimate, it's something I haven't done yet, because I didn't think it was important for this hearing, but something which I may attempt in the future.

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

CHAIRMAN HALL: The Federal Aviation Administration.

MR. STEETER: No questions, Mr. Chairman.

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

MR. RORIGUES: No questions, Mr. Chairman.

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

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

CHAIRMAN HALL: Dr. Ellingstad.

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

CHAIRMAN HALL: Dr. Loeb.

DR. LOEB: I have no questions.

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

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

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

MR. KITTEL: That is correct, sir.

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

Why don't we, before we move to the next panel, take a short break until -- we'll come back promptly at 10:30, and start promptly at 10:30.

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

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

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

(Therefore, the witnesses were duly sworn.)

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

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

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

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

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

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

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

During the NSTB investigation, he has been responsible for inspecting fuel probes and compensators, and associated wiring from the accident aircraft and another Boeing 747 for anomalies that might contribute to ignition of fuel.

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

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

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

Jerome Hulm is manager of electrical systems in Boeing, 16 years in the Boeing Company, involved in the design of wiring installations for the air force AWACs, and tanker and E-6 aircraft. He also participated in the design analysis and test certification of FQIS for the Boeing 737, 57, 67, and 77.

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

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

All these people have been entered in our Web site, in our NSTB Web site. 1'11 turn the microphone over to Mr. Bob Swaim.

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

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

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

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

We looked at the possibilities and found no evidence of overheating in the motor cavity, such as lack of cooling, through inadvertent operation, we found no evidence of a seized rotor, or worn bearings that could have caused friction or rotational drag, short circuiting within the motor cavity, short circuiting at the electrical connector that would have had to come through the motor cavity, we found no evidence of a case breach, due to an electrical short circuit.

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

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

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

We've been looking at strayed electrical sources that could have been possible. We found no evidence of power cables or short circuits that shorted and burned through the top of the fuel tank to ignite the ullage. We looked in the area, the dry bay, between the forward spar and span-wise beam three, and found no evidence of a fire pre-existing in that area, a short circuit beneath the fuel tank, igniting the tank, or a leak from the tank.

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

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

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

We examined for short circuits providing powers to FQIS wires in the flight engineer’s fuel gauge, or at the connector that the gauge attaches to, that was recovered from the wreckage.

CHAIRMAN HALL: Did you state what FQIS was?

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

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

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

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

We looked for the possibility of leaking hot air damaging the Fuel Quantity Indication System, and the power wire insulation above the tank, melting the wires together, providing power, and we looked and found no evidence of fuel vapors igniting from the heat of bleed air after a temperature control failure at the engine, allowing straight hot air from the engine bleed to reach these ducts that are in the area of the fuel tank.

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

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

We looked into the possibilities and did a lot of testing of electrostatic ignition. The background photo shows a clamp that is not electrically bonding to the tube it's mounted on. We looked at the possibility of the fuel flow rate having induced an electrostatic charge into the tube that you're looking at, the larger tube, and possibly charging a tube connector that was not electrically bonded.

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

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

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

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

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

The area is still under investigation --

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

MR. SWAIM: Okay.

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

MR. SWAIM: That's absolutely correct.

DR. LOEB: Okay. Thank you.

MR. SWAIM: One of the terms we've been using, we never close out consideration of any of these areas, we set them aside. So the areas I've just presented are areas that right now we've been working through, and we found evidence against, or found no evidence of, and for one of those reasons we've set it aside in this accident. That's true.

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

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

The second bullet, energy, we've been looking into, or are currently looking into, is the possibility Of, open investigation, energy being induced into the fuel quality system, combined again with latent failures, or foreign material, or copper sulfide deposits in the fuel tank.

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

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

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

MR. GERKEN: Before I get started I’d like to just give just a brief overview of what electrostatic charging is, for the benefit of the families and those in the audience that don't understand that. It's a very simple concept, actually, and we generate charge through contact and separation between two materials.

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

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

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

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

I give you a photograph of the clamps that Bob had alluded to, the various types of clamps that might be present in the center wing tank of a 747 aircraft. Particular attention should be paid to the Teflon clamp, which has very good electrical isolation from the fuel tube it's around.

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

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

MR. GERKEN: We believe that to be a form of nitrile, but we weren't even sure on that one, as a conductive property, though, and 1'11 get into that in a little bit.

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

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

DR. LOEB: Thank you.

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

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

Very simply, and I want to make this clear, our testing at Wright-Patterson was a fuel impingement-type test, that is, fuel that might be leaking from a cross–feed manifold line onto these conductive items that are isolated, so the focus of our work was fuel impingement .

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

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

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

MR. GERKEN: Okay. We sprayed fuel, in fact the test apparatus is up here, too, we pumped fuel through the system that you see here, the orifice in question, which varied, was within the test chamber, fuel was sprayed from the orifice, onto the test specimen, that you can see below, and then a voltage measurement was taken from the test specimen, external to the cabinet, by way of a charge plate monitor.

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

MR. GERKEN: Yes.

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

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

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

DR. LOEB: I'm also hoping to set this up for the audience. Can you give an estimate of what the electrostatic discharge is when you walk across the carpet and put your hand on a metal object, such as a doorknob, what that may be, relatively, in terms of jewels?

MR. GERKEN: Okay.

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

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

CHAIRMAN HALL: Okay.

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

DR. LOEB: Thank you.

MR. GERKEN: Phase two. We weren't satisfied with our work in phase one, in terms of fuel temperatures used, spray distances, target angles, fuel conductivity, some key players in the generation of charge, so phase two was dedicated to a target plate, eight–by–twelve inches, that we could easily move in different directions, and try and categorize all the different variables that we're looking at here, and, of course, once again, we were still focused on the isolation of the object.

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

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

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

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

CHAIRMAN HALL: Mr. Gerken, can an anti-static additive have any effect on that?

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

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

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

This figure shows the apparatus that Dr.

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

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

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

MR. GERKEN: Okay.

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

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

Results were a little bit more exciting when you artificially charged the fuel. Joe also used several additives, which had an effect on the amount of charge generated, but the maximum that we were able to see, with a simple, I guess, Gulf 178 additive, at 333 parts per million, which is no longer available, and then at 1,000 parts per million we were getting voltages up in the 4,800–volt range, obviously beyond the 3,200-, 3,500-volt range that I had mentioned earlier as being significant.

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

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

MR. SWAIM: I’d like to add here, he was developing -- let’s go back a step. Dr. Joe Leonard is probably one of the world’s experts, he is one of the world’s experts in electrostatic charging with fuels, and he has worked for 30-some years for the Naval Research Laboratory, and when the Chairman asked us to find the best, well, we did.

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

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

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

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

MR. GERKEN: That’s fine. Thanks .

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

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

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

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

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

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

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

MR. GERKEN: Well, the work at Wright-Patterson, again, was due to direct fuel movement against the test specimen, very similar to what I mentioned when I started, contact and separation of two materials generates electrostatic charge, that's tied into the energy aspect of the investigation by focusing on the capacitance, the bucket of charge, and the potential, the voltage that you reach on those clamps in this case.

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

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

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

MR. SWAIM: Very good. Can static develop in refueling on the ground? I know there were a couple of accidents in 1970.

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

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

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

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

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

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

MR. GERKEN: That's correct.

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

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

MR. GERKEN: That's correct.

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

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

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

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

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

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

DR. BIRKY: Okay.

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

DR. BIRKY: Okay. Okay. Thank you.

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

Is there some reason that these ungrounded pieces were in the tank? Whey were they there? Mr. Thomas or Mr. Hulm?

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

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

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

The previous –– excuse me, I don’t know the gentleman’s name, Gerken is it, described the concept of a bucket of water carrying an electric charge, that is the capacitance. If we have a large metal object, it becomes a large capacitor, and it can pick up large amounts of charge, and that becomes a hazard to the airplane.

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

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

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

MR. SWAIM: Jerry, do you have any guidance on how large a piece of medal can be to be in the fuel tank unbended?

MR. HULM: The standard that was used in the development of all of our models is out of MILB 50-87, which establishes a three-inch rule. If the linear dimension and direction is less than three inches, the component does not need to be bonded.

MR. SWAIM: Okay. What is --

CHAIRMAN HALL: Can somebody put that into English?

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

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

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

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

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

MR. HULM: Correct.

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

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

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

What we found in that, those incidents, there was some minor damage to the airplanes, they weren't major fires, what we found was the amount of static charge being developed by the fueling system, the trucks, if you will, that are fueling the airplane, was significantly higher than we'd ever experienced, and the data eventually pointed to this number ten people that Joe Leonard was using in the prior investigation.

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

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

MR. SWAIM: Okay. Thank you, Ivor. This year in the Safety Board's lab we opened a -- I'm changing off the static subject –– this year we opened a fuel quality compensator from the TWA 800 wreckage, and we found a black spot on a crimped wiring islet. After examining the spot under magnification, research, not surprisingly, for the number of airplanes they have, led us to the air force laboratory at Wright-Patterson again for a second subject. The air force has a specialized laboratory that examines wires and switches, and it turns out they had extensive experience with probes, and similar black markings.

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

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

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

MR. SLENSKI: Yes, Mr. Chairman.

CHAIRMAN HALL: Good.

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

Again, the fuel probes are basically large capacitors, tubular construction, you're measuring the capacitance between an inner and outer electrode. What we have to remember is that capacitance is a function of the applied signal wiring, probe construction, and the ratio of the fuel to air between the electrodes, and any resistance changes can obviously affect this performance.

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

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

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

Again, in the lower left-hand corner, the way this became apparent is that our maintenance personnel were experiencing measurement problems on the fuel quantity systems of several types of aircraft, they also noticed black marks on the fuel probes, and in that situation they obviously were concerned, could this be an arc that occurred in the fuel probe, and that's how we became involved in this analysis.

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

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

In the cases we're looking at here, if you measure these resistances, or probe the resistances, we're looking at from one to a hundred kilo–ohms, and that's significantly low enough to actually affect the operation, and that will give you inaccurate readings of the fuel probes.

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

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

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

Now, if we go directly to the lower one on this quadrant, what we looked at previously was an optical version of that coating. What we're looking at here is an scan electrode micrograph of that same residue, and the SEM, or scan electrode microscope, is beneficial to us, because you get great depth of field.

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

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

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

In addition, the sulfur will also react with copper that may be exposed, and you form copper sulfite, and these are these semi–conductive compounds that appear to be black or gray on these probe surfaces.

If we can first go up to the lower left quadrant, 1'11 just focus on this example again. Residues on the wires, most of these probes, in some cases, have been on the aircraft over 25 years, and, again, we need to point out this is an aging phenomena, a degradation of materials over many years in fuel.

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

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

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

Now, if we go over to the lower right, I don't know if this is going to show up too well, maybe we can zoom in on that area there. That's better. This is just how we prove whether or not what we're looking at is actually there on the surface.

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

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

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

In this case here, if we look at that red square or rectangle we have here, the problem in this case is our maintenance is reporting a fuel quantity problem on the probe system, and what they found with isolation once we removed these wires is that there was low resistance between that terminal in that lower blue splice, which is ground, basically, and in this case we're getting resistances in the high kilo–ohms range, 100 K, 100 kilo-ohms, and again, that was affecting probe operation.

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

MR. SLENSKI: Sure.

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

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

DR. LOEB: Okay. Thanks .

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

MR. SWAIM: Mr. Slenski, I have a question for you. You were showing us the film, it kind of looks like flaking paint, or something --

MR. SLENSKI: That's correct.

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

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

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

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

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

MR. SWAIM: Thank you.

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

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

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

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

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

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

The center is a section, and I think if we can zoom in on that center there, I think it's the most interesting. There's actually black residues on this, and in this case this is carbon build–up, and so we have a sooting inside the tube, and what our maintenance personnel have reported is the fuel probing malfunction, they removed it off the aircraft, they were testing the probe, and when they applied their test voltages, there was basically a small explosion inside the fuel probe.

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

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

The source of the ignition is what we'll be discussing of that previous probe, and then, again, this occurred actually in the compensator area, and if you'll look at the upper left corner, where we've dissected the probe there, the red rectangle shows you the actual short area, and the nylon piece there, that little spot right there, is the actual arc site, so we actually had arcing between that red wire and that green wire.

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

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

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

This is an experiment we ran in the log, and I think if we just look at the lower left quadrant, again, this is a buildup of the cooper sulfite residue and silver sulfite residue, and they're typically combined, you'll find them both together. This was on a terminal in -- again, I just want to show that this is a different type of probe system.

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

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

This was done in a laboratory experiment, and in this case, how much energy we were using, I can go over that. This was a DC power source in this case, it was 10 milliamps and 13 volts, and in this case, first of all we have to convert that to power, so we're talking about 13 milliwatts, and then to get the energy, you have to consider the amount of time that you apply that power, so for the sake of here we'll say one second, if it's one second you're looking at 13 mini-jewels of energy, and obviously that's a function of time.

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

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

Sulfur nor fuel reacts with the silver and the copper, and I think one question you might ask, and 1'11 answer that now, well, how do you solve the problem. One is if you have nickel plating, you don't seem to see this reaction, so many of our newer probe systems use nickel–plated wiring, and nickel surfaces.

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

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

MR. SWAIM: Thank you very much. I know Dr. Birky is itching with a question, so 1'11 let him --

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

MR. SLENSKI: I know Mr. Swaim had asked me that question, and that was a very old system, and quite a few years ago, and my understanding, and maybe I need to explain what I do in the air force, where I've researched that, and we do investigate fuel failures, and we provide that information to our program offices and fuel personnel, and they will take that information, and usually fix the problems that we're finding.

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

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

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

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

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

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

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

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

MR. SLENSKI: I beg your pardon.

CHAIRMAN HALL: Dr. Birky, can I -- I'd like to get into -- we've got Mr. Slenski up here right now.

MR. SLENSKI: Yes. Yes.

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

MR. SLENSKI: Yes.

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

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

CHAIRMAN HALL: So the taxpayers pay your --

MR. SLENSKI: That's correct.

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

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

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

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

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

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

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

MR. SLENSKI: That’s correct.

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

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

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

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

MR. SLENSKI: That’s correct.

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

MR. SLENSKI: We can address first in the mishap handbook. As an example, what we published was a handbook for investigators and people who conduct the investigations to use as guidance, and I think we've actually published around 350 to 400 copies of that, and distributed that actually throughout the world, to get that information out. I briefed the World Air Force on our results, other countries, and the U.S., so we've tried to get this --

CHAIRMAN HALL: The FAA?

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

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

MR. SLENSKI: That's correct.

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

It looks to me like that you might tell me if there are other people at Volpe, or Oklahoma City, or Atlantic City have done work in this area as well, but what I wanted to know, it seems to me you've done a substantial amount of work in this area, we've got a lot to learn from you, and is there anything we can learn or understand, because we happen to be in that business ourselves of investigating accidents, but our main interest is then using that information to prevent accidents, so that's where I'm coming from.

MR. SLENSKI: To respond to that, as an example, we discussed wiring issues. We're running a program now to find ways to inspect wires using non-destructive techniques, and 1'11 discuss that in the aging aircraft panel.

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

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

CHAIRMAN HALL: But in your studies you

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

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

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

CHAIRMAN HALL: In the air force?

MR. SLENSKI: In the air force. Correct.

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

MR. SLENSKI: That's correct.

CHAIRMAN HALL: Mr. Johnson.

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

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

MR. SLENSKI: I can add that as an example, what I did with the handbook is we went to our safety center down in Albuquerque and brief all the investigators of our findings. We've gone to our depos, maintained aircraft to get those results out to them for their information. So we tried to disseminate the information. Again, we're a research lab, we're not --

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

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

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

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

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

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

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

MR. HARTONAS: We have recently become familiar with the findings with copper sulfur in probes . We have issued a proposed rule that will provide for protection from copper sulfur. We're considering additional action in the future that will have to do perhaps with replacement of probes once we have concluded that it's necessary.

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

MR. HARTONAS: During the course of this investigation.

MR. SLENSKI: Thank you.

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

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

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

MR. SLENSKI: Well, again, that's one of the problems I've run into. Some of this is -- I've given the information to the organizations. I sometimes don't know if they've followed-up or implemented those recommendations . We'd have to get back with you on that to see a specific inspection.

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

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

MR. SLENSKI: That's correct.

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

MR. SLENSKI: Well, I think some of the issues will probably be discussed in the aging aircraft panel. I have a presentation there on failure mechanisms of wiring, which 1'11 be getting into.

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

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

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

MR. SWAIM: No, no. I --

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

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

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

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

CHAIRMAN HALL: Well, let's just say that we will –– if some people need to move in and out, excuse themselves, we understand, but we will continue then to 1:00 o'clock, and break again, as we did for lunch, between 1:00 and 2:00, so that people can make some plans for lunch, and know what the schedule is. So we'll now continue until 1:00 o'clock, with Mr. Johnson.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MR. SWAIM: That's appropriate.

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

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

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

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

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

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

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

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

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

The points of interest in this image are the strain relief plant that is in the image there, to restrain the ship's wiring. The wiring, I think it's of interest to mention, is ship's wiring, and the probe is brought into, and I guess attached to the wiring inside the tank.

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

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

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

In that area the Hi-Z wiring are shielded wires, and what that means is that there's a poor conductor with a layer of Teflon insulation, and around that insulation is a fine weave of silver-plated copper braid, and that silver-plated copper braid, well, actually, that's, I think, Fiberglas, but that's a good sort of similar kind of construction there.

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

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

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

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

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

MR. HULM: Yes. I can address that.

CHAIRMAN HALL: Okay. Thanks .

MR. HULM: The Hi-Z and Lo-Z refers to low impedance, high impedance, as related to the way the indicator works, whether it's a low impedance circuit inside or a high impedance, it's got a lot of resistance, or low resistance.

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

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

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

Mr. Slenski was mentioning copper sulfite deposits, copper and silver sulfite deposits. You'll note in this image just adjacent to the red insulator on the crimp–on connector, between the crimp–on connector and the heat shrink, there's a rather dark stain that is present on the Teflon insulation. That was determined to be copper, and -- well, let me back up.

