NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

- - - - - - - - - - - - - - - - - - -X

In the Matter of: :

THE INVESTIGATION OF THE :
USAIR, INC., FLIGHT 427, :
A BOEING 737-300, N513AU : DOCKET NO. SA-510
ALIQUIPPA, PENNSYLVANIA, :
SEPTEMBER 8, 1994 :

- - - - - - - - - - - - - - - - - - -X

Springfield Hilton Hotel
Caribbean Ballroom
6550 Loisdale Road,
Springfield, Virginia 22150

Wednesday,
November 15, 1995

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

APPEARANCES:

Board of Inquiry

Jim Hall, Member, NTSB
Chairman

William G. Laynor, Technical Advisor,
Office of Managing Director

Ronald L. Schleede, Deputy Director
Office of Aviation Safety

Michael L. Marx, Chief,
Materials Laboratory Division
Office of Research and Engineering

John Clark, Chief, Vehicle Performance Division
Office of Research and Engineering

APPEARANCES: (Continued)

Technical Panel

Thomas E. Haueter
Gregory Phillips
James Cash
Thomas Jacky
Malcolm Brenner

Staff:

Michael Benson,
Office of Public Affairs

Daniel Campbell, Director
Office of General Counsel

National Transportation Safety Board
National Safety Transportation Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

Parties to the Hearing

Federal Aviation Administration
Department of Transportation
Harold Donner

AAI-100
800 Independence Avenue, S.W.
Washington, D.C. 20591

Boeing Commercial Airplane Group
Mr. John Purvis
7342 East Marginal Way South
Bldg. 3-800.3, Bay A2
Seattle, Washington 98108

Air Line Pilots Association
Captain Herb LeGrow
535 Herndon Parkway
Herndon, Virginia 22070

USAir, Inc.
General Malcolm Armstrong
115 Commerce Drive
RIDC Parkridge 2
Pittsburgh, Pennsylvania 15275

APPEARANCES: (Continued)

International Association of
Machinists and Aerospace Workers
Mr. Jack Wurzel
73 Auburn Street
Saugus, Massachusetts 01906

Parker Hannifin Corporation
Mr. Steve Weik
14300 Alton Parkway
Irvine, California 92718-1814

Monsanto Company
Mr. Frank Jakse
800 N. Lindbergh Boulevard
St. Louis, Missouri 63167

C O N T E N T S

VALENCIA, CALIFORNIA

I N D E X

I N D E X (cont'd)

P R O C E E D I N G S

[Time noted: 9:00 a.m.]

CHAIRMAN HALL: Please be seated.

Good morning and welcome. We will convene this public hearing that is being held in connection with the investigation of the aircraft accident involving USAir, Inc. flight 427, a Boeing 737-300, tail number N513AU, that occurred on September 8th, 1994 at Aliquippa, Pennsylvania.

I am Jim Hall, Chairman of the National Transportation Safety Board, and Chairman of this Board of Inquiry.

Today we are reopening our public hearing concerning the accident that occurred on September 8, 1994 at Aliquippa, Pennsylvania, involving USAir, Inc. flight 427, which resulted in the loss of all 132 souls on board.

The hearing is being held for the purpose of supplementing the facts, conditions and circumstances discovered during the on-scene investigation. This process will assist the Safety Board in determining the probable cause and in making any recommendations to prevent similar accidents.

Reopening a public hearing is a rare event for the Safety Board, but it represents the importance we place on finding the cause of this accident. As you know, this is the second B-737 accident since 1991 for which there is no readily apparent cause. While there are similarities between the two accidents, there are also differences.

Since Safety Board investigators arrived on the scene of the accident in Aliquippa, this has become one of the most complex and extensive aircraft investigations in National Transportation Safety Board history. So far, the investigating team, comprising the Safety Board and party specialists, have expended approximately 50,000 investigative staff hours in direct support of the investigation.

In January we conducted four and one-half days of public hearings in Pittsburgh, Pennsylvania, receiving testimony on such issues as the Boeing 737 lateral and directional control systems design, certification and service history; flight crew training for recovery from unusual attitudes; management and FAA oversight of USAir flight operations; manufacturers' service difficulty programs and continuing airworthiness standards and practices; and standards for enhanced flight data recorder parameters.

Since that time, many more tests and analyses have been conducted on the evidence, and Mr. Tom Haueter, our investigator-in-charge, will bring us up to date on the progress of the investigation in just a few minutes.

It is understandable why there is much public interest in this investigation and that is why the Safety Board conducts much of its work in the public eye. We have heard much speculation about the cause or causes of this accident from people not involved in the investigation. This also is understandable.

However, I saw an item in Newsweek magazine some weeks ago that a prominent member of the aviation bar said that we at the Safety Board know that the rudder caused this accident; we were just not making it public. Another lawyer was shown in the same article holding up the servo valve for a rudder power control unit, claiming to have discovered a defect in this component.

These claims, quite frankly, perplex me. If indeed somebody has found a "golden nugget" or answer for either one of these accidents, it is odd that he would choose to meet with Newsweek and not the Safety Board. Since the accident, I have met on several occasions with representatives of family members, many of whom are in this audience this morning, who lost loved ones on flight 427. There is nothing I want to accomplish more in my time of service on this Board than to find the cause of this crash.

I can only say that if we knew what caused this accident, we would not be expending thousands of hours a month on this investigation. We wouldn't have spent a million dollars last month on a flight test.

We want very much to solve this accident. We want to know what went wrong. We certainly would not endanger the lives of the public by not acting on our findings. We are, of course, looking at rudder issues very hard and they will be examined again very closely at this hearing. But we need proof to find and cure real problems.

Let me again make it very clear to anyone who feels he or she has information that would help us here. We are always ready to consider hard evidence that will withstand the scrutiny of trained investigators, not wild accusations that are eagerly bandied by people looking for a sound byte on television.

When I opened the hearing in Pittsburgh, I described the purposes of hearings like this in a manner that I think bears repeating this morning.

Public hearings such as these are exercises in accountability. Accountability on the part of the

Safety Board that we are conducting a thorough and fair investigation on behalf of the American people; accountability on the part of the FAA that it is adequately regulating the industry; accountability on the part of the airline that it is operating safely; accountability on the part of the manufacturers as to the design and performance of their products; and accountability on the part of the working force, both pilots and machinists, that they are performing up to the standards of professionalism expected of them.

These proceedings, as you will find, tend to become highly technical affairs but they are essential in seeking to reassure the public that everything is being done to ensure the safety of the airline industry in this great country.

This inquiry is not being held to determine the rights or liability of private parties. That will happen in other forums. And matters dealing with such rights or liability will be excluded from these proceedings.

Over the course of this hearing, we will collect information that will assist the Safety Board in its examination of safety issues arising from the accident. Specifically, we will concentrate in the next few days on the following issues:

First, the Boeing-737 Critical Design review Findings and Recommendations. This review, as you remember, was underway at the time we had the Pittsburgh hearing. The FAA was not in a position to give us a final report. They will do so at this hearing.

Information on the Boeing-737 Directional Control System; information on the Quick Access Recorder Data; information on the Wake Vortex Flight Test; the Aerodynamic and Kinematic Studies; the Hydraulic System; Human Orientation and Disorientation Studies; and Boeing-737 Flight Control Events.

At this point, I would like to introduce the other members of the Board of Inquiry.

Sitting to my right is Mr. William G. Laynor, the Safety Board's Chief Technical Advisor. To my left, Mr. Ron Schleede, the Deputy Director of the Office of Aviation Safety. Again, to my right, Mr. John Clark, Chief of the Vehicle Performance Division. And finally, to my left, Mr. Michael Marx, Chief of the Material Laboratory Division.

At the table seated to my right, the audience's left, is the Board of Inquiry's Technical Panel. The persons on the Technical Panel are Mr. Thomas E. Haueter, the Investigator-in-Charge; Mr. Gregory Phillips, the Senior Systems Investigator; Mr. Thomas Jacky, the Vehicle Performance Investigator; Dr. Malcolm Brenner, seated at the table to the rear, our Human Performance Investigator; Mr. James Cash, our Senior Acoustics Investigator and Mr. Dan Campbell, is seated behind me. He is the Safety Board's General Counsel and he is here to provide any guidance, as required.

Also with us in the audience today is the Vice Chairman of the National Transportation Safety

Board, Mr. Bob Francis.

Mr. Mike Benson from the Safety Board's Public Affairs Office is here to assist the news media that is covering this event and any matters and concerns that they may have.

In addition, Mr. Jamie Finch, my Special Assistant; General Kenneth Jordan, the Managing Director; Mr. Peter Goelz, the Director of Congressional and Intergovernmental Relations; Ms. Julie Beal, the Director of the Safety Board's Public Affairs Office; and Ms. Shelly Hazle, my Confidential Assistant, are also here to assist me.

Also, Dr. Bernie Loeb, who is the Director of our Office of Aviation Safety, is also seated to my rear.

And finally, from the Safety Board, I would like to recognize Carolyn Dargan and Rhonda Underwood who are both here assisting us in all the administrative matters.

All these members of the Safety Board are paid by the taxpayers, work for the general public and are available to be responsive to you and try to answer any questions or concerns you may have at any of the breaks.

Let me state now that neither I nor any other Safety Board personnel will attempt during this hearing to analyze the testimony received nor will any attempt be made at this time to determine the probable cause of this accident. Such analyses and cause determinations will be made by the full Safety Board after consideration of all of the evidence gathered during our investigation.

The report on the aircraft accident involving flight 427, reflecting the Safety Board's analyses and probable cause determinations, will be considered for adoption by the full Board at a later public meeting, which will be held at the Safety Board's headquarters in Washington, D. C.

The Safety Board's rules provide for the designation of parties to a public hearing. In accordance with these rules, those persons, governmental agencies, companies and associations whose participation in the hearing is deemed necessary in the public interest and whose special knowledge will contribute to the development of pertinent evidence are designated as parties. The parties assisting the Safety Board in this hearing have been designated in accordance with these rules.

As I call the name of the party, and they're seated at the tables in front of me, I would appreciate if the designated spokesperson will please give his or her name, title and affiliation for the record and please introduce the other individuals that are at the table with you.

First, I would like to call on the Department of Transportation, Federal Aviation Administration.

MR. DONNER: Good morning, Mr. Chairman. My name is Bud Donner and I'm the manager of the FAA's Accident Investigation Division. With me are Victoria Anderson from the Office of Accident Investigation; Tom

McSweeny, the Director of the Aircraft Certification Service; Michael Zielinski, an aerospace engineer from the FAA in Seattle; Werner Koch, Mechanical System Engineer, FAA Certification Office, Dallas, Texas; and Mr. Thomas Newcombe, an Aviation Safety Inspector from our Seattle Aircraft Evaluation Group.

CHAIRMAN HALL: Thank you very much. We appreciate your presence this morning.

The Air Line Pilots Association. Captain?

MR. LeGROW: Good morning, Mr. Chairman. My name is Captain Herb LeGrow. I was the coordinator on the USAir 427 accident. I just recently retired from USAir and am consulting with the Air Line Pilots Association.

Seated with me are Captain John Cox, who is the central Air Safety Chairman for USAir-Alpha; Captain Dan Sicchio, the Chief Accident Investigator for USAir-Alpha; Mr. Jim Johnson, counsel for the Air Line Pilots Association; Captain Robert Sumwalt, an investigator on the Human Factors Group on the 427 accident; Mr. Keakini Kaulia, Engineer Staff with our staff in Washington.

CHAIRMAN HALL: Thank you very much. We appreciate your participation.

USAir, Inc. General?

GENERAL ARMSTRONG: Good morning, Mr. Chairman. I'm Malcolm B. Armstrong, USAir Vice President for Corporate Safety and Regulatory Compliance. With me at the table this morning are USAir Senior Director of Flight Operations, Captain John Murphy; the Director of Flight Safety, Captain George Snyder; two members from Dombroff and Gilmore, law associates, Mr. Mark Dombroff and Mr. Dane Jacques. And our Manager of the Boeing 737-300 and -400 fleet, Captain Jim Gibbs.

CHAIRMAN HALL: Thank you very much for your participation.

Boeing Commercial Airplane Group?

MR. PURVIS: Good morning, Mr. Chairman. I'm John Purvis. I'm Director of Air Safety Investigation for the Boeing Commercial Airplane Group. Seated at our table are the following people: Rick Howes, who has been the coordinator for this accident ever since day one. He works for me. Jean McGrew who is our 737 Chief Project Engineer. Dick Kullberg, who will be a witness later on. He's a 737 Hydraulics and Flight Controls Engineer and also a designated engineering representative. And two counsel; Tom McLaughlin and Bruce Campbell.

CHAIRMAN HALL: Thank you for your participation.

The Monsanto Company?

MR. JAKSE: Good morning, Mr. Chairman. My name is Frank Jakse. I'm Technical Service Manager for the Ski-draw aviation hydraulic fluid. To my left is Mr. Jim Stegel.

CHAIRMAN HALL: Would you please turn your mike on, please, and begin again.

MR. JAKSE: Is it on now?

CHAIRMAN HALL: Yes. Thank you.

MR. JAKSE: I'm sorry.
My name is Frank Jakse.
CHAIRMAN HALL: Well, it's on. I guess just if you could get a little closer to the microphone, please.
MR. JAKSE: How about that? Is that better?
CHAIRMAN HALL: Can people hear in the audience? It's difficult to tell here.
Yes. Please go ahead.
MR. JAKSE: Okay. I'm sorry. I'll start over.
My name is Frank Jakse. I'm Technical Service Manager for the Sky-draw Aviation Hydraulic Fluid. To my left is Mr. Jim Siegel. He's Business Manager for Aviation Fluids. To my right is Mr. John Cowden, Legal Counsel.
CHAIRMAN HALL: Thank you very much.
Parker Hannifin, Incorporated.
MR. WEIK: Good morning, Mr. Chairman. My name is Steve Weik, representing the Parker Hannifin

Corporation, Bertea Aerospace. I'm an Engineering Manager of the Customer Support Operations.

To the right of me is Walter Walz, Chief Engineer at the Customer Support Operation. I have Frank Silane, outside counsel, and Steve Vaughn, inside counsel.

CHAIRMAN HALL: Thank you.

And the Association of Machinists and Aerospace Workers?

MR. WURZEL: Good morning, Mr. Chairman. My name is Jack Wurzel and I'm a member of District 141 Flight Safety Committee and I was also coordinator for the Machinists Union on the flight 427 accident investigation.

Also, members of the Flight Safety Committee on my right are Mr. Mike Gardner; on my left, Mr. Olney Anthony; and also, Mr. Terry Kleiser.

Thank you.

CHAIRMAN HALL: I want to at this time publicly thank all the parties for the assistance and cooperation they have displayed during the course of this investigation.

On November 13th, the Board of Inquiry held a prehearing conference in Washington, D. C.It was attended by the Safety board's Technical Panel and representatives of the parties to the hearing. During that conference, the areas of inquiry and the scope of issues to be explored at this hearing were delineated and the selection of the witnesses to testify to these issues was finalized.

Copies of the witness list developed at the prehearing conference are available at the press table. There are numerous exhibits to be used in this proceeding. Copies of the exhibits are also at the press table for review.

The Safety Board has provided a complete set of exhibits to Kinko's Copy Center, located at 7040 Old Keene Mill Road, Springfield, Virginia. Copies of the exhibits can be obtained on request at the individual's own expense at Kinko's.

The witnesses testifying at this hearing have been selected because of their ability to provide the best available information on the issues of aviation safety. The first witness will be Mr. Tom Haueter, the Investigator-in-Charge of the accident investigation, who will summarize certain facts about the accident and the investigative activities that have taken place since then.

Mr. Jim Cash, seated at the table with Mr. Haueter, will then provide the findings of the acoustic examination of the cockpit voice recorder tape from flight 427.

The remaining witnesses will be questioned first by the Board's Technical Panel, then by the designated spokesperson for each party to the hearing, followed by the Board of Inquiry.

As Chairman of the Board of Inquiry, I will be responsible for the conduct of the hearing. I will make all rulings on the admissibility of evidence and all rulings will be final.

The record of the investigation, including the transcript of the hearing and all exhibits entered into the record will become part of the Safety Board's public docket of this accident and will be available for inspection at the Board's Washington office. Anyone wanting to purchase a transcript, including parties to the investigation, should contact the Court Reporter directly.

At this time, I would like to acknowledge some other officials who are observing this hearing. If you would just please stand when I call your name and I'll go through these very quickly.

CFM International, Mr. Paul Mingler. Thank you.

The National Air Traffic Controllers Association, Mr. William West.

The Transportation Workers Union Number 545, Mr. Juergen-Peter Schuetz.

The Association of Flight Attendants, Ms. Nancy Gilmer.

Mr. Derek Blackall with the Civil Aviation Authority of the United Kingdom.

Mr. Chee from Singapore Airlines.

Mr. Chan with the Civil Aviation Authority of Singapore.

Mr. Dave King, with the AIIB of the United Kingdom.

And Rich Mercadonte of the Senate Aviation Committee.

Finally, and most importantly, I want to recognize and welcome the family members of the individuals who lost their lives in the crash of flight 427.

With that, we will begin this proceeding and I will turn it over to Mr. Haueter -- or Mr. Schleede, since Mr. Haueter is our first witness. I'm sorry.

(Witness testimony continues on the next page.)

THOMAS E. HAUETER, INVESTIGATOR-IN-CHARGE AND SENIOR
ACCIDENT INVESTIGATOR, NATIONAL TRANSPORTATION
SAFETY BOARD, WASHINGTON, D. C.

Whereupon,

THOMAS E. HAUETER,

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:

THE WITNESS: Good morning.

MR. SCHLEEDE: Mr. Haueter, would you give us your full name and business address for our record, please?

THE WITNESS: My full name is Thomas Edward Haueter. I'm Senior Accident Investigator for the National Transportation Safety Board.

MR. SCHLEEDE: And how long have you worked for the Safety Board?

THE WITNESS: For approximately 11 years.

MR. SCHLEEDE: Could you briefly describe your education and background that qualifies you for your present position?

THE WITNESS: I have a commercial pilot's license. Started flying in 1967. Have instrument rating. I have a degree in aeronautical and astronautical engineering from Purdue University. I have an MBA from George Mason University in operational systems.

MR. SCHLEEDE: Thank you. You may proceed with your statement.

THE WITNESS: Thank you.

It's a little long. I'll try to read it so I don't miss any facts here.

On September 8, 1994 at about 7:03 Eastern Daylight Time, USAir flight 427, a Boeing 737-300, registration N513AU, crashed while descending to land at Pittsburgh International Airport, Pittsburgh, Pennsylvania. The airplane was being operated as a scheduled passenger flight under instrument flight rules from Chicago-O'Hare International Airport, Chicago, Illinois, to the Pittsburgh International Airport.

During the approach to landing, control of the airplane was lost and the airplane crashed near Aliquippa, Pennsylvania. The airplane was destroyed by impact forces and fire. All 132 persons on board the airplane were fatally injured.

During the previous public hearing held in January of this year, I provided a detailed description of the events leading up to the accident and the status of the investigation. I would now like to provide the events that have transpired since January.

Several of the investigative groups have completed their work. These areas are: structure, powerplants, weather, air traffic control, survival factors, operations, witnesses, flight data recorder, cockpit voice recorder and maintenance records.

A partial technical review was held with the parties to the investigation and it was agreed that the investigation into these areas was completed.

The investigative groups that are still active are: systems, aircraft performance, acoustics and human performance.

The wreckage of flight 427 was released to USAir on April 3, 1995. Several components were retained by the Safety Board, such as the rudder power control unit or PCU, the standby rudder actuator, actuator rods, trim system components, and autopilot systems. The Safety Board may obtain additional parts from the wreckage if needed. In fact, electrical connectors from the electronics bay were recently retrieved to be examined for evidence of "blue water" contamination.

On May 3, 1995, the FAA released the findings of its critical design review team which was tasked to examine the control of the B-737 from a certification standpoint. The report will be discussed during this public hearing. The report augments the Safety Board's investigation.

The team made 27 recommendations intended to enhance the safety of the B-737 and other transport category airplanes through design, maintenance and operational means. However, the team did not identify any specific design deficiency or failure mode that would result in an uncommanded flight control deflection of the magnitude necessary to explain the 427 accident.

During the week of September 5, 1995, the airplane performance group conducted a series of tests that collected real world data on the effects of a B-737 entering the wake vortices of a B-727. The tests used a highly instrumented USAir 737 and the FAA's 727, which had been equipped with smoke generators.

During the tests, over 160 vortex encounters were accomplished at distances of about four, three and two miles. Prior to the wake vortex flight tests, simulator validation tests were performed with the 737.

A thorough evaluation of all this data has not yet been completed by the Aircraft Performance Group. However, based upon the initial findings of the flight test, it was found that further refinement of the 737 engineering simulator and kinematic studies is required.

The initial results of the wake vortex flight tests, the simulation validation tests and the kinematic studies will be discussed at this hearing.

With the assistance of representatives from the Air Accident Investigation Branch in England, a program was established to examine Quick Access Recorder data from 737's operated in Europe and the United Kingdom. The data will be examined to determine if there are any events where the rudder exceeds the yaw damper authority or pilot inputs or if there are any unexplained rudder events.

The systems group completed a detailed dimensional analysis of the rudder power control unit from flight 427. There were no discrepancies found. Additionally, the group examined possible effects of a locking up or restricting the motion of several hinge points in the rudder PCU feedback loop and simulating a jam of the input rod to the PCU. In all cases the unit behaved as anticipated. The tests found that jamming the input rod would not result in a runaway condition when the yaw damper was exercised.

The systems group has identified a Boeing 737-200 series that is being removed from service and provided to a museum. The systems group plans to use this airplane to conduct several tests of the complete rudder system. These tests will include back-driving the rudder power control unit, cable cuts, dynamic inputs and impulse loads to the rudder system.

Some of these tests could result in structural damage to an airplane. Therefore, it is fortuitous that a B-737 became available that is going out of service.

Data are continuing to be collected and analyzed on all reported unusual events regarding the Boeing 737 series. These events will be discussed at this hearing.

The Human Performance group is examining all possible pilot reactions to unexpected events, such as severe roll, and unusual attitude recovery procedures. There is considerable anecdotal information on these issues but little factual or statistical information.

The group used NASA's vertical motion simulator to develop a better understanding of the forces experienced by the pilots of flight 427 at the onset of the upset. During the hearing, we'll take testimony from a NASA expert on spatial orientation and disorientation.

During the previously mentioned simulation validation and wake vortex flight tests, recordings were made of the cockpit sounds. These have been useful for comparing to the cockpit voice recorder sounds from flight 427. In a moment, Mr. Jim Cash will provide a presentation on the findings of the acoustics group.

Additionally, the group has examined cockpit voice recorder sounds from United 585, Colorado Springs, Colorado and from several other cockpit voice recorders from other 737's.

I wish to report that all of the 19 investigative tasks identified during the January 1995 public hearing, all have been completed and many of those issues will be discussed at this hearing.

Additionally, on February 22, 1995, the Safety Board issued recommendations to the FAA to enhance the number to parameters recorded on Boeing 737's and other transport category airplanes. The FAA and industry actions on this issue will be discussed at this hearing.

Areas that are no longer being pursued in the investigation are: criminal intent; engine reverser deployment; slat/flap extension; spoiler extension; cargo door, service door or other entry door opening in flight; cargo shifting; electromagnetic interference, engine mount/pylon failure; floor beam failure; and bird strikes. Obviously, based on information, we could reopen any of these areas.

A key part of the investigation is that the flight data recorder provides that there was a heading change or yawing of the airplane which preceded the upset. This would indicate a movement of the rudder or the introduction of an unknown yawing force. The investigation continues in the following issues to determine the source of that yaw, such as: a pull, break or jam of the rudder cable; wake turbulence/vortices; pilot inputs; hydraulic fluid contamination; yaw damper failure; dual hydraulic failure; standby rudder actuator; rudder power control unit and servo valve; structural failure; and electrical short circuits.

Mr. Chairman, this completes my statement. Mr. Jim Cash can present the findings of the acoustic examination.

(Witness excused.)

CHAIRMAN HALL: Mr. Cash, if you'd please come forward.

(Witness testimony continues on the next page.)

JAMES R. CASH, SENIOR ACOUSTICS INVESTIGATOR, NATIONAL TRANSPORTATION SAFETY BOARD, WASHINGTON, D.C.

Whereupon,

JAMES R. CASH,

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. SCHLEEDE: Mr. Cash, would you give us your full name and business address, please?

THE WITNESS: My name is James Robert Cash, the National Transportation Safety Board, Washington, D. C.

MR. SCHLEEDE: And what is your position at the Board?

THE WITNESS: My job is Senior Cockpit Voice Recorder Specialist.

MR. SCHLEEDE: And how long have you worked at the Safety Board?

THE WITNESS: Approximately 13 years.

MR. SCHLEEDE: Would you give us a brief description of your education and experience that brings you to your present position?

THE WITNESS: I have a BS degree from Syracuse University in electrical engineering and I was an Air Force pilot, flying F-4's for approximately eight years.

MR. SCHLEEDE: Thank you. You can proceed.

THE WITNESS: Good morning, ladies and gentlemen. I would like to start my presentation this morning by briefly describing how a cockpit voice recorder works and how sounds get to the microphones to be recorded on a voice recorder.

The cockpit voice recorder receives its electrical power from the aircraft, so any time there is power in the aircraft the voice recorder is running. The unit is an endless loop recorder, constantly erasing the older information, recording the newer information.

When electrical power is removed from the unit or after the airplane crashes, the recorder contains information from this point back, usually 30 minutes.

The recorder consists of four channels of audio information. One of the channels contains the audio information from the captain's audio selector panel. This channel records the same information, the same sounds that the captain was listening to on his headset.