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

MR. JOHNSON: Right there at the --

MR. SLENSKI: Okay.

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

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

MR. JOHNSON: Yes. Okay.

CHAIRMAN HALL: Now, that's copper sulfite?

MR. JOHNSON: Yes. Yes, sir.

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

MR. JOHNSON: Okay. On the right-hand side of that image you'll notice a -- well, first of all, the steel clamp has been rotated almost 180 degrees out of its normal position, to allow the movement of the wires from beneath it to show -- I wanted to show you the surface, the opposing surface right beneath the steel clamp. That surface is neuraled, or serrated, and the shape of those protrusions is a very sharply pointed combs, that's a field of very sharply pointed conical structures.

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

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

This page contains some images of -- and this is strictly a sampling, this is by no means all-inclusive, 1 just wanted to portray a sample of what we found in our inspections here. The image -- well, first, a general comment is the note indicates these were damaged sites that we found that were apparently caused by contact of the PTFE, or Teflon insulation, with an adjacent surface, a form of compression damage.

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

I might also point out there that the black residue present, we determined that that also had high concentrations of silver, and copper, and sulfur, indicating to us that the fuel had reached the braid, the shielding braid of that Hi-Z wire, and we had gotten the flow of these deposits out onto the surface.

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

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

MR. SWAIM: Thank you.

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

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

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

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

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

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

MR. JOHNSON: No. The only damage that I have images here to present that was caused by the neural surface on the terminal block is the one in the upper left-hand quadrant there. The other three images, the other two sites represented by those three images were caused by, I guess, compression with adjacent surfaces, and in both cases, those turned out to be smooth surfaces.

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

MR. JOHNSON: We found just one site that was contained within the clamp itself, where when the clamp was tightened down, it –– well, let me back up a page here. Yes, if we could back up to the previous page and look at the lower right–hand image, you can see –– it was on this particular assembly, as a matter of fact, you can see there’s a pinched area there in the heat shrink, and when I removed that heat shrink and looked at the Hi-Z pigtail lead that was directly beneath that pinch mark, there was a indentation in the Hi-Z pigtail wire at that point, and when I was looking at that under high magnification, I was able to visualize the poor conductor through the insulation, the insulation had thinned to the point where it was possible to actually -- the insulation was still intact, however, it was apparently thinned enough to allow light to pass and reflect back for me to be able to observe the core wire, or core conductor.

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

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

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

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

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

DR. LOEB: Okay. Thank you.

MR. JOHNSON: I would estimate that I looked at least four of this style in my 105 evaluation.

DR. LOEB: Okay. Thank you.

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

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

That was of great interest when we had a group of -- Mr. Swaim and a group of interested individuals came to our laboratory. They requested that we do cross-sectional inspections, which we did, and you can see in the lower left–hand corner the result of that. In the area about the middle of the image above is where this cross-section was taken, and --

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

MR. JOHNSON: This is still of the --

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

MR. JOHNSON: Yes.

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

MR. JOHNSON: Yes, sir.

DR. LOEB: Thanks .

MR. JOHNSON: This was what we observed. Each of the wire strands there, for reference, is about eight-thousandths of an inch in diameter, 32-gauge strands, and you can see that the insulation has been thin there at the top portion, plus it's been thinned to less than eight-thousandths of an inch, and you can also see the significant deformation that's taken place and sort of creating an egg shape in the overall appearance of the cross-section.

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

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

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

MR. SWAIM: Very good. Thank you.

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

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

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

The one just to the left of it, the tall peak, is sulfur, and then the peak, the shorter peak just above the number one on the "X" axis is a copper peak, there's another one out at about the number eight on the "X" axis there.

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

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

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

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

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

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

CHAIRMAN HALL: Okay. Fine . I just want to be sure that it's clear that this is not from the accident aircraft.

MR. SWAIM: It is, and we made sure that all of the slides were titled with the N93105 at the top. 1'11 take action, if it's not in the record, to get it into there.

CHAIRMAN HALL: Thank you.

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

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

MR. SWAIM: Was this a high amperage, what type of amperage were you running at this point, a very low amperage?

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

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

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

It turns out that when we did elemental analysis of the material that's shown as a dark stain on the upper left-hand image, most very closely matched that for polyurethane, and the folks that did the analysis for us felt very strongly that that was thermally damaged polyurethane coating.

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

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

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

MR. SWAIM: Dave, excuse me.

MR. JOHNSON: Yes.

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

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

MR. JOHNSON: Okay. I have to rely on the cataloging that was done by others, so 1'11 --

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

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

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

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

The insulation is Teflon, PTFE-type material, and there are broken strands of the wire visible there, and the wire looks -- gave the appearance of having been pulled probably back through a clamp, it was heavily skinned, and the damage was of the nature that would imply the insulation was skinned off due to a more tensile load having been applied.

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

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

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

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

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

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

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

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

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

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

I wanted to show this image, because it has two points of interest. One is the heavy embossing that the pressure from the braid material left behind on the wiring, and the second is the residue, again, silver, copper, and sulfur-rich residue that we found there.

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

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

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

DR. LOEB: Could you make it very clear where you found the copper, and silver, and sulfur deposits? Specifically, where was it on this wire insulation, on the silver braiding, or --

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

DR. LOEB: Right . Thanks .

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

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

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

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

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

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

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

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

Mr. Slenski’s work has demonstrated that. We didn’t have time to really get into that sort of detail on this particular study, that’s, I guess, work we still have to do.

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

MR. SLENSKI: Well, what 1’11 comment on is, when I have shown examples of that problem on that one connection where we had residues between the crimped joint and the termination, the recommendation we made is to use shrink wrap around there and protect the exposed conductor, which they had done, and that solved the problem.

MR. SWAIM: It did solve it.

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

MR. SWAIM: Simply putting shrink wrap on --

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

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

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

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

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

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

MR. SLENSKI: What I can recall is we have found the residue form in as short a period as ten years, and it possibly could be shorter, so it will be a function of the amount of sulfur in your fuel, the amount of exposed area, and temperature, most likely, because what we're looking at here is, again, a degradation mechanism, it is somewhat of a corrosion reaction, which will be driven by a heat, obviously, service area.

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

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

MR. SWAIM: Okay. Very good. One more observation from sort of the overall pool of things that we looked at. The deposits we saw on the non-mishap, these same deposits that we saw in the non-mishap equipment appeared to be much more dense and more completely covering this Hi-Z area, this Hi-Z lead area, on the compensators. They are more consistent, more dense on those than on the probes. I'm led to believe that the compensators were located low in the tank, and might therefore be submersed for greater periods of time at a stretch, beneath the level of the fuel. I did not get an opportunity to review the positioning of these equipments in the tank, but that's a possibility.

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

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

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

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

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

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

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

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

MR. HULM: Well, we’ve had the opportunity to examine -- well, first of all, you're going to have to kind of highlight the differences between the probes that the air force is looking at, and the fuel probes in the Honeywell system installed on the 747 airplane.

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

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

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

So the exposure on the probe itself is a lot less, and I think that's a little bit indicative by what Mr. Johnson noted when he performed the insulation resistance test on the probes removed out of 93109, the derelict airplane, or the other service airplane. Even with the sulfite deposits he did see there, there was no indication that there was breaching of the insulating capabilities of the probe.

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

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

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

CHAIRMAN HALL: Do you share information?

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

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

MR. HULM: Again, the inspection service

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

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

MR. HULM: Yes, sir.

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

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

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

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

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

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

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

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

MR. SLENSKI: That's correct.

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

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

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

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

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

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

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

We do have a service bulletin that we are preparing, to go in the center tank, and to take a look to find any of these terminal blocks that are in the airplane, that we're seeing the majority of the damage on, and if those blocks are present, to remove them out of the airplane, put in probes with the series four and later terminal blocks, and either wiring that was attached to those terminal blocks will be, either that entire harness in the center tank will be removed and replaced, and the wiring to that terminal block will be re-terminated, to eliminate any possible damage.

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

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

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

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

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

AFT E RNOON S E S S I ON

(Time noted: 2:00 p.m.)

CHAIRMAN HALL: 1'11 reconvene this public hearing of the National Transportation Safety Board that's being held in connection with the investigation of the aircraft accident involving Trans World Airline, Inc. 's Flight 800, a Boeing 747-131, that occurred eight miles south of East Moriches, New York, on July 17, 1996.

We are presently in the middle of a presentation by the Ignition Sources Panel that Mr. Swaim is conducting, and we're going to continue this afternoon with our examination of potential ignition sources.

I know this is a long panel, and I appreciate very much the participation of the panelists and everyone's indulgence. I want to be sure we get all the information on the record, because I think this is showing us how many potential ignition sources there could be, if something went wrong.

That's why I was extremely pleased yesterday to hear -- well, I was very pleased to hear the FAA tell us yesterday they would be reconsidering our recommendations to address the problems of explosive fuel vapors and the results, in light of our recent tests.

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

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

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

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

It was in that situation there how we became involved being a materials lab, we routinely, again, conducted failure analysis investigations, and we were selected to look at the probe, because they were trying to understand what had really occurred, was it an arcing event that occurred in the fuel probe, if not, what is its residue?

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

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

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

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

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

DR. LOEB: That’s right.

MR. SLENSKI: So they probably looked at

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

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

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

DR. LOEB: -- or do you know?

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

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

MR. SLENSKI: Okay. 1'11 see if we can get that information.

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

DR. LOEB: Well, the real question is: How did we learn, how did you learn about this continuous problem, and was it primarily through the operating crews, the pilots squawking the system, or was it --

MR. SLENSKI: Sure.

DR. LOEB: -- through the maintenance folks, or __

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

DR. LOEB: Okay. Thank you.

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

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

We were concerned that as we went to more electric aircraft, we needed to address electrically related failures and mishaps, and we just so happened -- that program was actually initiated in 1989 through the Small Business, and it was to collect data to help us understand how to do analysis and collect components, and really, in that particular study, fuel probes were not, although I think they are mentioned in there when we looked at the large body of data, which you had mentioned before, fuel probes really did not come out as a major problem, although we did surveys in those areas, we had reviewed data on fuel probes.

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

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

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

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

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

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

MR. SLENSKI: Okay. Thank you.

MR. SWAIM: Mr. Hulm, the testing that Boeing did on the 23-year-old probes in September of 1996, I believe, were those removed from the airplane with the wiring still attached, or was the wiring removed, probes taken out, and then put into whatever your test rig was?

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

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

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

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

CHAIRMAN HALL: Was that something they were looking for in the inspections then?

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

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

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

CHAIRMAN HALL: Okay.

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

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

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

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

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

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

MR. SWAIM: Since the air force is using airplanes of equivalent or slightly older years than the commercial flight, and the air force is using a slightly more sulfur-rich fuel in JP-4, or at least used to before JP-8, Mr. Slenski, do you think that could have a bearing on the air force having found a problem with this in 1990?

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

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

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

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

CHAIRMAN HALL: So somebody would know what the composition of the fuel is you use, and wouldn't that be important to you in doing your work?

MR. SLENSKI: For our analysis, if you go back and look at some reports, we did have the fuel analyzed, the JP-4 analyzed in one of our reports, and as I think Mr. Swaim had mentioned, we changed over to JP-8 pretty much anyway in our aircraft several years ago.

CHAIRMAN HALL: Do you know why that decision was made?

MR. SLENSKI: I can't really. I'm not, again, a fuels person, and unless someone else here -- 1 don't know if Steve has any comments on it.

CHAIRMAN HALL: No. I don't want any speculation. If somebody knew, that would be fine.

MR. SWAIM: Very good. For the record, Mr. Chairman, you'd asked about the parked airplane that we got these other probes out of. The good folks from TWA made a call back to Kansas City, I understand the airplane came in for a de–check, actually I found this through -- the airplane came in for a de-check, a heavy maintenance check, and the maintenance check had not been completed when they decided to cease using the airplane. It was parked in Kansas City on September 26, 1994. The total time was 95,004 hours, so it was a couple thousand ahead of the accident airplane. The total landings were 17,941.

CHAIRMAN HALL: When did you climb in it, into the tank, or get the stuff out of there, do you–all remember the date on that?

MR. HULM: If not, 1'11 get it for the record.

CHAIRMAN HALL: I want to be sure we're very clear that it's not –– that presentation did not come from TWA 800, and what we were looking at was from an airplane that had been sitting for some period of time, so be sure that's clear on the record.

Is this a good time, I'm just going to ask this question, because it's been on my mind, and I'm trying to understand. As you-all know, on the cockpit voice recorder, at 20:29:15, there's a voice that says "Look at that crazy fuel flow indicator there on number four. "

Mr. Hulm, do you-all know what -- can you tell me what that fuel flow indicator, where that -- the wiring on that, and that probe, and what you might know about that, or what –– what is your–all's opinion on that comment?

MR. HULM: The fuel flow indicator itself is totally separate from the fuel quantity indication system, it's not related in any way, it doesn't monitor or measure fuel in the tank with fuel probes, or anything like that.

CHAIRMAN HALL: It's not in any way connected.

MR. HULM: No. It's two totally separate systems, they don't share any sort of data between them, or anything. It's an independent system, just a measure of the fuel going into the engine, and it’s kind of a backup to the quantity system, to provide a check between the two.

CHAIRMAN HALL: So it’s not attached to any of the probes or anything?

MR. HULM: No, it’s not. There’s a separate -- I guess maybe Mr. Thomas might be better to address ––

CHAIRMAN HALL: Well, it was widely reported, of course, when we released the cockpit voice recorder, Monday, and I thought it would be appropriate. I’m sure you–all have been aware of that since the beginning of the investigation as to whether you had any thoughts on that, or what had been done in that area, because it is so, what is it, a minute -- within a minute before we lose contact with the –– the electricity ceases.

MR. THOMAS: Mr. Chairman, if I can -- the fuel flow meters are installed on the engine, they provide a signal of how much fuel -- they obviously provide a signal of how much fuel the engines are using, it’s a simple turbine device that puts out a pulse.

Normally, if the engine fuel flow meter starts misbehaving, it may be there’s ice, or whatever, that may be affecting that turbine performance for a short time, it will just wriggle and it will go away. It has absolutely nothing to do with the gauging system for the tanks. We use it as a completely separate backup. If one of the gauging systems on a given tank was to fail, you could continue to use the flow meter to track how much fuel was coming from that tank. It's a backup system.

CHAIRMAN HALL: Okay. Please proceed, Mr. Swaim, I just wanted to clarify that at this point.

MR. SWAIM: Okay. We had an illustration, I'd be hoping this would all come up later. In the wing center section there are seven small vertical lines connected by lighter lines that are red. The pencil point is right now indicating the left aft fuel probe.

The heavy red line that comes out of the rear spar of the tank comes down along a wiring run, with other wiring, it comes up the side wall of the airplane, into the overhead, it would be over the left-most passengers, and then forward under the upper deck windows on the left side of the airplane, and then crosses over the roof of the airplane, and goes into the flight engineer station. So that's the routing for the center wing tank wire harness.

The blue routing that comes in from the right wing is the routing for the fuel flow that we were able to find. It comes into where the pencil point just was, right there, and that's in the electronics compartment behind the nose gear.

The only place that the group has been able to find a common run of wiring is, as Ivor said, not between the fuel flow and the fuel quantity, but from that electronics compartment, up to the flight engineer's panel, through the wiring that goes to the volumetric shut-off box, part of the ground re-fueling equipment, and there is a common routing in that. I think that's a pretty good graphic answer.

CHAIRMAN HALL: Well, and I guess didn't we have a problem with fuel in the airplane on the ground?

MR. HULM: Well, that's more where I was going with the --

CHAIRMAN HALL: Okay.

MR. HULM: –– other questioning.

CHAIRMAN HALL: Well, then 1'11 shut up and you-all go on, as long as we're going to cover all that, Mr. Swaim, because all that is on the record, and people would want to be –– we need to be sure it's covered.

MR. SWAIM: I'm trying to. The center tank, to go back to my train of thought here, the airplane, the accident airplane, Mr. Hulm, it had an increase over the last several months of its existence of writeups, maintenance actions against the ground refueling equipment.

Does the ground refueling equipment rely on the compensator from the center tank, for that tank, obviously?

MR. HULM: Could you please re-state the question? Sorry.

MR. SWAIM: Sir, the ground refueling, the volumetric shut-off box, does it take signals from the compensator from the center tank, for refueling that tank?

MR. HULM: I'm drawing a blank here.

MR. SWAIM: Okay. It's a detailed question. I apologize. It's a detailed question. Obviously, there's no preparation for this kind of thing, so okay. Let's try --

DR. LOEB: Do you want that provided for the record?

MR. HULM: I can definitely get hat for you.

DR. LOEB: I mean I think we need to do that, at least, and/or if you have any information that does speak to that, you might want to bring that up.

MR. SWAIM: Well, I think the proper person, I think, for that would have been Mr. Taylor, from Honeywell, yesterday.

CHAIRMAN HALL: Is he still here? He has left. Very well.

MR. SWAIM: Okay. We will be investigating that further. As I've mentioned, and will keep mentioning, this is an open part of the investigation, it really is.

CHAIRMAN HALL: Let me just say, Mr. Swaim, so it's clear to anyone who is watching these proceedings, that we are in the process of an investigation, and we have an obligation to explore these issues. That does not mean that any of these issues are going to lead us to conclusions, and at present, we do not have any, and there will not be a probable cause that will come as a result of this hearing, but the things that are identified in the maintenance records, and identified in the cockpit voice recorder, flight data recorder, need to be covered, and the public view, as part of this investigation, so if you're doing that, proceed ahead.

MR. SWAIM: Thank you, sir.

MR. RODRIGUES: Excuse me, Mr. Chairman --

CHAIRMAN HALL: Yes?

MR. RODRIGUES: -- the answer to your question, Bob, is yes, it does use a volumetric shutoff in the center tank.

CHAIRMAN HALL: Thank you.

MR. SWAIM: Okay. We will be following-up, obviously, as the Chairman mentioned. I had a question to the FAA. Mr. Hartonas, before this investigation what awareness had the FAA had into sulfide deposits such as copper silver sulfide?