Another channel is for the co-pilot's information. Again, it's identical --

CHAIRMAN HALL: Are we going to dim the lights slightly? Can you see the screen in the rear?

(Pause.)

Just wait one moment. I think I see someone from the hotel.

Mr. Benson, you may see if we can get someone to help us with the lighting when we have these, or train someone.

(Pause.)

Why don't you continue, Mr. Cash, and we'll hope that they'll dim the lights here in a moment.

THE WITNESS: Okay. Again, the first channel of the audio information is from the captain. The second channel is from the co-pilot. The third channel, which is, on a three-crew member airplane, is normally connected to the third crew member's audio selector panel. In these two-crew member airplanes similar to the Boeing 737, it's usually wired to the observer or jumpseat audio selector panel.

The fourth CVR channel contains audio information from the cockpit area microphone. This open microphone is usually mounted in the overhead instrument panel between the crew members and is our primary microphone for picking up all the cockpit sounds or noises.

On this aircraft the two crew members were wearing individual headset microphones. These are hired hot to the CVR recorder. This hot term means that whenever sounds were picked up by the crew headsets, microphones were recorded directly on the individual audio tracks of the CVR.

In addition to the normal area microphone and the two crew member microphones which were both hot, the microphone selector switch on the jumpseat audio selector panel was inadvertently left in the oxygen mask position. This enabled the microphone in the oxygen mask to be hot, similar to the captain's and co-pilot's headset microphones. So for this investigation we actually had a total of four microphones that were picking up the audio information and recording it on the CVR.

CHAIRMAN HALL: Mr. Cash, this is minor, but the CVR is all you have mentioned. It's a cockpit voice recorder; right?

THE WITNESS: Yes, sir.

CHAIRMAN HALL: And would you mind telling everybody in the audience just a little -- what it looks like and where it's located?

THE WITNESS: The cockpit voice recorder is a crash protected unit which is usually -- in this airplane it is actually mounted in the aft cargo compartment. It's designed to, again, record 30 minutes of audio information, in addition to the flight data recorder, which is another recorder that looks very similar to it.

Just quickly to go over where the microphones are. The captain obviously is in the captain's seat; the co-pilot; the open area microphone is in the overhead panel between the two crew members. In this case, the jumpseat microphone, which was the oxygen mask, is stored in a little plastic enclosure that's in the entranceway of the cockpit door, looking down on it. So it's in a little plastic enclosure just to the right as you come in the cockpit.

The sound information arrives at various microphones via several methods. The first and most predominant method is by airborne sound waves in which the sound energy is transmitted via the air to the microphones in the cockpit. This is the main transmission mode for the sounds recorded on the CVR.

The second mode of the sound transmission is structure borne sounds. These are sounds transmitted up through the metal structure of the aircraft. These sounds normally are very low frequency as compared to the airborne sounds. The cockpit area microphone, and to a lesser extent the jumpseat microphone/oxygen mask, are really the only two microphones capable of picking up structure borne sounds.

The sounds recorded on the CVR may be composed of either of these two sounds or maybe a combination of the two sounds. One characteristics of the structure borne sound is that they normally travel through the metal eight to nine times faster than they do through the air.

By knowing the speed that sound travels through the air, approximately a foot every 100th of a second, and by measuring the time differences between the arrival of the structure sound and the arrival of the air sound, we are able to calculate the approximate distance -- and the direction if we have multiple microphones -- that the source of the sound was from the microphone. Later in my presentation I have a slide that depicts this event.

This slide shows the sounds that we found on the various channels of the cockpit voice recorder from the accident aircraft. The slide starts just prior to the initial upset and continues for approximately 10 seconds. From this slide you can see a picture of the various audio sounds that were found on the individual channels.

The top trace is a picture of the information found on the captain's channel. The second trace is the one on the co-pilot's channel. The third trace is the open area microphone and the fourth channel is the mike in the oxygen mask in the jumpseat/observer's channel.

Because of the nature of the area microphone, the same speech found on the crew channels, if he says it loud enough, will appear on the area microphone and, if it's reasonably loud, it will even appear on the jumpseat microphone of the CVR.

Just so you have some idea of what this means here. Again, this is the captain's channel, the co-pilot's channel, the area microphone and the jumpseat microphone. The co-pilot initially says, "I see the jetstream," which is what the wave form looks like for the text here. At the same time, the captain -- this is when he says, "Geez." And then a breath, which is characterized as a breath in and out on the CVR transcript. This is, "Whoa," and then "hang on, hang on."

The same information is actually down here on the area microphone channel. It's a little more difficult to see, but really, if you look for a one to one correspondence, you do see that.

On the area microphone channel we have what are characterized on the CVR transcript as three thumps, and that's these little guys right here. Again, they're on the -- it's probably too little for most people to see, but they are down here on the jumpseat channel also. The same thumps appear here, here and here on the jumpseat channel. There's a louder thump here which is pretty predominant on the jumpseat channel, too.

This is the kind of information that we have to work with.

This next slide is the cockpit area microphone channel at approximately the same time slice as the preceding slide. Instead of showing the simple wave form, I'm showing the same information in the frequency domain. This type of plot is commonly called a spectrogram or voice plot -- voice print format.

When you look at the frequency plot, several different additional pieces of information become apparent. The constant frequency trace shown in the red, which is -- can you move that up a little higher? It's hard to see but it's this constant line here.

The frequency is increasing this way and time is going this way.

AUDIENCE: Your microphone, please.

THE WITNESS: I'm sorry. The frequency is increasing in this direction and time is increasing in this direction. So low frequencies would be down in the bottom of the chart; high frequencies are up here.

A constant frequency, which is what this line represents, is a steady line. This represents the sound the engine was making. Again, the voice. This is "I see the jet stream," is right here. The three thumps are right there, there and there. It's difficult to see. The louder thump is right here. But the thing I want you to see is the engine trace on there.

This constant frequency trace shown in red is the sound signature made by the aircraft engines. The sound is produced by the rotation of the first stage of the fan in the engine, very similar to the noise that a household fan would make. The frequency of the sound is dependent on how fast the fan is turning in the air.

It is not apparent from this slide but if I were to increase the scale, two separate traces can be observed. These two traces are due to the fact that the two engines were operated at a few tenths of a speed different from each other.

You can see from this plot that the engine sounds change intensity. The change is depicted by the changes in the redness of the line just after the initial upset. We identified this abnormality early in the investigation but had no explanation as to why the engine sounds got louder just after the event.

If you remember this here, I'll come back to it in a few minutes.

Several other events are depicted on the frequency slide. Just after the first officer finishes saying "jet stream," you can see what I described as the thumps recorded on the CVR. These thumps are found both on the area microphone and the jumpseat channels of the CVR. The sounds are very low frequency and of relatively low intensity as compared to the other events on the CVR.

Sever other events are depicted on the frequency plot. There are additional thump sounds very similar in characteristic to the first series and the voice prints of the crew members' speech are also shown.

To further investigate the thumps found on the accident CVR, we conducted several tests on identically configured Boeing 737 aircraft. One test was conducted on the ground. On this test we struck various places on the aircraft with a rubber mallet while recording the sounds. The resulting data allowed us to validate our assumptions as to how the various sounds reached the CVR microphone.

In this slide you can see the various wave forms. The top one, again, is the area microphone and the second one is the jumpseat microphone. The sound was made by striking the aircraft structure with the rubber mallet in the forward cargo compartment. In this data we were able to see both the arrival of the structure sound, which I'll show you here in a second, followed several hundredths of a second later by the arrival of the air sound.

These tests also gave us some indication of the frequency makeup of the sound. Again, you have to know what you're looking for, I guess. The original sound starts here. The structure sound arrives here. The air sound arrives here. Same thing on the jumpseat microphone, which is a little more pronounced. The structure sound arrives here and the air sound hits it when it comes right here.

Also you'll notice the time difference. If you go straight up on the line, the structure sound actually arrives at the jumpseat microphone first, which means that it was coming -- since that's more to the rear of the aircraft, it's actually hitting that one first and then hitting the area microphone. so you can kind of get an idea of which direction it's coming from.

As a result of the tests, we were able to verify both the direction the sounds came from, as well as the approximate distance the source was from the microphone. By using the same technique, we were able to determine the approximate distance and the direction that the thumps on the accident CVR are coming from.

As you can see on this slide, the arrival time of the various wave forms in the accident recording are not quite as easy to identify as the ground test recording. The thump sounds on the accident recording are not very loud, and with the addition of the normal background noise of an aircraft in flight, the onset of the thump sounds tended to be masked.

To aid us in determining when the thump sounds started, we used a signal processing function that calculates the total sound energy contained in the signal. With this plot it becomes easier to determine when the two components of the sound arrives at the microphone.

Again, this is the cockpit area microphone, the jumpseat microphone. This plot goes with this guy and the bottom on goes with the jumpseat microphone.

The reason I put this up here, it's very difficult to tell when one wave starts and when the next wave starts. One is actually here and the other one, I think, is actually here. With the energy plot it's relatively easy to tell that one starts here and the next guy starts right here. That was the reason I wanted to show this.

Again, there is a time delay between the two microphones, meaning sound is coming up from the rear of the aircraft, hitting he jumpseat microphone first and then the area microphone.

We calculated the source of the thump sounds to be approximately 20 feet towards the rear of the aircraft from the area microphone. This places the sound source approximately in the vicinity of first class rows 1 and 2 of the airplane. The frequency composition of these thump sounds on the accident airplane were very similar to the ground test rubber mallet strikes. This is not totally unexpected because the frequency composition of the recorded sounds have more to do with the sound transmission characteristics of the aircraft, the metal skin of the aircraft, than they do with the initiating event.

Even though these tests did tell us some properties of the sounds, they didn't really help us determine what the source of the thumps on the accident CVR were.

In the Fall of this year we conducted a controlled flight demonstration that involves flying a similar Boeing 737 aircraft in the wave turbulence of the Boeing 727 aircraft. This test was conducted to determine the characteristics and severity of the wake at various distances behind the 727 airplane. There'll be more testimony in this hearing explaining the exact details of the test, so I won't take the time now. But during the test demonstration, cockpit sounds were recorded when the aircraft encountered the wake. I have a short videotape that has what the wake looked like and sounds. It kind of goes fast but you can hear the thumps when it goes through the wake.

(Whereupon, a videotape presentation was shown.)

THE WITNESS: Sometimes when the airplane would go through the wake we wouldn't get a sound and sometimes you would get a sound. It was kind of random in nature.

If you listen, in the background you can hear the engines moving around. That's that steady line trace that I was referring to. You can hear the engines. In two seconds here there's a louder one coming up which I do a lot of work on.

Again, sometimes through the wake you didn't get any noise at all.

This is the cockpit view which is the pilot's eye view, looking straight out the front of the cockpit into the wake.

I have another view which is the tail view of the aircraft. The camera was mounted high on the vertical tail. This gives you some idea of what the -- this is not the same test but earlier that day. Gives you some idea of what the wake looks like from kind of a back view.

Again, there's going to be more video shown in the following testimony on the wake.

CHAIRMAN HALL: Jim, even though it will be described later, I think it's important to point out here that the visual scene we're seeing is not the same scene that the flight crew of 427 would have seen out their window. The wake is accented by smoke generators coming off the preceding plane; right?

THE WITNESS: Also, the sound that we used is from the flight test, not from the voice recorder from the accident airplane.

The pilots initially reported on the first day that some of the wake encounters did make a distinct sound in the cockpit. The sounds they heard, though, are not reported as being identical to the recording to the sounds on the accident recorder. When we reviewed their cockpit voice recorder after the flight, the wake encounters did sound identical to the ones found in the accident aircraft. Again, this is due to the structure sounds being added to the air sounds that the crew was hearing because they're only hearing the air sounds.

On the wake turbulence tests, we were again able to calculate the approximate distance and direction that the wake encountered thumps. Most of these thumps documented to date originate at 20 to 26 feet back from the area microphone. Again, the frequency composition of the wake was very similar to the thump sounds heard on the accident aircraft.

The overall consensus by the spectrum committee was that the source of the thumps on the accident CVR was most probably an encounter with wake turbulence of a preceding 727 aircraft.

As I mentioned before, an unexplained increase in the amplitude of the noise of the engines were heard on the accident aircraft. Again, that's that red line that changes intensity here and again in here. It actually gets louder here. Comes from almost nothing and gets pretty loud and then fades away and gets louder.

During a review of the audio data accumulated during the six days of the wake turbulence testing, we noticed a similar change in the amplitude of the engine sounds during some of the test maneuvers. One of the test maneuvers was unrelated to the 727 wake turbulence but was conducted to validate some of the flight characteristics of the Boeing 737 aircraft.

Again, the specifics of these maneuvers will be subject to much discussion in the following days. One of these maneuvers was called the steady heading side slip test. This controlled test was accomplished by slowly inputting the rudder while opposing the resulting yaw with opposite aileron to maintain a constant heading and level flight. These tests were all conducted at similar altitudes, speeds and configurations as the accident aircraft.

During these tests, using both left and right rudder input, the engine sounds were noted as getting louder when a rudder input from between 7 and 14 degrees was made. This level of increase was very similar to the increase noted on the accident aircraft.

On this plot I have plotted the actual intensity of the engine sounds. I extracted the engine noise from the spectrum plots and plotted the increase of engine. The top one that you see is from the wake turbulence test with the left rudder input. The middle one is the right rudder input and the bottom one is the 427 accident.

As you can see the intensity increase with the rudder input, a little more on the right and left. And the accident airplane increased intensity, leveled off, decreased and then increased again.

The exact reason why the engine sounds increased is not really understood. The spectrum group did conclude that the sound signatures on the accident aircraft matched the engine sound signatures identified on the test airplane, the wake turbulence test airplane, with a rudder input of between 7 and 14 degrees.

This concludes my presentation. We have made some headway in finding out the origin of several of the unknown events on the CVR. Our work is still not done. We have further tests schedule in conjunction with the other investigative groups to try to identify all of the unknown sounds on the accident recorder.

CHAIRMAN HALL: Thank you, Mr. Cash.

(Witness excused.)

CHAIRMAN HALL: Mr. Haueter, have all the exhibits been entered into the record?

MR. HAUETER: Yes, they have.

CHAIRMAN HALL: If so, then we will call our first witness, Ms. Anne Evans. Ms. Evans is a Senior Inspector of Air Accidents (Engineering) for the Air Accident Investigation Branch in Farnborough, England.

Mr. Schleede will swear the witness in.

(Witness testimony continues on the next page.)

MS. ANNE EVANS, SENIOR INSPECTOR OF AIR ACCIDENTS
(ENGINEERING) AIR ACCIDENT INVESTIGATION BRANCH
FARNBOROUGH, ENGLAND

Whereupon,

ANNE EVANS,

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

MR. SCHLEEDE: Ms. Evans, please give us your full name and business address?

THE WITNESS: My name is Anne Evans and I work at the Air Accident Investigation Branch, Department of Transport, DRA, Farnborough.

CHAIRMAN HALL: Ms. Evans, it's difficult to hear in this room. I hope it's not as difficult in the audience as it is up here. But if you could please speak as closely to the microphone as you could, we would appreciate it.

THE WITNESS: Okay.

MR. SCHLEEDE: And again, what is your position at the AAIB?

THE WITNESS: I'm a senior investigator of air accidents, specializing in flight data recorders and cockpit voice recorders.

MR. SCHLEEDE: And how long have you worked at AAIB?

THE WITNESS: I've been there for eight years. And prior to that, I was at the CAA, responsible for their participation in QAR studies.

MR. SCHLEEDE: Thank you.

Mr. Jacky will proceed.

MR. JACKY: Thank you.

Good morning, Ms. Evans.

THE WITNESS: Good morning.

MR. JACKY: The topic I wish to discuss with you this morning is regarding a Boeing 737 quick access recorder or QAR data search that the NTSB has contracted with an European airline. If you could please refer to Exhibit 13X-E, please.

THE WITNESS: Yes. I have it here.

MR. JACKY: I might explain, before I ask any questions, that as part of the agreement that the NTSB has entered with this airline, is that we will not use the name of the airline and have it remain anonymous.

Before we discuss the data search program, could you, please --

CHAIRMAN HALL: Mr. Jacky, before we begin into this, would you mind -- somebody, explain to the audience what a quick access recorder is very quickly so everybody knows what Ms. Evans is going to be speaking to?

MR. JACKY: That was my first question to Ms. Evans.

CHAIRMAN HALL: Fine. Yes.

THE WITNESS: Okay. A quick access recorder is a recorder, an additional data recorder, fitted for maintenance and monitoring purposes. It's function is basically similar to a flight data recorder, except the recording medium is generally a cassette of magnetic tape or it can be an optical drive. And this is easily removable from the recorder itself post-flight.

It records the same information as the mandated accident recorder and in a lot of cases, a lot more data, additional parameters and high sampling rates as also included. The data is recorded via the same acquisition unit as it used for the accident recorder.

MR. JACKY: In terms of this airline and the data search, does the airline record the same amount of parameters on the flight data recorder as on the quick access recorder?

THE WITNESS: No. There are many, many more parameters recorded on the QAR. In this case in particular, what was of interest to us is the fact we have rudder pedal and rudder panel position.

MR. JACKY: How does the purpose of the quick access recorder differ from the flight data recorder in terms of accident investigation?

THE WITNESS: The QAR is not designed for accident investigation. The cassette is not crash protected and it's not designed to survive an accident. The airline fits a QAR because they have an interests in actually utilizing the data for monitoring purposes. And that can be engine health monitoring or, as a case in study we do, operational monitoring.

MR. JACKY: In terms of the airline and the program that they have with the quick access recorder and searching for the data, could you explain how that works very briefly?

THE WITNESS: They have a computer program which has a number of predefined special events, as they're called. And these are a whole variety of events of interest, such as how it approaches hard landings, excess bank. And each cassette is analyzed for this set of special events.

MR. JACKY: And how does the airline accomplish that?

THE WITNESS: The cassettes are removed on a daily basis from each aircraft and processed through a very large computing department.

MR. JACKY: And is that done automatically on every airplane?

THE WITNESS: Yes. Every airplane.

MR. JACKY: And all throughout this airline's fleet?

THE WITNESS: Yes.

MR. JAKSE: How does the program actually search through and determine and find operational events?

THE WITNESS: As I spoke, there are a number of pre-defined events. Say for example in the case of a hard landing event, there's a pre-set threshold and if the parameter exceeds that threshold, that event is then flagged by the computer program and that produces an output. If there are no events in flight, the cassette is just processed through and recycled.

MR. JACKY: Does the airline use flight data recorder information for the search also?

THE WITNESS: Not normally. They wouldn't replay the data recorder. It's a totally automatic process using the cassettes alone.

MR. JACKY: Thank you.

Who in the airline determines what events are to be looked at?

THE WITNESS: This program has been built up over a number of years. Initially it was part sponsored by the UK CAA and there were a number of areas of interest to the CAA and also the Air Safety Branch within the airline has interest. But it's really determined by the fleet, the fleet managers of the airline itself.

MR. JACKY: And is the program ongoing? Does the airline have the ability to add additional events into there as need be?

THE WITNESS: Yes, indeed. Events can be added very quickly and there's also some onboard processing with the most recent aircraft.

MR. JACKY: So that if the airline noticed that certainly some sort of event was happening over and over they could add a program to look for that specific event?

THE WITNESS: Yes, they can.

MR. JACKY: Are you aware of any sort of programs like this that are running in the U.S.?

THE WITNESS: I'm not aware of any, no.

MR. JACKY: Has the AAIB ever used the quick access recorder data search in support of any of their investigations?

THE WITNESS: We did use a similar sort of study in an incident investigation on an 747 aircraft where we looked for elevator splits. And that was done by the QAR with onboard processing.

MR. JACKY: And during an investigation by the AAIB, would you be more apt to read QAR information or the FDR information?

THE WITNESS: I think in the case of an incident where the QAR was undamaged, our first course would be to replay the QAR because it records much more information than the FDR. Once we've satisfied ourselves that that data is valid, we wouldn't then need to replay the FDR. And it also gives us much more information on previous flights, for example. We have a number of cassettes which we are able to use for that aircraft and indeed the whole fleet.

MR. JACKY: So you have a historical record of that airplane?

THE WITNESS: I'm sorry?

MR. JACKY: Would you have a historical record of that airplane then?

THE WITNESS: The airline would. Yes.

MR. JACKY: As far as the program that the NTSB has entered with the QAR data search, could you please explain how you became involved with the program?

THE WITNESS: Yes. The NTSB heard of our work on another event that I mentioned, the 747, and approached us to set up the study and act as a liaison with a number of airlines and investigate what was possible.

MR. JACKY: And how many airlines did you contact?

THE WITNESS: We contacted three airlines, two of which were readily able to help us because of their computer systems.

MR. JACKY: And where were these airlines located?

THE WITNESS: Within Europe.

MR. JACKY: Could you explain, please what are the objectives of the program?

THE WITNESS: Yes. As the program stands, we want to monitor rudder operation and yaw damper operation and we're doing that by histograms which log the amount of time spent at various rudder positions. And we're also deriving yaw damper activity by using rudder pedal and rudder position to compare the two and therefore derive the yaw damper activity.

So we're doing a statistical analysis of what is actually happening to the rudder and the yaw damper movement and we're also looking for events which are disagreements between the rudder pedal and the rudder panel position as we have defined, and also looking for lateral acceleration events above a certain level which could be indicative of a yaw.

MR. JACKY: Before we dig deeper into the data and the initial data that we've received from the program, could you explain which airplanes the program is looking at?

THE WITNESS: At the moment it's looking at 737-400 aircraft.

MR. JACKY: And how many airplanes are involved?

THE WITNESS: Twenty-five aircraft.

MR. JACKY: Has the data sampling rate of any of the parameters been changed for the program?

THE WITNESS: Yes, indeed. We increased the sampling rate on both rudder pedal and rudder to twice a second and we also added the yaw damper discrete for on/off.

MR. JACKY: Is it easy for the airline to accomplish those changes?

THE WITNESS: Yes, it is. It's a software change on the acquisition unit.

MR. JACKY: If I could ask you to refer to page number 9 on the Exhibit 13X-E and if I could have the overhead slide, also, please?

THE WITNESS: Yes. I have it.

MR. JACKY: Before we get into this chart, could you please explain exactly, as far as what a histogram is and what does that accomplish?

THE WITNESS: A histogram is a way of presenting statistically data. And what we're looking at here is a variety of rudder positions from minus 5-1/2 degrees to 5 degrees, and dividing time intervals and logging how long is spent at each rudder position.

MR. JACKY: Okay. And where on that chart would that be described? Maybe you can just walk us through that chart, please.

THE WITNESS: Okay. Rudder position is shown here and the data was divided into various flight phases: takeoff and climb; climb, cruise and descent; and approach and landing. We show here time in each phase. You'll see most of the time has been spent obviously in the climb, cruise and descent phase.

Down here are the various rudder position lots and in each column we show the number of seconds spent in each of those rudder positions. So, for example, from around about the zero here, from minus a half degree to half a degree, you can see most of the time is spent.

MR. JACKY: So that chart would give you an idea of where the rudder is during each phase of flight?

THE WITNESS: That's right.

MR. JACKY: And on the phase of flight, what altitude is being the cutoff point for a determination between the different flight phases?

THE WITNESS: 5,000 feet. So, takeoff to 5,000 feet would be the first phase and above 5,000 feet would be the climb, cruise and descent phase.

MR. JACKY: Okay. Thank you.

If then we could move on to in that same exhibit, page number 16, please.

THE WITNESS: Yes. I have that here.

MR. JACKY: And if you could, again, walk us through the chart.

Before you do that, please explain what is meant by yaw activity and how that is derived.

THE WITNESS: Okay. The yaw activity is derived by a comparison of the rudder panel position and the rudder pedal position. We derived rudder panel position from rudder pedal, compared that with the actual panel position and the difference is the calculated yaw activity.

On the 737-400, we have a three degree yaw damper authority and so here the yaw damper activity is divided between minus three degrees and plus three degrees. Again, the data is divided into three flight phases and time is logged in seconds in each of these positions.

MR. JACKY: So then in theory, would the results of the yaw activity always -- or what would you expect the results of the yaw activity to be? Within what limits?

THE WITNESS: What you'd expect to see is that most of the time is spent again around zero. In other words, the yaw damper is not actually applying any rudder. We see as we get to the limits of the authority, around about minus three/plus three degrees, there's very little time spent at that position.

MR. JACKY: So what values would you expect the yaw activity to be that would cause you concern?

THE WITNESS: We've set the event where an event to flagged to beyond two degrees, which is within the yaw limit, but it gives us some data to look at. So we have a few events where the yaw activity is greater than two degrees in turbulent conditions. And we haven't found anything beyond the three degree limit or significantly beyond the three degree limit.

MR. JACKY: In addition to the histograms that we've talked about, there are additional specific events that the program encompasses. Would you explain what those are, please?

THE WITNESS: Yes. As I mentioned, if your activity is beyond -- we've set the limit at two degrees. We actually get an event output from the computer program. It comes out automatically. And that gives us a trace which we can actually look at and determine what's happening to the aircraft.

We set the event limits at two degrees so we can have some information to look at. We have detected a number of events, obviously, when the yaw damper is working beyond the two degree, but we haven't found any events that are beyond 3.2 degrees, which is within the resolution and accuracy of the data we have.

MR. JACKY: And for the amounts or the disagreements that have been flagged so far in the program, what has been the largest difference?

THE WITNESS: The largest one has been 3.2 degrees in a fairly turbulent approach. And as I said, 3.2 degrees is within the tolerance of the calculations and the calibration of the aircraft.

MR. JACKY: Are there any other events that the program is searching for?

THE WITNESS: Yes. We also have a lateral acceleration event. So if the computer detects a lateral acceleration beyond .1 degree, an event is automatically output. We have detected one of these events, which again was in a turbulence approach.

MR. JACKY: And for this event, was there any sort of large heading change in the data?

THE WITNESS: No, no. It was just a turbulent approach.

MR. JACKY: The information that's shown in the histograms here -- or how do you get that information and how is that translated back to the NTSB?

THE WITNESS: As each cassette is replayed, the program analyzes the data for time spent in each rudder or yaw damper activity position. That data is then logged in a database within the computer and we're able to interrogate that periodically and get an update. And at the moment, we've been transferring that finally to the NTSB.

MR. JACKY: And how often are these transfers made?

THE WITNESS At the moment, we're still in the early stage and we've been -- we've had I think two transfers of data over the last few weeks.

MR. JACKY: And when did the program start?

THE WITNESS: It started in mid-October. We had some problems with the software getting on line, so we've been running live for about two weeks now.

MR. JACKY: And how long do you expect the program to last?

THE WITNESS: We can leave the data running or leave the events running for as long as necessary. We would expect to run the program for about six months before producing a final report.

MR. JACKY: Has the airline expressed any interest in the program?

THE WITNESS: They're very interested and I think would be keen to keep the events in once the NTSB interest is finished.

MR. JACKY: Getting back to the actual information that is recorded on the QAR's, what sort of surface positions and cockpit control positions are recorded on these?

THE WITNESS: Yes. The rudder panel position and the rudder pedal position are recorded.

MR. JACKY: And how about the other controls within the cockpit?

THE WITNESS: Yes, indeed. Both the pilot input position for the control column and control wheel and the ailerons and elevators are recorded.

MR. JACKY: Does the regulatory agency that controls this airline, do they require those parameters to be recorded?

THE WITNESS: It's very dependent on the age of the aircraft. For these particular aircraft, it is not a requirement to record both pilot input and surface position.

MR. JACKY: So why would the airline go ahead and record that information?

THE WITNESS: They have an interest, obviously, in the data they're recording. It's useful for them. So they're keen to fit extra parameters because they actually find that useful in their own investigations.

MR. JACKY: Are there any additional events that will be looked for in this program search?

THE WITNESS: Yes. At the moment, we're looking to increase the program to look for control wheel position and do the same statistical study and histogram using control wheel position and also look for cases of excess rudder.

As you've seen from the histograms, usually rudder position is around about zero, so we're going to look for cases where there is an excess amount of rudder being used, which obviously shouldn't be the case unless you have an engine failure.

MR. JACKY: And was this part of the program initiated with the original portion of the program?

THE WITNESS: No. We hope to implement that by the end of November.

MR. JACKY: Are you familiar with the U.S. regulations as far as information that is recorded on flight data recorders?

THE WITNESS: I'm not familiar with U.S. regulations.

MR. JACKY: So you couldn't make any comparison between the European authority and the FAA?

THE WITNESS: I think I wouldn't like to speak in detail but I think they are broadly similar.

MR. JACKY: And would you have idea as to why the Safety Board would have to go to a European authority to ask for this sort of a data search?

THE WITNESS: As far as I'm aware, no U.S. operator has the capability to analyze this sort of information. And QAR's generally aren't fitted to U.S.

aircraft.

MR. JACKY: Turning to another subject, I would like to ask you to please reference Exhibit 13X-C, please.

THE WITNESS: Yes. I have the exhibit here.

MR. JACKY: And I would ask you to turn to page number 5 and Item Number 50, row number 50.

THE WITNESS: Item Number 50. Yes.

MR. JACKY: Okay. Recently the NTSB was informed of an event that British Airways had on a 737-200 airplane and I was wondering if you had any knowledge of this event.

THE WITNESS: Yes. I've done the flight recorder analysis from this event. It occurred in a post-maintenance test flight at an altitude of 29,000 feet -- I'm sorry -- 20,000 feet, 290 knots. And the aircraft suffered a number of roll oscillations that went on for a period of six minutes.

MR. JACKY: And what is the status or is the AAIB investigating this incident?

THE WITNESS: Thisincident is the subject of an AAIB formal investigation and we are still continuing that investigation.

MR. JACKY: Is there any information that you could give us regarding this incident?

THE WITNESS: I think the investigation is still at a very early stage and we have no conclusions to present here.

MR. JACKY: One final question. I asked you regarding the comparison of the -- or regarding the CAA's regulations as far as the flight data recorders. Do you have an estimate of what number of parameters are required to be on say 737 airplanes that are flying within the UK?

THE WITNESS: It's very varied because of the dates of first certification and individual airplane certification. My understanding is that an aircraft of the age of the Pittsburgh 737 would have required 11 parameters but for aircraft, obviously newer aircraft coming onto the register post-1989, that's much increased.

MR. JACKY: And the number of parameters that are recorded on the 737-400's that are being used for this data search?

THE WITNESS: Of the order of 80 analog parameters plus some discretes as well.

MR. JACKY: So would you have an estimate of the total number of parameters then?

THE WITNESS: I think the total number is somewhere around 2OO.

MR. JACKY: I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Thank you, Mr. Jacky.

Any other members of the Technical Panel have questions for this witness?

(No response.)

If not, we will at this time turn to the parties. What I would like to do is what we did in Pittsburgh. If you have an interest in asking a question of this witness, if you would please have your representative raise their hand and that would keep us from having to go through the list every time to see.

Do we have any of the parties that would like to ask questions of this witness?

(No response.)

If not, we will move to the Board of Inquiry. Mr. Clark?

MR. CLARK: I have no questions.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HALL: Well, the Chairman would just like, Ms. Evans, to point out that in this investigation we have sought out the international assistance and international cooperation from around the world and I want to note that the AAIB, which is the British equivalent of the NTSB, I would like to thank you and your organization for your support of this investigation and your work with us, and note that this has been done at the expense of your own organization, which we greatly appreciate.

And I also want to acknowledge at this time that in terms of the sound spectrum analysis, we have sought out the assistance of our counterparts with the Russian version of the NTSB and they have provided assistance to Mr. Cash in that area, as well.

As I understand it, Ms. Evans, you have started out on this quick access recorder, which as I understand is a flight data recorder without the essential crash protection items that can be quickly removed and read out. And we do not have that. Airlines are not using that in this country. Therefore, we have gone to Europe and sought the cooperation of airlines, which we appreciate. They've asked not to be identified but we appreciate their cooperation.

And we started, if I'm correct, in October with the recorder, quick access recorder, that gives us the rudder -- what is it -- pedal and rudder panel. Is that the correct description?

THE WITNESS: Yes.

CHAIRMAN HALL: Information. Surface information. And we are monitoring that.

And how long do we intend to monitor that?

THE WITNESS: For approximately six months.

CHAIRMAN HALL: Six months. And we just are in that about a month; right?

THE WITNESS: Yes.

CHAIRMAN HALL: And basically, you've covered this morning some information on the beginning of that. And the reason we're doing that is that we hope that we'll be able from that information to see if there are any anomalies or rudder deflections that the Board -- that would assist us in this investigation.

Is that correct, Mr. Jacky?

MR. JACKY: That is correct.

CHAIRMAN HALL: Is there anything else that the general public ought to know about what Ms. Evans is doing and the work they're doing that would contribute to the public understanding of what is a fairly technical process?

MR. JACKY: The only thing that I might add would be that in regards to the information that we're looking at, we're looking at both the input to the surface position, as well as the output, so we see what is being commanded inside the cockpit and also what is the result of that input. And also that we're looking at many thousands of hours of information and searching through that in order to look for these type of events.

CHAIRMAN HALL: Okay.

Ms. Evans, thank you very much for your attendance and coming all the way over here and we appreciate it very much. And you're excused.

THE WITNESS: Thank you very much.

(Witness excused.)

CHAIRMAN HALL: Before we begin our next witness, we will take a break for the benefit of all involved for approximately 15 minutes. And we will start this promptly at 10:45. So if you want to be here, be ready in your seats at 10:45.

We stand in recess.

(Whereupon, a recess was taken.)

CHAIRMAN HALL: We will reconvene this inquiry of the National Transportation Safety Board and I would like to call the next witness, Mr. Michael Zielinski, an Aerospace Engineer, Project Officer, Critical Design Review Team Leader with the Federal Aviation Administration in Seattle, Washington.

(Witness testimony continues on the next page.)

MICHAEL ZIELINSKI, AEROSPACE ENGINEER, PROJECT OFFICER
CRITICAL DESIGN REVIEW TEAM LEADER, FEDERAL
AVIATION ADMINISTRATION, SEATTLE, WASHINGTON

Whereupon,

MICHAEL ZIELINSKI,

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. SCHLEEDE: Mr. Zielinski, give us your full name and business address, please?

THE WITNESS: My name is Mike Zielinski. The address is Renton, Washington, Northwest Mountain Region.

MR. SCHLEEDE: I'm sorry. I didn't hear the last part.

THE WITNESS: The address is Renton, Washington, Northwest Mountain Region FAA Office.

MR. SCHLEEDE: Ad you work for the FAA?

THE WITNESS: That's correct.

MR. SCHLEEDE: In what position?
THE WITNESS: I am an Aerospace Engineer Project Officer within the Standardization Branch within the Transport and Airplane Directorate.
MR. SCHLEEDE: Could you briefly describe what your responsibilities are in the position?
THE WITNESS: My current responsibilities are to monitor all transport category activity as far as the Atlanta Certification Office and the LA -- that is Los Angeles Aircraft Certification Office.
MR. SCHLEEDE: Would you give us a brief description of your education and background that qualifies you for your position?
THE WITNESS: I have a bachelor's degree in aeronautical engineering. I've worked in industry 18 years, 10 of which have been as an FAA designated engineering representative, flight analyst. I've been employed at the FAA for the past 12 years.
MR. SCHLEEDE: Could you just briefly tell us what a designated engineering representative does?

THE WITNESS: I had the responsibility for reviewing data as a consequence of flight testing in support of development of airplane performance for the Airplane Flight Manual.

MR. SCHLEEDE: Thank you. Mr. Phillips will proceed.

CHAIRMAN HALL: Mr. Phillips, before you begin --

Mr. Zielinski, this is the second time. You testified in Pittsburgh, did you not?

THE WITNESS: That is correct.

CHAIRMAN HALL: And I believe in Pittsburgh you gave us a progress report on the work of the critical design review team.

THE WITNESS: Yes.

CHAIRMAN HALL: And I asked at that time if you would mind coming back if we had a second hearing to give us a report on that and you said you'd be glad to.

THE WITNESS: Yes.

CHAIRMAN HALL: And I appreciate you being here.

Mr. Phillips?

MR. PHILLIPS: Thank you.

Good morning, Mr. Zielinski?

THE WITNESS: Good morning.

MR. PHILLIPS: Can you hear me?

THE WITNESS: It's a little --

MR. PHILLIPS: Okay.

CHAIRMAN HALL: Is it on?

MR. PHILLIPS: It's on but it's low.

Okay. As the Chairman noted, we got a chance to talk with you back in January in Pittsburgh. I'd like to for a few minutes recap some of that testimony with just some general questions about where we were back in January when we talked with you.

In the last public hearing, it was my recollection that the report wasn't finished at the time. Is that correct?

THE WITNESS: That's correct.

MR. PHILLIPS: And at what stage of completion was it at that hearing?

THE WITNESS: We anticipated at that time we needed at least two more months to complete the document.

MR. PHILLIPS: Was there investigative work being done or was it management reviews or what?

THE WITNESS: Both.

MR. PHILLIPS: Both. Okay.

And the team was still together functioning as a CDR team?

THE WITNESS: That's correct.

MR. PHILLIPS: Recalling your original testimony about the makeup of the team, exactly what was the CDR? And could you tell us a little bit about the team members that were selected?

THE WITNESS: Okay. The CDR, the critical design review, was with respect to the 737 flight controls and a charter was developed in October of '94 and it was felt that a team should take a fresh look at the design of the flight control system on a 737 with regard to possibly identifying any deficiencies that might contribute to the ongoing accident investigation with regard to the Pittsburgh accident.

There were eight to nine members at any given time during that process, which went from October of '94 through the end of April of '95. The document was completed May 3rd of '95.

We, that is the Transport Directorate, believed that it would be valuable to have people that were not intimately involved with the certification of the 737 but yet having expertise in transport category airplanes in the various areas, like systems, operations, maintenance, airworthiness, et cetera.

We also believed that it would be important to include people outside the FAA, and to that end we had representation from Transport Canada, the United States Air Force and a representative from the NTSB.

MR. PHILLIPS: In selecting the team members, were these volunteers or were they selected by FAA management?

THE WITNESS: A mail message went out to all of the Aircraft Certification Offices within the FAA Aircraft Certification Service asking for nominees and consideration of the task. And following the identification of candidates and then in consideration of their willingness to participate, knowing how it might interfere with their workload, et cetera, we arrived at the selection of people that we have.

MR. PHILLIPS: Was this a full-time job for the people on the team?

THE WITNESS: For some individuals, yes. Others it was probably on the order of 25 to 50 percent of their time, depending upon -- in the beginning, I think we had a very concentrated effort. And as time went on, as the document developed, the amount of time spent by the individuals diminished.

MR. PHILLIPS: Where did the initial concept of the team originate? What set the charter and the foundation for the review?

THE WITNESS: Well, the idea for the effort came out of the Seattle Aircraft Certification Office. I believe Mr. Don Rig-gin, who is the Office Manager, felt that something else had to be done and he thought this was a possibility. He checked with upper management as to the feasibility, considering the costs and resources within the FAA, and it was decided that this would be a worthwhile effort.

MR. PHILLIPS: Had there been other CDR's done by any of these team members? Had they participated on other CDR's?

THE WITNESS: There had been other critical design reviews. I believe one of our members of this particular one had participated in others. They're a bit unique, each one being quite different.

MR. PHILLIPS: Along those lines, the charter, at least the area of coverage for the CDR was fairly specific. Can you give us some idea of what defined the range of your examination or investigation?

THE WITNESS: Well, certainly we are driven by the accident -- accidents, I should say. And flight controls was the area we wanted to focus. The decision was made that the effort would be without any inhibitions, inhibitions from the standpoint of the probability of the occurrence. It was rather more of a hazard assessment, a qualitative hazard assessment.

So the potential for anything occurring, that is failures, multiple single failures, was open for review by the team.

Also, we included any consideration for the service experience, that is by operators, as may be exhibited by SDR's, manufacturer generated service bulletins, service letters, et cetera. So the service history of the airplane and the design and the potential for failures was the consideration for the team.

MR. PHILLIPS: You mentioned in your opening statement there both accidents. What accidents would those be?

THE WITNESS: I'm sorry. The Colorado

Springs and the Pittsburgh events.

MR. PHILLIPS: In the initial -- you mentioned probabilities without -- review without consideration or inhibition. Did you take into account during your review the certification basis for the airplane?

THE WITNESS: Yes, we did. The document, that is the report on the critical design review, contains our review of the initial certification of the 737-100-200 and the models 300, 400 and 500. It was to give us a measure of where or what the certification basis was for those airplanes with regard to today's requirements.

MR. PHILLIPS: Can you give us a brief summary of what is a certification basis? When we use those terms, what are we talking about?

THE WITNESS: An applicant, a manufacturer of an aircraft, approaches the FAA with a design concept and is requesting certification of the design. In this case, a transport category airplane. And at that time of application, we look at what is the current amendment level within the certification rules. And it's that level that's applicable to that particular airplane.

MR. PHILLIPS: And an amendment is an update to a Federal Aviation Regulation?

THE WITNESS: That is correct.

MR. PHILLIPS: Okay. In doing a review where the certification basis isn't a foundation for your examination, does that make available to you more avenues of exploration? Can you use new rules to evaluate the airplane against?

THE WITNESS: Okay. A bit of background on the 737, the various models. The airplane was originally certified, I believe, in 1967. That is, the 100, 200. And beginning in '84, the other three models, 300, 400 and 500, were certified against the same type certification basis. And that is, that we did not apply the -- directly apply the latest amendments as they may exist say in 1984 against the

737-300, 400 and 500, except for those parts of the airplane that had significant change.

For example, the introduction of a new engine on the airplane certainly wouldn't meet the latest requirements at the time of certification. Or for that matter, any significant systems or structure changes would certainly have to meet the latest amendment level.

But things that have not changed, we did not impose any later modifications to the rules on the existing airplane.

MR. PHILLIPS: How are the decisions arrived or come to on what amendments to oppose or what changes to require for a new derivative certification? Is there a process that involves a review panel or exactly how does that start off, please?

THE WITNESS: Well, the certification basis is certainly set by the time of the application. If it's an amendment to the type certification basis, our current policy is to ask the applicant to assess the opportunity to certify to the current amendment level, although it's not a requirement, and to show how or why that may not be appropriate, given the service experience of the airplane and/or the inapplicability of the new amendment level.

MR. PHILLIPS: You mentioned earlier a functional hazard assessment as a type of review for your CDR group. What is a functional hazard assessment?

THE WITNESS: Advisory Circular 251309 identifies what is a functional hazard assessment. It in essence is a qualitative approach to failure analysis, as opposed to a probablistic. And it depends upon to a significant degree engineering judgment with regard to the hazardous nature of single multiple failures.

MR. PHILLIPS: So, let's talk a little bit about qualitative, qualitative and probablistic. Can you categorize or give us more of a layman's explanation of that terminology?

THE WITNESS: Probablistic is in reference to the failure rate consideration for various elements of a component in combination with other elements of that component which would ultimately give you a probability of an entire unit or component failing.

Within 25 -- that is, Advisory Circular 251309 are identified what are considerations as far as the probability of failure and a degree of hazard associated with that probability.

MR. PHILLIPS: Did 251309 exist at the time of initial certification of the 737?

THE WITNESS: No, it did not, as far as the Advisory Circular is concerned.

MR. PHILLIPS: Yes. The regulation existed but the Advisory Circular came out at a later date. Approximately when did that come out? Ballpark.

THE WITNESS: I don't recall. I believe it was the '70s, if I'm not mistaken.

MR. PHILLIPS: And then revised in about eight months later?

THE WITNESS: There was a revision 1A of that document.

MR. PHILLIPS: And what is an Advisory Circular? What does that do and what kind of bearing does that have on certification?

THE WITNESS: Advisory Circular is in reference to a particular regulation, with regard to the means of showing compliance. It's an interpretation. Not the only means, but it is a means for showing how you might go about complying with a particular regulation.

MR. PHILLIPS: So if it has a number of 251309, that means it's relative to that requirement or regulation and that's a means of compliance?

THE WITNESS: That's correct.

MR. PHILLIPS: I think, Mr. Donner, in that pile on the floor -- 1 may be wrong in that identification of date for 251309. There's an AC on the floor there that will show what the particular date was. We'll get back to it later.

THE WITNESS: That's fine.

MR. PHILLIPS: In your CDR review, you looked at service history of the airplane. How did you do that? What information did you have available to you?

THE WITNESS: We had three individuals on our team that were, let's say, operation, airworthiness, expertise. We had a principal maintenance inspector in avionics and we had the principal maintenance inspector from a Canadian operator and we had a master sergeant, Air Force, that dealt with the T-43.

Those individuals went into the various data sources with regards to the service history of the components involved in the flight control system of the airplane. The significant difficulty of reports, the aerospace safety reporting system. We reviewed past service bulletins generated by the Boeing Company and associated service letters and many other sources.

We reviewed the AD history; that is, Airworthiness Directive history on the 737 to tell us if there were areas of particular concern, frequency of failure, et cetera, which would give us focus as to any considerations for possible recommendations on corrective action.

MR. PHILLIPS: Could you tell us what a service difficulty report is, an SDR?

THE WITNESS: An SDR, it's as defined, I believe, in regulation 21.3, as far as those kinds of things reported by the operators to the FAA. The process being that as a report is generated that information goes to the Aircraft Certification Office that has the type certificate for that particular airplane.

It's then distributed to the various branches for their review, as to any concerns with regard to safety or let's put it in the context of continued airworthiness of the airplane and whether any action, mandatory action, might be necessary.

And what I mean by mandatory action, that's with respect to the generation of an Airworthiness Directive.

MR. PHILLIPS: Are the operators required to write SDR's?

THE WITNESS: Per the regulation.

MR. PHILLIPS: So an SDR, if there's a discrepancy or difficulty, you would expect to find one for every time that occurred on a specific airplane or type of airplane or fleet?

THE WITNESS: That is the expectation.

MR. PHILLIPS: Okay. And in the processing of this data by the ACO, Certification Office, for review for safety issues, is there a formalized process that identifies trends or developing trends in SDR activities?

THE WITNESS: As I mentioned, the SDR comes into the Aircraft Certification Office that has responsibility for that particular airplane and that information gets distributed to the various specialty areas within that office for them to track the trend and establish whether or not there are any safety issues/concerns.

MR. PHILLIPS: How complete is the information on the SDR? Does it provide sufficient information to make a critical assessment of the safety hazard involved in something?

THE WITNESS: The SDR's unfortunately are not as complete and detailed as we would hope down to the point of identifying cause. A component may be removed but not necessarily what the particular fault found was. So the process is incomplete.

MR. PHILLIPS: Who initiates an SDR? A mechanic?

THE WITNESS: Or the operator.

MR. PHILLIPS: Someone at the operator? Okay.

And as part of your review for the CDR, you reviewed the SDR history for this airplane for the flight control systems?

THE WITNESS: SDR's are usually categorized by ATA chapter and various numbers indicate elements within, in this particular case, the flight control system. And we interrogated that system for those ATA chapters that affect flight controls.

MR. PHILLIPS: Did your review also include any comparison of other aircraft, other type aircraft for the number of SDR's against that type of system?

THE WITNESS: No, we did not look at the SDR's on other aircraft but we did look at the design of other aircraft. In particular, the DC-9/MD-80 series.

MR. PHILLIPS: Did you find anything in your review or did the team find anything in the review that you considered a significant number of SDR's against any particular system? Did you attempt to quantify how many were too many?

THE WITNESS: There within the documents are several tables that identify single failures, latent failures. And I think we've identified in that table the SDR's that indicate or support the kind of failure mechanism we've identified within a table.

We've also included in the appendix some information with regard to service bulletins and service letters that also were somewhat indicative of the failure.

What we are looking for is, having gone through the hazard assessment, was there any substantiation for that hazard actually occurring. And through the SDR's, the Aviation Safety Reporting System and the other data sources, we're looking to substantiate the potential for the failure to occur.

That's all referaced in those tables.

MR. PHILLIPS: I realize that.

The ASRS, Aviation Safety Reporting System, could you give us a brief description of what that is and who maintains that?

CHAIRMAN HALL: Before we move to that, could we get an explanation of a single failure and a latent failure since we're talking about them, so we know what those two items are?

MR. PHILLIPS: Sure can.

THE WITNESS: Simply put, Mr. Chairman, it's

-- a single failure, the term that we've used in our document, is detectable. Latent failure is undetectable. That is, undetectable or not identified to the flight crew.

Again, Advisory Circular 251309 is clear with respect to what constitutes a latent failure.

MR. PHILLIPS: Okay. Back to the ASRS issue. Again, a brief description of what that is and who maintains that database.

THE WITNESS: I believe the process is identified as an appendix in the documents. That is, the critical design review document. My recollection it's a NASA supported collection system funded by the FAA and it's open to any individual involved with the operation of an airplane; mechanic, pilot, et cetera. That they could submit a report with regard to an anomaly, an incident of concern to them, and it's guaranteed that the report will be anonymous.

It goes into a database that we then have access to. I believe the system started in '85, started about that time period.

MR. PHILLIPS: And did you have a person from NASA on your team?

THE WITNESS: No, I did not. In fact, the person that helped us with the Aviation Safety Reporting System data was the NTSB representative.

MR. PHILLIPS: There was an NTSB representative with the CDR team?

THE WITNESS: That's correct.

MR. PHILLIPS: And what was his function with the team?

THE WITNESS: As with a number of the team members, they played a variety of role besides their particular specialty. They also helped in the review and development of any concerns with regard to the data. The NTSB representative helped us in clarification of the recommendations that were developed by the NTSB against the 737 that might have impact with regard to flight control. I think that was the principal area of expertise, or I should say assistance, with regard to the CDR.

MR. PHILLIPS: As part of the team's work, did you review any reports from the NTSB on the accident investigation at Colorado Springs?

THE WITNESS: We had access to some of the report, not all. The effort at the onset was to independent of the accident investigation, but at the same time we were very much attracted, you might say, to what did they learn. And we did have some limited amount of information, but certainly not all.

MR. PHILLIPS: Were there any constraints placed on giving you or making access to that information to you?

THE WITNESS: No.

MR. PHILLIPS: So you got everything that you required for your assessment?

THE WITNESS: Right.

MR. PHILLIPS: As part of your work, I believe you had a pilot with your group, at least one. And you did some simulation work at Boeing. Could you summarize that real briefly?

THE WITNESS: In the process of reviewing the analyses, failure analysis provided by the Boeing Company, we decided that it would be beneficial to exercise some of the failure modes in using a simulator. Boeing made available their engineering simulator and we had put together a test plan, which is also identified in the document with regard to various conditions.

The principal focus, of course, was the flight control as a consequence of using ailerons and spoilers, flight spoilers and the rudder. We did look at the symmetries with regard to leading and trailing edge flaps. We looked at the normal operating envelope. We did attempt to focus in the speed regime of 190 knots and configuration flaps one for a number of the failure considerations.

We looked at jams. We looked at failures. We looked at jams, partial jams, full jams, from the standpoint of using the example of the wheel. The control wheel was jammed at 45 degrees, I believe, and at a full throw. We looked at the consequent ability with the remaining flight control to continue to fly the airplane. And in some cases, we attempted to land the airplane. Of course, all in the simulation.