MR. HARTONAS: Yes. As I stated earlier, Mr. Swaim, is that the FAA had no previous knowledge of copper sulfur deposits. We became aware of it during this investigation.

MR. SWAIM: Okay. Thank you.

MR. HARTONAS: However, in the course of this investigation, as we identify here today, and it was presented during this hearing, the copper sulfur deposits, including damaged wiring insulation off the FIQS system, drew some safety concerns as potential ignition locations. I recently introduced AD to provide protection for the wiring of the FIQS, we'll address both of those.

MR. SWAIM: AD or NPRM?

MR. HARTONAS: It's an AD, it's a proposed rule under the umbrella of airworthiness directives.

MR. SWAIM: Okay. Very good. Question from that comment for Mr. Hulm. Is there a reason that the fuel quality system wiring was protected only at the gauge, when we have the fuel quality system wiring tied to other wires and routed with other wires between the tank, the flight engineer station, down to the electronics compartment, and so forth, as we saw in that graphic?

MR. HULM: So when you say protected at the gate here, you're referring to the current limiting circuitry within the gauge itself --

MR. SWAIM: Correct.

MR. HULM: -- correct? I think that was just the normal course of the design itself. The majority of the wiring from --

CHAIRMAN HALL: That design didn't change on any subsequent models, or is that consistent on all your models?

MR. HULM: Correct. It's basically the same we use on all of our models. The wiring from the flight engineer's disconnect, down to the center tank disconnect, and to all the main tanks, really, I mean to all the tanks, from all the indicators is basically the Teflon wiring, with the nylon over blade across it, and that protects some abrasion.

There is some of the normal ship's wiring between the flight engineer's, the actual indicator, about three feet of wiring that goes to the disconnect, and then down to the all-shutoff unit, and we use our standard wire routing practices within the airplane to make sure that we have any separation from structure for the wire bundles.

Within the pressurized vessel itself, the wire bundles are clamped with either a circular clamp every 24 inches, or else there's another clamping arrangement used, where it's like a channel clamp that will hold bundles, and there's a foam bar that will go across the top to keep that in place, to make sure that it was secure.

There are tie wraps around the bundles to hold them and make sure they're not moving around a lot, and things aren't flopping around, to make sure there's no interference with structure, and any time there's a penetration through a sharp edge or anything, you'll have plastic grommets to protect the wiring, also.

Within the tank itself, when you look at the wire routing within the tank, again, we use stand-offs to keep the wire away from structure. We utilized the Teflon wiring within the tank, also. Again, there's grommets wherever there's a penetration through structure to make sure that there would be no chance to nick or abrade the wire itself.

We used good practices in routing the bundle, and I don't think that the main reason for any physical separation of the harness from any other wiring would be mostly a concern with interference from other electrical systems causing an inaccuracy in the gauging system, so with these particular systems, at the time they were designed, it was not determined to be necessary.

So the view then is, if you do get an outside electrical short on the FIQS wiring itself, nothing will happen, because the components and the cells in the tank are designed to withstand the 115 volts AC that you may get into the wiring.

MR. SWAIM: Because of the quarter-inch gap in the fuel probe components that Mr. Taylor was talking about, that's the --

MR. HULM: Correct. We do the 1,500-volt AC insulation resistance test, I mean the dielectric withstanding test and the 500 DC insulation resistance test.

So those components can withstand that, and the minute you get the short, you're going to cause a malfunction of your indicator, and it would be noticed by either the flight crew or ground maintenance, and that particular section would be corrected and repaired.

DR. LOEB: Let me just see if I understand. You're saying the protection from the possibility of a second failure, a short circuit, is that you would get an erratic gauge indicator, and that's the protection from that.

MR. HULM: Well, the real protection is the fact that the components in the tank can withstand the 150-volts AC.

DR. LOEB: Well, they can withstand that, providing there's no additional failure, there's no short circuit, or something of that nature that would give you a short across it that you would not want.

MR. HULM: Correct.

DR. LOEB: So if that is the case, then the only protection we have right now is some sort of an erratic gauge indicator that may alert the crew that something is happening.

Is there any downside to a surge protection system --

MR. HULM: That we --

DR. LOEB: -- is there any downside to it?

MR. HULM: To a surge protection system?

DR. LOEB: Yes. For the wiring going into the tank.

MR. HULM: One of the issues we've looked at, I think as a result of what the FAA has released, and the end paper that they put out, one of the recommendations was to add surge protection at the spar disconnect going into the tank, and some of the issues there that need to be addressed is the fact that a lot of time these components are passive in nature, and if they do fail, you'll never know until --

DR. LOEB: You mean you have a latent failure.

MR. HULM: It depends on how the unit would be designed. If you have some sort of surge protector, you've got to design the proper enclosure to ensure that it's going to be there at the time that you need it.

DR. LOEB: Well, I would agree with that, but the point that you just made is that some of these failures could be latent, you don't know that they're there --

MR. HULM: Correct.

DR. LOEB: -- that's exactly what is of concern, and I recognize that originally the system was designed that way. I guess my question is going to be you now, did anyone think about this kind of added protection following the Philippine Airlines' 737 explosion?

MR. HULM: Not to my knowledge, I think, again, because the exact cause of that particular accident was unknown, and nobody really addressed the issue of --

DR. LOEB: Well, what was ruled out was the possibility of any external cause for that explosion, meaning that it had to be something internal, therefore, somehow in that accident, energy got into that tank from the system, and there was no consideration of adding some additional protection such as a surge protection system.

MR. HULM: I'm probably stepping a little bit outside of my area of knowledge as far as the Philippines accident, and everything that's associated with that, but I'm not aware of any study they did in that regard.

DR. LOEB: Okay.

CHAIRMAN HALL: Well, if there is any, you can provide it for the record.

MR. HULM: Yes, sir.

MR. SWAIM: Mr. Hulm, Boeing released the service bulletin for the center tank inspections, 2205, which is nearly a hundred pages of instructions. Would it, in its present form, address the problems, the breaks in the insulation, or the copper sulfide that we've been seeing here today?

MR. HULM: No, it would not.

MR. SWAIM: Okay. But the revised service bulletin would, is that right?

MR. HULM: That's correct.

MR. SWAIM: Okay. Are all the airplanes already inspected, the 52 that you mentioned yesterday, going to have to be reinspected for the new service bulletin?

MR. HULM: I think that's a determination that needs yet to be made. We haven't made a decision on that yet.

MR. SWAIM: Okay. Mr. Hartonas, I understood from Mr. Cheney yesterday that the FAA is waiting for the revision to come out with an NPRM or an AD airworthiness directive on that, is that right?

MR. HARTONAS: The FAA is closely viewing the impact of multiple tank entrances, with the fact that there's already been discovered, damaged wiring insulation or damaged probes. We want to minimize tank entrance, when we go in there we want to make it worthwhile with meaningful inspections.

MR. SWAIM: Is that a yes or a no? Are we going to AD it or not?

MR. HARTONAS: The FAA is going to most likely move with an NPRM or AD action for tank inspections .

MR. SWAIM: Most likely is safe, that's fine.

MR. HULM: Mr. Swaim, I wonder if I could make a correction to --

MR. SWAIM: Please.

MR. HULM: -- what I just said earlier? The real fix for the nick wiring and stuff that you referred to on the previous question, the real fix for that is the surface bulletin, the re-work service bulletin that we'll be generating from the series three terminal block, not the inspection bulletin.

We're really trying to keep any re-work instructions out of that inspection bulletin, and keep that purely just to inspect and determine the condition of the aircraft. If any corrective action is required, then we'll go back and release the appropriate service bulletin to address that specific situation.

So the inspection bulletin will not address the issues as far as the nick wiring and the things you see, that's where the series three terminal block service bulletin, that one will address those issues.

MR. SWAIM: Okay. I guess I'm coming down to the kind of question that the Chairman has been asking, how long is all this going to take, first, for the service bulletin, then for the NPRM, or AD, and then I guess back for another service bulletin? How long are we talking?

MR. HARTONAS: Mr. Swaim, I want to clarify the statement I made previously. Once we have a comprehensive inspection plan, the FAA will definitely do that. We're in the midst of preparing that comprehensive inspection plan with Boeing.

MR. SWAIM: It has to be worked out, we understand that. Mr. Hulm, I believe you may even had said yesterday, January, next month, the inspection service bulletin --

MR. HULM: January of next month for the inspection bulletin revision, and we're looking at late January, early February for the bulletin for the series three terminal block.

MR. SWAIM: And then, Mr. Hartonas, how long will it take to make that mandatory through an AD, if it comes through, I understand, in a typical -- we're not trying to pin you down, I'm just trying to get a general idea of how long we're talking for this process.

MR. HARTONAS: Well, seeing that this is a priority right now, to this tragic accident, it will be just a matter of a few days before the FAA has the AD ready.

MR. SWAIM: Would this be the kind of inspection, Mr. Hulm, or Mr. Hartonas, I'm sorry, that would be go out and inspect all the airplanes within six months, or would this be within the next de–check, or four years?

MR. HARTONAS: We haven't gone that far in the development of it. We're still looking -- we're still trying to make sure all the parts are there, and try to assure that once we do go out with it, the airlines have the materials and the instructions they need in order to accomplish the service bulletin itself. It doesn't do us any good releasing it, telling them to do it in three months, and then we can't supply the parts for them to do the re–work.

So that issue is still being worked through Boeing, we're still talking to our suppliers, making sure the appropriate wiring is there, the wiring bundles, and all the terminal blocks that they need to upgrade these probes are available.

MR. SWAIM: I think that's a good point.

It's not just Boeing, and the FAA, and the airlines, there's a lead into this, isn't there? There's some kind of logistics before you release a service bulletin, correct?

MR. HULM: Correct. There's a lot of coordination to go on, even with the FAA and everything that we've been doing here, all of our suppliers that -- we have a different supplier for the tank harnesses, it's quite difficult to make long-lead items, especially with the connectors themselves, and the terminal blocks, we have another supplier for those at this present time, and then the logistics of making sure that if probes are returned, that the facilities are there to re-work them in time, and turn them around, and get them back to the airline, so there's quite a lot of work to do in order to get one of these service bulletins out, and particularly this one, because the components involved and the age of the airplane.

MR. HARTONAS: Mr. Swaim --

MR. SWAIM: Please.

MR. HARTONAS: -- the FAA agrees with that statement. We recognize that these inspections are going to be very meaningful and important; however, we constitute a lot of maintenance activity, and perhaps this maintenance activity may be repeatable. That is the reason why the FAA proposed additional protection to the airplane's wiring, so that additional maintenance activity, or the burden to the airlines is minimized.

DR. LOEB: The additional protection being the surge protection, or --

MR. HARTONAS: The airworthiness directive at this time provides for surge suppression or shielding separation, it doesn't pin down a specific method.

DR. LOEB: Now, that is an NPRM at this point. The is not an AD. It has 90 days on it, is that correct?

MR. HARTONAS: Yes, it does.

Dr. LOEB: After that, an AD, when it is issued, will provide about how long, do you know, for --

MR. HARTONAS: One year.

DR. LOEB: One year. So that this additional protection that you're talking about is out in the future, just like the inspections would be.

CHAIRMAN HALL: He answered the question. Let's move on.

MR. SWAIM: Great. Thank you. Since all this has to be done for the center tank, and the different Boeing representatives illustrated and demonstrated how similar the center tank and the other tanks in the airplanes are, why hasn't the FAA called for these same inspections in the other fuel tanks?

MR. COLLINS: The center tank is the most flammable environment, as the NTSB flight test has shown, so that's our first priority. We are evaluating the other tanks, though, as follow-on action, and a lot of that action will be based on what we learn out of inspections and the program with the center tank.

We have plans for a comprehensive program on all airplanes, not just the 747, and that would cover all tanks, also.

MR. SWAIM: Okay. Can you expand on that comprehensive program for all airplanes?

MR. COLLINS: Yes. That was outlined in Administrative Garvey's letter to Chairman Hall, in response to your recommendations, and it said, we're going to propose action applicable to the fleet of large transport airplanes, and one of the requirements is to have each type certificate holder develop a fuel tank maintenance and inspection program, and require each operator to have an FAA-approved fuel tank system maintenance program, and require review of the original certification compliance findings to the fuel system requirements, to re-validate that failures within the fuel tank system and fuel system will not result in ignition, and also, interim required procedural changes to prevent operation of any electrically driven fuel pump and fuel tanks, with adjacent heat sources, unless that pump's inlet is fully submerged in liquid.

One alternative to that would be if they had a flame arrester installed on the pump inlet, as interim action.

MR. SWAIM: Good. I'd like to come back to that thought in a couple of minutes, and I would like to talk about pumps in a couple minutes. Before we get off wiring, Mr. Slenski, we've been looking at pictures, a couple of pictures of the various wiring bundles.

There's a document in one of the exhibits, it's exhibit 9c, page 197, it's an OSHA document that -- I'm sorry, 9c, 49 -- that says electrical arcs can be 35,000 degrees Fahrenheit, and expand wire, the copper, 65,000 times, and that's what that big flash and spark are.

My question is: Can nylon or Teflon insulation withstand those kinds of temperatures, Mr. Slenski?

MR. SLENSKI: In reference to an arc?

MR. SWAIM: Yes, in reference to an arc in a tightly wrapped bundle, if you get two of the chafe together, or however short.

MR. SLENSKI: In that situation, the Teflon would probably sublimate, vaporize instantly, and melt away from that area very quickly.

MR. SWAIM: So there is a possibility of putting power onto the wrong wire, if there's an arc in a bundle?

MR. SLENSKI: The question is what the arc would do to the bundle, adjacent wires, is that what you're asking?

MR. SWAIM: Yes.

MR. SLENSKI: I'm sure there's going to be damage to surrounding wires, to some extent, and, again, Teflon melting is way below that temperature, and so as you mentioned, arcs are very hot, but they're also very isolated and limited in the area, that you probably would cause some damage in the surrounding insulation.

MR. SWAIM: Question for you. You examined some other wiring when you were looking at the scavenged pump relay, and I know you found something of interest on that, a crack in the insulation. Do YOU have anything that you can speak to, as far as that, in this flow?

MR. SLENSKI: I've got two charts that can discuss some of our findings, if you'd like.

MR. SWAIM: If we could do that fairly quick, yes.

MR. SLENSKI: Basically, the first chart here will hopefully set up -- if we could look at the right top corner there, quadrant, what we're looking at there is the actual scavenge pump relay, and the wiring that was attached to that relay that was submitted to us for analysis, and in this case, we requested a look at the electrical context for evidence of anomalies such as melting, pitting at the context, and just briefly we really -- we found no evidence of that in these contacts.

However, in the inspection of the exhibit, when we examined a wiring, we noted that this particular insulation, which has been referred to in the past as Poly-X, was marked with a process called hot stamp marking, and with this process here, the wire is marked basically for purposes of maintenance, and also so you can track and identify the wire. So if we zero in on the lower right quadrant, this is the actual marking process.

And, again, this is the actual process, it comes down on the wire and penetrates the insulation, normally, slightly, to emboss the wire with the nomenclature.

In this case here, it has been a fairly deep penetration, as we're seeing in these photos here. The seven-four, as you can see, has been rotated, in the middle photo, you can see where it's penetrated the insulation, and the top shows a close-up of that particular seven, and we felt that was excessive penetration of the insulation.

Now, if you look over to the left lower corner, this is off another mark, basically, a dash of some type, and there was actually a crack emanating from that particular hot stamp mark, and actually exposed a conductor.

Now, we did not see any evidence of arc tracking or arcing from that event, and I think we need to recognize this type of cracking could have occurred during the actual breakup of the aircraft.

MR. SWAIM: This is from the accident airplane, right?

MR. SLENSKI: This is from the mishap aircraft. That's the wiring off the scavenge pump.

The next chart has a little more detail here, if we go to the upper left quadrant. This is a cross-section now of one of these wires, and now you can see the actual penetration of this hot stamp process into the insulation.

This insulation consists of three layers. There’s an outer white layer, an inner amber-colored layer, and a middle amber–colored layer, and an inner white layer. As you can see here, it penetrated all three layers.

If we go over to the right side, you might want to back off on that a little bit so they can see. Let’s look at the lower right corner cross-section there. That’s a longitudinal cross-section, showing several marks of wire, and you can see how it’s penetrating the insulation, but also note that from the lower right, to the top left, you can see a marked increase in the depth of penetration there. This is just showing you that this mark is inconsistent.

If we go up further, just to the top of that, that’s a close-up of one of those penetration areas, and we can see that, in this case here, looking at my notes here, that there’s 1.1 roils of insulation left, or 20 microns of insulation left.

This is normally, I believe I’ve looked at numbers here around 8 mil of insulation, or eight–thousands of an inch of insulation.

So our concern here, this is just an observation, that you might want to go look at the hot stamp process and other parts of the aircraft that was used on this wire.

MR. SWAIM: Mr. Chairman, the point here is, and the reason I asked Mr. Slenski to bring that up is, we will be back in the hanger shortly, up in Calverton, looking for more wiring, especially of that combined routing between the flight engineer station and the electronics bay, but that is the most shredded portion of the airplane. In the center photo behind us, Boeing said there is 150 miles of wire.

CHAIRMAN HALL: But you'll be able to know where the wiring came from, is my question.

MR. SWAIM: Yes, sir. Every six inches the wire is marked with a unique mark --

CHAIRMAN HALL: The hot stamp.

MR. SWAIM: -- as Mr. Slenski just showed you, and the marking tells us right where that wire came from, or at least the routing that wire came from.

CHAIRMAN HALL: And you said that hot stamp might be a problem, Mr. Slenski, is that --

MR. SLENSKI: I think it's recognized in the industry.

CHAIRMAN HALL: Gauging it down to the

Chairman's level here, is that something we should be concerned about?

MR. SLENSKI: Anytime you have a process that penetrates insulation, you need to be concerned. Now, this is a standard technique for marking, controllable, it's not a problem. We've used it in industry for quite a few years. It's being used today. I think back then -- I think we have better controls today, but I think, you seem to recognize that if you're going to mark wire by this process, you have to be very careful on the controls.