MR. PHILLIPS: Why did you select 190 knots and flaps one as a datapoint?

THE WITNESS: Well, it was one of the datapoints and we wanted to make sure we covered the event that was significant with regard to the Pittsburgh accident.

MR. PHILLIPS: So the data was provided to you to say that the accident --

THE WITNESS: That's right.

MR. PHILLIPS: Okay. You mentioned that you did some testing for jams. Was there any particular concern that drove you to looking at the jam condition or was it just one of several?

THE WITNESS: In our review of the failures analyses, the question came up with regard to jam at what position. Where does the flight control input jam? And the FAA has a regulation, 25.671, that talks about is normally encountered. And our investigation as to what does that mean, we've come to a conclusion there was no specific, meaning it was very subjective.

In the event of showing compliance with the regulation normally encountered was up to the individual conducting the flight test to establish along with the manufacturer. We felt very uncomfortable with this subjectivity. In fact, it ended up being one of our concerns, as identified in a recommendation in the report. And along with that, we wanted to look at, okay, if the jam occurred here or at full deflection, is there an issue from the standpoint of controllability, recovering from the upset condition.

MR. PHILLIPS: Did you have any reason to think that jams would occur only at a full travel position or neutral position? Was there any basis from your service history study of the SDR's that would indicate you should be looking in those areas or was it just thoroughness?

THE WITNESS: No. The data that we got from the reporting system is very specific that could answer that kind of question that says where, if any at all, jams were reported. It was only through the review of the failure analysis that we were concerned with what does normally encountered mean. And therefore, the need to explore that future.

A recommendation in Section 15 of the document does provide for doing something about that, requesting either policy or possibly regulation be developed that would further clarify what normally encountered means. This is an issue that came out of our looking at the 737 but certainly is not applicable only to the 737. There's other aircraft that certainly would be, let's say impacted if we ultimately end up with criteria. And therefore, they have the potential for having difficulty with that criteria.

We're in the process of -- or we have, I should say, developed an issue paper. An issue paper is a document that identifies an FAA concern with regard to compliance with a particular regulation. It's a document that is developed in the process of certification of an airplane. And within this particular issue paper that I'm referring to, we are attempting to identify criteria that should be used to establish what normally encountered means.

This is not to say that it's the only set of criteria. Certainly the applicant can respond to that and say that, well, with regard to your criteria, we've conducted possibly a survey. It shows that it may not be quite applicable. So it's still a developing process open to review and substantiation of what does normally encountered means.

It's a difficult term but it is something that's used in a number of places within the regulations with regard to flight control and we felt, as a team, it needs definition. Again, to emphasize, it's not just a 737 issue.

MR. PHILLIPS: Are you aware that there's ever been an attempt to define normally encountered by an issue paper or any other action before?

THE WITNESS: Our assessment of the history of various certifications indicated there was not.

MR. PHILLIPS: So if the flight control surface -- if you can deflect it to its maximum travel in flight, could you -- by any means, could you consider that a normal encountered deflection or does that fit into your definition?

THE WITNESS: It's unlikely. Although I must say that our team members did feel that if there's that amount of control available, is there the potential for utilizing it. Now the issue is that a normal situation and is there a requirement to show controllability for the extreme case.

I believe ultimately in our recommendation, for instance with regard to the rudder, we did identify failure of the modes consequences not shown to be extremely improbable as those conditions that you would not have to show controllability because of the extremely improbable nature of the failure and a consequence of being at say null rudder deflection.

MR. PHILLIPS: Could you tell me what extremely improbable means to you or to the FAA?

THE WITNESS: To the FAA, it's as prescribed in -- again, Advisory Circular 251309, revision 1A. It identifies the probability, extremely improbable being an event that is -- the potential for its occurrence may be one in a billion. A billion flight hours, for example, has not yet occurred with regard to the operations certainly of the 737. It's on the order of 60-some million hours at this time.

So if a failure or a combination of failures was determined to be extremely improbable, the expectation is it would not occur in the life of the fleet.

MR. PHILLIPS: So paraphrasing that, if it's extremely improbable, it could never happen in a 737 or a DC-10 or whatever?

THE WITNESS: With the current level of 60 million hours, you'd have to have 15 times that amount of experience and when that might be achieved, so -- it's anybody's guess whether the airplane would be around that long. I'm sure Boeing hopes it would be, I suppose.

MR. PHILLIPS: Does the term extremely improbable used in the certification of the 737, did it need to meet that criteria when it was certified?

THE WITNESS: No.

MR. PHILLIPS: Would it be --

THE WITNESS: Let me clarify. It was an engineering judgment as to the hazard associated with single multiple failures as opposed to a probablistic determination that the combination of events would be a 10 to the 9th or less.

MR. PHILLIPS: So would it be required of a newly certified airplane, then? Extremely improbable criteria?

THE WITNESS: Yes.

MR. PHILLIPS: Is that generally more stringent than what was required of the basic certification of the 737 series?

THE WITNESS: Yes.

MR. PHILLIPS: In the initial certification basis, what was the criteria for failure? What was the terminology used and --

THE WITNESS: Boeing conducted a failure analysis, and I'm sure they could expand upon that in detail. Single failures, a combination of failures; that is, single failure and single latent failure. And to what degree of hazard associated with that, again, I believe in the later models, as changes were introduced with the 300 and 400, they did apply a probablistic assessment. But for the 100, 200 airplane, that wasn't conducted, to my best knowledge.

And it was a judgment from the standpoint that any event of occurrence that could pose a hazard, there were alternate means or there was an action or a response that could be elicited from the flight crew in dealing with that failure.

And so you'll see in the failure analysis, in the event of these failures occurring, certain actions could be taken by the flight crew to alleviate any hazard associated with that failure.

MR. PHILLIPS: Was the failure analysis that you speak of, was that required by the FAA for certification?

THE WITNESS: Yes. It's part of the safety assessment requirement.

MR. PHILLIPS: And that's required of all airplanes?

THE WITNESS: Yes.

MR. PHILLIPS: Is that certification or is that failure analysis, is it modified as operational data becomes available on preliminary hazard assessments that have changed with service?

THE WITNESS: No. But there is another means for dealing with issues. In the process of certifying the airplane an assessment is made as to the hazards associated with failures subsequent to the certification of the airplane. We have what's called the continued airworthiness -- continued operational safety.

Within the FAA are various elements that contribute to the continuing safety of the airplane as the service experience dictates, as failure occurs, as incidents occur, as the manufacturer sees the need to modify the airplane. Service bulletins are generated. Service letters are generated to implement modifications or changes to maintenance or inspection or whatever.

The Flight Standard service element of the FAA contributes via its monitoring of the operation of the airplane and the events occurring within that particular operation. Those events, from the standpoint of failures, component removals, et cetera, that information is fed back to certification. That is, Aircraft Certification Service. And the cumulative information that is what comes from the operator, what comes from the manufacturer, is accumulated within the Aircraft Certification Office to determine whether or not an airworthiness directive needs to be generated.

So even though an analysis may be shown to be imperfect or incorrect as the service experience dictates, there are opportunities that the FAA has to correct that via development and issuance of an airworthiness directive that would mandate the corrective action to ensure the continuance of the operational safety of the airplane and in essence, continuance of what we bought into originally as the level of safety predicted by the analysis.

MR. PHILLIPS: I think we understand the continuing airworthiness concept, but is there a requirement for the analysis that was originally conducted to certify or justify the airplane be changed as this information becomes available? Is the document -- is it rewritten and reissued with modifications?

THE WITNESS: Are you talking about the failure analysis?

MR. PHILLIPS: Failure analysis documents.

THE WITNESS: No. The failure analysis is not revised as a consequence of the service experience, although that service experience may cause the generation of service bulletins that then become a production line item for subsequent models or I believe -- and Boeing certainly can expand upon this, how service bulletins are introduced into newly produced airplanes.

MR. PHILLIPS: When you have no operational experience on a newly certified airplane, the basis of your functional hazard assessment or failure analysis, you mentioned as engineering judgment. Whose judgment is it that the analysis is adequate, complete?

THE WITNESS: Well, it's the collective judgment of the FAA, whose responsibility is to determine that compliance has been shown, as well as the responsibility of the applicant.

(Pause.)

You have to excuse me. I was going to make a point. I can't recall. Repeat your question, please.

MR. PHILLIPS: Well, I just asked whose responsibility is it for the failure analysis? Who provides it and how is it put together.

THE WITNESS: Okay. You asked engineering judgment.

MR. PHILLIPS: Right.

THE WITNESS: The engineering judgment aspect, what's meant by that is the collective experience of individuals and their having conducted certifications or been involved with airplanes having similar design features. In other words, if you were to establish that a failure analysis for say the 737, you certainly would look at the experience gained on other airplane models that have similar systems or components. And with that, assess whether or not the analysis is reasonable and applicable.

CHAIRMAN HALL: Mr. Phillips, I'm just -- so I can follow this now, is this -- the failure analysis document is what you're saying, Mr. Zielinski, was created in 1969 on this plane when it was originally certified?

THE WITNESS: Original certification was in '67. The documentation was provided prior to that time.

CHAIRMAN HALL: And that document is not updated?

THE WITNESS: That's correct.

CHAIRMAN HALL: With each model that comes along.

THE WITNESS: Until another model comes along and/or changes are made to that particular airplane.

CHAIRMAN HALL: So the series, 100, 2OO, 300, 400, is that document updated or it stays the same?

THE WITNESS: Unless additional features are incorporated on a particular model, the document doesn't change.

CHAIRMAN HALL: Well, on this particular plane, has that document been updated?

THE WITNESS: For additional equipment, like a change in the autopilot, the incorporation of other design features modifications. Any time a significant modification is introduced, the failure analysis needs to be updated.

CHAIRMAN HALL: And you monitor that in your shop?

THE WITNESS: It's a requirement.

CHAIRMAN HALL: Through that process?

THE WITNESS: Right.

CHAIRMAN HALL: Okay.

THE WITNESS: But we do not adjust past analyses by service experience except for, as I indicated, the application of the Airworthiness Directive process.

MR. PHILLIPS: So to have a thorough understanding of how relevant an initial failure analysis may or may not have been, you would also need to have the service history, AD history, service bulletins to go with that initial analysis?

THE WITNESS: That's why our process, as far as the CDR team. Just to emphasize, the people were not necessarily familiar with the airplane but they were expert in their particular area of specialty. They were provided that familiarization. They were privy to the analysis in support of the certification of the airplane and then we looked at the service history of the airplane in substantial or corroboration of analyses and/or judgments that were provided as far as failures and their associated hazard.

MR. PHILLIPS: Going back into the CDR report briefly, the areas that members studied included your flight controls but you also considered an area of hydraulic fluid contamination. Why was that selected? Was there a driving force behind looking into that area?

THE WITNESS: This is one of the advantages of a fresh look at a design. The team began to ask questions, simple questions with regard to sensitivity of hydraulic components, with regard to contamination. And as we explored that question, we also asked that of Douglas as well, with regard to their approach considerations.

We found that there certainly were recommendations by the manufacturer from the standpoint of when to change the hydraulic fluid. But the standards and/or ship shear capabilities, say for example, of those valves were not necessarily a standard. They were different. Various components had different capabilities. Not to say that the different indicated an unsafe feature necessarily but the fact that they were different.

And so, an attempt to assure ourselves ultimately that the consideration, similar considerations applied in the development and ultimate certification of components, we suggested that fluid contamination and particulate contamination and chip shear capability are items that ought to be reviewed from the standpoint of a need and ultimate application of any standards that might be appropriate.

And in this particular case, with response to our recommendation, I believe, the Society of Engineers have identified a committee, six, I believe, and Mr. Paul Knerr can speak to that in a little more detail, as to their activity to review contamination, review any concerns with regard to particular contamination as far as hydraulic fluids are concerned and/or chip shear capability of various components. In this particular case, flight control hydraulic units.

MR. PHILLIPS: Did you team make any findings about the hydraulic fluid contamination issues related to the 737 airplane?

THE WITNESS: No findings. I think we just had some concerns. I believe Mr. Werner Koch can speak a little further to any concerns that the team had.

MR. PHILLIPS: Mr. Koch is the next witness and we'll address those issues with him.

Did your work in this area result in any recommendations?

THE WITNESS: Yes.

MR. PHILLIPS: And before we go into that a whole lot, what I'd like to do is maybe in the end summarize the recommendations. Right now, I'd just like to stick with the area here.

But you did make a recommendation in regards to hydraulic fluid contamination?

THE WITNESS: Yes, we did.

MR. PHILLIPS: I see also you did some work in the autopilot area. Could you briefly describe your team's work in that? Concerns or considerations?

THE WITNESS: We did look at the autopilot as far as failure modes and potentials for concern ultimately to determine whether or not there were any significant deficiencies or things that we would feel ought to be corrected.

Our review the autopilot as such from the standpoint of continued safe flight and landing did not indicate that any corrective action was necessary.

MR. PHILLIPS: So your team didn't identify any problems with the autopilot in the 737?

THE WITNESS: Not that there are any

problems, but rather that there's no hazards associated with some of the failure modes, the failure modes that we looked at.

MR. PHILLIPS: Did you consider the failure analysis that you used in the hazard assessments as adequate for your study?

THE WITNESS: Yes.

MR. PHILLIPS: You made a group of recommendations at the end of the report and they're grouped into four areas; regulatory interpretative material, certification process, design issues and continued operational safety issues.

Is there any reason why the groupings fell that way or is that just a good way to do it?

THE WITNESS: Well, our intent initially was to review the features and any potential concerns about the flight control system on the 737. But in the process, we identified a number of issues that were not germane only to that airplane. And we began to see that we had some internal problems with regard to identification of policy and/or standards that should be applied to airplanes of this category; that is, the transport category.

So we began to see that there were some regulatory interpretive issues that needed to be addressed. Then there certainly were some design issues peculiar to the 737 that needed to be address, and as opposed to issues concerned with maintenance and operation of the airplane.

So we felt it appropriate to segregate the concerns we had into the categories we've identified.

MR. PHILLIPS: Starting with the regulatory interpretive material, I see that there are four recommendations in that area and the opening text, I believe, on page 39 of Exhibit 9X-A, starts out with a reference to 575.671, the normal flight envelope, exceptional piloting swing strength.

There's some question in the report about -- specifically says may not be sufficient.

Have you got that page there?

THE WITNESS: I have page 34.

MR. PHILLIPS: The very first paragraph, the next to the last sentence says these regulations may not be sufficient. And then the recommendations follow.

To arrive at this statement, did this require consensus of the team? Was it a unanimous decision? Or how did this text come about in this form?

THE WITNESS: Page 34?

MR. PHILLIPS: It's circled. They've circled the 39 in the bottom right corner.

MR. SCHLEEDE: He's referencing the original document, the pages that are --

MR. PHILLIPS: We need the actual exhibit.

CHAIRMAN HALL: It's page 39 of the exhibit; right?

MR. SCHLEEDE: The handwritten 39.

MR. PHILLIPS: Yes. He has the original report, which there's a few additional introductory pages.

CHAIRMAN HALL: Now where is this language? Under which recommendation?

MR. PHILLIPS: It's at the very first paragraph. It start FAR 25.671.

CHAIRMAN HALL: Okay.

MR. PHILLIPS: I'll give you a couple of minutes to find that there.

(Pause.)

And I guess my question -- I'll restate it. Beginning with the second sentence which references the regulation, it says the CDR team believes the interpretations that have been applied in the past regarding the amount of flight control input to be considered in showing compliance with the referenced regulations may not be sufficient.

THE WITNESS: That's right.

MR. PHILLIPS: My question is -- the CDR team, by that statement, is that a consensus of the team or is it agreed upon or negotiated or how do we end up with that statement?

THE WITNESS: It certainly was the team consensus. In fact, that's true of all the recommendations. There was not -- there wasn't -- I'm trying to recall each one of the recommendations. There's 27 of them.

I don't believe there was any position stated within the CDR review of the recommendations that was contrary to what was written.

MR. PHILLIPS: Okay.

THE WITNESS: The --

MR. PHILLIPS: Go ahead.

THE WITNESS: The statement of sufficiency.

Is that what your concern; what does it mean?

MR. PHILLIPS: Yes. I'd like to have a little description of that.

THE WITNESS: I think I mentioned earlier our concern about what normally encountered means and I think that's what we're trying to say. That a subjective approach to normally encountered is not sufficient and we wanted a more specific criteria that could be readily adapted to other airplanes, a standardized approach to normally encountered. Therefore, equal treatment with regard to certification of this category of airplane.

MR. PHILLIPS: So, the driving force behind this statement isn't specifically the 737 requirement? It's for all transport airplanes?

THE WITNESS: Well, like I said, we started with the 737 in our investigation of trying to establish normally encountered. We did interview certification offices with regard to, well, how was this applied on other aircraft. And the response was very subjective -- was that it was a subjective application. And we felt it was appropriate in consideration of the effort we were putting out to identify the fact there was a need for standardization on what does normally encountered mean.

MR. PHILLIPS: Okay. And under the area of certification process, I see three recommendations. Can you summarize those into a brief statement as to the subject matter for those?

CHAIRMAN HALL: Which three?

MR. PHILLIPS: Recommendation 5, 6 and 7 on page 40.

THE WITNESS: On page 40? Okay. These are -- it's a logical grouping, that is, 5, 6 and 7. And fundamentally it speaks crew action, crew action as a consequence of failure analysis.

What's happening here is that the failure analysis provided by the manufacturer indicates that as a consequence what may make the failure an acceptable situation, that is, that it's not unsafe by any means, is that the crew will respond. And the crew will take a particular action, be it a switch, be it a determination of operation of a hydraulic system, possibly.

In any event, there's a response. Let's say an expected response.

What we found in our review was that this expected response or action item didn't have a good trail from the standpoint of implementation.

The next question we asked -- okay, if this expected -- if this response is an acceptable response or is what makes the failure analysis acceptable, then how is that action carried over into ultimately the operation of the airplane?

Is it a procedure? Is it a crew training item, or possibly is it intuitive?

And so what concern was had was there didn't appear to be a formal process. That's not to say that none existed or nothing equivalent existed, but rather that there was no formal process that said here's an action item; yes, it is or isn't appropriate for incorporation into training or flight procedure, flight manual identification or whatever. The process was not formal.

Now, in our discussion of this particular recommendation with Flight Standards Service personnel within the FAA, the belief was that to a degree it did exist, but it was not a formal exercise where -- here's a document that says this is the response of the flight crew and this is how it's been disposed of.

And we were concerned that if in those cases an action item made a difference to the acceptability of the failure analysis, there must be a way to show indicate that that action is indeed an expected response; be it through a written procedure or it's been judged to be an intuitive action by the flight crew.

It was very uncomfortable for us from the standpoint that the links weren't all there and our brief investigation showed -- and for the few cases we looked at, there was no connection.

MR. PHILLIPS: Specific to the 737 in those areas, did you find any failure analysis or hazard assessment action required by the crew that wasn't either defined in a training program or intuitive?

THE WITNESS: Two members of our team reviewed the failure analysis action item with regard to its incorporation into any documentation, be it an

Ops Manual, Operations Manual, developed by the manufacturer, flight manual, any supplementary information. We didn't look at documents that may be produced by the operator. We only looked at those documents produced by the manufacturer.

So we can't say that potentially that action item was necessarily covered by any one operator but our initial investigation -- I think what it reviewed more was that there was no process to verify whether or not the action was an intuitive response expected as a consequence of training or that there was a procedure written up against it.

And so this, I must say though, is not just a Boeing 737 problem. I think in our discussion with McDonnell-Douglas and what is their process with regard to this, it was very unclear that there was a formal process to deal with this same issue.

So, although our sample is limited in the case of only having looked at the 737 and the DC-g/MD-80 series, I believe this is an internal issue within the FAA as well. And that's why a recommendation looked to Advisory Circular 251309.1A and subsequent revisions to clarify. Action items consequent to a failure analysis need to be dealt with, and any recommendation for how that process should occur.

MR. PHILLIPS: Okay. In the area of design issues, which begins on page 41 of Exhibit 9A, I see eight recommendations and I'd like to spend just a minute with recommendation number 9, which is at the bottom of page 41.

And it reads: "Ensure the capability of the Boeing 737 lateral control system to provide adequate directional control is clearly demonstrated throughout the airplane operating envelope after these failures unless they are shown to be extremely improbable by the most rigorous methodology available."

I'd like to talk about a couple of different elements of that recommendation.

You're asking the SACO, which is the Seattle Aircraft Certification Office, to carry out this recommendation. Is there something in your studies that indicated that the lateral control system could not provide adequate directional control throughout the airplane operating envelope?

That's the first part of that recommendation.

THE WITNESS: Well, first off, as a consequence of review of the failure analyses, we did ask the question of has there been a demonstration with regard to controllability of the airplane as a consequence of any failure that resulted in a fixed rudder position.

And this led us to also looking at the same situation in the simulator. And I believe information provided by the Boeing Company indicated that certainly at some point an operating envelope, including the configuration of the airplane, there may be limited authority from the standpoint of the lateral control system dealing with a full rudder deflection as limited by blow down or as limited by the aerodynamic loads on a rudder.

And I must qualify that in either case, from the standpoint of failures not shown to be extremely improbable, we felt -- well, of course, if you can show -- let's say a probablistic analysis shows that a full rudder deflection is limited by the aerodynamic loads is not -- or is an extremely improbable event, then it would no be necessary to demonstrate. But for those that are not, we feel that it was reasonable to expect that controllability of the airplane be demonstrated.

And what I mean by controllability is that not only can I continue to fly the airplane but I can maneuver the airplane to a successful safe landing. And so we didn't feel that in our review of the failure analyses that this was occurring. And I must say again that having looked at another airplane series, the DC-9/MD-80, there was a similar situation where it was not demonstrated with regard to the controllability and continued safe flight of the airplane was demonstrated apart from a failure analysis says that it's okay.

And that having looked at some conditions, it wasn't necessary to look at all conditions.

MR. PHILLIPS: The last part of the recommendation states: Unless they're shown to be extremely improbable -- which you've just referenced -- find the most rigorous methodology available.

That would be in terms of the 737 the new requirement. You said earlier that the extremely improbable was not consideration for failure for the certification of this airplane.

THE WITNESS: That was not the an original requirement but Boeing has developed the analysis and has presented that information to the Seattle Aircraft Certification Office and they are reviewing that data.

MR. PHILLIPS: So the probability or probablistic analysis of the failures has been done by Boeing and is being reviewed by the FAA at this time?

THE WITNESS: That's correct.

MR. PHILLIPS: And is the requirement for that -- is there a new regulation or something that drives that or is that just a request on the FAA's part?

THE WITNESS: I think it's a response -- a feeling of responsibility to show the FAA that what Boeing had determined was an acceptable situation was indeed acceptable from a probablistic standpoint.

Yes, we did ask for the information, but I feel it was -- Boeing can answer it for themselves.

MR. PHILLIPS: Okay. We will have other people testify about that this week.

When do you expect the review to be done by the FAA and made public or available?

THE WITNESS: There are a number of recommendations to which Boeing has responded to as far as providing the FAA data and we had received that data, I believe, as late as October. I believe it was around the 20th of October. And it is our goal to have a review of that data complete by the 30th of November.

MR. PHILLIPS: The 30th of November of this year?

THE WITNESS: Of this year. Yes. I'm sorry.

MR. PHILLIPS: Will there be some kind of report made on that or is that just an internal review?

THE WITNESS: It's not clear to me exactly how we might formally dispose of the recommendations. Right now my task is to continue to track the disposition of the recommendations and the consequent action by the FAA. In fact, it is identified in the document, I believe in the lead in to section 15, where the CDR team has a responsibility to continue to track.

My hope is that formal closure of the recommendations will occur from the standpoint of any requirements for mandatory action or that the submitted analyses and/or response from the manufacturer is acceptable.

MR. PHILLIPS: Is the team still working together? Is it still assembled or available?

THE WITNESS: It's available. And it's ready to take any action necessary. We, like I said, have this responsibility to continue to monitor the disposition of the recommendations.

MR. PHILLIPS: Is there a process set up to get closure on the recommendations similar to the NTSB system, to say that the recommendation closure was acceptable or unacceptable to the team for the work needed to be done, alternative actions required? Is there a formal process?

THE WITNESS: No. We have not formalized that.

MR. PHILLIPS: Is there any plan to do anything like that?

THE WITNESS: Well, personally I have a concern of maybe a lack of closure and continuing discussion with no real termination. Again, I believe as responsibility indicated in Section 15, we'll continue to press for some resolution to the recommendations.

MR. PHILLIPS: Who ultimately would have the responsibility for seeing that the recommendation effort, follow-up effort was completed or needed more work?

THE WITNESS: That responsibility is the Transport Airplane Directorate Manager, Mr. Ron Wojnar.

MR. PHILLIPS: And his office is in Seattle?

THE WITNESS: That's correct.

MR. PHILLIPS: Just a couple of things in closing. Did this CDR meet your expectations? As the leader, did you feel that you accomplished what you had intended? Did you need more manpower? Just anything generally in your mind that sums up your feelings about the adequacy of this effort?

THE WITNESS: I believe it was a good process. It was good from the standpoint of the inclusion of people outside the FAA for their input and perspective. At the outset, we had said our responsibility was the flight control system, but we eliminated the pitch axis. Our focus was lateral control, directional control and those elements, flight control elements, that affect that control.

And the reason for the elimination of the pitch axis, and I think we've identified that in our report, was it didn't appear to be implicated in the referenced accidents. Although we did become familiar with it, we chose not to spend the amount of effort necessary to review that thoroughly.

We felt although we were not directed to have the report done in a certain amount of time, that there was still an expectation it would be done promptly. And, of course, as you've asked questions in January, "Where is the document?" And I couldn't produce the document. And we committed to having it complete by the end of April.

I feel secure in that judgment still at this time. The resources that we had I believe were adequate. The level of expertise I believe was adequate. You could always do more possibly. In retrospect, I think I would have loved to spend more time on a probablistic analysis as opposed to relegating the consequence review of that to somebody else. I would have liked to have had the team spend more time, having looked at the hazard assessment, the qualitative approach to spend more time looking at the quantitative analysis and to make some determinations relative to that.

As such, with some let's say implicit constraint on how much time was available and also just the availability of these people to string them out for, as it was, more than six months on this activity, we just couldn't do as maybe a complete a task as we'd like.

MR. PHILLIPS: The CDR process, did it lead you to think that the FAA needed to do more CDR's on other airplanes without the benefit of an accident driving it?

THE WITNESS: I think any comprehensive in depth review of an airplane's design, especially let's say an airplane that's been in service for a number of years, the subsequent experience of that aircraft is of value. It not only reveals any deficiencies that we might have in process but also things that may have been overlooked. And the closer you are to a project, possibly the more apt you are to not spend the time and look at some of the details of events, whereas an outside group as say the CDR team was, I believe that process does give you might say a second set of eyes reviewing the same information and possibly identifying issues that have been overlooked and should be considered.

So I believe it's a valuable tool. Obviously in this case I think it has generated much value. Unfortunately, it hasn't identified potentials as far as the accident. Maybe it did. Don't know. But nothing's conclusive. But it did identify things that we can fix internally and areas that have changed within our own regulations, our own interpretation application, that should be fixed. We've learned a lot from the whole exercise.

MR. PHILLIPS: I guess you almost answered my final question but I'll ask it anyway. Did your review find anything that would indicate a probable cause for this accident or a lack of -- from what you've heard in earlier testimony and your reviews of our materials, a lack of direction or understanding in finding the accident cause for either accident, Colorado Springs or Pittsburgh?

THE WITNESS: No. I can't say that we have, unfortunately. I wish I could. One thing we did not have in the event say we did something like this again, to have the benefit of the accident investigation and knowledge gained would maybe help as well. I think the intent of separating that and thinking that that would be a good idea, I think at some point in time would have been well to become thoroughly knowledgeable of what information was gained by the investigative part of the effort so that there would be possibly a new strategy that we could have taken in our analysis that we may have not seen.

And so the benefit of the knowledge could have been worthwhile. We didn't really avail ourselves of that.

MR. PHILLIPS: That's all the questions I have right now unless you have something you'd like to add as a closing comment or something that I may have forgotten to ask that you'd like to answer.

THE WITNESS: The other element I might add is that in our review of the airplane and all failure modes and effects, we didn't see anything that required immediate corrective action.

What I mean by that, and just want to make sure it's understood, immediate corrective action in our minds was the requirements to write an Airworthiness Directive as a telegraphic document and/or immediate adoptive document. It's not to say that consequent to the review by the Aircraft Certification Office that there may not be an AD. I can't say that there won't be. But it's clear to us that there is no need based on our knowledge of failure modes and effects for any immediate corrective action.

MR. PHILLIPS: That's all I have. Thank you very much.

CHAIRMAN HALL: Very well. We'll now move to the parties.

Would any of he parties who would like to question this witness please raise their hand?

I see FAA. I see the Air Line Pilots Association. I see Boeing.

We'll begin at this end of the table with Mr. John Purvis, Boeing Commercial Airplane Group.

MR. PURVIS: Mr. Zielinski, a lot of the work occurred at Boeing during your review process. Is that correct?

THE WITNESS: That's correct.

MR. PURVIS: Did the Boeing people that were involved and the company fully cooperate with your CDR team and make available to the team all of the information and data that you requested?

THE WITNESS: That's correct.

MR. PURVIS: Also, there's an exhibit that was added recently. It's 9X-N, if you have that. It's the Executive Summary. I'm not sure that was listed for his because it was added after the witness list.

THE WITNESS: I have a copy of it.

MR. PURVIS: I think it's near the end. Anyway, it's listed in the corner as Slide 10. I don't think those pages are actually numbered.

CHAIRMAN HALL: No, they aren't.

MR. PURVIS: I have a viewfoil of that, made from that direct page. Could we use this?

THE WITNESS: Would that be Slide 10 in the lower left corner?

MR. PURVIS: Mr. Chairman, would it be allowed to use a viewfoil since --

CHAIRMAN HALL: Yes. There's no problem.

MR. PURVIS: Okay.

CHAIRMAN HALL: You want to put it up, put it up. This is Exhibit Number 9X-N. It's in the docket as SA-510. It's a Critical Design Review Executive Summary and we have up on the viewgraph one of 12 slides that are with this presentation. This is Slide 10.

MR. PURVIS: First of all, my question would be did the CDR team also prepare the Executive Summary?

THE WITNESS: Yes, it did.

MR. PURVIS: On that slide there are some of the points you've talked about. The first one: The 737 meets all certification requirements. And I guess you can read them down, about some that you just talked about.

No design defects were identified that would require immediate corrective action. I think you just hit that one.

And earlier you talked about: No scenarios identified that would explain either of the accidents. I think you touched on that, at least on 427.

Do you agree with those?

THE WITNESS: Yes, I do.

MR. PURVIS: And the last one: 27 recommendations were made. This is a summary of the report to enhance already safe design of the '37 and improve the certification process.

Is that agreed to by the team also?

THE WITNESS: Yes.
MR. PURVIS: I have no further questions.
CHAIRMAN HALL: Verywell. We'll move to the Air Line Pilots Association.
Captain?
MR. LeGROW: Thank you, Mr. Chairman.
I guess it's afternoon. Good afternoon, Mr. Zielinski.
THE WITNESS: Good afternoon.
MR. LeGROW: Just a couple of questions.
First of all, in your testimony, you testified the Boeing 737 and its derivatives were certified in 1967. Is that correct?
THE WITNESS: No, it's not. The 737-100, 2OO, I believe, was 1967. The 300 and on, 400 and 500 airplanes, began certification in '84. Boeing could clarify the specific dates.
MR. LeGROW: But they used the same criteria as the 100?
THE WITNESS: It wasn't identical. From the

standpoint of those changes that were made to the airplane, certainly had to meet the current level. So with the incorporation of the CF-56 engine as opposed to the JTAD. There were certainly structural changes that needed to satisfy the current amendment level at the time.

I believe there were also introduction of certain system changes. Again, it had to meet the current amendment level. But those things that were unaffected by the introduction of the newer model, it was not required that they meet the current amendment level. And I can't recall. There may be -- and I believe Boeing could expand upon that. Boeing may have volunteered to meet higher amendment levels in certain things. It's not clear to me. Maybe Mr. Purvis could review that.

MR. LeGROW: Could you tell us whether the lateral and yaw control capabilities of the airplane had been changed in the 300, 400, 500 series airplanes?

THE WITNESS: Capability?

MR. LeGROW: Were there any changes to the lateral and yaw controls of the two airplanes?

THE WITNESS: The yaw damper did change from the standpoint of its authority. I believe there were three authority levels of the yaw damper on different models. Again, Boeing could be more specific to that issue.

As far as throw authority, hydraulic system potential impact, I don't recall. There was a ground spoiler modification, possibly. I don't remember.

And of course, there were some changes to the leading and trailing edge on the 300 relative to the 100 or 200 airplane.

So there were some changes. We did not see any significant -- anything of significance with regard to authority if you're looking at directional versus lateral.

MR. LeGROW: Are you familiar with the certification criteria of the 777?

THE WITNESS: I was ant involved in that

certification.

MR. LeGROW: If you would, would you please refer to page 17 of Exhibit 9X-A?

CHAIRMAN HALL: Is that exhibit page 17?

MR. LeGROW: Page 17 as marked in the exhibit, Mr. Chairman.

THE WITNESS: This is the Critical Design Review?

MR. LeGROW: Yes, sir.

THE WITNESS: Okay.

MR. LeGROW: I refer you to -- in results, B results, paragraph 2. Could you explain to us exactly what is meant by that last sentence?

THE WITNESS: This was a consequence -- that is, the basis for the statement in this paragraph was a consequence of our exercise in the Boeing engineering simulator. We did look at various conditions, this being one, where you had a rudder hardover for the condition of flaps 190 knots. The pilot response was required to present entering the inverted flight regime at a high altitude and speed.

In our exercise, we realized that if the pilot did not -- and again, this is the rudder hardover full deflection as limited by the aerodynamic loads. If the pilot did not get on the controls and the speed regime, there was much difficulty.

MR. LeGROW: Would you just for my benefit, I guess, define precise pilot control? I'm not sure I understand what is meant by precise pilot control.

THE WITNESS: Where is the word precise pilot control?

MR. LeGROW: It would be the last --

THE WITNESS: Oh, okay.

MR. LeGROW: -- sentence in paragraph 2.

THE WITNESS: The slow and required precise pilot control. Okay. I was the observer -- was an observer of the exercise, not being in a cockpit but outside the cockpit as far as the simulation. We had two FAA pilots that were exercising the test plan and my best recollection as to what they meant by precise pilot control is with regard to the pitch and not utilizing the pitch axis much in the recovery. That is, pulling the stick back too far.

MR. LeGROW: Okay. Thank you.

I'd like to refer to page 21 of the same document, please. In paragraph B, the last sentence, specifically. It starts: Since full rudder hardovers and/or jams are possible.

Could you explain to us exactly what the meaning of that sentence is?

THE WITNESS: Our hazard assessment or I should say our review of the failure analysis provided by the Boeing Company. We looked at failures of the rudder and that is, the rudder is then left at some deflection. In the mind of the two pilots that had -- 1 should say one was a full-time member. One pilot was a full-time member. The second one was only utilized with regard to the simulation exercise.

But the pilots felt that it's possible. We didn't examine the probability at this time and that's

-- I think earlier, I would have liked to have spent more time in reviewing failure analysis and probabilities. But at that time, the pilots on the team felt that there is a possibility in their judgment that there could be a rudder hardover. And therefore, the remainder of the sentence, alternate means for control, et cetera.

MR. LeGROW: When Mr. Phillips was questioning, you referred to probabilities. And I think you used the word extremely improbable as you referred to failure analysis. Is that correct?

THE WITNESS: Yes.

MR. LeGROW: Was I correct in understanding that a billion hours was what you used to describe extremely improbable?

THE WITNESS: The Advisory Circular 251309.1A speaks to the extremely improbable event as one times 10 to the 9th negative. So that you're looking at the potential of one in a billion flight hours, for example, of something occurring. And our recommendation with regard to the demonstration of the jams, failures, et cetera, not shown to be extremely improbable is along the lines of -- and considering that if it is extremely improbable or if it's not likely to occur in one in a billion, considering where the fleet is today, that it's not an issue.

But for those failures where at some deflection it may be less than 10 to the 9th, that's something that ought to be considered and looked at from a demonstration standpoint.

MR. LeGROW: You wouldn't consider two failures in five years 10 to the minus 9th then?

THE WITNESS: No.

MR. LeGROW: Thank you.

Also, one last question. During your simulator tests at Boeing, when were those tests conducted? Do you recall approximately?

THE WITNESS: Well, we initiated our exercise in October of '94. I believe it was prior to Christmas that we had the exercise in the simulator. The document may have a date in it.

MR. LeGROW: So the data used for this document, for the CDR, used the data from Boeing subsequent to the tests that were conducted this past Fall at Boeing and at Atlantic City?

THE WITNESS: Right. Their model, their aerodynamic model as it existed at that time. Certainly didn't have the benefit of the recent information.

MR. LeGROW: So the data that the CDR team collected was using the model prior to this Fall, the test this fall at Boeing?

THE WITNESS: That's correct.

MR. LeGROW: Thank you, Mr. Chairman. I have no further questions.

CHAIRMAN HALL: Thank you, Captain.

Mr. Donner, with the Federal Aviation Administration.

MR. DONNER: Thank you, Mr. Chairman.

Just two questions, Mr. Zielinski.

You talked about service difficult reports sometimes not containing a great deal of information. Do they contain enough information that should the engineer want to contact the operator for more data he would be able to do so?

THE WITNESS: I think by all means, if there's any indication of concern. And the lack of clarity in the SDR, it's a responsibility of the engineer to find out more. If there's any doubt or suspicion that there's a safety issue, it certainly turns on a process that begins to investigate it further.

And yes, there should be an effort, without a doubt, to obtain more information.

MR. DONNER: Okay. And one more question. Concerning the NTSB representative on your team, was he considered as full a time player as any of the other representatives?

THE WITNESS: Yes.

MR. DONNER: Back at the beginning of your testimony you asked for a date on Advisory Circular 251309.1A. The current date that I have on yours is 6/21/88.

Thank you, sir.

CHAIRMAN HALL: Thank you.

We will move back. The Chairman forgot to call on the Technical Panel to see if there were other questions. And I understand Mr. Haueter has a couple before we move to the front table.

MR. HAUETER: Thank you, sir.

Just a couple of clarifications. When the 300 series was certified, was a probability assessment done of the lateral or directional control systems?

THE WITNESS: There was -- I don't recall there being a review of that system.

MR. HAUETER: Well, of either systems, lateral or directional.

THE WITNESS: Let's see. There was a change to the hydraulic system as far as A and B and the pumps, engine driven pumps and electrical pumps. I don't recall that that had any impact on the analysis. I guess I'd have to ask Boeing if that recollection's correct.

MR. HAUETER: The CDR team did not conduct any flight tests as part of your evaluation of your effort?

THE WITNESS: We were not involved in or conducted any kind of flight test of an airplane.

MR. HAUETER: On Recommendation Number 9 from your team on page 41 of the report, I'm curious of the wording. "Unless found to be extremely improbable by the most rigorous methodology available."

What kind of methodologies would those be? What's involved in that type of a --

THE WITNESS: This was an interesting one. We felt very concerned about this issue of directional control versus lateral control. And to us, it was not sufficient to do things how we'd done it in the past. And we felt that -- and that's why this rigorous methodology available and the note following that made reference to a methodology that was used as it applies to the thrust reversers and concerns that we had with regards to failure assessments of thrust reversers. And we felt that was a good example of the approach that ought to be taken.

The critical of the situation certainly required a rigorous approach. And in light of let's say the recent development of a very involved, complex, comprehensive analysis like the thrust reverser should be the approach taken by the manufacturer as well as the ACO.

So, I think what it's expressing is a level of concern. We want to make sure that when somebody says this is extremely improbable, the basis for that is done with much rigor and support and it's not just an engineering judgment that it's okay.

So, enough said.

MR. HAUETER: To follow-up, would you consider the current certification regulations for a brand new design would follow a similar most rigorous methodology available?

THE WITNESS: Well, my hope is that it would. I think the experience of what we've been through -- and it's been a lot with regard to the '37 and trying to identify cause -- that we feel we must be more thorough in our approach to failure analysis, and particularly as it affects the flight control of the airplane.

MR. HAUETER: One last question. Based on some of the new findings, like from the flight tests that have been mentioned and things like that, is there any consideration to having the team get back together and reevaluate your findings and plans?

THE WITNESS: Not at this time. I think those findings are -- there's still some maturation required of that and I believe it will be up to our management as to the incorporation of these findings and the need to go back and review what we've done, does this have any impact, et cetera.

I believe it certainly behooves us to assure ourselves that any new data doesn't cause any more concern. At least to that extent we should do that. That's my personal opinion.

MR. HAUETER: Thank you, sir.

CHAIRMAN HALL: Very well. We'll move up to the front table.

Mr. Clark?

MR. CLARK: The 737-300 was certified in 1984 or the basis was establish. Specifically in the area of the rudder package, did any of that certification basis change at that time?

THE WITNESS: I believe the only modification was in rudder trim. It went from mechanical to electrical. I believe that was the only significant change in the rudder.

MR. CLARK: Did the FMEA change at that time for that particular area?

THE WITNESS: No.

MR. CLARK: No new testing was required of the rudder package either?

THE WITNESS: Not as I recall. I think we need to make sure we're clear on terms. The failures modes and effects analysis to some people means something and a hazard assessment also means something. They portray different approach, or I should say one is more qualitative and the other is quantitative. The hazard assessment that we had looked at, the qualitative hazard assessment would not change with the introduction of the 300.

MR. CLARK: When you were at Boeing, were you involved in the certification effort in the rudder system?

THE WITNESS: When I was at Boeing?

MR. CLARK: Yes.

THE WITNESS: I was involved with -- I guess going back quite a few years. What did I do? Okay. I remember. It was in '66, I believe. I was involved with the determination of landing performance and stall speeds. That's right. Stall speeds on the 737-100-200 airplane. I did not get involved in flight control apart from stall characteristics.

MR. CLARK: In your review during the CDR, did you address any of the issues of using a single rudder or a single rudder package and how that played out in the certification effort?

THE WITNESS: Single rudder package? Are you meaning -- what do you mean? The power control unit or the cables?

MR. CLARK: The rudder PCU.

THE WITNESS: We identified some concerns with regard to design function. We identified some potentials for latent failures and those are qualified in the single failure tables in the document. But from a design concept, we thought it was a very simple, uncomplicated approach to directional control.

MR. CLARK: Did you have any discussions about the dual concentric servo valve or whether that provided a redundant feature and how that affected or was brought into play in the certification process?

THE WITNESS: Oh, we had heaps and gobs of discussion about the dual servo valve. First off, understanding how it works, trying to get that under our belt. And then the potentials for any kind of jam or failure mode that could subsequently with the next failure result in an uncommitted rudder.

We, as I say, identified the possibilities in our document. I believe Boeing in their subsequent analysis on the rudder certainly addresses that as far as the probabilities of occurrence, et cetera. That data has been delivered to the Seattle Aircraft Certification Office to review and establish whether or not it's applicable and that the probabilities that they used are appropriate.

But I must say we did spend a fair amount of time trying to understand its function and potential for failure.

MR. CLARK: Did the group draw any conclusions about using a dual valve as a redundant feature in a system or would that be considered a single point failure?

THE WITNESS: No. We did not consider the dual spool valve as a design issue from an approach being taken. We thought the concept -- we had no problem with the concept. It was more of what kind of failure modes might exist. But we felt that the redundancy of the valve from a design standpoint, along with the standby rudder was an acceptable approach.

MR. CLARK: You say it was?

THE WITNESS: Was. Is.

MR. CLARK: Did you attempt to review any of the prior history, the basis or the thought process that was going on in 1965 when this system was being certified?

THE WITNESS: Oh, well, that was a little more difficult. I think Boeing was even hard pressed to tell us some of the history of why did you take this approach. I believe maybe we have a better understanding today after having asked the question a number of times. But we didn't challenge the approach taken by Boeing as far as the design is concerned.

MR. CLARK: I believe you, within the simulator effort, looked at flaps 1 configuration, 190 knots, as related to rudder hardovers. Did you look at any other speeds or configurations in that regard?

THE WITNESS: Yes, we did. We looked at approach configurations. We looked at the higher speed, higher altitude conditions. There's a test plan in the document in one of the appendices that fully outlines it. I think it was over 50-some odd conditions that we looked at. We wanted to make sure we covered the event condition but we wanted to make sure at the same time that there were no anomalies in any other part of the flight envelope.

We feel we'vemade a fairly legitimate review of the envelope with regard to flight control.

MR. CLARK: Okay. Thank you.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: Yes. I just have a few questions.

I understand that the review was done on the standby rudder components also and that you had made a recommendation dealing with galling that occurs in the bearing?

THE WITNESS: That's correct.

MR. MARX: And I believe that's Recommendation 14.

CHAIRMAN HALL: That's on page -- Recommendation 15? On page 43 and page 44 of the exhibit.

MR. MARX: Yes. That's page 15, Exhibit Number 9X-A, isn't it?

What is your understanding of the --

CHAIRMAN HALL: Mr. Marx, you might tell us what galling is before you lead off into this.

MR. MARX: It's movement between two parts that produces wear and friction and causes a material transfer between components.

I just wanted to get some understanding of what it is that -- how this galling affects the main PCU or the yaw damper and uncommanded movements. Do you understand how that -- how this galling could do that?

THE WITNESS: Well, if you approach galling from the standpoint that there's a potential for grounding of the input, that could impact the control of the rudder. I think more of a concern here for us was that it's an alternate means, in the event of a loss of a hydraulic system, that the alternate means is preserved. Alternate means being in this case a standby rudder along with the remaining hydraulic system. Standby rudder PCU, that is.

So I think our concern was more from the standpoint that if it's an alternate means, contributes to flight control of the system, it ought to work. If there's a problem with it, it ought to be fixed. As opposed to that this has a potential for being grounded; therefore, could have some ultimate impact on uncommanded rudder movement.

MR. MARX: So it's only as if it's used as a standby unit?

THE WITNESS: Right. And one of our

recommendations, I think, is to exercise the standby system, which apparently is not the case except at certain intervals.

MR. MARX: Was consideration given to the fact that the galling could occur and affect the main PCU and cause uncommanded movements into the main PCU?

THE WITNESS: Well, if the galling results in essential grounding of the input to the standby and you have a yaw damper input, there's the potential, I believe from the failure analysis, to possibly get more than three degrees of yaw damper authority. But it's not much more. Boeing can correct me on this, as regards to their failure analysis, but from it being in itself an unsafe condition, I don't believe we've taken that position with regard to this other than it's an alternate means. And therefore, the alternate means, if there's a problem, ought to be corrected.

This, I believe, is identified in our document from the standpoint of if there's no alternate means for flight control, there should be a concerted effort to make sure that it works and that the resulting utilization of that control is acceptable.

MR. MARX: Thank you.

If we had galling that causes a -- I don't know what word you've particularly used in this instance. A freezing of the components. That would be a single failure? That would be something that we could observe?

THE WITNESS: Right. I think this would be something that Werner Koch, Mr. Koch, could further expand upon as far as issues or concerns about the galling of the standby.

MR. MARX: Okay. I guess I've got to ask somebody else that question.

Well, would you consider a freezing of the standby rudder, followed by a freeing of it as a latent failure or a primary failure or single failure?

THE WITNESS: It freezes, then it unfreezes?

MR. MARX: Yes.

THE WITNESS: I think the duration for which that would be undetected is fairly short because there would be -- again, either Boeing or Mr. Koch could further expand upon that. As far as the impact on flight crew making an input, certainly the yaw damper could continue to function but as far as flight crew trying to make an input, they would certainly be impacted by grounding of the standby rudder.

MR. MARX: Well, would you consider galling to be a design defect?

THE WITNESS: If it occurs. What would be the other cause? Is it design related? Is it not design related?

MR. MARX: I noticed that you indicated there was no design defects that you could find that would have anything -- 1 don't remember what the specific words that you used.

THE WITNESS: Well, let's clarify that. I think it's immediate corrective action. What that means is that the defect that we see is a safety issue that must be corrected now. And the way to do that is to write an airworthiness directive that says if we found that galling was indeed a safety issue that could cause -- would prohibit continued safe flight and landing, that an AD would come out the door immediately. But we do not see that in this category.

MR. MARX: I just have one final question and it has to do with -- do you know what the FAA has done in regards to this particular recommendation or should I ask somebody else?

THE WITNESS: Well, we asked Boeing to fix it.

MR. MARX: I mean, has there been anything done so far? Has Boeing come back with a design to change it? Has the FAA implemented --

THE WITNESS: I believe --

MR. MARX: This is dealing with Recommendation 15.

THE WITNESS: Uh-huh. See, Boeing provided a response, I believe mid-October. Said that no mandatory action is required. But I believe they are initiating an effort to correct the problem.

MR. MARX: I have no further questions.

CHAIRMAN HALL: I just want to try and understand one point. Did you say that galling per se is a design defect?

THE WITNESS: I don't know what other mechanism might cause it to occur. If it's not design related, I don't know what other mechanism there is to cause it to occur.

CHAIRMAN HALL: I ask again. You're saying that it doesn't require immediate corrective action then. It's a design defect that you identified that does not require immediate corrective action?

THE WITNESS: That's correct.

CHAIRMAN HALL: Okay.

Mr. Schleede?

MR. SCHLEEDE: Yes, sir.

Mr. Phillips asked you questions, several questions, regarding the 1960's failure analysis that was used as a basis for the certification of the airplane and I want to follow up on one of the questions he asked.

He asked you about did you find, for any action items that required flight crew actions to resolve, were the procedures in place for such flight crew actions. And your answer was -- I don't think -- 1 never got a yes or no when you answered.

THE WITNESS: Well, okay. Yes. We found that there were no follow-up in some cases, but we did not look at every failure analysis for the directional and lateral system. But it was enough indication to us that besides asking the question, you know, is there a process to deal with this, for us to make a recommendation that there should be.

So, yes, we did find some cases where the action item did not get any follow-up, but it was not comprehensive in looking at all failure analyses.

MR. SCHLEEDE: Well, in one particular that i recall from it that was for a jam situation or a failure mode in the rudder system that would -- one of

the resolutions was for the flight crew to turn the A &
B system off. Are you aware of that particular action
item?

THE WITNESS: Well, there's a number of failures that it was suggested that the flight crew could take that action. But whether or not that procedure -- 1 can't speak to whether that action item was indeed incorporated into any procedure or crew training.

MR. SCHLEEDE: You can't recall or did your team determine whether it was or --

THE WITNESS: Yes. As with a lot of teams, you know, one person doesn't do everything and we have a pilot. We had a systems specialist. We had people specializing in continue airworthiness from the ops and maintenance side. And so the way we structured our approach to this is that we divvied up the workload.

In my hesitation, you might detect -- does this guy know what he's talking about. But my recollection of the team member that had the responsibility to review the action items was that -- and those action items that we did review, there was no connect between the failure analysis and the documentation that says it's intuitive or it's incorporated into an operations manual or a flight manual.

And that was enough evidence for us to make the recommendation there must be a process that properly disposes of these action items.