CHAIRMAN HALL: Do we know how much of the wiring we have already, Mr. Swaim?

MR. SWAIM: Well, from previous trips to Calverton, having lived up there for a little now, we have parts of that harness in at least three general areas of that six-acre hanger that I'm aware of. It is a fairly hefty wire bundle, it's -- Larry is working to put a picture up that's just a small portion of that bundle. There we go. This is the photo I used yesterday. There are two fingers sticking through the hole in the right side, where his finger just showed. The bundle is about three, three-and-a-quarter inches in diameter, where it goes off to the left of the photo .

Right now it's a lot of shredded individual wires, and different piles of wires that are around the hanger. This is what I've said over and over, it's an active investigation, we keep going back, we keep spending weeks up there looking at just this type of thing.

CHAIRMAN HALL: But if it arced, we might be able to find out within --

MR. SWAIM: It's a needle in a haystack, but we will be looking.

CHAIRMAN HALL: Thank you.

MR. SWAIM: Mr. Hartonas, the surge suppression the FAA is considering, there were some press reports regarding induced energy tests -- actually, before I speak to you, Mr. Hartonas, let me ask Mr. Hulm about the induced energy tests that were picked up by the press. We've done a lot of testing with Boeing. Can you elaborate on those induced energy tests, tell us something about those?

MR. HULM: Yes, sir. As part of the investigation, we were asked to look into a number of different things, and this is just one area we wanted to gather some more information on. We did this in concert with the NTSB and the FAA.

The question was posed, how much energy can we induce from wiring that's adjacent to the FIQS wires -- let me start over again. The question was, the FIQS wiring from the flight engineers panel, down to the EA bay, how much coupling do we get from adjacent wires, and can that energy from that adjacent wiring get into the FIQS wiring, and then into the tank?

The technical term is induced electromagnetic interference . They're like electrical transients, and the nearest way to put that, I think maybe in real-world terms so people can understand it, it's like a magnet.

If you take a magnet, the closer you move it to like a paper clip, the stronger the field becomes, and all of a sudden you pick up, and if you move it away you can kind of feel the pull and the lessening of the strength, and if you go really fast, you kind of get a transient, that's what it would look like, you kind of feel a pull on your finger, and it will go away, and that's what these wires do as they generate electrical and magnetic fields, when an electrical pulse goes through them, and that pulse then gets transferred over to adjacent wiring, and that's the kind of thing –– we were asked to look at that and determine exactly what it would take to cause any sort of problem with the equipment in the tank.

So what we did was we got a full ship's head of center tank probes and the compensator, we got the wiring, the actual airplane wiring, and these stuff, and we got the wiring all the way from the spar, up the flight engineer's panel, we mocked up a little flight engineer's panel, with the national indicator that's used on the airplane, so that we have a relatively simulated environment, we thought, as close as we could get it to a laboratory, which is to simulate an airplane.

There's multiple phases to the testing, and it's a rather long test that we have in progress, and we're right in the middle of the fourth phase right now, but the first phase is to just check out the system to make sure we're correct, and we did, and it was okay.

The second phase was to induce these type of transients on the power wires going into the indicator and see if anything could get through the indicator, and into the wiring, and into the tank, and that looked okay, there were no problems there.

The third phase of that testing was what I would term as a severe stress test, and it did not necessarily represent anything we knew could be on the airplane at the time, but it represented to us an environment that we should examine.

So what we did was we took 75 feet of wiring, and basically wrapped it around the FTS wiring that we had in the lab, and this was the ship's portion of it, and we attached that to a transient generating device.

In this case it's a giant relay coil. What happens with relays is that when you turn them on and off, they'll degenerate a nice voltage transient for you that can get coupled onto your wiring.

So when we did that under normal airplane conditions without any faults induced into the tank, there were no problems. We didn't see any arcing or any breakdown within the tank units themselves, or in the tank wiring.

The next part of that testing was to insert a piece of debris between the inner tube on the probe, and the inner surface of the outer probe, and what we did was we actually shorted that piece of debris directly to that inner tube, and then laid it up against the outer tube, so there was not a direct short circuit there, but it was laying up against it.

When we did the transient testing under those conditions, there was a small arc between the inner surface of the probe, or that outer tube, to that piece of debris we had, and that debris was either -- we used two different kinds when we were doing this testing -- either a thin piece of strand of steel wool, or a piece of lock wire, and in both instances we had little arcs that we could see at a curve right at that junction, where those two met each other.

CHAIRMAN HALL: They were arcs.

MR. HULM: Yes, sir, visible arcs. The next part of that is we had to determine how much energy is in those arcs then. There was a tremendous amount of time and a tremendous amount of effort put into that, because this is basically new stuff, and nobody has done this type of testing before, and it was a very difficult procedure to go through, and it took probably almost a month-and-a-half of steady testing in order to get to a method that we had some relative confidence in, even though right now we still need some way to collaborate some of the information we did get.

What we did find out is that we did have one instance during the testing, out of 70 different measurements that we took, or 70 different transients that we generated, where we exceeded the .2 mini-jewel limit that is the industry standard as far as our ignition energies.

At that point in time, the NTSB and the FAA have been participating totally with us on this, and they've been witnessing all of our testing and everything. We had to make a decision whether this represented a real airplane environment, and we're basically conducting an experiment at this time, and we had to determine if there was an actual threat on the airplane, so what we did is we conducted the test on a 747 at the same era that the TWA 800 airplane was built, and it was configured very similar to the TWA 800 airplane.

We were able to use that airplane, it was an in-service airplane, so it wasn't like it wasn't in salvaged condition or anything. We were able to use the power system on that airplane for the testing, so we got as much of a real environment as totally possible, and what we did was we took our own set of probes down with us, and basically disconnected those from the tank, so we would not induce anything into the tank that we did not want to, because we wanted to make sure we didn't cause a hazard or anything, since that was an in-service airplane, and we connected it up to our own little ships at -- to our probes outside of the tank, so we reconstructed basically what we had in the lab, using a real airplane, and were able then to hook up our test equipment to these probes to determine and measure the voltage specs that we were getting on the wiring, going into the tank.

There was a lot of work that went into this test. We did a lot of analysis, looking at all the airplane wiring, relative to the FIQS wiring, making sure that when were doing a test that we exercised every component we knew that could be a possible inductive source for energy into that tank.

That testing showed that the voltages that were being induced in the wiring, as part of the real airplane itself, were extremely lower than what we were getting in the lab, and there was no indication from that test that any arc could be generated from the voltage transients that we saw from the airplane.

So that’s kind of like where we’re at with the testing right now. What we’re going to be doing is taking that information and moving that into a laboratory environment, so we can do some additional investigation now on some of the information that we got from the airplane itself, and try some different failure modes that we weren’t able to do on the airplane, because it was an in-service airplane, and we could not damage it in any way. So we’re still just -- that’s kind of like we are at in the investigation right now.

MR. SWAIM: Very good. I’d like to mention at this point that this has been a very long, drawn–out process, Mr. Chairman, it is not something that can be done quickly, and we've been getting a lot of support out of Mr. Hartonas and the FAA, and Mike Stockhill, out of our Seattle office, staying with Boeing on this program.

Mr. Hulm --

CHAIRMAN HALL: Before you get off that, let me ask --

MR. SWAIM: No, I'm not getting off it.

CHAIRMAN HALL: Okay. Well, go ahead.

MR. SWAIM: Okay.

CHAIRMAN HALL: I've got a question before you get away from it.

MR. SWAIM: Yes, sir. You mentioned you'd wrapped in the previous lab test the 75 feet around the harness, was that tightly wrapped like a coil, or was that a slow, just general spiral type of wrap?

MR. HULM: From what I understand, it was a slow, general spiral, maybe like a circle every foot or every two feet, but it was secured around the bundle itself, it wasn't laying loosely up against it.

MR. SWAIM: Okay. Now, what was the highest voltage you saw in those tests?

MR. HULM: In those tests it was

approximately 1,600 volts.

MR. SWAIM: Okay. What was your primary voltage, the voltage induced into the 75 foot, was it 1,600 volts that you put into that original 75 foot?

MR. HULM: I don't recall that offhand, what the induced side was. I'd have to check, look at the lab tests.

MR. SWAIM: Mr. Hartonas, you were there, do you remember?

MR. HARTONAS: I believe it was 28 volts.

MR. HULM: No, that's the power that was supplied to the coil itself. What sort of transient the coil was generating, that I don't know. That's what you're asking, right?

MR. SWAIM: Very good. Mr. Chairman?

CHAIRMAN HALL: Well, my question is, you are familiar with the systems group report --

MR. SWAIM: Yes, sir.

CHAIRMAN HALL: –– which I've read, along with a little bit of other information, and on page ten of that there's a footnote down at 13 that says "The fuel quantity indication system and the number four engine fuel flow wires pass fluorescent cabin white wires of up to 350 volts AC in the shear grouting."

If you read all of this together, then you know that there was the crazy fuel indicator we talked about, we know that they had a problem with the plane accepting fuel at loading, that was -- if I'm incorrect on any of this, correct me, but I'm taking this, that they had to pull the circuit breaker to fuel the plane, and that there had been some electrical problems with the lights.

Now, is the model you are recreating going to kind of explore, to be sure that, what's that word you used, where it jumps, or transfers, or --

MR. HULM: The electrical transient --

CHAIRMAN HALL: Yes.

MR. HULM: -- induced electrical transient.

CHAIRMAN HALL: Are you going to address that, is that being addressed?

MR. HULM: I don't know if the testing we'll do will specifically address the issue you're talking about. I think -- I don't -- as part of the investigation, this testing is basically rated to what we could induce. I think that will cover any sort of transient that may have been induced by the lighting wiring itself.

The specific wiring that you're talking about, the highest voltage that we have routing with the FIQS wiring that we have identified, was some cabin lighting was back by the sidewall of the airplane, and that was only 200 volts.

CHAIRMAN HALL: Is that footnote correct, Mr. Swaim, is there 350 volts there, or is that not correct?

MR. SWAIM: I believe from the wiring diagrams we've looked at, it's correct. The primary input might be a little under 200 volts, as I remember. I'm doing this off the top of my head, sitting here. We'll go back and we'll explore that, and make sure.

CHAIRMAN HALL: Well, you just read all this and those things kind of jump out at me. They may not jump out at anybody else, but they --

MR. HULM: The analysis that we did showed that the highest voltage we had routing with the FIQS wiring was 200 volts. There is 300 volts in the airplane, and it may be this particular lighting circuit you're talking about, but that did not show up in our review as routing with the fuel quantity wiring, although it may be --

CHAIRMAN HALL: And you've gone through all the maintenance writeups on this airplane and the maintenance history, which we're going to get into in a later panel, as part of this --

MR. HULM: I personally have --

CHAIRMAN HALL: You personally –– you have not.

MR. HULM: No, I have not.

CHAIRMAN HALL: Is there somebody with Boeing that has that responsibility?

MR. HULM: Yes, sir.

CHAIRMAN HALL: Okay. I want to ask that question, because that's what I get when I read all this information, I would like to know whether that is a problem or not a problem.

DR. BIRKY: I have a couple of questions I would like to pursue about that, if I could. I assume from your discussions that --

CHAIRMAN HALL: Wait just one minute now, here we go, and then 1'11 be quiet, and you–all have the floor again. This is in exhibit 9A of your docket SA-516, and I'm on -- and this is on page 112, where it says that "The raw bundle 1360 has a fuel flow number four sigma wires, routed partially with bundle W350 on the right side of the forward fuselage, close proximity of fuel flow wires to 350 volts, AC power, and that wire is 1306–L1892–22, of the cabin fluorescent lighting transformer T-63, at station 360." If you could look into that, Mr. Hulm, I would appreciate it.

MR. HULM: I just think we were

miscommunicating a little bit. You're talking fuel flow again and I was talking fuel quantity, so that's the difference, but we'll look into that for you then. Thank you, sir.

CHAIRMAN HALL: According to his footnote it all comes together, it's bundled together.

MR. HULM: We'll look into that.

CHAIRMAN HALL: Okay. Go ahead, Dr. Birky.

DR. BIRKY: I assume that when you're doing these inductants tests, which I will call them that, if that's appropriate, you're not using the shielded wire to the tank, is that correct?

MR. HULM: We're using the configuration that was on the TWA 800 aircraft. That does contain a Hi-Z wire that is shielded, yes, but not the overall shield, as on some of the later 747s.

DR. BIRKY: So you're wrapping both wires together around the bundle, is that correct?

MR. HULM: We're wrapping the wire that's inducing the energy onto the FIQS wiring around all three wires that are going into the tank.

DR. BIRKY: Okay. When was that change made to all the wires that go into the center tank?

MR. HULM: At line number 244, there was some manufacturing instructions released at that time to add additional shielding from the flight engineer's panel disconnect, down to the spar on all the FIQS wiring in the airplane.

DR. BIRKY: And the voltage you get is dependent on what factors when you do that test?

MR. HULM: The transfer voltage?

DR. BIRKY: Yes.

MR. HULM: It depends on the proximity of the source to the wire.

DR. BIRKY: And the number of turns per the length?

MR. HULM: Yes. The number of turns is more to make sure that you've got a really tight connection between the bundles, as opposed to adding additional energy into the -- you know, the more you would do that, it would induce more energy, but for the purposes of this test, it was almost negligible, that wasn't really taken into account.

If you took a piece of wire and you wrapped it, you know, within every quarter inch you had a turn, that's going to induce more energy than if you had it spread out over a longer distance, but the number of wraps we had, like one or two per foot, would not make a significant difference in the results. The idea there is that the wires couple tightly close to the

FIQS wiring.

DR. BIRKY: And was that designed to approximate the way the wires might be run in the aircraft?

MR. HULM: No, that was not designed to approximate any sort of installation that would be in the airplane. The test is basically a stress test on the system to see if we could get some sort of energy into the tank.

CHAIRMAN HALL: Well, I think it would be helpful if the results of that test could be made available for the public record, is that a problem?

MR. HULM: I don't know that to be a problem.

CHAIRMAN HALL: Good.

MR. SWAIM: We have some mention of that in the systems group report, as it is. It's an ongoing, open test. We've gotten to the third --

CHAIRMAN HALL: Well, Mr. Swaim, as you know, the American people rely on us to be their independent person on these investigations --

MR. SWAIM: We will put it in there, sir.

CHAIRMAN HALL: -- and Boeing is an outstanding corporation, and they've got 200,000 employees, and build excellent aircraft, but we're testing something here, and it might possibly -- it may or may not have anything to do with what caused this accident to occur, and we need to ensure that the test protocol and what's being done is understood and available for everybody, or you and Dr. Birky need to go and do your own tests for us.

MR. SWAIM: Yes, sir.

CHAIRMAN HALL: Okay?

DR. BIRKY: Can I come back and ask Mr. Hulm another question at least on this test. You indicated that the shielding was on both wires has been changed on subsequent aircraft. Do you know why that was done?

MR. HULM: What's written in the manufacturing paper, because it was released to do that, was that they were having problems with the accuracy of the system at the low end, when the gauge was reading near zero, and they were attributing that to interference from different systems in the airplane, so they added the additional shielding and removed that interference so that they could calibrate the indicators correctly.

DR. BIRKY: So the shielding does percent RF pickup, is that correct?

MR. HULM: That's correct. Yes.

DR. BIRKY: That's all for right now. Thanks .

MR. SWAIM: I have one last question in this area. You've not had a chance to go back, and you don't know what my question is going to be anyway, so --. Two months before the accident the number four fuel flow indicator, quote, "Pegged high and inoperative," unquote.

According to Ms. Eckrodes (ph.) factual report on maintenance, factual report, exhibit 11A, page 24, "The writeup said that the maintenance personnel suspected wiring, but that the system passed all tests." Is this the kind of thing that, you know, transient like this, that you're talking about with your EMI problems, your interference type of problems?

MR. HULM: Well, without speculating too far, these transients are very short in nature, you're talking milliseconds --

MR. SWAIM: Milliseconds .

MR. HULM: Yes. -- if not microseconds in some instances, so I don't think any -- anything that could be observed, like a fuel flow meter problem, would not be as a result of these type of transients.

MR. SWAIM: Mr. Hartonas, is an electrical engineer with the FAA, and looking at it from your standpoint, I mean there's the Boeing standpoint, and you've been doing your testing, and we've been doing testing with the parties, which includes you, that the FAA has got its own expertise, what do you see as far as latent failures, or single-level failures that could affect this fuel quality system? Do you see anything?

Is there anything the FAA is doing that we're unaware of?

MR. HARTONAS: The FAA has participated in this investigation from the start, and we diligently have gone out looking for possible ignition sources of a latent nature. We could include failures of a latent nature, such as conductive debris in the tank, that could bridge probes. We could say that the copper sulfur may be of a latent nature, bridging probes.

MR. SWAIM: But if you have conductive debris in the tank, and I know in our systems factual we mention --

CHAIRMAN HALL: What is conductive debris, so, again, 1'11 understand?

MR. SWAIM: Okay. If we have bits of metal from the sump or the bottom of the fuel tank that gets picked up, and we found documented in the factual reports, the nine exhibits, that some, say, steel wool, and some other metal were found in the fuel pumps, so I'm saying now, without the background, if some of that safety wire, steel wool type of debris -- what kind of problems could that create for the fuel probe, let me put it that way.

MR. HARTONAS: I didn't quite finish. I mentioned the copper sulfur perhaps being a dormant developing type failure, a latent failure, conductive debris, in the same category. Damaged wire insulation also falls under the category, but you also need two conductors to fail, or the insulation of two conductors to fail.

Those in themselves, those in themselves could not be an ignition source, could not spark an ignition. You would have to have some type of energy getting into the tank, a hot short, perhaps, or an induced transient, which could be -- lightening produces such transients.

Those voltage sources, in combination with conductive debris, copper sulfur, the damaged wire insulation, or damaged probes, are the ones that could present the combination for a possible ignition source. That is why the FAA has taken the prudent action, as we have with the NPRM.

CHAIRMAN HALL: Does that answer your question?

MR. SWAIM: I think it does. It does.

MR. HULM: I wonder if I could clarify one thing, though.

MR. SWAIM: Please.

MR. HULM: Mr. Hartonas referred to lightening as being a possible source like this. I think people must understand that these airplanes are protected against lightening strikes. The proper shielding exists on the wiring along the leading edge of the wing itself, and the structural design of the airplane, which Mr. Thomas could speak of more fluently than I could, is designed to protect against lightening strikes, so in that instance I guess I'd like to clarify that. Our systems are protected against that source of energy in the tank.

MR. HARTONAS: I agree with that statement, Mr. Hulm. I was referring to the broken shield that was discovered in the exhibits, certain shields tend to deteriorate with time on the airplane. I just don't like to speculate on scenarios.

The NPRM, in fact, is out for the comment period, 90 days, and we'll review all the data and findings in the conclusion of those 90 days.

MR. SWAIM: But let me go to Mr. Slenski for a moment. Is this a way that, I know I'm jumping into the aging panel, but is this the way that shielded wiring brakes down, where the shielding can penetrate or somewhat penetrate to the inner conductor?

MR. SLENSKI: Well, actually, that's an interesting question, because you might ask, why do we put silver on copper anyway. We put it on there to make it conductive, because copper oxidizes fairly quickly, normally, silver stays fairly surface conductive, and part of the shield integrity is to maintain very low conductivity, it all interfaces in connections .

So if you degraded that silver interface, you could actually increase resistance of your shield, and that would lower your shielding capability, basically.

MR. SWAIM: Okay. But one aspect of Mr. Hartonas's answer, could that provide us with a small spark gap, essentially, if the inner insulation is breached by degrading shielding?

MR. HARTONAS: We recommended the testing for different scenarios in failing a shield. I think it's part of the continuing investigation.

MR. SWAIM: Okay. Very good.

MR. SLENSKI: What you're saying is possible, no doubt about it.

MR. SWAIM: Has it been seen as a breakdown, an aging mechanism of shielded-type wiring?

MR. SLENSKI: The shielded wire, what I was referring to, there had been issues where loss of conductivity, if you're talking about breakage of the shield, and somehow getting arcing, I --

MR. SWAIM: Or to puncture the inner insulator with the broken shielding.

MR. SLENSKI: Now, what you're talking about is the primary conductor shorting to the shield.

MR. SWAIM: Yes.

MR. SLENSKI: That's definitely -- that has been a problem.

MR. SWAIM: That has been. Thank you.

MR. SLENSKI: I have seen failures associated with that.

CHAIRMAN HALL: Do we have a picture of that, with the shield, and a --

MR. SWAIM: Mr. Johnson had a picture where he had looked at the shielding, and they might be able to flip that up. There is the shielding inside the outer layer of insulation, inside that shielding is another layer of insulation, and I should probably let Mr. Slenski explain it, and Mr. Johnson, rather than myself.

MR. JOHNSON: I think what you're pointing out here is obviously the --

MR. SWAIM: The shield is something on the wire, it's not something separate.

MR. JOHNSON: The shield is there to protect, obviously from electrical shielding, but underneath that shield is another primary conductor that's also insulated, and the scenario you're dealing with here is if you penetrate that primary insulation, you could actually have a short between the shield, which is ground, and your primary wire, which may have a potential on it, and I have seen that in the field, as a failure.

CHAIRMAN HALL: Thank you.

MR. SWAIM: As a matter of clarification, a question from the tech panel here, the Madrid 1976 747 that was involved in an accident, was that a similarly manufactured airplane to the TWA 800 airplane, was that of the same vintage, do you know?

MR. THOMAS: As far as I know, yes, it was a very similar vintage airplane.

MR. SWAIM: Very similar along the production, that they would have been wired approximately similar?

MR. THOMAS: Yes.

MR. SWAIM: Okay. In that one, do you remember, Mr. Thomas, what the cause of that accident was, or Mr. Hartonas?

MR. HARTONAS: I did not investigate that accident; however, it was stated that it was due to lightening strike. How exactly it happened, I have not read the report.

MR. SWAIM: Very good. Thank you. Mr. Thomas, do you have anything to add to that?

MR. THOMAS: No. As far as I remember, it was attributed to a lightening strike. I don’t believe any definitive ignition inside the tank was identified from the lightening strike.

MR. SWAIM: Very good. Since we have Mr. Thomas again, we’ve been dealing very heavily with -- well, let me ask one last question regarding the fuel probes . We have two of the fuel probes that Mr. Johnson showed us before we were removed them from the airplane, these are still in the airplane, and with the wiring coming up beneath those fuel probes, there is apparently little commonality to how the wiring is routed to the fuel probe, up through the clamping, into the terminal block.

Is there a Boeing specification back in the seventies that would have said, this is how you route these wires into this field probe?

MR. COLLINS: The way that’s usually controlled is that there are drawings, a threedimensional drawing of the probe itself, and it shows the wiring going to it, and it should have been standardized at that point in time.

I'm not familiar exactly with what those show, but as part of the series three terminal block, when we go in and look at these probes, we'll ensure that we standardized the wiring to each probe so that it's non-interference will not cause any more damage to the wiring itself.

MR. SWAIM: In the service bulletin?

MR. COLLINS: Correct.

MR. SWAIM: Okay. Could you please provide us some kind of a description to how it was done, after the hearing, as a follow-up action, provide us some kind of a record as to how it was done back then, would that be possible?

MR. COLLINS: Yes, sir, 1'11 try to find that for you.

MR. SWAIM: Okay. Thank you. Mr. Thomas, in theory, or in actual history, actually, Mr. Collins, I'm sorry, what kind of pump failures could or in the past have led to ignition of fuel tanks, that you're aware of?

MR. COLLINS: I'm not personally aware of any fuel tank explosions that were caused by fuel pumps.

The things I've investigated or dealt with --

MR. SWAIM: But in the literature?

MR. COLLINS: You talked about some failures earlier that the group had looked at under this investigation, and that listed some areas where we have concerns that types of failures may create ignition sources inside the pump, and things like that, which is why the pumps are explosion proof.

I mentioned earlier a reevaluation of fuel systems and part of that is to look at the possible mechanical failures, contamination being brought into the inlet of a pump, and we will be requiring that the sections of pumps and heated tanks, or tanks near heated equipment, that those pumps stay covered with liquid, or have a flame arrester to preclude any flame that may, or spark that may be in the inlet of the pump from igniting vapors. But I don't know of any from the stuff I've looked at, that have actually occurred.

MR. SWAIM: Okay. Larry is working on bringing up a photo of material, foreign material found in some fuel pumps, and I believe this is in the exhibits.

Most of it is tank sealant, sealant from the bottom corners of the tank, and it is mentioned, I know in the factuals were mentioned pieces of metal found in some of the pumps or pump housings. What can this do to the pump internally? Is this something that is not a problem, Mr. Collins?

MR. COLLINS: Sufficient contamination may lock the rotor, so the motor is trying to turn the pump, and it can't turn. That's one of the basis of a qualification test run, before the system is certificated to show that that doesn't create temperatures, and that they create auto–ignition.

MR. SWAIM: Okay.

MR. COLLINS: We did look at some pumps in this investigation that had contamination in there, but I don't recall any signs of damage to the pump, or heard any reports of it causing ignition-type damage.

There were some that were reviewed, and the maintenance records where they had been removed, and there were foreign objects in the inlet, but I don't recall the specifics of the removal causes.

MR. SWAIM: Okay. We have a picture up there of tank sealant, I used that term without explaining what it was. It's the rubberized sealant that the finger is pointing to.

Mr. Thomas, in fuel pumps, how coarse of a piece could get through -- well, is there a screen between flakes of paint sealant from places like this, and the pump itself?

MR. THOMAS: Yes, there is.

MR. SWAIM: How fine or how coarse, actually, of a piece could get through that screen?

MR. THOMAS: The screens on the larger pumps are full mesh, which means if you look at the microphone, you’re looking at a mesh. If you could have four of those wires per inch --

MR. SWAIM: A quarter-inch, essentially.

MR. THOMAS: Basically, it’s slightly smaller than a quarter-inch length of the wire sizes, yes.

MR. SWAIM: Okay. So slightly less than a quarter-inch.

MR. THOMAS: Yes. On the scavenge pump, there are 12-mesh, so a tenth–of–an–inch on the very bottom of the scavenge pump, and then a quarter–inch mesh, one inch up.

MR. SWAIM: Is it conceivable that a piece of conductive debris could get through there, or metal, a piece of metal could get through there and caught in the impeller, and through being rubbed against the pump housing, create a hot point, and that point, just going somewhere, is that conceivable?

MR. THOMAS: It’s hard to conceive of that. Let me walk through that process.

MR. SWAIM: Okay. Please.

MR. THOMAS: You have the -- the pump is running 99.99 percent of its time pumping, doing what it’s supposed to do, pumping fuel. Most of that debris is probably washed into the pump, if you can imagine small pieces going through a fine-mesh screen, being sucked by the fuel, being carried along by the fuel into the pump.

In the case where the pump is -- so a jam at that point, as Mr. Collins said, if you got into the pump and jammed, the pump would stop, and the circuit breaker would lull, and the pump would stop working, or alternatively, small pieces would flow through the pump impeller, the impeller has fairly large passageways anyway, would flow on, and would eventually get caught in the engine filters themselves. So that’s the normal process that would take place.

If you look at the case where the pump is dry, in other words, the tank is empty, and the pump is left running, which is maybe a few minutes until the flight engineer turns the pump off, the pump has a very low suction capability to pull air through the pump.

We have a check valve on the discharge side of the pump, which is specifically designed to make sure the pump can’t force air into the engine features, because the engine itself doesn't like air, it tends to cough and burp.

So we make sure that when the override pump runs out of fuel, that check valve goes closed, so it tends to be a natural protection against the override pump, in this particular case, forcing air into the engine, so that really makes the pump work as a very poor air pump, it doesn't want to suck things up when it's running on air. So you kind of have this mixed match.

If I have a piece of debris being flushed along by the fuel, it jams the pump, or the pump is in the fuel. If you have a piece of debris when the pump is running dry, then the pump can't suck the piece of debris up into the inlet, so it tends to be self-protecting.

1 could imagine an extremely remote case, something happening in the last two seconds, where the pump runs out of fuel, but it's an extremely remote case, I can't even imagine it happening, in reality.

CHAIRMAN HALL: Could we find out and establish how many pumps there are, what we referring to, in the center tank?

MR. SWAIM: In the center tank? Go ahead, Mr. Thomas .

CHAIRMAN HALL: No. How many pumps there are in the whole thing.

MR. THOMAS: Okay. As I explained yesterday, was it yesterday --

CHAIRMAN HALL: I think it was, yes.

MR. THOMAS: -- or the day before yesterday, they have two override pumps in the center wing tank, and a scavenge pump, there's three. Two are relatively large pumps that are designed to supply fuel to the engines, and a very small pump, this size, which is the scavenge pump, that is designed to pick up the remnants of the fuel in the bottom of the tank, where the big pumps can't pick up themselves.

CHAIRMAN HALL: So all this conversation we just went through, does that apply to all three pumps --

MR. THOMAS: Yes.

CHAIRMAN HALL: -- or just to the scavenge pump ?

MR. THOMAS: It will apply to all three pumps.

CHAIRMAN HALL: Okay.

MR. SWAIM: The point I'm going to here, though, is we did find material in the pumps, but metal, and this rubbery tank sealant, and it has been found to not be beneficial for the pump. Why isn't there more of a screening put in there? Would it be possible to put in some type of a flame arrester, such as we have for the vents out at the wing tips?

MR. THOMAS: The short answer, where we designed the systems, the interest was keeping large pieces of debris out of the pump, so the pump wouldn't get jammed by a large piece of the debris.

In looking at this whole accident, and trying to say what else could we do, there was the question that the Chairman asked on Monday, what else could we do to the airplane to help improve it, we have started looking at putting a kind of flame arrester installation in the scavenge pump.

We're testing that right now even as we speak to try and determine the right configuration for that, a flame arrester in the scavenge pump inlet.

That would provide protection against some strange ignition source that may occur in the scavenge pump itself, even though we have no data in history that says it happens. We're, again, extending ourselves over and above what we've done. We're looking at that very hard at this point.

The concern we have is, now, do we start picking up lots of little pieces of debris on that flame arrester, which is a very small hole, it's fifty– or sixty–thousandth of an inch in diameter, a series of them in almost a honeycomb design. Whether or not we now start accumulating more --

CHAIRMAN HALL: Is this a phenomena, also, Mr. Thomas of aging, that the tank flakes, or does a new tank flake, or have you ever looked at all that?

MR. THOMAS: I'm not a sealant expert, so I really don't know. I can certainly inquire of our people.

CHAIRMAN HALL: Yes. We're going to get into the aging aircraft panel again, and I just didn't know, is that something that's --

MR. THOMAS: I don't know whether it's an aging problem, or small pieces of sealant. As the photograph showed earlier, you kind of put the sealant around the bolts and along all the interfaces, whether or not a small piece at the end will come loose, be jarred loose, I don't know if that's an aging problem or not. I will certainly happily take an action item to have it looked into.

CHAIRMAN HALL: Thank you.

MR. SWAIM: We found a photo here of what we're talking about. There is the inlet and the screen for the scavenge pump anyway. Now, I believe that one has a finer filler, does it not?

MR. THOMAS: Yes. That’s the 12-mesh. The screen itself is approximately two inches high. The bottom inch is a 12-mesh screen, and the tenth-of-an-inch hole diameter at top is, I believe is a quarter–of–an–inch mesh, the top one inch of the screen.

MR. SWAIM: Are there any potential problems with putting a flame arrester in this inlet? I’m not trying to appear beneficial to you, it’s just that I’d hate to go through this accident investigation and do my next one, because the flame arrester created a problem.

MR. THOMAS: As far as the scavenge pump is concerned, the biggest question is how quickly would the screen plug up. In other words, you’re changing from this normal kind of screen to a finer diameter screen, would it plug up and cause additional maintenance problems. I don’t see that there’d be a safety issue.

MR. SWAIM: But this is the exterior of the tank, right?

MR. THOMAS: This is the inside of the tank. No, sir. This is the inside of the tank.

CHAIRMAN HALL: So this part is inside,

because that scavenge pump, part of it’s outside the tank, right --

MR. THOMAS: Yes.

CHAIRMAN HALL: -- but this is inside.

MR. THOMAS: Yes. This is, basically, you can leave the picture there, this tube that you see in the picture, this thing is almost immediately in the middle of the tank, centered in the tank. The tube itself runs aft to the rear spar, so it’s about six- or eight-foot run of tubing to the pump itself, and what we’re looking at is, can we put a flame arrester in that tube that will provide additional protection and enhancement to the design.

CHAIRMAN HALL: So it wouldn’t be where you could clean it out, really.

MR. THOMAS: You would have to go into the tank to clean it, and that’s the issue I was addressing.

CHAIRMAN HALL: Did I keep hearing you-all say that it’s bad to go into the tank? Can someone explain in the simplest terms possible why it’s bad to go into the tank --

MR. THOMAS: I think that --

CHAIRMAN HALL: -- other than I understand you have to take the plane down, and empty the tank, and do a lot of things. Is there a safety reason?

MR. COLLINS: The main concern we have is causing damage, due to the tank entrance, to systems that could later cause failures, damaging wires, or components probes.

CHAIRMAN HALL: So whoever is in the tank is an unguided missile, or something, and damaging things that --

MR. COLLINS: No, I didn't say that, but there is a risk any time you open a system for maintenance .

CHAIRMAN HALL: Okay. That's why -- I just didn't know whether it was something else. I thought I understood that, but I wanted to be sure.

MR. THOMAS: All of the mechanics who are allowed tank entry have to go through very specific training for tank entry, it's a very confined tank. Try and crawl into a fuel tank -- the 747 is a big airplane, fairly short guys like myself can stand up in the center wing tank.

The wing tanks are very small, they're very difficult to crawl into, and there's just a general philosophical concern of people just banging things as they're trying to get out, and those kinds of issues. The mechanics are trained to be very careful in doing so, but it is that finite risk of something happening.

CHAIRMAN HALL: Maybe the IM can tell us the size of the person that goes in the tank. Go ahead, Bob .

MR. SWAIM: Okay. We found that this is a compensator in the bottom of the fuel probe in the center tank of that derelict airplane we were discussing before, 105, and the wires hanging down to the compensator, and the tube that's under, is to the right side of the picture, it's a greyish, silver tube, has got a number of dents pointed out with the arrows, so you can see, there is some kind of possible damage that we've seen in our investigation, which is essential to what Mr. Thomas was saying.

Mr. Collins, what are the requirements for protection of fuel pumps from foreign objects?

MR. COLLINS: It's a basic requirement that to perform their function between maintenance intervals, and for the pumps, there are no scheduled maintenance intervals, and if they don't create failures, an adverse failure, stopping the function safely would be an acceptable failure, for instance.

The cause of an ignition source is definitely not an acceptable failure, so they have to be installed to protect against any kind of adverse failures.

MR. SWAIM: Okay. A point of clarification for Mr. Thomas. Yesterday, somebody had mentioned the vent system having a flame arrester in the 747, the way it was said, it was generic. Did the accident airplane have a flame arrester system?

MR. THOMAS: No, it did not. It had the equivalent of a flame arrester system known as a surge tank suppression system. This consists of a photoelectric cell looking at the tube from the outboard, outside of the airplane, into the search tank.

That photoelectric cell is looking for a fire coming in from the outside of the tank, out from the atmosphere, outside the airplane, into the fuel tank. The photoelectric cell is wired to, I believe it's three Freon canisters that act as fire extinguishers, so the intent of the system is if it detects a fire coming in from the outside, say in a ground fire condition, it would fire those freon bottles and flood the search tank with a freon fire extinguishing agent and stop the fire from progressing into the rest of the airplane.