MR. SCHLEEDE: Okay. And I remember you discussing the process itself, but help me understand if in fact the original basis, failure analysis that was used in the certification, had an action item that was to be resolved by a flew crew action and there was no procedure or no training for that. Did your CDR team make an assessment as to what to do with that kind of an item?

THE WITNESS: No, we did not. We identified the issue. We told -- in our documentation. We asked Flight Standards to review flight crew training requirements in consideration of the failure analysis and action items. And we asked that the Transport Directorate consider the incorporation of 251309 a requirement to develop a process.

So from the standpoint of -- okay, what did we do with the 737, it was to task the Flight Standards organization to look at these action items and look at training programs to see if the action items is warranted as far as its incorporation into any kind of training syllabus.

CHAIRMAN HALL: And your team did not consider this was something that required immediate corrective action?

THE WITNESS: No, it did not, other than the recommendations that we made in the documentation.

MR. SCHLEEDE: So, I'm still trying to understand it here. The airplane was certified. Several things were used to certify the airplane. And part of the basis for that certification is the failure analysis. Is that correct?

THE WITNESS: That's correct.

MR. SCHLEEDE: So if there's an item in there, whether it's probable or improbable or whatever that says jam in a dual servo valve or in the hydraulic system that causes a hardover and the resolution of that is flight crew turn off the hydraulic system, and there's no procedure in the flight crew manual or training on that, does that meet the certification basis?

THE WITNESS: No assessment was made that the flight crew wouldn't do that. And we identified the issue to the Aircraft Evaluation Group who's got the responsibility for crew training. We've identified the issue to the Aircraft Certification Office with regard to the issue and we left them with the responsibility to review those action items.

The fact that the crew does or doesn't take that action, I think is one that involves a number of elements, operations and engineering to assess. First off, there's a lot of responses from flight crew relative to failures. That is not a training issue. And somebody has to make a judgment that the crew will or will not do this particular action, in this particular environment for this particular configuration, flight, et cetera. And having made that judgment then and asserting that it's not an intuitive response then, and if it's important to accepting the analysis, if the flight crew does not accomplish this action, does this result in a -- is there a safety of flight issue.

So, we could not make -- there was nothing in place to make that analysis. And so we said somebody's got to do this. That's why there are like three recommendations in our document that says this is something that's fallen through the crack. Let's be honest about it and deal with it properly. And we did not ourselves go through that process of creating something that could then make the judgment as to whether or not the flight crew will or will not respond in the particular way that Boeing assumed or presumed in their failure analysis.

MR. SCHLEEDE: Okay. Thank you. Just one more area of follow-up. When you mentioned the recommendations, I know Mr. Phillips asked you some questions on that and it wasn't clear. Who is the one person or organization responsible for the close-out of these recommendations?

THE WITNESS: Well, it got initiated by the Transport Airplane Directorate and it will get closed by the Transport Airplane Directorate.

MR. SCHLEEDE: And I know you mentioned some of them. Are there any of them closed?

THE WITNESS: I believe there is -- there's been a response and the development of an issue paper relative to what normally encountered means. We've identified what criteria believe are appropriate. I believe Boeing has modified the maintenance and inspection procedures with regard to rudder cables and we believe that's appropriate.

Those are the only two I see closure at this time.

MR. SCHLEEDE: Did you testify that you are individually or your team is consulted on these as they're closed? Is there a formal process for your team or yourself to review these and the closure?

THE WITNESS: There's been a lull in the team activity from the standpoint of getting the ball rolling, so to speak, from the office responsible. In this case, the Seattle Aircraft Certification Office requesting information from the Boeing Company and that being returned. It has now been returned.

And yes, we will be involved. In fact, I know that some of the team members have been contacted already with regard to response from the Boeing Company. So, yes, we are involved in that process of assessing that response and what we're going to do about it.

MR. SCHLEEDE: Thank you very much, sir.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Mr. Zielinski, just a couple.

I'd like to get clarification on a couple of issues.

First of all, the original FMEA, I understand an original FMEA was provided by Boeing as part of the certification process in 1967. Is that correct?

THE WITNESS: As part of the certification of the airplane, Boeing provided a failure analysis, qualitative failure analysis with regard to single failures and this was done prior to certification. I don't know exactly when, but certainly it wasn't before the airplane was certified.

MR. LAYNOR: And I was asked to clarify FMEA, failure mode and effect analysis.

Presumably, your team reviewed that analysis that was provided at that time. Did your team find any failure modes that were not considered in its review?

THE WITNESS: I can't recall. Were there any doubts? What we did -- I'll tell you what we did do.

We looked at every failure analysis documented by the Boeing Company in support of the certification of the airplane. I don't recall any failure mode where we identified the lack of any analysis, other than the need for a probability assessment of the rudder as opposed to a qualitative assessment.

MR. LAYNOR: All right. My next question was were there any probability studies provided along with the original certification failure analysis?

THE WITNESS: A probablistic assessment at the time?

MR. LAYNOR: A probability assessment.

THE WITNESS: Not that I'm aware of. The documentation that we looked at was a qualitative failure analysis in support of the certification program. There may have been, but at least in support of the 1967 certification of the airplane, I don't recall seeing any probablistic assessment. Certainly there was, as the airplane was modified and the introduction of later models, 300-400-500 airplane, that the changes in some cases were assessed from a probability standpoint.

MR. LAYNOR: I'm trying to get clear in my own mind whether the original certification in 1967 was based on improbability of failure or control of the airplane by alternate means in the event of a failure.

THE WITNESS: The development of a probablistic assessment is a consequence of engineering judgment. It's a logical approach to determining the hazard associated with failure, single and multiple failures. I believe -- 1 personally believe that engineering judgment -- in essence, when you say I've looked at this failure, I've looked at this failure in combination with other failures, and it's my belief that the probability of this without numbers is improbable, whatever that means.

And we've lived that way for a long time in the construction and development of airplanes. It was a lot based on what engineering judgment resulted in. Consequently, we've learned a lot of things. Our database has grown with regard to transport category airplanes. And we now can approach it more rigorously from the standpoint of probability of failure. But that's not to discount the use of engineering judgment.

You have to look at it this way. I can discount a probablistic analysis based on my engineering judgment, but I also can discount my engineering judgment based on an probablistic analysis.

I use both tools. I use them both. I use the analytical techniques in conjunction with my knowledge of the failure modes and effects, my knowledge of other comparable systems of similar design, my knowledge of service experience of other aircraft.

So it's not an end-allthat extremely improbable means this. I made the calculation; therefore, it's acceptable. That's not enough necessarily. I still may require the failure to exist -- to occur, and look at the consequence response.

We have some considerations for certain mechanisms that although they're shown to be extremely improbable, we still would like the failure to occur and look at the consequent result.

So we're not always driven solely by the probablistic assessment but use it as a tool to make a judgment as to is there a safety condition or safety concern.

MR. LAYNOR: That still leaves me a little bit wondering about my original question. Was the certification -- the acceptance of the certification of the aircraft based on the assessment of the certification authorities that the failures were improbable or was it based on the assessment by certification authorities that the airplane could be controlled by alternative means in the event of a problem area, or do you know?

THE WITNESS: Okay. Let me try again.

MR. LAYNOR: Well, --

THE WITNESS: It's both. Okay?

MR. LAYNOR: Okay.

THE WITNESS: An analysis was made, a qualitative assessment made. There may or may not have been an alternate means of flying the airplane. But because of the remote nature or the improbable occurrence of this failure coupled with that in the judgment of the people that have the responsibility for making the judgment, said it was okay. In some cases, there is no alternative. In other cases, there are.

Each failure, ach failure in combination with another failure is a separate assessment. You judge them individually. And there's real danger in making a -- we're going to do it this way and ignore other opportunities for assessment.

Does that help? I'm sorry if I'm not getting to the --

MR. LAYNOR: A little bit.

THE WITNESS: Maybe there's somebody else who could answer that.

MR. LAYNOR: Well, let me ask it another way to try to clarify it in my own mind. Was is a fully deflected uncommanded movement of any of the flight control surfaces considered as a failure that was not improbable during the point of certification?

THE WITNESS: Not improbable.

MR. LAYNOR: Maybe we can pursue that with a later witness.

THE WITNESS: In our discussion of the failure analysis in the rudder, there were many failure considerations, most of which the failure resulted in not a fully deflected rudder. I believe there were one or two occasions -- and Mr. Kullberg could talk to that with regard to consideration for a rudder being fully deflected.

The consequence of that in that original failure analysis was that the lateral control system is sufficient to deal with that deflection. So in that case it was not -- I'd have to go back to Dick and you'll have to answer that, Dick, but I can't recall the qualification of whether or not that particular case was an improbable consideration. But I do recall the reference to the lateral control system as being adequate to deal with the issue.

MR. LAYNOR: If the Boeing 737-300 had been certificated to a new type certificate in 1984, would the requirements for the flight control systems have been different than having been grandfathered back to the '65 type certificate?

THE WITNESS: I believe we'd see some significant differences. Yes.

MR. LAYNOR: Could you describe any off hand? What considerations would be given to a new type certificate?

THE WITNESS: Not being a designer and my own opinion, there probably would be an attempt to maybe design a system like they did in the 57-67, I would suspect, because that's about the same time period that those airplanes came into existence and I believe the concepts, the conceptual approach applied to the 57-67 in consideration of the current regulatory amendment level, would have dictated a different design. I would think it would be not a whole lot different than 57-67.

MR. LAYNOR: But you can't be specific --

THE WITNESS: What those differences are?

MR. LAYNOR: -- regarding what considerations would be given today to that design? And again, we might be able to pursue that with a later witness.

THE WITNESS: No, I can't. I'm sorry. I can't.

MR. LAYNOR: In considering recovery by alternative flight controls, I think one of your recommendations is need for a better definition for what kind of pilot response would be considered. Am I interpreting that correctly? Do you feel like there's a -- your team felt like there had to be a better definition for a pilot response that would be acceptable response to a flight control system failure?

THE WITNESS: I wonder if you could be a little more specific. There's a couple of things we've said about pilot response in various recommendations but it's more implicit than it is explicit.

MR. LAYNOR: I don't have the recommendation number right at hand but I thought that one of the recommendations that I saw in here was the need to -- number 2? Is this recommendation 2 that you're talking about?

THE WITNESS: Yes. A better definition.

CHAIRMAN HALL: That's Recommendation 2 on page 39 of the exhibit.

THE WITNESS: Okay. This recommendation must be taken in context with Recommendation Number 1, alternate means of flying the airplane. I believe the driver in this particular case was the lateral control system.

Any event that there is a jam of aileron in consideration of what's normal, normally encountered -- here we go again, you know, what's normally encountered -- that when utilizing the alternate means, in this case it would be continue to control the airplane laterally through the aileron transfer mechanism.

And depending upon the degree, that is, how much of a jam there is, therefore, how much aileron has been deflected, would dictate how much control force requirement is on a pilot that is now using the aileron transfer mechanism.

In this case we, in our simulator exercise, did look at a number of scenarios where the jam occurred half full wheel and therefore the need to fly the airplane through this mechanism. And the force required was high. And we wanted to make sure that all the folks, that is, the certification people, were aware that these mechanisms, these alternate devices as a general category, as opposed to specifically the transfer mechanism in the case of the 737, that when using an alternate means for flying the airplane it shall not require exceptional pilot skill and strength.

And we believe -- did make some reference to FAR Part 25.143 as far as the temporary and prolonged forces as a measure of what might be considered something beyond what a normal pilot might be expected to provide.

MR. LAYNOR: So there are response times and how much of an unusual attitude that could develop before response is taken. That's all taken into consideration there?

THE WITNESS: Well, in this particular recommendations, the response time wasn't so much an issue as much as it was pilot strength and skill. The response time, I think, is later on in Recommendation 19. That's on page 45, where we are recommending that in this particular case, the 37 flight crew training program ensure the use of proper procedures for recovery from flight path upsets and flight crew awareness regarding loss of airplane performance due to flight control system malfunctions.

What's behind that is the proper procedure is a time issue. Recognition is an issue of the failure event proper responses and this awareness of loss of airplane performance. What's behind that is in our exercise in the simulator, we looked at spoiler stuck up and a failure mode where that might occur and the consequent loss of airplane performance was rather dramatic. And I think what we're seeing here is that

that realization of that loss of performance is of significance. And if that were to occur, the flight crew should be aware of the high sink rates that may be associated with it.

Does that help?

MR. LAYNOR: Yes, sir. Thank you. And in considering such response or standards for certification based on pilot response, do you believe that operation on the autopilot at the initial event should be considered?

THE WITNESS: The operation of the autopilot as a --

MR. LAYNOR: As it might mask an initial recognition of an event?

THE WITNESS: Well, it's certainly a consideration, without a doubt.

MR. LAYNOR: Let me ask one last question, and it happens to be the next recommendation, Recommendation 20 on page 46. You don't have to refer to it but it discusses the overhaul of flight control components by persons other than the PMA and original part certificate holder.

Can you briefly summarize what the team's findings and concerns were regarding replacement of flight control system components by people other than the original manufacturer?

THE WITNESS: Okay. Let's take 20 and 21 together. I'll speak to both of them.

There are elements within the flight control system that we've let say put into the category of primary. That is, if these elements were not properly maintained, repaired and returned to service, we'd have some real concerns. What's going on here is that we certainly do allow a construction of parts, that is, PMA can produce parts for replacement into flight control systems but there's also an opportunity for others to possibly create these parts as part of their SFAR 36 authority in the repair of, in this case, say a primary control unit or part control unit.

Our concern was that if it's other than the

PMA that is providing a replacement part, we must ensure ourselves that the replacement part is indeed equivalent and we've identified that there is an opportunity for that equivalence to not necessarily occur.

That doesn't mean that it's an unsafe condition but we felt, considering the critical nature of some of these parts, that we need to be better assured that when that part is constructed and installed, that there's no compromise as to the performance function and safety of that particular element in the flight control system.

We are taking steps to make sure that when something like that is done, that is, a repair of a primary element in a flight control system is conducted, that the construction of that repair element is done with the assurance that it's design performance is equivalent to what was originally certified.

And to make sure that happens, it's our effort to require that an Aircraft Certification Office that is monitoring an SFAR 36 operation, that when they repair primary control elements, flight control elements, that the design fabrication of the repair part or the part that's to be installed as part of the repair meets the same standards as was expected for the original certification.

For that to occur, let's say for example Los Angeles is monitoring or is providing surveillance supervision of an SFAR 36 approval, that that office will coordinate with say the Seattle Aircraft Certification Office to assure itself that it has the latest information with regard to design, any associated tooling, any acceptance test procedures, so that we are assured that the consequent function of the repaired part is equivalent to the original certification.

That's a lot. It's a lot of words, I know. Maybe it's babble to a lot of people. But the point is that there's stuff out there that we want to make doubly sure that we have not compromised the safety of design.

MR. LAYNOR: Okay. Thank you very much.

CHAIRMAN HALL: Mr. Zielinski, you have been up here a good amount of time and I am the last person that will ask you questions. But let me say at the beginning I appreciate very much the time you've taken in responding to the questions of the Board of Inquiry.

And let me thank you for the work of the Critical Design Review Team. Obviously, that's I think important work and important recommendations. And I'm sure, given your background and qualifications, you're to be complimented for being selected to head that team.

I would like to just get into some sort of basic matters. Who or what initiated this team being formed?

THE WITNESS: I think fundamentally it's the frustration of not being able to find cause with the Pittsburgh accident.

CHAIRMAN HALL: I guess -- was it the

Administrator or was it someone else in the organization that said we need to form this team, go form it?

THE WITNESS: The original suggestion came out of the Manager of the Seattle Aircraft Certification Office.

CHAIRMAN HALL: Very good. And the team was organized and you were selected, nine individuals, and given a charter. And I believe you said earlier that you all had not become familiar with the accidents and one of the things that you, if you had to do the process over, and we all -- hindsight is always 20/20, that you would have wanted to become more familiar with the accidents.

And that just kind of left a question in my mind because it seemed to me that if this was really initiated because of these two accidents, why you all weren't more focused on those accidents.

THE WITNESS: Okay. Let me put it in perspective. The reason for the separation was so that if you eliminated certain elements, that would follow suit. If the accident investigation said this is not a consideration, don't bother with it, so therefore, why continue to do the CDR in this area. But that wasn't our charter. There still might be deficiencies. They may not be causal to the accident but they still would be deficiencies relative to the flight control system design.

So we wanted to at least start that process where we were not part of the accident investigation. We were looking at the design of the airplane independent of that. But at some point in time, I think now that we've completed the majority of our work, now look at what has been gained out of the accident investigation to find out if there's another strategy or other approaches that should be taken.

So it was to prevent a premature elimination of areas of investigation on our part that we kept the two activities separate.

CHAIRMAN HALL: Now, whose decision was that?

Was that the team's decision or was that the direction that you received?

THE WITNESS: That's the direction that we undertook the project.

CHAIRMAN HALL: Very well. Now, on page 38 of this Exhibit 9X-A, it says, as a result of having conducted the Boeing -- and let me ask first to lay the groundwork for this. What date did you all complete and this document was submitted?

THE WITNESS: I'm sorry?

CHAIRMAN HALL: What date did you complete your report and it was published? Was it April?

THE WITNESS: This document was completed May 3rd, '95.

CHAIRMAN HALL: May 3rd?

THE WITNESS: That's correct.

CHAIRMAN HALL: And it says here, "As a result of having conducted the Boeing 737 flight control system critical design review, the team believes there are a number of action items that should be addressed by the Seattle Aircraft Certification Office, the Transport Airplane Directorate Standards staff, the Aircraft Engineering Division or Flight Standards Service, as may be appropriate to any particular or all models of the Boeing 737."

And I think you then came up with &a-- some 27 recommendations, as you say, that are made to enhance an already safe design of the Boeing 737 and improve the certification process.

Now, this material has been in the hands of those offices since May. When will we get a report from them on the action they're going to take in regard to your recommendations and who's the individual in the FAA, if you do not know, that we could address that question to?

THE WITNESS: I believe the end responsible person is the Transport Airplane Directorate Manager, Mr. Ron Wojnar. The --

CHAIRMAN HALL: But some of these organizations are not under his control.

THE WITNESS: No. But at the same time, all these issues emanated from his request, as far as the charter of the organization and responsibility. Although recommendations may have been an action item for Flight Standards, they are still aware of the responsibility to respond to Mr. Wojnar.

CHAIRMAN HALL: Well, do you expect as the head of this team to get a written response to your report or what type of response are you expecting to get in regard to the recommendations that this team has made?

THE WITNESS: My expectation is not for a report to me. My expectation is that the Aircraft Certification Office, as managed by Don Rig-gin, will respond to Mr. Wojnar as far as the disposition of the recommendations.

CHAIRMAN HALL: Well, Mr. Haueter, let's see if we can't get hold of this gentleman while this hearing is going on and see if he can tell us when there will be a response to these recommendations.

MR. HAUETER: Okay.

CHAIRMAN HALL: Or, if Mr. McSweeny, who is testifying later, can give us that information.

First of all, I applaud your work. This investigation has consumed thousands of taxpayer dollars and thousands of dollars that are being contributed by the parties in this investigation. And if work is found, I think the public needs to know when the work -- you know, if these recommendations have been made, when we're going to see a report on the recommendations.

Just a couple of other things. You also said that you all didn't look at the operational history in regard to what the pilots I guess do. And yet in your charter, it states here that you're supposed to, in developing the analysis, the team should assume the worst case reaction of the crew to any malfunction.

Can you in layman's terms tell me what that means and how you were able to determine what was the worst case reaction?

THE WITNESS: Worst case reaction is a judgment from the standpoint of delaying the response to an upset condition or in the event of, for example, a feel spring as part of the feel system in the rudder. We identified the potential for a spring being a latent failure. Now, that's arguable, in some cases, that the pilot could detect spring failure, which would mean that there's reduced force requirement on the rudder pedals. But in some cases it would not be.

So we felt the worst case is that it would not be. And therefore, qualified the spring failure as a latent failure. And I must say that we were not specific as far as degree of delay or how much of a delay was taken in response to failure. What I'm referring to are the exercises we conducted in the simulator. Flight crew response to -- that is, the two pilots, FAA pilots that we had and how they reacted to a failure being introduced.

In the worst case, they looked -- approached -- they, the two pilots, approached the failure differently and it was the conservative approach that we based our recommendations on.

Does that help?

CHAIRMAN HALL: I think that helps. It was just curious to me that you wouldn't have looked at the flight manual -- I mean, the pilot's manual for say United and for USAir since those were the two accidents that really initiated this special review in terms of seeing what the pilots were trained to do.

THE WITNESS: You mean a possible wrongful response relative to their training?

CHAIRMAN HALL: I'm sorry?

THE WITNESS: I guess I'm still trying to get a clarification. Are you talking about a wrongful response or -- a worst case response is not a wrongful response.

CHAIRMAN HALL: Well, I guess -- and I'm not an engineer. I'm not a technical person. But in order to determine a wrong response, I'd think you'd first want to know what the right response is. Does that

make sense or not?
Well, let's move on.
You stated that you felt that it was good that you all did this review and it provided a fresh look at the design. When was this plane originally certified? Or can you tell me when the failure analysis document, what was the date? When was that generated initially on the 737?
THE WITNESS: I don't know the date of the documentation. Boeing would have to provide that. But it was prior to certification, without a doubt.
CHAIRMAN HALL: And you have mentioned that you all didn't look that much at the accident scenario. Is that correct?
THE WITNESS: Not initially.
CHAIRMAN HALL: I guess, again, when we talk about all of this and the simulations of 190 degrees flaps one, that was consistent with the USAir flight 427; correct?
THE WITNESS: Right.

CHAIRMAN HALL: And how was that selected?

THE WITNESS: That information was readily available. We thought we -- in making sure that we're covering the envelope, we certainly cover the event to see if there are any anomalies there.

CHAIRMAN HALL: And this team is still together?

THE WITNESS: As required, to review disposition of the recommendations. Yes.

CHAIRMAN HALL: Have you all been asked to review anything?

THE WITNESS: What do you mean? Subsequent to our final documentation or something?

CHAIRMAN HALL: Since May?

THE WITNESS: Oh, yes. I've certainly looked at all the responses to -- what Boeing has provided. I've funnelled the responses back to some of the team members. The one team member I have not worked with has been the NTSB representative.

CHAIRMAN HALL: Well, one of the results that was on Slide 10 states that no specific scenario is identified that could explain either of the accidents. Could you tell me how you come with that result without looking specifically at the accidents?

THE WITNESS: Because the activity was so closely you might say affiliated with the accident, we asked ourselves the question; based on what we know, what information that we've gotten, even though we haven't been involved in the accident investigation, per se, we did have some access to some of the documentation. We did look at the flight data recorder information. We had to ask ourselves are we seeking anything.

Even though we weren't part of the investigation, we felt we would be asked that question. From what we knew at the time, even though we weren't part of the investigation, formally a part of it, did we see anything that might. And we felt we had to answer that question.

CHAIRMAN HALL: Mr. Zielinski, I hope you understand the inconsistency I'm having to deal with here in my mind. And I think -- I know that you all have done the best job that you could do and there are nine able people. But if we come up with a result that says no specific scenario is identified that can explain either of the accidents, and then you say earlier that you all wish you had become more familiar with the accidents, that leads me to wonder how that statement could be made. Because I think that statement does provide some representation to the public from the FAA that we've looked at this in light of these accidents and we can't come up with a specific scenario that could explain either of the accidents.

THE WITNESS: It's not to say that any of the deficiencies we identified aren't the cause. I think what we're saying is the failures we looked at from what we knew at the time and let's say our last snapshot of information was as of the end of April, we couldn't identify anything that might be causal to the accident, based on the information we had.

We felt we had to make the statement.

CHAIRMAN HALL: You did not identify any failures of the system that the flight crew could not recover from?

THE WITNESS: We have identified possible failures where recovery is doubtful and I think we've qualified that in the documentation.

CHAIRMAN HALL: And I assume that the team would be willing to continue in light of the new information that we have obtained from the wake vortex tests? Obviously, I know everybody works for somebody but the team would be glad, if their supervisors said reassemble and go forward, to take a look at the information that we got up in New Jersey?

THE WITNESS: Let me put it this way. The team being exposed to the accident and being involved in the CDR would very much like to be involved, continue to be involved, without a doubt. We wish we could have found the problem.

CHAIRMAN HALL: Well, the Chairman wants

anybody to be involved that feels like they can help identify and put closure to this matter. And certainly if we could have a conversation with I guess Mr. McSweeny when he's here and see if there's a continued role that you all might need to play as a result of the extensive work that you have done.

Well, we have kept you up here a long time, Mr. Zielinski, and I appreciate, again, the work that the team did. I think it's important. I appreciate your candid and forthright presentation and response to the questions.

We have run to 1:30 and that's past dinner time in Tennessee. And so we'll take an hour and come back at 2:30.

(Witness excused.)

(Whereupon, the luncheon recess was taken at 1:30 p.m.)

AFTERNOON SESSION

(Time noted: 2:40 p.m.)

CHAIRMAN HALL: We will reconvene this Board of Inquiry and would call the next witness, Mr. Werner Koch, Mechanical Flight Systems Engineer, the Aircraft Certification Office, Federal Aviation Administration's Southwest Region, Dallas-Fort Worth, Texas.

Thank you, Mr. Koch.

(Witness testimony continues on the next page.)

WERNER KOCH, MECHANICAL FLIGHT SYSTEMS ENGINEER
AIRCRAFT CERTIFICATION OFFICE, FAA-SOUTHWEST
REGION, DALLAS-FORT WORTH, TEXAS

Whereupon,

WERNER KOCH,

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. SCHLEEDE: Mr. Koch, give us your full name and business address, please?