The flame arrester was, in effect, a no moving parts replacement for that system. The surge tank suppression system had several problems of people shining flashlights up and saying, is this where the system is, and the photoelectric cell reacting to the flashlight, and firing the system, and the mechanic than has to go in there an replace the freon bottles.

So those kinds of issues encouraged us and a lot of the operators to switch to a flame arrester system.

MR. SWAIM: Mr. Collins, building on that, what are the regulatory requirements the FAA has to prevent ignition from coming in through the vent system, or from going tank to tank through the vent system.

MR. COLLINS: The regulations requiring flames coming in the vent system are really a lightening protection issue. There’s a rule-making project to require flame arresters at the vent entrance on the airplane, and that’s to protect against ground fire effects coming in the vent system. Again, that’s a rule–making project, it’s not a regulation at this time.

MR. SWAIM: Okay. Tank to tank.

MR. COLLINS: Tank to tank, the method of preventing flames from going to tank to tank is to prevent a flame in a tank in the first place. There is no requirement to have any sort of tank–to–tank flame arresters, or anything like that.

The problems inherent with that is when you install a flame arrester in the vent outlet, you also have to protect against clogging or freezing over with ice of that vent flame arrester, so you need to have relief valves during climb and during descent, to protect against over pressure in the tanks, or under pressure during flight. So there is no regulation requirement for flame arresters between tanks.

MR. SWAIM: Very good. Mr. Chairman, it’s been a long time coming, I’m coming down to the end of that list of questions.

CHAIRMAN HALL: All right.

MR. SWAIM: I’d like to ask my fellow members of the technical panel.

CHAIRMAN HALL: All right. Dr. Birky, do you have any additional questions?

DR. BIRKY: I have a couple, if I might.

CHAIRMAN HALL: All right.

DR. BIRKY: The first one is, I’d like to go back to Mr. Hulm a little bit, and I guess I’m missing something in this RF induced voltage experiment you were doing with 75 feet of wire. What were you trying to simulate with that experiment?

MR. HULM: We were just stressing the system to a very high level to see what would happen in the tank under normal operating conditions and under failure conditions. We weren't necessarily trying to simulate any known airplane environment. We were taking a past, what we know today, and trying to find out if there's something else we don't know about.

DR. BIRKY: And that wire bundle that you -- you had this FIQS wire running in, do you have something that turns off at a high enough rate that you used as -- relate to do, switching on and off?

MR. HULM: The wire that induced the voltage onto the FIQS wiring itself, that wire is hooked up to a switch, which is hooked up to a relay, so we could turn on that relay and turn off that relay, and every time we did that, that induced a very short voltage --

DR. BIRKY: I understand that.

MR. HULM: I'm sorry. Maybe I'm missing your question then.

DR. BIRKY: Well, I guess, isn't that induced voltage dependent upon the rate at which you turn the power on and off, the voltage?

MR. HULM: Well, the switch time is what's -- we used the standard switch, and that's really what controlled the rate of change between --

DR. BIRKY: So you manually used the switch, you didn’t use the re-power relay for that.

MR. HULM: Well, yes, it was just a normal switch, with a spring contact on it, and that had a certain transition time, and that’s the what then controlled the length of the transient that was being induced onto the wiring.

DR. BIRKY: And you were able to get 1,600 volts in the experiment, is that correct?

MR. HULM: We had a very large power contactor–type relay, that’s the kind we were using, I mean a very large relay coil attached to that wiring, yes. We were able to generate up to 1,600 volts.

DR. BIRKY: What was the primary voltage again, I’ve forgotten, 32 or 28 volts, is that correct?

MR. HULM: It was a 28-volt relay coil, yes. It was a 600 milliamp coil. That’s the rating of the cross electric current that it took to actuate the coils, which is a very large relay.

DR. BIRKY: Well, the size of the relay doesn’t determine how much voltage you get induced in that, does it?

MR. HULM: Well, it will determine the actual length of it, because it will store a lot more energy, right? So that particular coil itself was generating very large, very long transients.

DR. BIRKY: Okay. Well, we can pursue that later --

MR. HULM: Okay.

DR. BIRKY: -- privately, I think.

MR. HULM: Yes, sir.

DR. BIRKY: The second question I had was dealing with, yesterday we talked about this inspection system, I don't think we asked you what were the primary findings, what you did find from those aircraft you inspected, the 52 aircraft you inspected to date. You gave us a conclusion from that, but you didn't tell us what you found in those 52 aircraft.

MR. HULM: What we did find was that a large majority of the airplanes met the original manufacturing specification, and of those that didn't, there were none that exceeded a hazard level for the airplane that would result in some sort of an ignition source in the tank that we were concerned with.

What we're finding from the airlines, in their report back, and what we have in our information is that as they do these measurements, and they record the data for us, if it doesn't meet the original manufacturing specification, which allows a certain amount of degradation before you hit any sort of hazard level, is that they re-work the bond or the ground back to the original manufacturing specification, and that's the kind of data we're getting back.

DR. BIRKY: So some of the wires you inspected did not have proper grounding on components, is that what I'm hearing you say?

MR. HULM: It's mostly a matter of degraded bonds or grounds, is that they've kind of slid over time, which is kind of to be expected. Most of them had stayed within, but over time they've just slightly drifted out of tolerance.

DR. BIRKY: How would you decide if they're out of tolerance that they would not be a risk or an increased hazard to an ignition?

MR. HULM: That's a detailed analysis. We have an entire group working on the data itself, and reviewing all of the information coming back from the airlines, and we look at each installation individually, and determine exactly what the particular bond or ground was there for, and based on what's there, whether it's static, then we evaluate if it's still within acceptable limits or not, and we've found everything so far within acceptable limits.

DR. BIRKY: I thought you said some of them were outside the --

MR. HULM: They were outside the original manufacturing specification. I mean there's still a buffer between that and something then that would result in an ignition -- if it goes slightly out of the manufacturing spec, it's not a hazard to the airplane.

DR. BIRKY: Do you have a criteria by which you make those decisions, whether they are a risk or not, or when you go back and re-do it, the bonding?

MR. HULM: Well, we make them -- the instructions in the service bulletins themselves say that, because the original manufacturing specification says to go ahead and re-work it, so we don't say, well, if it's this much above the original manufacturing, then you can leave it alone, we just say bring it back down to the original condition, when it was as the airplane was delivered.

CHAIRMAN HALL: Now, that's over time. What's over time? Can you put a definition on that?

MR. HULM: Well, we're inspecting the entire 747 fleet, so it's -- right now it's 30 --

CHAIRMAN HALL: When would have been the last time they checked? Were they checked on C-checks?

MR. HULM: These particular bonds and grounds are never checked in the tank.

CHAIRMAN HALL: Never checked.

MR. HULM: That's correct, sir.

DR. BIRKY: I have no further questions.

CHAIRMAN HALL: Thanks . Let me understand this, you mean the things inside the tank that are supposed to be grounded are never checked.

MR. HULM: If a component is removed for any sort of maintenance --

CHAIRMAN HALL: Then it's checked.

MR. HULM: -- and it has a bond and ground, once that's installed back in, it has to be installed per the manufacturing drawing, and all the other bonds and grounds are not checked on it, as far as I know.

CHAIRMAN HALL: What's the air force policy on that, do you-all know?

MR. SLENSKI: I'm not aware of the air force policy on that.

CHAIRMAN HALL: Could you find out for me, Mr. Slenski?

MR. SLENSKI: The question is: Do we check bonding inside of tanks?

CHAIRMAN HALL: Yes.

MR. SLENSKI: We'll try to get the information.

CHAIRMAN HALL: If you could, I would appreciate it.

DR. LOEB: What he means is other than on condition, I mean is there some periodic --

CHAIRMAN HALL: Schedule of maintenance.

DR. LOEB: -- or scheduled maintenance that looks at those issue.

MR. SLENSKI: The question then is concerning scheduled maintenance.

DR. LOEB: Yes. I mean he understands that obviously if there is a problem, then it's looked at, but other than on condition, is there any kind of scheduled or periodic --

MR. SLENSKI: 1'11 see if we can get the information.

CHAIRMAN HALL: Thank you.

MR. SWAIM: I had a question from some of our colleagues here. Mr. Thomas, do you have any history that you know of, of a cracked pump body? I'm going to come to Mr. Collins next.

MR. THOMAS: No, I do not. No.

MR. SWAIM: **No**. Okay. Mr. Collins, can you think of any actual cracks in the pump housing that breaches the pump housing?

MR. COLLINS: No, but you've reminded me that there was a condition on another airplane, it's not one that I work, but there was a part of the inlet that was separating, and that's the subject of an airworthiness directive.

MR. SWAIM: Of the diffuser?

MR. COLLINS: Yes, I believe so.

CHAIRMAN HALL: Mr. Swaim, where are you on questions now?

MR. SWAIM: I'm reading one from the back row, I'm about done.

CHAIRMAN HALL: Okay. Because I'd like to finish up, and let's give the parties a chance, and I'd like to take a break before we do that.

MR. SWAIM: Absolutely.

MR. COLLINS: The diffuser, as I recall, we have an AD out that requires carrying a certain amount of fuel, to, again, keep that inlet covered --

MR. SWAIM: Okay. Thank you.

MR. COLLINS: -- so it's never dry, and that way if there is any sort of degeneration or spark in there, it would not cause fire.

MR. SWAIM: Okay. Thank you. That's it.

CHAIRMAN HALL: All right. Well, we want to be sure we give the parties ample time to question this panel, but we'll take a break until 4:15, and reassemble back here at 4:15, promptly. Stand in recess .

(Thereupon, a short break was taken, after which the following proceedings were had:)

CHAIRMAN HALL: We will reconvene this hearing of the National Transportation Safety Board. We are in the middle of a discussion of our second panel, on ignition sources. We have just completed questions by the technical panel, and the Chairman has one clarification that he'd like to get with Mr. Thomas before we proceed to the parties for questioning.

Mr. Thomas, as you know, there was a 747 that was in a fatal accident on May 9, 1976, in Madrid, that I think was one serial number off of the TWA 800, or a sister ship on the line at about the same time, if that's correct, or --

MR. THOMAS: I don't know the exact spacing, but they were very close.

CHAIRMAN HALL: They were close together.

MR. THOMAS: Yes, sir.

CHAIRMAN HALL: That was a fuel air explosion that was -- the Board did not do the investigation, but we were, if I understand, a party to the investigation, and the cause was lightening, and you mentioned that Boeing had taken some steps, and I think because there's been so much conversation about that particular accident, it might be good for you to just briefly mention that, and what Boeing has done since that time on lightening protection on the 747 --

MR. THOMAS: Okay. Certainly.

CHAIRMAN HALL: -- so we don't leave any doubt in the public's mind in that area.

MR. THOMAS: Okay. 1'11 try and do that. Yes, the airplane, the Madrid airplane was struck by lightening, the probable cause was an ignition, or some kind of ignition, I believe in the outboard main tank. I don't remember the exact details.

Subsequent to that accident, although it was established where exactly the ignition source was inside the fuel tank, we went through the design very carefully to look at possible ways we could get energy from a lightening strike into the fuel tank.

The fuel tank itself is a big aluminum box, which acts as a Faraday cage to keep -- basically to carry the lightening currents down the outside of the tank, rather than allowing currents to go into the tank and cause any kind of problem.

We also had, if you will, a failure in that mechanism to keep the lightening strike currents on the outside of the Faraday box, so when we went through, we shielded the FIQS wiring, there's some short run of wiring in the leading edge, we shielded that wiring, there was a question over whether there were some leakage of induced current, as we've been talking about in the last session, propagating through the plastic access doors. We changed those access doors.

I believe there was a question on one of the valves in the rear spar, as to how it was bonded, and we corrected that. All of those actions were AD'd on the airplanes, and I presume, I don't have the data, but I presume that the TWA airplane was covered by those Ads.

CHAIRMAN HALL: You have not had any difficulty with that problem since then, since you made those changes, that you're aware of --

MR. THOMAS: No, no.

CHAIRMAN HALL: -- through your current system that you-all described the other day --

MR. THOMAS: That's correct.

CHAIRMAN HALL: -- where you-all were notified of problems. Very well.

MR. THOMAS: Mr. Chairman, while I have the microphone, can I --

CHAIRMAN HALL: Sure.

MR. THOMAS: I realized as I got off the podium here, I had not finished my answer to Mr. Swain's question on flame arresters.

CHAIRMAN HALL: If you would reacquaint us with the question then, so we can --

MR. THOMAS: The question was to do with putting flame arresters in inlets of pumps.

CHAIRMAN HALL: Right .

MR. THOMAS: We went in length describing the scavenge pump and its function, and where it was in the tank, and putting a flame arrester in the scavenge pump inlet, and the question was, were there any problems associated with putting a flame arrester in the inlet of a pump to provide additional protection to that pump, and I answered the question that the scavenge pump, the only question would be plugging that flame arrester with debris, and the need to go into the tank to clean out the flame arrester on a regular basis.

If you apply that same argument to the main boost pumps that supply the engine, you now have a very, very different consideration, because now you have the potential for plugging the boost pumps that feed the engine with debris, you also have the potential of plugging that flame arrester with ice.

A normal way of getting rid of water that comes -- we bring water on board when you fill the airplane, some amount of water comes in, a lot of water condenses from the airplane descending. The normal process for us removing that water is to use a scavenge system that picks up water from the bottom of the tank, and actually throws it into the engine, into the pumped inlets, so that water goes at a very fine mist into the engine, it gets consumed by the engine, but at a slow enough rate that the engine doesn't know it's happening.

If you put a flame arrester in that pump inlet, you now have a very high probability of plugging that flame arrester with ice, and then the pumps would choke, and we basically would have an airplane without boost pumps running. So it's a very different situation between a scavenge pump, which is, in effect, a secondary feature of the airplane, and the main engine feed systems, it's a very different question. I want to make sure the record reflected that.

CHAIRMAN HALL: And I think it's very, very appropriate.

MR. SWAIM: Thank you.

CHAIRMAN HALL: Thank you, Mr. Thomas.

MR. COLLINS: Mr. Chairman --

CHAIRMAN HALL: Yes, Mr. Collins.

MR. COLLINS: –– if I may correct a statement I made earlier, too, when Mr. Swaim asked me about the requirements for installation of fuel pumps in transport airplanes, I meant to mention the requirement for -- there is a requirement for inlet screens on boost bumps, and we talked about the screens, but there is a federal requirement for that, also.

CHAIRMAN HALL: Okay. Very good. Thank you. Now, I'm trying to remember where we left off. It is Honeywell, Inc.'s time up at bat. Honeywell, Inc., do you have any questions for this panel?

MR. THOMAS: Thank you, Mr. Chairman. No, we have no questions.

CHAIRMAN HALL: Crane Company Hydroair, do you have any questions?

MR. BOUSHIRE: Thank you, Mr. Chairman. Crane Hydroair has no questions.

CHAIRMAN HALL: The International Association of Machinists and Aerospace workers, and I assume that you-all represent some of the machinists --

MR. LIDDELL: Yes, sir.

CHAIRMAN HALL: -- the mechanical people who get inside the tanks.

MR. LIDDELL: Yes, Mr. Chairman.

CHAIRMAN HALL: Do you have any of those folks at the table that actually do that work?

MR. LIDDELL: Speaking to you.

CHAIRMAN HALL: Very good. Well then I'm

sure you must have some questions, or maybe you can help us and clarify anything you hear that we've been discussing today, that may or may not be correct, because you have actually been inside a center tank.

MR. LIDDELL: Yes, sir, numerous times.

CHAIRMAN HALL: Well, please, proceed.

MR. LIDDELL: Yes, sir. My first question is for Mr. Swaim. Do you happen to know if the aircraft 93105 was in an airworthy condition?

MR. SWAIM: No. As I had mentioned repeatedly, but I'11 be happy to say it again, to our best knowledge, that airplane came in -- the information, as a matter of fact, you provided me, was that the airplane had come in for a de-check, that's a very heavy maintenance check, and I'm sure you know the interval better than I do, Mr. Liddell, the airplane had come in for a heavy maintenance check, and while it was in for maintenance, they decided it was no longer economically viable to keep operating it, and it had been parked almost two years before we examined it, and I don't think you were there when I was in it, but you had one of your associates with me.

MR. LIDDELL: Yes. Do you know how long it was sitting open, and what condition it was in? Was it in a preserved condition?

MR. SWAIM: No. It was not in a preserved condition. I was told when I was there that it had been opened up in the –– as a matter of fact, when we were looking at probes and testing the previous September, September or October, I believe it was September, and that was, I believe, and this is in answer to the Chairman's question, in April.

MR. LIDDELL: Could you give us a short description, or tell us what is the purpose of the volumetric shut–off valve? Or maybe Mr. Hulm could tell us.

MR. SWAIM: I think that's a more appropriate question for the manufacturer. Mr. Hulm.

CHAIRMAN HALL: Did you hear Mr. --

MR. THOMAS: Let me make sure I heard the question. What is the purpose of the volumetric top --

MR. LIDDELL: Yes, its purpose and operation.

MR. THOMAS: The purpose of the volumetric top-off system is to shut off the fuel flow into the tank when you're fueling the airplane. The gauging system is, in effect, reading pounds. At some point, when you're trying to put in, and I can exaggerate here, if you're trying to put in 100,000 pounds of fuel into a tank that only holds 80,000 pounds, you can't do that, because you're going to basically dial in that amount.

If it's a very light fuel, like JP-4, you try and put in 80,000 of fuel into a 80,000 tank, it may not go, there may not be enough volume in that tank for light fuel, to actually take on board that much fuel. The volumetric top-off is really intended to protect the tank from overfilling, when you deliberately try and put a lightweight fuel into the tank, and try and actually put too much fuel into the tank.

MR. LIDDELL: So would it be fair to say that this device would shut off periodically to prevent that condition from happening?

MR. THOMAS: It would normally shut off, as far as I know, when the fuel is very close to the top of the tank.

MR. LIDDELL: Mr. Chairman, if you want to know the procedure for entering a fuel tank, we'll go through that now.

CHAIRMAN HALL: Please.