THE WITNESS: My name is Werner Koch. I'm located in Fort Worth at the FAA Regional Office on Meacham Boulevard.

MR. SCHLEEDE: And your position with the FAA?

THE WITNESS: A certification mechanical systems engineer there in the Airplane Certification Office.

MR. SCHLEEDE: And briefly, what are your

duties and responsibilities in that position?

THE WITNESS: Is to review mechanical systems type data, approve that kind of activity with regard to type certification projects, STC's, supplement type certification projects, type changes and so forth.

MR. SCHLEEDE: Could you briefly describe your educational background that qualifies you for your position?

THE WITNESS: My educational background is I have a B.S. in ME from the University of Texas and a M.S. in ME from the University of Southern California.

MR. SCHLEEDE: Thank you very much.

Mr. Phillips will proceed.

MR. PHILLIPS: Good afternoon, Mr. Koch.

THE WITNESS: Good afternoon.

MR. PHILLIPS: B.S. in ME, that's bachelor of science in mechanical engineering?

THE WITNESS: Yes, sir.

MR. PHILLIPS: And master of science in mechanical engineering?

THE WITNESS: Yes, sir.

MR. PHILLIPS: How long have you been with the FAA?

THE WITNESS: I've been with the FAA approximately five years.

MR. PHILLIPS: And prior to that, what did you do?

THE WITNESS: Prior to that, the previous 16 years I was with Bell Helicopter in the Hydraulic Design Group. I led that group for about eight years. I was an FAA designated engineering representative for about 13 of those years. And prior to that, I was with E Systems as a design engineer for component suppliers, hydraulic component suppliers.

MR. PHILLIPS: So is it safe to say most of your career you've been involved in hydraulic component design?

THE WITNESS: I believe that's right.

MR. PHILLIPS: In your duties with Bell before you came to the FAA, did you ever have specific

design responsibility for hydraulic control valves, actuation systems?

THE WITNESS: Yes. The Hydraulic Design Group that I was either in or led for a number of years had that responsibility to provide the hydraulic systems for the helicopters.

MR. PHILLIPS: And in that job you were involved with testing of hydraulic systems and procurement specifications, things like that?

THE WITNESS: Yes. Design and the testing qualifications.

MR. PHILLIPS: How about certification? Have you been involved in certification of any aircraft?

THE WITNESS: Yes, sir. Yes, sir.

MR. PHILLIPS: For Bell?

THE WITNESS: Yes. For our commercial vehicles.

MR. PHILLIPS: When you were selected for the CDR team, I realize that you came somewhere after the program began. Could you tell us the time when you

started and circumstances where you came into the group?

THE WITNESS: I was asked to join the group, oh, 50 percent or better through the activity, to aid or supplement the hydraulic component and specifically, actuator experience on the team.

MR. PHILLIPS: So did you consider that you were called in as an expert for hydraulics design for the purpose of this review?

THE WITNESS: I was added to the team to augment or supplement the experience of the team in that area. Yes.

MR. PHILLIPS: Within that team, did any of the other members have any specific hydraulic design experience?

THE WITNESS: I don't believe so.

MR. PHILLIPS: Did any of them have, to the best of your knowledge, any prior experience in flight control certification design?

THE WITNESS: I can't answer that.

MR. PHILLIPS: Okay. That's fair.

We've heard quite a bit of testimony this morning from Mr. Zielinski. We don't want to repeat that. But what I would like to do is go into some detail your role on the CDR team in relationship to your expertise in hydraulic system components.

And to start that off, I'd like to ask what kind of materials did you have to review the hydraulic system design or flight controls design for the review?

THE WITNESS: I had some training material, I guess, that was provided by Boeing. I think I had some training material that was from one of the airlines in both the flight controls and hydraulics. I was provided some background from Mike, of course, and other team members to bring me up to speed. Plus folks at the ACO in Seattle were very helpful, as well as, of course, Boeing people in flight controls and hydraulics that were helpful.

MR. PHILLIPS: Did you review any failure analysis or documents provided by Boeing for failure analysis?

THE WITNESS: I did go over some of the failure analysis but I tried to limit my effort in the hydraulic componentry area.

MR. PHILLIPS: Mr. Zielinski testified this morning that engineering judgment is an important part of failure analysis. Fundamentals, anyway.

In your engineering judgment, were those analyses that you looked at adequate to explain or did they represent a reasonable failure analysis of that component?

THE WITNESS: I believe so. In general, I believe that's the case. Yes, sir.

MR. PHILLIPS: And are we speaking specifically of the main rudder power control unit or the rudder control system?

THE WITNESS: The analysis that was provided. And there've been some subsequent analysis provided as a result of Boeing's response to our recommendations. I've reviewed those. Just started to review those.

And I know that's the Seattle ACO's responsibility to address those initially, but I have started to look at those. But I guess I haven't studied them enough to totally absorb it all.

MR. PHILLIPS: Is there a requirement for you to study those and get back with someone on what you see?

THE WITNESS: I guess I've been asked to review those and I intend to do that. I don't know. I have not been asked to respond to those officially.

MR. PHILLIPS: So you were part of the team that made recommendations in the package --

THE WITNESS: Yes, sir.

MR. PHILLIPS: -- that happened near the end of the work?

THE WITNESS: Yes, sir.

MR. PHILLIPS: In reviewing the materials for the team's work, did you -- were you provided any test data from Boeing or from any other manufacturers as to performance on any of these components?

THE WITNESS: Are you talking about the qualification or certification type or acceptance testing on a unit to unit basis?

MR. PHILLIPS: That would be part. More specifically I'd like to know was there any testing done specifically at the request of your group? Did you review any data for that?

THE WITNESS: I don't know that we -- that I reviewed any data that we specifically requested of tests to conduct.

MR. PHILLIPS: So there were some engineering simulations or flight simulations done but the group didn't ask for any other lab work to be done on any hydraulic components or systems?

THE WITNESS: I don't believe so.

MR. PHILLIPS: In your review, did you use any materials from the accident investigation? Any factual reports, anything like that?

THE WITNESS: Yes. I did review some of the material. I guess the report that addressed some of the testing that was done at Parker and at Boeing facilities.

MR. PHILLIPS: Did you participate or watch any of the testing that was done for the Pittsburgh accident at Parker or at Boeing?

THE WITNESS: Yes. At Boeing.

MR. PHILLIPS: And what specific test was that?

THE WITNESS: The chip shearing test that was conducted there sometime in December or January.

MR. PHILLIPS: And under whose direction was that testing being done? Do you recall?

THE WITNESS: I believe that was under your direction at that time.

MR. PHILLIPS: I recall that.

As you watched that test setup, what did you believe the intent of that test was at the time, the purpose?

THE WITNESS: To determine the ability of that valve in the rudder PCU to shear the largest chip that you could inject into that valve.

MR. PHILLIPS: Why were we concerned about that?

THE WITNESS: Well, that particular actuator, the control valve in that particular actuator has a limiting aspect to it with regard to how much force you can apply to clear a jam or shear a chip. And it was a concern I guess not only of the team, of the CDR team, but other principals also in the investigation, that perhaps that might be a limiting condition. That is, the force available to shear a chip might be less than what it would actually require to shear a chip of the largest magnitude that you could ship into this valve.

MR. PHILLIPS: So, did you see -- let's talk a little bit about that limitation to the chip shear capability.

Can you briefly describe to us what you understand creates that limitation?

THE WITNESS: Yes. The rudder PCU is what we term in industry an integrated actuator. That is, it accepts both mechanical inputs from the pilot's pedal as well as electrical inputs from the yaw system. And as a result of that, there's summing linkage in that unit and springs associated with this for redundancy and also for just implementation of it.

Consequently, when a pilot input is applied that exceeds a certain level, these springs back off and the energy actually goes into compressing a spring rather than moving the valve.

So it's the unique design. It's not -- the rudder PCU, I don't want to give the impression that it's a unique design, but it is a design. Because it's typical of many other integrated actuator packages that have been designed and they're successfully being used. But the implementation of that is such in that unit that at a certain level you do limit the amount of force you can apply to clear a jam in the main valve.

MR. PHILLIPS: Would that be a design consideration for the manufacturers or the engineers to specify a minimum amount of chip shear capability?

THE WITNESS: I would think that would be the customary way you would control that. Yes.

MR. PHILLIPS: Do you know if this package has such a requirement in any of its drawings or specifications?

THE WITNESS: I don't know that.

MR. PHILLIPS: In chip shear, you observed the testing. Do you recall the test setup specifically?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Could you give us a rundown exactly what that test, bench test looked like?

THE WITNESS: It was basically the actuator setup with the valve modified to be able to insert various materials into the orifice. The input was powered with a pneumatic cylinder through a force transducer. I don't recall exactly how that pneumatic system was set up. I think they had -- this was conducted in a Boeing -- 1 forget the name of the lab there. But anyway, in a Boeing facility.

MR. PHILLIPS: The EQA lab?
THE WITNESS: Yes. But the pneumatic actuator was used to apply force through the force gauge to the input, and consequently into the valve.
MR. PHILLIPS: Did the fact that the pneumatic force was driving that chip shear test, would that have been any different -- the outcome been any different if it had been a hydraulic force or electrical force?
THE WITNESS: Not in my mind. No.
MR. PHILLIPS: And I think, if you recall, we -- during the testing, we held the secondary spool fixed and then we inserted a portion through to the primary and then sheared it with the primary.
Would holding the secondary spool in the fixed position affect the outcome of being able to determine the effects of a chip sheared in the primary and secondary interface?
THE WITNESS: I don't believe so.
MR. PHILLIPS: Did you see any attempt to

look at the secondary servo valve housing interface chip shear capability in that test setup?

THE WITNESS: No.

MR. PHILLIPS: As far as the selection of materials to shear, did you see the process or how the chips were selected or manufactured?

THE WITNESS: I think the selection of a material was made prior to my joining the team but they were -- just observing while the pieces were inserted, it seemed a correct and reasonable way to do that to me.

MR. PHILLIPS: How did they insert these chips into the orifice? Do you recall?

THE WITNESS: Mechanically with -- by hand or tweezers, I believe. The orifices are small and consequently the material that was inserted into these orifices was of a small nature.

MR. PHILLIPS: Do you recall what the results were of inserting these various chips into the orifices and shearing them?

THE WITNESS: In general, yes, sir.

MR. PHILLIPS: And specifically, did you see the valve -- did you see it not shear or shear pieces of material?

THE WITNESS: There was one material that -- well, to back off just a little bit. The idea was to apply up to 40 pounds or 44 pounds. And if it didn't shear at that level, we would back off. And only one of some 10 or so -- there was only one of those 10 or so specimens that didn't shear in less than the 40 or 44 pounds.

MR. PHILLIPS: Was there any effort to examine the interfaces to see if there were markings for proof that a jam had existed or markings?

THE WITNESS: Yes. The valves were examined after the chip was sheared after each one of the tests. These were individual tests that were designed to shear these individual specimen material. And in all cases, I believe, we were able to detect obvious rollover of the land where the shearing took place.

MR. PHILLIPS: So based on your engineering experience and judgment, would you consider this test a valid indicator of the chip shear capability of the servo valve assembly?

THE WITNESS: For the configuration that we tested. Yes.

MR. PHILLIPS: Let's talk a little bit about -- while we're talking about the servo valves and the spools, let's talk a little bit about a phenomenon called silting.

Are you familiar with the term silting?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Could you describe it for me, please?

THE WITNESS: Well, in an engineering environment, I guess, we use the term silting as it applies to small particle,; perhaps sub-micron particles as opposed to the large pieces that we've tested in our previous discussion here.

These small micron -- small sub-micron

particles tend to or can tend to be driven if a condition is such by differential pressure across the annulus of a spool and sleeves valve and can cause, depending on what the clearance is in this valve, depending on the pressure, differential pressure across the land, for instance, can cause some increase in friction of this valve.

MR. PHILLIPS: That's silting? Okay.

THE WITNESS: Yes. That's my crude definition of silting. Yes. It has a lot of -- it can happen in a lot of ways but that's certainly one way and probably one of the more frequent ways that silting does occur.

MR. PHILLIPS: Okay. So if I back up a little bit and simplified it, maybe we could call it small particles. You said sub-micron small particles in fluid that a lot of them build up and do something to the valve and increase the friction or forces on the valve at the land face?

THE WITNESS: Yes, sir.

MR. PHILLIPS: At the land edge.
Is silting generally evident in your experience in valves? Can you disassemble a valve, test a valve, to indicate that silting has been a factor in that valve's operation?
THE WITNESS: Whether it has been a factor?
MR. PHILLIPS: Has bee.
THE WITNESS: I can't say that positively. No, sir.
MR. PHILLIPS: Do you know of any test that can be done that would indicate a valve's been silting or operating in silting conditions?
THE WITNESS: Whether it has previously been involved in a silting condition?
MR. PHILLIPS: Yes.
THE WITNESS: I don't know off hand. No, sir.
MR. PHILLIPS: In silting, in the fact that it affects the friction forces as you've described them in the spools, the interfaces of the spools, is the

manufacturer of the spools, the lands, critical to whether silting is a problem or could be a problem?

In other words, the underlap and overlap conditions?

THE WITNESS: I believe, and just based on my engineering judgment and my limited experience, I believe that an overlap valve might have more of an increase in friction resulting from silting than an underlap configuration.

MR. PHILLIPS: And why would that be? In an underlap valve, then, if you have a small gap that exists at the neutral position, does the flow around the land allow that to clear itself?

THE WITNESS: In an underlap condition -- in an underlap valve. Yes, sir.

MR. PHILLIPS: Do we have underlap or overlap conditions in this spools of this servo valve of the main PCU?

THE WITNESS: Yes. I believe the specification requires a slight underlap on the primary valve and then a slight overlap of 2-1/2 thousandths on the secondary.

MR. PHILLIPS: So on one part of the system it's underlapped and the other part it's overlapped?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Would it be evident and based on your knowledge of this package, would it be evident to a mechanic or to a pilot that a valve has -- silting has happened or it's caused friction forces to increase between the spools?

THE WITNESS: Not to my knowledge, I don't believe.

MR. PHILLIPS: Did you make any recommendations in your report in regards to the operation or the design of the servo valve specifically?

THE WITNESS: I believe we made mention of the limited jam clearing capability of this actuator and that's included in one of the tables, I believe. And I believe it's Recommendation 4. And also 12 and

13 addresses it.

MR. PHILLIPS: In your engineering judgment and your review with the CDR team, could you have recommended to the CDR team any additional testing to add to your recommendations or clarify the work that you've done after the fact with some hindsight?

THE WITNESS: I believe that in hindsight I might have recommended some additional testing with regard to this silting activity. And part of that, Greg, is simply because we haven't found the smoking gun. And I think that my philosophy is that you've got to do some testing.

MR. PHILLIPS: So you've got some concerns about the potential for silting? You think it needs to be looked at?

THE WITNESS: I believe so. And it's partly as a result of we haven't found anything else. I think that might be one of the logical steps to proceed with further.

MR. PHILLIPS: Okay. We'll move along from that right now.

In your review we heard some discussion earlier today about galling relative to the standby rudder power control unit and the input shaft and bearing. Did you examine galling or the effects of galling on the system in the CDR?

THE WITNESS: Yes.

MR. PHILLIPS: Did you make any determinations as to how it would affect the system?

THE WITNESS: Yes, I think we did. We observed that, and as a result of that galling, what the effect might be. Yes, sir.

MR. PHILLIPS: And what do you think the effect would be if you found a galled input shaft bearing?

THE WITNESS: We're talking about the standby actuator?

MR. PHILLIPS: The standby. Yes.

THE WITNESS: Well, there are any number of scenarios, I guess, Greg. Certainly one condition is that it simply galls at the surface neutral position. And if that's the case, there's very little effect other than increase in pilot pedal force with regard to a mechanical input.

Now with regard to a yaw input, that's a different story. Now the surface is going to move. And how much it moves depends on what the amplitude of the yaw damper signal is.

MR. PHILLIPS: Do you have any kind of feeling whether or not a galled standby rudder input shaft could cause a full rudder deflection in this airplane?

THE WITNESS: I believe it's possible if the pilot doesn't react. I think the analysis that Boeing provided indicates that it takes pilot reaction in terms of a fairly significant amount of pedal force to prevent that.

MR. PHILLIPS: Was this analysis provided after the CDR recommendation or was it before or --

THE WITNESS: I believe there was some

provided prior to, but it was my understanding at the time -- and again, I entered the activity on this team rather late, but in retrospect, it turns out that Boeing had done -- 1 thought initially it was just an analysis and I was concerned about that. But it turns out that they had conducted some test prior to that and established what the spring rate in that system was that would allow the pilot to overcome an issue of that type.

MR. PHILLIPS: Do you know of any other conditions that would cause the rudder on this airplane to fully deflect with or without a pilot command? Let's do the without a pilot command to start with.

THE WITNESS: Any other being beside a rudder jam?

MR. PHILLIPS: That would be one.

THE WITNESS: I mean a standbyudder jam.

MR. PHILLIPS: Right.

THE WITNESS: Well, of course, the dual concentric valvæ,jam in both of those in one direction.

MR. PHILLIPS: Would jam in either one individually cause it to run away hardover?

THE WITNESS: No, no. Not with the pilot's input.

MR. PHILLIPS: As part of the flight 427 accident investigation, the systems group conducted some testing relative to positioning primary and secondary spools of the servo valves at extreme limits of their travel. Are you aware of that testing?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Have you looked at that data?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Could you briefly describe what you saw as the intent of that test?

THE WITNESS: I'm not sure what the intent of the test was. I wasn't a party to that. I just observed the results in the report.

MR. PHILLIPS: And to refresh your memory just a little bit, I believe that the tests were conducted by holding the primary and secondary independently or at different times at full travel positions, or estimated at full travel positions, measured full travel positions and then measuring the residual pressure differential. What would that tell an engineer? What would that test mean?

THE WITNESS: Well, it told me that the orifices that were available under those conditions were not equal between the primary and the secondary and the differential pressure or residual pressure that was measured was simply the resulting pressure when you're looking at -- running fluid at 3,000 psi through a series of orifices and you pick off the pressure at these various junctures.

MR. PHILLIPS: What would the result be to the rudder or to the pilot?

THE WITNESS: I believe there was one condition where it would -- I guess this was with the secondary position hardover where there was a significant amount of residual pressure which would tend to offset the rudder.

MR. PHILLIPS: Did the CDR team do any testing or do any kind of review of residual pressure differential tests or anything?

THE WITNESS: No, sir.

MR. PHILLIPS: Was there any discussion of that in any of the failures analysis that you reviewed?

THE WITNESS: No, sir.

MR. PHILLIPS: Is it a valid engineering practice to look at things like that? Have you done it before or seen people do that?

THE WITNESS: I personally haven't looked at that specific issue. I've worked with dual concentric tandem control valves but they were always of a slightly different nature. This issue didn't quite apply.

MR. PHILLIPS: Is this servo valve unique in any way to a dual tandem concentric servo that you've seen before?

THE WITNESS: It's different than what we use at Bell Helicopter, for instance, but it's not different than what's used other places in the industry but I'm personally not familiar with them.

MR. PHILLIPS: As part of your CDR team work, I see that you made some field trips; one to Parker?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Could you tell me a little bit about that visit and what you learned on that trip?

THE WITNESS: It was primarily to gain first hand information on the details of that actuator since I was thought to be the expert on that effort with regard to the CDR team, to get the first hand information, talk to the designers, exactly how the design was arrived, who did the design and exactly how it worked, the various ratios to determine -- one of the things that I wanted to determine for sure was what the jam clearing capability was precisely.

And then also, observed the manufacturing of this control valve. It was a familiarization trip primarily.

MR. PHILLIPS: Did you look at any valves being tested that had been returned from manufactures -- or operators?

THE WITNESS: Yes, sir.

MR. PHILLIPS: And could you -- do you recall the test methods that were used?

THE WITNESS: Parker has an ATP. It's an approved ATP which they use.

MR. PHILLIPS: And an ATP is a --

THE WITNESS: Acceptance test procedure. It's a test procedure generated by the OEM and probably approved by Boeing, but that each serial number, each delivered unit or each overhauled unit is tested to.

MR. PHILLIPS: And the rudder PCU assembly is tested separate from the servo valve. Did you see the two separate tests being conducted?

THE WITNESS: I believe I -- yes, I did witness parts of this, yes. Certainly not the whole thing. I didn't spent a great deal of time, but enough to convince myself that I thought the OEM was doing an effective job of providing acceptable units.

MR. PHILLIPS: Is Parker the only manufacturer for the main rudder power control unit?

THE WITNESS: To the best of my knowledge they're the only -- I guess Boeing approved manufacturer.

MR. PHILLIPS: Do you know if other people have the authority to overhaul or repair the main rudder power control unit?

THE WITNESS: Yes, sir.

MR. PHILLIPS: And who would that be?

THE WITNESS: The one I'm familiar with and that I've visited the facilities is Fortner Manufacturing and Engineering in Glendale.

MR. PHILLIPS: Glendale, California?

THE WITNESS: Yes, sir.

MR. PHILLIPS: And what do they do to the part or what can they do to the part?

THE WITNESS: They overhauled the servo valve. They were in a position to do that based on

their delegation by the FAA, I believe.
MR. PHILLIPS: So an operator can send his servo valve to Fortner for repair and have it returned to service and it would be an FAA approved part then?
THE WITNESS: Correct. And what?
MR. PHILLIPS: It would be an FAA approved part if they had been authorized to work on it?
THE WITNESS: I believe that's correct.
MR. PHILLIPS: The CDR report talks in some detail and we mentioned it briefly this morning, Recommendations 20, 21 and 22, I guess, on page 46 of Exhibit 9-A, 9X-A. And in regards to PMA approval of non-OEM, non-original manufacturers, is that a standard in hydraulics design? In your experience, is approval of non-OEM manufacturers normal, standard, expected?
THE WITNESS: I'm not sure.
MR. PHILLIPS: Are you aware that this servo valve does have matched primary and secondary spools?
THE WITNESS: Yes, sir.
MR. PHILLIPS: And would an OEM or would an

SFAR 36 PMA approved facility have approval then to manufacture or remanufacture a set of spools?

THE WITNESS: I believe that they did have. Yes, sir.

MR. PHILLIPS: Back on the subject of failure analysis for just a little bit, in conducting failure analysis based on probablistic materials, how does a hydraulic designer when he initiates a new design, how does he know how to calculate the chip shear capability that he needs and how would you start out with a blank sheet of paper in doing the right thing the first time?

THE WITNESS: I guess if I were doing it and had to determine what I wanted for jam clearing or chip shearing -- 1 like to use the term jam clearing because that's more generic, I would indicate a force level that I thought was sufficient to -- you know, based on my experience and industry experience was sufficient to clear jams.

MR. PHILLIPS: But if your valve design required two jams to happen, would that change your approach to that? Would you lower the level because the probability of second jam would be less?

THE WITNESS: Again, my personal experience or my personal preference, I guess, would be that would not affect the level because of common cause failures.

MR. PHILLIPS: We've talked about a number somewhere around 40 pounds for this particular valve. Do you have a feeling of what's an adequate or more adequate number for chip shear capability?

THE WITNESS: Again, it's very subjective. This configuration has flown 67 million flight hours where I've been told that that has not been a problem, so I guess I can take that as a fact. But I guess I feel that's still a marginal level of force to be able to clear a jam.

MR. PHILLIPS: Does that operational experience then, does that weigh heavily into this engineering judgment criteria?

THE WITNESS: Well, it weighs in. Yes.

MR. PHILLIPS: Could the possibility exist that there have been jams that have just been undetected or haven't been found or commented on?

THE WITNESS: I don't know that.

MR. PHILLIPS: Who would know that? Would that be -- how would we find out if wanted to ask that question to the best source?

THE WITNESS: I guess somebody that has that experience or has conducted a test to that effect. And I guess that might even be a recommendation to do that.

MR. PHILLIPS: Could we rely on operators who have overhaul capabilities and approvals to feedback to us and let us know when they've seen jams? Would that be a valid source or would we need to go back to Parker and Boeing?

THE WITNESS: Well, certainly anyone who's had that experience in the problem is getting some reliable data.

MR. PHILLIPS: And just a couple of things here in closing. From your observations of the CDR team, did you find the effort worthwhile?

THE WITNESS: Oh, yes, sir.

MR. PHILLIPS: Very productive?

THE WITNESS: Yes, sir. I thought it was very productive. Yes, sir.

MR. PHILLIPS: Have you ever been involved with any other CDR efforts?

THE WITNESS: No.

MR. PHILLIPS: This is the first for you?

THE WITNESS: Yes, sir.

MR. PHILLIPS: Would you recommend that CDR's be done on other airplanes without the benefit of an accident leading you into it?

THE WITNESS: A CDR or something to that effect if budget is available, I think would be helpful. Yes, sir.

MR. PHILLIPS: Were you satisfied with the makeup of the team? Did you feel like you needed another hydraulics expert or fluids expert or anything like that?

THE WITNESS: I thought the makeup of the team was adequate. Yes, sir.

MR. PHILLIPS: And did you ever feel the need to have any more support from the accident investigations? Did you need data that you weren't provided or asked for?

THE WITNESS: No. I thought that we were provided with ample data, as a matter of fact. It was sometimes more than ample.

MR. PHILLIPS: Do you have any recommendations for continuing the investigation that you can make to the systems group as far as additional areas you'd like to see based on your experience in the CDR report? Anything you'd like to have us take a look at?

THE WITNESS: Only in the area of continued testing, perhaps, of that valve arrangement with regard to silting. And again, it's -- you know, it's somewhat of a long shot but that might be a place to look next.

MR. PHILLIPS: I have nothing else unless you have something you'd like to add.

THE WITNESS: I don't have anything else.

MR. PHILLIPS: Thank you.