MR. LIDDELL: Okay. Before an entry into a fuel tank, it has to be open and vented, and purged of all fuel fumes. In some cases, you do enter it with fuel in it, but most cases in a de-check, and in the discussion we had --

CHAIRMAN HALL: Well, tell us what -- do you know what de-check, how often that is?

MR. LIDDELL: De-check is usually three to four years, depending upon the operational hours of the carrier.

CHAIRMAN HALL: Somebody can answer that. How many hours is a de-check? Does it depend on -- does TWA know how often you do de-checks?

MR. YOUNG: We do it on calendar time, Mr. Chairman.

CHAIRMAN HALL: On calendar time. Okay. Thank you.

MR. LIDDELL: After this is done, entry is made into the tank. It's not so much how tall you are, the entry is about two-by-three feet, semi-circular. Once you get in, you have no light. The pictures I've seen around here show the center tank lit up to where you could see everything. All you can see is what's in front of your face with a flashlight.

If you have people that get claustrophic, they have a condition. In a closed environment it takes two people to go in and do this task, plus one on the outside to help anybody who gets sick inside, out.

Then once you go in, you can't see. The reason the FAA and Boeing have an adversity of people going in and out of center tanks is, if you can't see anything, you can damage it, you can hit it with your feet, and then you may not even know that you've damaged it. It usually takes, for a center tank, eight hours work for two men to inspect, not fix, just to find out what's wrong.

CHAIRMAN HALL: Well, that's very helpful, Mr. Liddell. That gives us a good understanding of what's required there. So the whole thing is dark.

MR. LIDDELL: Yes. Completely dark. There's no light at all. It's void of light.

CHAIRMAN HALL: You've got your flashlight, and that's it.

MR. LIDDELL: Right in front of your face only, as far as you can see.

CHAIRMAN HALL: Okay.

MR. LIDDELL: I have no further questions, after that.

CHAIRMAN HALL: Anything else that you-all that work on these tanks, you know, that need to be added or asked of this panel?

MR. LIDDELL: Not at this time.

CHAIRMAN HALL: The rest of the information that's been told is fairly accurate.

MR. LIDDELL: Yes. Thank you.

CHAIRMAN HALL: This whole panel -- has

anyone on the panel been in a tank? All right. Trans World Airlines. Captain?

MR. YOUNG: Thank you, Mr. Chairman, TWA has no questions at this time, and I have not been in a tank.

CHAIRMAN HALL: Okay. Neither have I, sir, and although I think we have, several of our folks now have been. Mr. Steeter, with the Federal Aviation Administration.

MR. STEETER: Yes, Mr. Chairman. I'd like to start off with some items here for Mr. Johnson. You showed a picture up there of a wire with an exposed conductor, and discussed the residue that you had picked off of that wire. I wasn't clear on that, I knew that that was a wire from the accident aircraft, but was it from the center wing tank?

MR. JOHNSON: I can't answer that right at the moment. I didn't pull all the captioning from the report. The image is in the docket with the report that we submitted, you may be able to tell from the information included there, but I don't have it with me, in front of me right now.

MR. STEETER: Okay. But it was from the accident aircraft.

MR. JOHNSON: Yes. It was from the mishap aircraft.

MR. STEETER: All right. Now, again, for Mr. Johnson, and this now goes to the fuel probes that came off of the out-of-service aircraft, where you showed us the pictures of the deposits that had been discovered on there. With this aircraft out of service, I'm presuming that it was defueld and the tanks were opened up, do you know that to be the case, or not?

MR. JOHNSON: No. That wasn't information that was provided to us.

MR. STEETER: Okay. Can Mr. Swaim answer that one? Was the aircraft in a defueled condition, Bob?

MR. SWAIM: Essentially. There were puddles in the tank, and the tank still had a pretty good smell. It wasn't as bad as going into a tank that had just been taken out of service. Essentially, defueled, yes.

MR. STEETER: So it did still have vapors in it then, correct? I mean you said you could smell it.

MR. SWAIM: It had a smell to it, a strong smell.

MR. STEETER: The reason I'm asking is, I'm wondering, Mr. Johnson, if you have any idea whether or not -- I'm trying to understand -- the sulfur comes from the fuel, is that correct?

MR. JOHNSON: Yes.

MR. STEETER: Okay. So if you had sulfur deposits on there, and then the probe ended up for two years not being immersed in fuel, does that have any effect on the buildup that you were seeing there, does it continue to grow, or does it become static, does it recede, or what effect does the dry air have on it?

MR. JOHNSON: I'm not sure. I don't know whether Mr. Slenski might have some --

MR. SLENSKI: Well, I think you have to have the continuous source of the sulfur to continue to grow the film on there, so I think it would depend on the concentration of the vapors, of the fuel in the tank, and the residuals that may be left in there.

But I would think pretty much you'd have to almost have immersion to continue to build up this film, and I think you alluded to this previously, it's also, from what we've seen, and this is something that probably has to be studied more, the potentials being applied to these circuits may accelerate this whole process.

You set up fields, and, again, we mention this as a corrosion process, and whenever you apply voltage in there, you can accelerate those types of processes.

MR. STEETER: Okay. So you would expect then, if I understand you right, that once the immersion is no longer occurring, whatever buildup you had on there would be static, at least, it would not grow.

MR. SLENSKI: It would definitely --

MR. STEETER: Okay.

MR. SLENSKI: -- I would think.

MR. STEETER: Okay. Understood. Thank you, sir. Mr. Hulm, there was a little bit of discussion earlier on the MILSPEC, and you referred to the three-inch rule when we were talking about whether or not you needed to ground or bond a clamp. My question is: I think you describe that as any dimension less than three inches requires no bonding. Could you clarify that? For example, if I had a clamp that had a total of a six-inch circumference, but it was only half-an-inch wide, would I have to bond that?

MR. HULM: I guess to answer your question what I'd like to do is, we've got bonding and grounding experts within the company that do this kind of thing, rather than trying to me answer it here, I'd rather get the answer to you --

MR. STEETER: That would be fine, sir.

MR. HULM: -- if that's okay.

MR. STEETER: Yes. That would be fine. Thank you.

MR. SWAIM: Of course, we'll be getting a copy of that, right?

MR. HULM: Yes, sir.

MR. SWAIM: Okay.

MR. STEETER: I'm sorry. That's what I meant. I was hoping it would go to the right --

CHAIRMAN HALL: Well, if you'd supply that for the record, we'd certainly appreciate it.

MR. HULM: Yes.

MR. STEETER: And that's where we need it, sir. Now, either from Mr. Hulm or Mr. Thomas, and I believe it was Mr. Hulm who said that there was no specific requirement to inspect any of the bonding points, or anything like that, in the tank.

However, when you do have a situation where you know you're going to go into the tank for some type of maintenance, such as that of a de-check, does Boeing have any policy in there, in maintenance guidelines, regarding zonal inspections, and things like that?

MR. HULM: Maybe Ivor can answer that question better than I could.

MR. THOMAS: To the best of my knowledge

there are requirements when you do a de-check, when you're doing a heavy maintenance check. As I said earlier, you're in the tank, looking at the structure, looking for deep cracks, those kinds of things. There is a requirement to do a zonal check on the system, to look around to see if everything is in working order.

There are other requirements that probably others can probably get into better than I can, in terms of checking things like the behavior of check valves on the pumps, make sure they're working, which requires breaking into the system, and restoring it. So there's a regular maintenance program going on.

The specific bonds, like a grounding slab, is the area where we've said, you know -- they're designed to be a good ground for the life of the airplane, and so the question that we're trying to answer in these inspections is really, does the data in the fleet confirm that those grounds work for the life of the airplane.

MR. STEETER: All right. Thank you, sir.

MR. JOHNSON: I have a bit of additional information relative to your question about whether that image we showed was from the center tank. We still don't know that, but possibly someone prseent may.

That was taken from sample number 29, out of the sample bag, or from a probe marked by someone previous to us, with an identification number 29. So I see some digging going on, we may be able to come up with an answer for that for you.

MR. STEETER: Well, while they're checking the data base over there, sir, if I could refer again back to Mr. Johnson for one other item. The picture that's right behind Mr. Hartonas there, of the damaged wire, I believe when you showed the full diagram up on the overhead, that there was a graph of the -- a spectrographic analysis that was done on that.

MR. JOHNSON: Yes.

MR. STEETER: I'm not sure, but I believe there was a peak off to the left side of that graph. Was that a carbon peak?

MR. JOHNSON: Yes. I think that's what it was. The real tall peak off on the left.

MR. STEETER: Yes. That's correct.

MR. JOHNSON: Yes, it was.

MR. STEETER: Now, what's the significance, if any, of the carbon peak, and my concern is, does that indicate any signs of any arcing of any type?

MR. SLENSKI: No, that doesn't. I don't believe so. First of all, the analysis here, as we've mentioned before, is EDS, you talked a little bit about this .

What that does is analyze the surface and a small bowl underneath the subsurface, and the full polymer is made out of a carbon chain. So what we're looking at is the carbon makeup of the Teflon.

MR. STEETER: I see.

MR. SLENSKI: We did not do surface analysis, which there are techniques available, that would be in the first couple atomic layers, but I don't believe -- 1 think what we're looking at there is just a Teflon --

MR. STEETER: So that's something that came out of the insulation then, in effect.

MR. SLENSKI: That's correct.

MR. STEETER: Okay.

MR. JOHNSON: And in looking at that particular damage site very carefully, under fairly high magnification, there was no evidence of melting, or beading, or anything that you might associate with an arc having been present at that site.

MR. STEETER: Okay. I understand. Thank you, sir. Chairman Hall raised some obvious points of concern about whether or not the FAA and the air force were sharing information, and you did mention that you had been to a meeting with the FAA, so I'm trying not to leave an impression that that was one meeting.

Do you work fairly regularly with the people at our Fire Safety branch at Atlantic City?

MR. SLENSKI: I've had considerable contact with a Mr. Hill and a Pat Cahill. When we've had issues, we've discussed it over the phone. Of course, with the NTSB investigators, this is not the first NTSB investigation we've done, so we've worked in other projects, and there has been a cross-flow of information.

MR. STEETER: Okay. Have you ever had any difficulty that you are aware of between the air force and the FAA, as far as sharing of information in safety matters?

MR. SLENSKI: In my personal experience, absolutely not. We've had a fairly good relationship.

MR. STEETER: All right. Thank you, sir. Mr. Collins, there have been numerous times, discussions about the agency's concerns, and Boeing made it obvious, too, about their concerns about getting into the fuel tanks too often, and you discussed the problems of potential damage to components in the tank, and I think we had some photos up there that showed that. Is there also an issue regarding the introduction of debris into the tank, in those cases?

MR. JOHNSON: Yes, there is, and here has been evidence of that found in the tank, of debris brought in.

MR. STEETER: Is there concern there, again, because that could be the type of debris that sets up these potential failure scenarios?

MR. JOHNSON: Yes. There could be block wire, for instance, that gets stuck on a piece of clothing, or something.

MR. STEETER: Okay. That's all I have, Mr. Chairman. Thank you.

CHAIRMAN HALL: Thank you, Mr. Steeter. Is that the only way to get in that tank, is just with a flashlight, I mean with lighting and video cameras, and all the things that are available these days, is that how it's done, Mr. Liddell?

MR. LIDDELL: Yes, sir, it has to be physically done by people.

CHAIRMAN HALL: Well, I'm not trying to get rid of your job now, I'm just saying, it would seem to me if you went in there with more lights, and a video camera, or something, then you'd have some record, I don't know, I was just --

MR. LIDDELL: Well, you would have the

problem of flammability, you'd have the fumes --

CHAIRMAN HALL: Flammability, and lights. Okay. Well, that's explainable.

MR. THOMAS: Could you put that view up again, it's particularly --

CHAIRMAN HALL: Yes.

MR. THOMAS: If you look at it, there's a person on the right-hand side of the screen, there's a pencil pointing at the hole, that is the hole you have to crawl through, right there, to get into the tank, and that's typical of any of our fuel tanks.

MR. SWAIM: And, of course, you're doing this on top of a ladder, hanging above the ground, probably what, ten feet over, and you basically have to do the Fosberry Flip in there. It's not an easy hole to climb through.

CHAIRMAN HALL: Are people specifically trying to do this, Mr. Liddell?

MR. LIDDELL: Well, specifically trying, if you get the job, and you're given training on how to get in, somebody shows you how, yes, sir.

CHAIRMAN HALL: And what to look for.

MR. LIDDELL: What to look for, and what not to do.

CHAIRMAN HALL: Good. All right. The Boeing

Commercial Airplane Group.

MR. RODRIGUES: No questions from Boeing, Mr. Chairman.

CHAIRMAN HALL: Okay. The Airline Pilots Association, Captain?

CAPTAIN REKART: Thank you, Mr. Chairman. Mr. Gerken, many hours ago you described the static electricity generating tests and their results, and just a few questions concerning how representative your setups were of the actual aircraft configuration and operation. Was there any attempt to replicate the conditions of TWA 800, specifically the fuel pressures that you were leaving, versus the pump pressures that were generated by the fuel pumps in the airplane, and the test sprays versus the tank geometry? I've got a couple more, but if you take those two first, 1'11 come back.

MR. GERKEN: It has been several hours ago. Pressure, we varied that through a whole realm of different pressures, from my understanding, 25 psi was used, which is very similar to pressure in the fuel lines, the orifices, we used eight to ten different types of orifices, from regular whole oracies, slots, there's a whole host of them, I don't know those right now, but to try and duplicate different types of leaks.

The jet fuel that we used to start the whole experiment on phase one was Jet A, from JFK, and we did vary the fuels throughout the experiment.

CAPTAIN REKART: You talked there momentarily about the filter paper. There was also screening used across the orifice face, I believe. What was the purpose for the screening?

MR. GERKEN: The screening in the orifice itself was used to stabilize the flow somewhat. When we used the slotted orifice, we got no control over the flow, whatsoever, and it's within the report, but as we saw variances in the flow, contacting our plate or test specimen, we saw differences in charging current and voltage, and we'd try to stabilize it a bit.

CAPTAIN REKART: You said you added water to the fuel to get a different result. In the 30-odd years that I've been flying, the only water that we've ever added to fuel was for takeoff on some of the military airplanes. What did that do to the fuel that you were using, specifically changing it from what was being used on TWA Flight 800?

MR. GERKEN: The use of the water in the fuel for the electrostatic testing was done by Dr. Leonard. We did none of that at Wright-Patterson, so I can't address it fully, but there had been numerous studies that show that water cumulation in the fuel does, indeed, increase static charging.

MR. SWAIM: Maybe I can ask Mr. Thomas, do we get water into the fuel of these airplanes in-service, and what kind of extents do you go, as far as the small jet pickups and such to mix the water? Can you help this?

MR. THOMAS: Yes, I tried to address that a little bit in the pump discussion. Certainly, there’s no free water in the fuel, as it comes on board the airplane. You have filters in the trucks, and coalesces, all designed to make sure you absolutely minimize whatever – that there is no water in the fuel on the way to the airplane. However, there is some dissolved water in the fuel.

As the fuel cools, that water will condense out and settle on the bottom of the tank. Also, when you breathe -- as the tank is descending, you’ll breathe in air, and dif that air has obviously got some kind of relative humidity, you’ll bring water into the tanks that way.

So the normal approach that the Boeing Company uses, we’ll provide a number of jet pumps, very simple –– no moving parts pumps, go to the bottom of the tank, with the intent of picking up the water as it drifts down to the bottom of the tank.

The discharge from those pumps, which is basically a mixture of fuel, and whatever water is picked up, is returned to the tank very close to the inlets of the main boost pumps, so the main boost pumps basically pick up that water, to gather all the fuel it's picking up to send to the engines.

You have a very, very fine, very low percentage of water mixed with the fuel on the way to the engine, and so it's basically a continuous scavenging system to pick up the water, and send it to the engine, and that's pretty standard on most of our airplanes. If you go back to the 707s, we didn't have it. All the airplanes come with a sump drain system, so you can drain the water off on a regular basis.

MR. SWAIM: Thank you, sir.

DR. LOEB: Captain Rekart, I think it's fair to say we did those tests just to see what would happen if, I mean it was a matter of trying to explore the various possibilities, and learn and understand, is that correct, Bob?

MR. SWAIM: Absolutely. Water is present in the system, we're just trying to be -- you're absolutely right, Dr. Loeb.

CAPTAIN REKART: I understand that, Dr. Loeb, I realize why you did the tests, but the rig itself was not dimensionally the same as the tank, nor was it modeled on the tank in any way.

MR. GERKEN: No, it was not.

CAPTAIN REKART: Okay. Thank you. That was the question.

Mr. Slenski, you showed some photographs of a military non-747 fuel probe, which had arcing damage, and I believe there's some metal transfer associated with that. What was the value of the electrical power, the energy necessary for that sparking? Was that laboratory induced, or was it service induced? Do you know how much energy that part was subjected to?

MR. SLENSKI: Are you referring to the fuel probe that ignited the residual vapors, or the test we did in our lab?

CAPTAIN REKART: I don't believe it was a test you did in the lab, I think it was a piece that you brought in from the field.

MR. SLENSKI: A field failure?

CAPTAIN REKART: Yes, sir.

MR. SLENSKI: I really don't have that information, as far as what -- it was the tester that's typically used with that particular probe system, and I know that's been asked several times. If we need to get that information, I can see if we can track that down.

MR. SWAIM: We’ve been searching for that piece of information. It was an obsolete tester, it’s called a capacitance fuel probe tester, MD2A, and it’s an obsolete piece of equipment, and we’ve been searching for that ourselves, I think just a few days before the hearing here. We’re probably going to get a copy out of an archive.

CAPTAIN REKART: Okay. Thank you. Mr. Slenski, your statement that copper sulfide deposits are a result of many years of exposure to fuel, have you seen any difference between the military problems and the civilian problems regarding exposure?

For example, a DC-9 may be fueled eight times a day, and in the process its fuel washed by the high-pressure fuel coming in. An airplane that sits on alert, or something like that, may not be fueled for three weeks. Do you see any difference in the operational use of the aircraft versus the buildup of the sulfur compounds?

MR. SLENSKI: Well, if you’re asking the question, to speculate on that, I mean I don’t have the data, because I haven’t looked at enough commercial aircraft probes to make that determination.

I think the situation here we're dealing with, keeping it immersed in the fuel is probably going to accelerate the process, and the types of fuels you use have an impact on that, also.

If there's more sulfur in the fuels, then I think this reaction will occur faster.

As I said before, I even think it's a function of the potential that's supplied to the system, so there are many factors in that. You're right, the use of the tanks may have impact.

CAPTAIN REKART: Okay. Mr. Chairman, the FAA just asked a question a little while ago, and I may be repeating their question, if you feel it is, 1'11 withdraw it, but when the FIQS discrepancies are discovered during the air force depot maintenance, that warrant corrective or preventive actions, how are these actions communicated to the other users of both that airplane and similar airplanes, if it happens to be like a Casey-135, or -- how does the civilian world get that information? Perhaps that's the similarity in the question that I was referring to, sir.

CHAIRMAN HALL: Well, I'd like to hear it answered again.

MR. SLENSKI: The question here again is, how do we transfer this information to the commercial?

CAPTAIN REKART: Yes, please.

MR. SLENSKI: I don't personally know that mechanism. Again, obviously, our contractors are similar for Casey-135, and Boeing airplane. There's going to be some cross feeder information there, I expect, but I don't know if there is a formal mechanism. Again, if that's the question --

CHAIRMAN HALL: Well, do you think you could find out before tomorrow, Mr. Slenski, if there's any difference between the way the air force performs maintenance on these center fuel tank systems and the FAA rules and regs?

MR. SLENSKI: I can try to get that information, by tomorrow, I'm not sure, we'll have to make some phone calls.

CHAIRMAN HALL: That would be very helpful, if you could, because all we're trying to do is be sure that if there's knowledge that impacts the safety of the operation, whether it's gathered or collected in the military service, of course, the vast majority of the military aircraft are Boeing, or McDonnell-Douglas, or Lockheed, and a lot of those are the same, you know, they've got a different name to them, it's essentially the same plane.

MR. SLENSKI: The question you're really

asking, do we inspect fuel probes, and do we have some process for inspecting fuel probes, is that what you're asking?

CAPTAIN REKART: If you find a discrepancy in the fuel probes, or if you find a defect, how do you get this information to similar users in the civilian arena?

MR. SLENSKI: Well, that's a different question, so that's what really we're asking now, is how do we disseminate the information.

CAPTAIN REKART: Yes, sir.

MR. SLENSKI: Okay. Mr. Chairman, is that --

CHAIRMAN HALL: Well, it's two different questions, one is how you disseminate it, and secondly, what is it.

CAPTAIN REKART: That's right.

CHAIRMAN HALL: I was mislead here by Mr. Swaim, I thought you-all were going to come equipped with all that information, I apologize to you-all, but I'm very interested in, is there anything different that the air force does in regard to these tanks, or is it all done the same, you know, the things we've heard about, the bonding, we heard this three–inch linear, it can be ungrounded.

I'm not a highly technical person, but I do know the difference between grounded and ungrounded, and if there are ungrounded things in the tank, is that the same thing in the air force as it is in the -- they're never inspected per FAA regulations, is it different in the air force?

Now, I understand, given all that, it's a different operation, it's a military service, the fuel may be different, but if you could get that information either tomorrow, or for the record, we would appreciate it, also as well, the Captain's question of, if you come up with important information regarding, say, the 737 equivalent, or the 747 equivalent, in the military, how is that information transferred between the FAA and the military?

MR. SLENSKI: For the record, I think we can get the information by tomorrow, but as far as our preparation here, it was primarily to discuss the testing we had done for the NTSB, so we really had not been prepared --

CHAIRMAN HALL: Well, I understand. Well, that's my misunderstanding, that's not your fault. I appreciate you–all being here, and you've made a real contribution, I'm not being critical, I'm just -- I'd just like to know that information.

MR. SLENSKI: Thank you.

CAPTAIN REKART: I apologize. Also, I'm a pilot, and my questions tend to be operational, and I realize that your expertise isn't in the operational side, and I certainly don't ask the questions to embarrass you, it's just that I was hoping to get an answer.

MR. SLENSKI: That's fine. If we don't have the information, we'll attempt to get it --

CAPTAIN REKART: Okay.

MR. SLENSKI: -- we just may not be able to answer it here.

CAPTAIN REKART: For Mr. Johnson, much of your presentation focused on the various degrees of pre-existing discrepancies in the FIQS wiring. Could you please comment on the difficulty in detecting these irregularities on in-service airplanes, without having to do any destructive testing? It seems like everything that you did was destructive testing, and needless to say, in line operations, you can't go out and cut the wires and examine them. Is there a quick and easy on how you can do it with non-destructive testing?

MR. JOHNSON: Relative to the exposed conductor, the compression damage --

CAPTAIN REKART: Relative to the sulfide

compound presentation on the wiring, and so on, and so forth.

MR. JOHNSON: Well, we've talked about indications coming from the fuel system itself as leakage currents begin to climb, not getting accurate fuel measurements, so that would be one indicator that you've got a degrading fuel system problem. But I'm not aware of anything in place today.

I'm sure a test could be devised to go after measuring those leakage currents. You'd have to do some characterization of known good systems, new systems, and then some further characterization of some that were known to have some residues present, and develop a fingerprint for the problem, and then you can carry out some testing that would, I think, give you the information about the condition relative to the amount of residues present, but I don't know of anything firsthand that's available. I can't tell you a test method readily available today for doing that.

CAPTAIN REKART: Okay. Thank you. I guess, Mr. Hartonas, can you discuss the design requirements and standards concerning the routing and the bundling of FQIS wiring with other wires carrying higher currents, is there a standard there that --

MR. HARTONAS: You're asking what the FARs are, pertaining to wiring, routing, and separation?

CAPTAIN REKART: Well, I'm asking if there is a standard that is dedicated to delineating the electrical potential between two wires that are bundled together, and so on, and so forth, and what kind of standard that is, and give us an idea of the requirement .

MR. HARTONAS: I believe that each manufacturer has developed their own standards and requirements for wiring separation and protection of one system from another. I cannot discuss each one of those. I have some personal knowledge of some manufacturers, but that information is proprietary.

I can tell you, however, that there are FARs that do require separation and routing, but there is a ground rule, and they will not tell you exactly how to do it. Is that helpful?

CAPTAIN REKART: Yes. Thank you. Just one more comment, Mr. Chairman, if I could, Mr. Liddell brought up a comment earlier about 105, aircraft 105, and we've called it a derelict, and we've called it several other things today, I would be very pleased if it were just referred to as a non-airworthy airplane, because that's basically what it is. Every other term that we've used so far to describe that aircraft, to my knowledge, is not an FAA-recognized term, being non–airworthy is, and that says what the airplane was.

In being non-airworthy, so were its components, and it pretty well describes the airplane and the components. If we could go with the term similar to that, I'd appreciate it.

CHAIRMAN HALL: Well, 1'11 refer that to my general counsel, and get back to you on that, because I don't know whether that's a legal matter or not. I know I don't like the word derelict, because that gives me a different picture than what I think we're talking about here.

CAPTAIN REKART: I don't know if it's legal, sir, but I don't want to get into that side of it.

CHAIRMAN HALL: 1'11 check on that. Is that the terminology the FAA would use, a non-airworthy airplane? Is there anything that covers those that are parked and taken out of service, sit out in the desert?

MR. COLLINS: I personally refer to flight standards to give us the correct terminology.

CHAIRMAN HALL: Maybe Mr. Dormer can find out the answer for us, and make some contribution to this effort.

MR. DONNER: It's fairly simple, it's either airworthy or it's not airworthy.

CHAIRMAN HALL: Well, Mr. McSweeney, is there an answer from the FAA table? We don’t want to be abusing the airplane?

MR. McSWEENEY: First, let me give you the FAR, to be airworthy means you are in compliance with the type certificate, and the condition for safe operation. There has to be a determination of that in each and every aircraft.

I would kind of disagree with the statement about unairworthy parts. You could have an airworthy part on an unairworthy aircraft, because the aircraft, as a whole, might not conform to its type certificate. Airworthy is a well-used term, and that’s what it means .

CHAIRMAN HALL: Well, I appreciate that clarification. Other questions, Captain?

CAPTAIN REKART: No more questions, sir. Thank you.

CHAIRMAN HALL: Well, that completes the round. Does anyone have anything else, from any of the parties? Mr. Steeter --

MR. STEETER: Yes.

CHAIRMAN HALL: -- the Federal Aviation Administration.

MR. STEETER: Thank you, sir, I just wanted to check before we finished here, and see if Mr. Swaim found that part number 29, and if we can answer that question while we're here.

MR. SWAIM: Certainly, I got a couple of things that we've found while we've been up here. Part number 29, in direct answer to your question, according to what we have, was out of either tank two or three, it's a similar part used in either inboard wing fuel tank. Part number 59 that Mr. Johnson was showing you in his photos, fragment 59, indeed, we have out of the center tank, it was Honeywell FG–420A12, for those with the exhibits.

In response to Mr. Liddell, I said that I believed that was in the tank in April, and I was off by a few weeks, it was May 20th of this year. I think that was all that I came up with.

CHAIRMAN HALL: Okay. Thank you. Other questions from the parties? Mr. Liddell, are you sure now – you represent the people that actually do this work, are there any other questions, are you satisfied with all the questions that we've asked here?

MR. LIDDELL: Yes, Mr. Chairman, I am.

CHAIRMAN HALL: Very well. Does the technical panel have any additional questions? If not, Mr. Sweedler.

MR. SWEEDLER: Yes, Mr. Chairman, I have a few. Mr. Thomas, is there a recommended inspection interval for 747 center fuel tanks?

MR. THOMAS: As far as I know -- well, let me -- there is a recommended interval, I do not know what it is. It’s basically tied to the structural inspections of the tank. In other words, you go into the tank on a regular basis, and I can’t confirm whether it’s a de–check, or somewhere in that region, to go into that tank to do structural inspections, and at the same time do zonal inspections of the systems in the tank.

MR. SWEEDLER: So there is some --

MR. THOMAS: There is a requirement. In fact, we’ll probably get into that in the aging airplane discussion tomorrow.

MR. SWEEDLER: Okay. Well, I can wait until tomorrow. I have a couple of questions concerning the Philippine Airline accident in 1991. There was some discussion yesterday from, I’m not sure which of the FAA witnesses, but there was some indication that the recommendations that the Board had made –– the Board made four recommendations after that accident, three of those were not accepted by the FAA, but the implication of the statement yesterday was that some of those recommendations were not going to be reconsidered, based on new evidence that was coming to light.

Could I ask you if either of the two FAA witnesses know which of those recommendations are now being reconsidered?

MR. HARTONAS: Mr. Chairman, I'm coming up to speed on the Philippines accident rather quickly. I don't have all the information yet. I know that we'll be taking a look at the data that was generated as a result of that investigation. Perhaps I could take an action item.

CHAIRMAN HALL: If you could just let us know, and provide that for the record.

MR. SWEEDLER: Thank you. That's all the questions I have, Mr. Chairman.

CHAIRMAN HALL: Dr. Ellingstad.

DR. ELLINGSTAD: Thank you, Mr. Chairman. I have just a couple of clarifying questions for Mr. Hulm.

First of all, revisiting the induced voltage tests that you did, let me just see if I understand, the voltage that was induced into the FIQS system was a function of the relay coil, and the 75 feet of wire that you had wrapped around it was essentially an extension of the coil, is that correct? It was a function of the coil being there that --

MR. HULM: That’s correct.

DR. ELLINGSTAD: Okay. Thank you. Just one additional one. With respect to your new procedures, with respect to inspecting components in the tank, could you comment just very briefly about the comprehensiveness of this? Are you examining the probes and internal components, or are you examining wire outside the tank as well?

MR. HULM: The inspection bulletin that we do have just concerns the components within the center tank itself, and we will be putting together a comprehensive list of different inspection items for the airlines to look at, and it will be based on the information that has come to light as a result of all the work that we’ve done with the NTSB and the FAA on this issue.

So we’re going to make sure we hit all the discrepancies we see in the different airplanes we’ve looked at, but right now we haven’t extended it past the center tank.

DR. ELLINGSTAD: Thank you, Mr. Chairman.

CHAIRMAN HALL: Dr. Loeb?

DR. LOEB: I have no questions.

CHAIRMAN HALL: I just have a few quick

questions. Mr. Slenski, your study that I referred to earlier, where you had the 652 mishaps which were caused by electrical failures related to instruments, wiring, and electronic components, do you know if any of those, or how many of those ended up in fuel air explosions?

MR. SLENSKI: I don’t have that information. In that particular study, the intent was just to collect the components that were involved, and we really didn’t have –– at this point we don’t have the data to correlate that actual number to the event on the aircraft. We can’t reconstruct that at this time.

CHAIRMAN HALL: Well, 1’11 ask Mr. Thomas and Mr. Hulm, do you know how many so-called fuel air explosions of Boeing -- do you keep a record of those, and how many there would have been, either during maintenance on the ground, in–service? We were aware, of course, of the Iranian airliner that we discussed, the Philippines, La Bianca, which was brought down because of a small explosive charge, it was a criminal act. Are there any others? And if you don’t know, I’m not trying to put you on the spot, I just –– I know these are very rare events --

MR. SWAIM: Yes.

CHAIRMAN HALL: -- but I’d like to be sure for the record we have what we do know about them.

MR. SLENSKI: We do keep records of these events, obviously. I don't have it off the top of my head to run through them. I think the FAA, in their April 3rd publication, requesting comments, against the NTSB recommendations, had a pretty complete list of those commercial and military aircraft.

CHAIRMAN HALL: That's where I've seen that. Is that part of our record?

MR. SLENSKI: Yes. I believe that's in the flammability reduction –– we'll have to correct that, if it needs it, with Mr. Anderson, when we do that panel.

CHAIRMAN HALL: All right. Well, let's do that, if we can. Well, good. Well, let's -- none of the parties have anything else, the technical panel, board of inquiry. Well, I'd like to go to each one of you gentlemen and see if you have anything else you -- 1 know some of you will be appearing again in another forum, right, tomorrow, but if you have anything that you think we should be aware of, looking at, anything the Board should be doing that would help us find the probable cause of TWA Flight 800's tragedy. Mr. Gerken?

MR. GERKEN: Well, as I mentioned earlier, Mr. Chairman, I think there may be a need for additional work in fuel misting and electrostatic charges that might be generated through atomization of fuel, and the possibility of filling that space with single polarity electrostatic charge, which could then charge up some of these conductors we're concerned about, and basically give us a different charge generation avenue, if you will, other than fuel impingement that I discussed earlier. I think that would be something we'd want to work on in the future.

CHAIRMAN HALL: Thank you very much. Mr. Slenski.

MR. SLENSKI: Well, Mr. Chairman, I think based on what we've heard, we'll probably be still studying some of these phenomena we've just discussed on the fuel probes, and I'm not sure where that's going to take us yet, but we'll be continuing to investigate that.

CHAIRMAN HALL: Thank you. Mr. Johnson.

MR. JOHNSON: I don't have any recommendations at this time for improving the effort. I would like to take the opportunity to thank you, Mr. Chairman, for the opportunity of participating in such an important effort. This is a real team effort for the air force.

There are several individuals I'd like to mention. Mary Ann Ramsey, Rick Rybolt, J. Edward Porter, Abigail Cooley, and Tom Dues were of particular assistance to me. We all hope that our contributions here will aid in furthering the investigation, and aid in helping the families deal with this tragedy.

CHAIRMAN HALL: Thank you very much, sir. Mr. Collins.

MR. COLLINS: No, Mr. Chairman, I don't have any specific recommendations. I've been working with the investigation of this accident, this tragic accident, since last July, 1996, and I know the Board has a lot of other things they're looking at, and I'm sure in the flammability reduction panel tomorrow, there will be other issues that will come up.

CHAIRMAN HALL: Mr. Hartonas.

MR. HARTONAS: We will continue supporting this investigation, Mr. Chairman. Thank you.

CHAIRMAN HALL: Well, thank you very much. Mr. Hulm.

MR. HULM: This is the last panel I have the opportunity and the pleasure to be on, and I want to express my appreciation to you for letting me be here. I hope I answered your questions adequately, and I really appreciate the support the NTSB is giving, especially in Seattle, we're working really closely with Mike Stockhill, I want to make sure he gets proper recognition, too.

Thank you, Mr. Chairman.

CHAIRMAN HALL: Well, good, and thank you, you did an excellent job of representing your company. Mr. Thomas .

MR. THOMAS: Since 1'11 be here tomorrow, I think, serving on the next two panels, I really want to second some of the comments down the table here, where obviously this investigation is leading to new research.

There's a large amount of information being put on the table today, also a lot of questions have been raised by that information, and we need as a team to go forward and work to understand those things, and I think that's a very important thing we all have to do, work together.

CHAIRMAN HALL: Well, I appreciate it. As you know, the foundation of the National Transportation Safety Board's investigations for 30 years has been the party system, in which we cooperate together with the single aim of finding what caused the accident, and making recommendations to prevent it from happening again.

We've been able to work with the parties in this investigation, as we have in past investigations, in a very constructive fashion, and I hope that we'll continue in the future.

I appreciate all of the resources that have been committed to this investigation by the various parties that are represented here in front of me today. This is, as you pointed out, a very important investigation, as all the investigations are that the Board undertakes, and we really appreciate the party system, we appreciate all of you-all's willingness to assist us in such a fine fashion, with this investigation. This panel is excused.

We will reconvene in the morning at 9:00 a.m., at which time we will begin which panel, Mr. Campbell?

MR. CAMPBELL: The Aging Aircraft

CHAIRMAN HALL: The Aging Aircraft panel, and we will stand in recess until 9:00 a.m.

(Whereupon, at 5:15 p.m., the hearing in the above-entitled matter was adjourned, to be reconvened at 9:00 a.m., on Thursday, December 11, 1997.)