CHAIRMAN HALL: Any other questions from the Technical Panel?

Mr. Haueter?

MR. HAUETER: Excuse me just a second. A couple.

If there were a jam of one of the servo valves, how could the pilot detect that or how would you know the one valve had jammed?

THE WITNESS: Again, it depends on the position of the jam, whether it's in neutral or hardover. If it's in neutral, might be a little difficult for the pilot to detect because he would simply detect a difference in max rate. In other words, if with both valves operating properly the rate is full stroke in two seconds, with one jam at null, the rate, max rate would be full stroke in two second.

MR. HAUETER: What if it jammed at someplace off null? Would that --

THE WITNESS: Okay. If it's -- 1 guess the other extreme. If it's jammed hardover in one direction, if the primary is jammed hardover in one direction, then he simply has to counter that with a hardover in the other direction to neutralize the effect and allow the surface to trail, basically, probably.

MR. HAUETER: But what you're saying is neutral jams could occur basically with very little indication or being known?

THE WITNESS: Well, it might be difficult for a pilot to detect because it's only the max rate that's affected. If he tries to apply a max rate, he would see a difference. Now, whether he would detect -- you know, whether it would register on him or not, I don't know.

MR. HAUETER: You mentioned that this dual concentric servo valve is not a unique design but it's different than the helicopter industry. Can you describe what the differences might be?

THE WITNESS: Well, in the 737 rudder PCU, the valve is a dual tandem concentric but both the primary and the secondary are used in normal operation. In the helicopters or the ones that I'm familiar with at Bell Helicopter, the secondary was essentially a bypass configuration so that if, for instance, you had a jam in the primary one, you used the secondary one to bypass the effect of the first one.

MR. HAUETER: Okay. Thank you very much.

That's all I have, sir.

CHAIRMAN HALL: Questions from the parties?

I see the hand of the Air Line Pilots Association. Anyone else?

Very well, captain.

MR. LeGROW: Thank you, Mr. Chairman.

Good afternoon, Mr. Koch.

THE WITNESS: Good afternoon.

MR. LeGROW: Just a couple of quick questions along the same line that Mr. Haueter was on.

You said that if you had a jam of one spool, that the crew would only detect it or it could only be detected with a full throw. Would you elaborate on that a little bit?

In your view, would that be something that a pilot in normal flight would be able to recognize?

THE WITNESS: I guess I'm limited in my ability to respond to that properly, Captain, because not being a pilot. I can only tell you what I believe would be the distinguishing characteristics. That if he did try to move it at full rate, that is as fast as you can, that that rate would be limited after a primary valve jam at neutral.

MR. LeGROW: Okay. Thank you.

In Mr. Phillips' questioning you said that there were some silting tests that were done, and in your view and hindsight that perhaps more testing could have been done or should have been done.

And my question is how much input did the members of this CDR team have in the tests that were conducted?

THE WITNESS: No. I don't believe there were any silting tests conducted, number one. I think I said that in hindsight -- if I said there were silting tests conducted, I misspoke.

MR. LeGROW: I misspoke the question. I'm sorry.

THE WITNESS: Okay. What I did say, that in hindsight and after all this time has passed and we still haven't found the golden nugget, so to speak, it may be time to get into areas like silting and do some testing.

MR. LeGROW: And my question is how much input were the members of the CDR team given in the tests that were conducted? In other words, were the team members -- did they have input in exactly what tests would be conducted or would not be conducted or is this something that was given to the members before the --

THE WITNESS: I think most of that was done in parallel with the CDR team effort. The accident investigation was done sort of in parallel. And I'm not sure just how much input the team members had to identify what tests should be done and how they should be done but there was some, obviously.

MR. LeGROW: Along the same lines, sir, it's my understanding that everybody that participated in the CDR were government employees, either the U.S. or Canada. Is that correct?

THE WITNESS: I believe that's correct.

MR. LeGROW: Do you think in just your opinion that it may have been valuable to have people from the private sector participating in the CDR?

THE WITNESS: I think&at's not for me to -- 1 don't have any response to that. I was just simply picked as a member by management.

MR. LeGROW: Were you here for Mr. Zielinski's testimony this morning?

THE WITNESS: Yes,sir.

MR. LeGROW: And Mr. Zielinski testified that he felt it would be helpful to participate in the accident investigation. I guess my question -- do you think in your view that it would have been helpful to have accident investigators participating in the CDR?

THE WITNESS: I think so. And we did have one member of the NTSB on our team.

MR. LeGROW: But he was a government employee. He wasn't from the private sector.

THE WITNESS: That's correct.

MR. LeGROW: Thank you very much.

I have no further questions.

CHAIRMAN HALL: No other questions from the parties?

We'll move to Mr. Clark.

MR. CLARK: I think you said that you were present when some of the chip shear tests were done or you witnessed the results?

THE WITNESS: Yes, sir.

MR. CLARK: Have you participated in that kind of event before in your design work to do chip shears, look for witness marks?

THE WITNESS: Yes, sir.
MR. CLARK: How extensive is your experience in that area?
THE WITNESS: Limited.
MR. CLARK: One or two designs? One design?
THE WITNESS: Yes. Yes. Where we at Bell Helicopter -- this is something that -- just to elaborate a little bit -- that's been done by several companies to establish a chip shear capability.
MR. CLARK: From what you saw and what you observed, would there be any changes or additions to those tests that you would recommend or were you satisfied with the extent of those tests?
THE WITNESS: I believe I was pretty well satisfied with the extent of those tests. As I indicated, I think those tests were valid for the test conditions, for the hardware that we were using. I think we had some real good valid results.
MR. CLARK: They all made sense to you?
THE WITNESS: Yes, sir.

MR. CLARK: Okay. Thank you.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: Yes. I just have a few questions.

You were mentioning silting and I would like to get your opinion on what you would expect to find if you could look at those valves at very, very high magnifications, what effect silting would have on the valve?

THE WITNESS: I don't know.

MR. MARX: Any physical changes?

THE WITNESS: I don't know.

MR. MARX: Marks or --

THE WITNESS: I don't know.

MR. MARX: And also, you mentioned something about -- I didn't quite follow when you were talking about galling in the neutral position, it would have no effect. Would it have an effect if it was outside of the neutral position? This is on a standby.

THE WITNESS: Yes. I believe I stated that if the standby actuator was galled at neutral, there would be virtually no effect from the mechanical inputs from the pilot and he would feel some additional force. Whether that would be detectable or not, I don't know. But there would be an effect from yaw damper inputs and the degree is questionable. I'm not sure I fully understand what would happen but we believe that it would not be a major catastrophic effect.

MR. MARX: Thank you.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Just one, Mr. Koch.

When you were addressing the subject of silting, it's effect on the servo valve performance, can you speculate based on your experience of how the yaw damper activity would effect the performance change?

THE WITNESS: I'm not sure I understand the gist of your question, sir.

MR. LAYNOR: Well, the gist of my question is if you have yaw damper activity in this valve, would you not have more or less frequent cyclic motion of the valve spools within the housing?

THE WITNESS: Yaw damper activity would tend to neutralize silting effects. Yes, sir. Is that what you're asking? Yaw damper inputs would cause the valve to cycle at whatever rate the yaw damper was applying that signal and would tend to alleviate silting effects.

MR. LAYNOR: Have you looked at any -- the recording traces of Boeing 737 rudder activity to make an assessment whether you think that would have an effect on the --

THE WITNESS: No, I haven't. No, I haven't.

MR. LAYNOR: Okay. Thank you, sir.

CHAIRMAN HALL: Mr. Koch, it's nice to have a witness whose accent I can understand very well.

(Laughter.)

Let me --

THE WITNESS: Thank you.

CHAIRMAN HALL: Let me just ask you a question or two. You came on the team you say late? And the individual you replaced, was he a hydraulics person?

THE WITNESS: I believe that's correct.

CHAIRMAN HALL: The silting, you said the silting needs to be looked at. How would you do that?

THE WITNESS: I haven't thought that out thoroughly. I think I indicated that as a result of the impasse or the lack of a smoking gun, I think that might be a logical place to look next. And just how you would implement that I'm not sure.

I believe I would try to set up a situation with that actuator or with oil from an operational aircraft and leave it some sort of a static condition with it at full pressure, 3,000 psi, and let that silting effect occur. That may occur for some period of time. And then look at the forces it takes to undo that silting effect. And do this a number of times just to get the feel of it.

There may even be some serendipitous results as a result of this or -- and you'd go on from there. As you learn from the initial test, then you would proceed to the next step of it.

CHAIRMAN HALL: Mr. Phillips, is that something we can do?

MR. PHILLIPS: Yes, it is.

CHAIRMAN HALL: Well, let's do it then.

Let me ask you one more question then. Is galling and silting is that something that goes together?

THE WITNESS: No, sir.

CHAIRMAN HALL: That's two different things?

THE WITNESS: There could be a relationship but that's normally not -- the two don't normally occur.

CHAIRMAN HALL: Okay. But you did say that galling could cause the rudder to fully deflect?

THE WITNESS: No.

CHAIRMAN HALL: No? Okay. Well tell me what galling can do then to the rudder in your opinion. That got my attention because I believed there was galling on both Colorado Springs and the Pittsburgh actuators; right? So I'm just wanting to understand that.

THE WITNESS: The effect -- I guess just in summary, the effect of this galling, sir, can be overcome by the pilot, is effectively the answer.

CHAIRMAN HALL: With a pedal movement or --

THE WITNESS: Pedal pressure and movement. Yes, sir.

CHAIRMAN HALL: And how much pressure?

THE WITNESS: I don't have those numbers. I think there are some initial witnesses to that.

CHAIRMAN HALL: Is that where we get into the 40 pounds you referred to being -- no?

THE WITNESS: No.

CHAIRMAN HALL: Okay. We'll get into that later.

THE WITNESS: Yes, sir.

CHAIRMAN HALL: But I wanted to clarify that in my mind. I have the advantage up here of not having a technical background so I'm trying to interpret all this.

But I think unless there are other questions from the table or the technical staff, that we thank you very much for your testimony and also your service on the CDR team.

Let me just before I excuse you, ask you do you think that there is any reason that this team should continue its work or any value to that?

THE WITNESS: Just my personal opinion?

CHAIRMAN HALL: Yes, sir. You may be furloughed so you might be able to give that. I don't know.

THE WITNESS: I think there would be a benefit, certainly.

CHAIRMAN HALL: Thank you very much.

THE WITNESS: Thank you.

(Witness excused.)

CHAIRMAN HALL: Now I guess we'll continue and maybe take a -- we will call Mr. Thomas A. Newcombe, Aviation Safety Inspector for Airworthiness with the Seattle Aircraft Evaluation Group, FAA, Seattle, Washington.

(Witness testimony continues on the next page.)

THOMAS A. NEWCOMBE, AVIATION SAFETY INSPECTOR-
AIRWORTHINESS, SEATTLE AIRCRAFT EVALUATION GROUP
FAA, SEATTLE, WASHINGTON

Whereupon,

THOMAS A. NEWCOMBE,

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. SCHLEEDE: Mr. Newcombe, please give us your full name and business address.

THE WITNESS: My name is Thomas Allen Newcombe with the Aircraft Evaluation Group of the FAA, Seattle, Washington.

MR. SCHLEEDE: And what is your position at the Aircraft Evaluation Group?

THE WITNESS: My position is the Aviation Safety Inspector-Airworthiness, MRB Chairman on the 737 airplane and ATR airplanes.

MR. SCHLEEDE: How long have you worked for the FAA?

THE WITNESS: I've been with the FAA nine years.

MR. SCHLEEDE: And would you give us a brief description of your education and background that qualifies you for your position?

THE WITNESS: I have an airframe and power plant rating, acquired at the Institute of Technology in Inglewood, California, and commercial airplane rating with instrument, multi-engine. I have 20 years of industry experience with different airlines, leading from mechanic, lead mechanic, to special projects engineer.

I was co-owner of a general aviation business with a fixed base operation and also a co-owner/operator of a flight charter service out of Hawthorne, California.

MR. SCHLEEDE: Thank you.

I think Mr. Phillips is going to get into asking you questions about the AEG and your responsibilities.

Thank you.

MR. PHILLIPS: Thank you, and good afternoon.

Mr. Newcombe, as Mr. Schleede just mentioned, you come from the Aircraft Evaluation Group?

THE WITNESS: Yes, I do.

MR. PHILLIPS: Could you tell us what that is and what they do?

THE WITNESS: The Aircraft Evaluation Group is kind of like the liaison between the Certification Offices and the Flight Standards District Offices. We interact with both in assuring that the instructions for continued airworthiness are initially developed and maintained to the level of safety of the initial certification.

MR. PHILLIPS: So what is -- before we get into that, you used the initials MRB Chairman. Is that Material Review Board?

THE WITNESS: No. That's the Maintenance Review Board.

MR. PHILLIPS: Maintenance Review Board. Okay. And what do you do in that function?

THE WITNESS: There again, on the initial -- we develop or help develop the initial maintenance inspection requirements to be done for the instructions for continued airworthiness, which eventually go to the operator of the airplane to develop his initial maintenance program.

MR. PHILLIPS: Other than maintenance, do you get involved in any other initial certification design activities?

THE WITNESS: Not too much on the initial design activity. Only if there's some airplanes in service and only with the maintenance program beforehand.

MR. PHILLIPS: Do you use failure analysis or hazard assessments as part of your normal job?

THE WITNESS: No.

MR. PHILLIPS: Were you part of the CDR team?

THE WITNESS: No, I was not.

MR. PHILLIPS: Have you read the CDR report?
THE WITNESS: Yes, I have.
MR. PHILLIPS: I'd like to talk a little bit about the section entitled Continued Operational Safety Issues. And you've said that's an area that the AEG is involved with.
Can you tell me what Continued Operational Safety Issues is or what would fit into that category?
THE WITNESS: Well, that in my opinion would be one that has already had an issue established on it that the design or the maintenance feature maintains an adequate level of safety or the initial level of safety.
MR. PHILLIPS: So would part of that process involve writing AD's? Would you be involved with writing an AD or issuing an AD?
THE WITNESS: I wouldn't be involved in writing it. I would be involved in reviewing it to make sure if there's any maintenance implications, that they can be followed through by the Flight Standards

District people in the field.

MR. PHILLIPS: Are you part of any process to review service bulletins or service letters from the manufacturers before they're released?

THE WITNESS: No.

MR. PHILLIPS: Do you have anything to do with determining whether they should be -- I guess if you don't review them, you don't determine whether they should be made mandatory or anything like that then.

I answered my own question.

THE WITNESS: No, I don't.

MR. PHILLIPS: In the CDR report there's a group of recommendations, 16, 17 and 18 on page 39 -- I'm sorry. On page 44, I guess, and 45 of the report. This is Exhibit 9X-A.

And one of the discussions is on the adequacy of maintenance task and associated intervals. Could you refer to that page, 44 of 9X-A?

THE WITNESS: 44, 9-A. Right.

MR. PHILLIPS: 9X-A.

THE WITNESS: Uh-huh. Which recommendation?

MR. PHILLIPS: We'll start with 16 but I want to begin with the opening paragraph there.

The CDR team recognized that maintenance tasks and the intervals of maintenance was a critical --

CHAIRMAN HALL: Recommendation 16?

MR. PHILLIPS: Yes.

CHAIRMAN HALL: And that's page 44?

MR. PHILLIPS: Page 44.

CHAIRMAN HALL: Yes. Let's just be sure if we're referring to the exhibits we identify the page for the benefit of the audience.

MR. PHILLIPS: Yes, sir.

As part of this ongoing operational safety, maintenance inspection intervals and tasks and the definition of those were addressed in the CDR report. Could you tell us on Recommendation 16, could you just discuss that recommendation for us briefly?

It says -- I'll read it. The recommendation is to review and revise as appropriate the 737 inspection tasks associated with latent failures identified in Tables 3 and 4 in Section 10 in accordance with MSG-3.

And a couple of questions there. First of all, what's MSG-3?

THE WITNESS: It stands for Maintenance Steering Group and that's a document that was developed by the Air Transport Association of America.

MR. PHILLIPS: Is that specific to the 737 and for all types?

THE WITNESS: All airplanes.

MR. PHILLIPS: And what would be in that document generally?

THE WITNESS: It's a logic process to come up with the initial maintenance inspection requirements for the systems and structures.

MR. PHILLIPS: Is the consideration of latent failures an important part of a maintenance program?

THE WITNESS: We don't consider latent

failures. Certification does, however. We do consider hidden failures. So it's a little bit different. It's a little different process.

MR. PHILLIPS: Could you briefly describe the differences between latent and hidden?

THE WITNESS: Well, what we consider a hidden failure would be hidden to the flight crew during the performance of their normal duties. And considered normal duties is when they're sitting in their seat for takeoff. So if it's in the latent failure, discussed earlier, was what Mike had read in the 251309 which we consider the opposite of -- not opposite, but we consider a hidden failure to the flight crew and not to the design of the airplane.

MR. PHILLIPS: Are you familiar enough with the design of this airplane and this CDR report to describe to us any potential latent failures in this airplane's flight control system?

THE WITNESS: I would not want to do that. That's not my expertise, latent failures.

MR. PHILLIPS: On Recommendation 18 on page 45 of Exhibit 9X-A, the team recommended that the MRB and PD inspection task description be revised. Could you briefly describe what the intent of this recommendation is?

THE WITNESS: Well, we're going to -- along with the Boeing maintenance and ground operations services, we're going to develop -- and this is a normal process used in the development of a maintenance program or the maintenance requirement is that you develop a team consisting of the operators, manufacturer of the airframe engine and any appliance that may be involved. And through that team, you get together and you go through the MSG-3 analysis to see if a task and an interval is required.

And what we'll do is we'll take the same process, develop what they call a policy and procedures handbook, and this is the guidance that will be given to the team on how they're going to do the analysis and come up with an interval, if appropriate, and then what to do after that.

MR. PHILLIPS: Could you tell us what a lC, 3C, 1A interval is?

THE WITNESS: When you're doing the inspection requirements and develop the maintenance program, it's normally broken down into levels of inspection or intervals. A C check could range anywhere from 2500 hours up to a certain other number with 1C would be a normal check. Usually they're done in multiples of these. You'd have 1C and 2C until you'd get up to maybe a D check. And that breaks down to also the A checks. You'd have multiples of A checks until you got to the level of a C check. And that's where you would stop the multiples of A.

MR. PHILLIPS: So what's the most comprehensive level of check? Is that an A or a C or D?

THE WITNESS: The most common?

MR. PHILLIPS: Comprehensive, most thorough.

THE WITNESS: The most comprehensive is a D or someone doing many multiples of a D, which is the most comprehensive. Then it goes down to the C, and the A being usually a weekly check with minor things to check.

MR. PHILLIPS: And so on Recommendation 18 on this page 45, the last element in this table is a standby hydraulic system, including a rudder function. This is less than or equal to a 1A check. That's the recommended inspection interval.

Does that mean that this check should be done less than once a week or once a week? How would I interpret that?

THE WITNESS: Should be done. Yes.

MR. PHILLIPS: Do you know if there's a requirement to do that?

THE WITNESS: Pardon me?

MR. PHILLIPS: Do you know today if there exists a requirement to do that check at the 1A level?

THE WITNESS: I believe on most -- let me clarify something. When we establish the maintenance requirements, this is the initial one that goes to the operators. Once the operator gets the Maintenance Review Board report, of course they have to implement normally all of the items that are in the MRB report.

Through their reliability program and through their experience and everything, they can through their local authority have items escalated. So initially, every airplane would start out with a 1A check.

MR. PHILLIPS: Do you, in doing your job, do you use service difficulty reports?

THE WITNESS: Yes, we do.

MR. PHILLIPS: And how do those get to you? Do you have a computer system there? Are they hard copy papers or --

THE WITNESS: We have a computer system, the ASOS system where we can access limited -- we have a contact in Oklahoma City that we can call or get a message to to get a more advanced or more complicated search. Then they would send that information normal mail.

MR. PHILLIPS: Based on your experiences and your position, how effective are the SDR's in reporting the maintenance issues in the fleet?

THE WITNESS: I think they're very effective. We get indication of what is failing. A lot of times, like we say, we don't get the full information of what the failed part was or what actually failed on that part but we know what it was. And then through our office we do, if we consider it a safety issue or could project into a safety issue, we would go further and get more information on it and contact additional people.

MR. PHILLIPS: How do you determine that it's a safety issue? I would assume on an SDR you'd have a part number and some description. Can just looking at that one form tell you that there's a safety issue involved? Is there any system that codes the SDR's as critical or non-critical?

THE WITNESS: There's only -- sometimes in the SDR system they do have a star border around it which is a highlight that it could be safety issue. Otherwise, we would take it into account with our experience determine whether this possible unit could affect the safety of the aircraft.

MR. PHILLIPS: In reviewing this SDR's are you segregated by ATA codes? Do you have one person who looks at flight controls, another person who looks at structures or how do you divide the workload?

THE WITNESS: Well, in our group we train to one airplane so we do the whole thing. And we do separate the SDR's through the ATA code system.

MR. PHILLIPS: So youhaving the responsibility for the 737 fleet at sometime or other the SDR's should come across your desk and you should have a look at it?

THE WITNESS: Normally, I'd have all '37. And at least once a week a pamphlet is sent out through Oklahoma City or from Oklahoma City to our office and each one in the office reviews his particular airplanes for the items that are in there.

MR. PHILLIPS: Do you recall any significant trends in the SDR activity or SDR reports concerning any of the 737 systems? Any common failures, problem areas?

THE WITNESS: No.

MR. PHILLIPS: And this is looked at -- did you say weekly or monthly or occasional?

THE WITNESS: Normally, weekly. And it depends on the input, how much information is in there.

MR. PHILLIPS: I think we had a comment earlier in the day that there's additional information available behind these SDR's. Is there a way to contact the person who wrote it to get more detail if you need to know more about that SDR?

THE WITNESS: Yes. We normally have daily contact with the principal maintenance inspectors for the operators that are assigned or that have our particular airplane. So if we find something that we need more information on then we will contact the principal inspector and have him either research his current database or he will go to the operator and get the information.

Very seldom do we ourselves deal with the operator. We try to leave that up to the principal inspector.

MR. PHILLIPS: Are the operators required by law to write an SDR?

THE WITNESS: On certain things, yes.

MR. PHILLIPS: And what would be an example of something they would be required to write an SDR on?

THE WITNESS: Any problem with the flight controls. The regulations usually state the items that they're required to report on. Some of them report almost everything any more.

MR. PHILLIPS: Do some operators write more SDR's than others?

THE WITNESS: No. They only write an SDR when they have a problem so it all depends on when there's a problem.

MR. PHILLIPS: I guess a better question is do you believe that every problem is recorded on an SDR?

THE WITNESS: Pardon me?

MR. PHILLIPS: Do you believe every problem is recorded on an SDR?

THE WITNESS: No.

MR. PHILLIPS: Recently, we've been -- the NTSB has been following a series of events involving 737 flight controls. I say recently. It's actually been over a period of years. And other aircraft, too. But would your office have responsibility for following in-flight events or upset events? Is there any reporting process that's required to the AEG?

THE WITNESS: Not so much a reporting process. However, we are involved in the incidents through the principal inspector. So we do get that information and we do a follow-up.

MR. PHILLIPS: I think along those lines, Mr. Jacky would like to ask some questions about some in-flight events, so we'll pass the baton here.

MR. JACKY: The exhibit to which Mr. Phillips was referring to is Exhibit Number 13X-C, if you could refer to that, please. And specifically, pages 4 and 5.

Mr. Phillips sort of hinted at what -- or took a couple of my questions, I guess. I'm wondering in the process of -- in your work when you see the list of SDR's, is there any sort of way of going back and looking at any sort of particular either flight control system or some sort of upset that would -- or to look at them categorically by type of system? Would that be the ATA code?

THE WITNESS: Yes, it would.

MR. JACKY: And is there any sort of process within your group that if any one such code kept coming up X amount of times that it would raise a red flag or something?

THE WITNESS: Normally that's what we -- we'd take a look at see -- we'd find a trend. If that code's coming up all the time, then we would normally gather those and go to the Aircraft Certification Office and discuss it with the engineer who has responsibility for the system.

MR. JACKY: And on these SDR's, are they coded by airline at all?

THE WITNESS: Coded by what?

MR. JACKY: Airline.

THE WITNESS: Aileron?

MR. JACKY: No. Airline. By air carrier.

THE WITNESS: Yes, they are.

MR. JACKY: And in the process of going through the SDR's, if one air carrier came up more than others, would that throw a red flag?

THE WITNESS: It would. And we would contact the principal inspector.

MR. JACKY: In looking at this list on page number 4, the items that I would like to reference you to are events that have been referred to the NTSB as being uncommanded rolls.

CHAIRMAN HALL: We don't believe he has the exhibit. See if you can assist, Mr. Schleede. It's 13x-c.

THE WITNESS: Okay.

MR. JACKY: And starting on page 5, Item Number 32, and on down through the rest of the page are several uncommanded roll events. And I'm wondering if in the process of the last few months if you or anyone in your group have noticed any sort of increase in SDR's or anything that might hint at a type of problem like this?

THE WITNESS: On these incidents in here we haven't. The SDR reports would not have been entered into the ASOS system and out to the field -- out to us. However, we have continued contact with the principal inspectors on all of these items and we have been doing the follow up with those.

MR. JACKY: And what have been the type of follow ups that you've been doing?

THE WITNESS: On the items that were removed from the airplane due to either response by the operator themselves or the NTSB or the FAA for recommendation of removal and items sent to the original aircraft manufacturer for teardown, we would -- and I've been to most of them -- go to the facility where they're going to do the testing and evaluate -- not evaluate the test but witness the testing and see if there's anything that came out of the testing that we could use in our determination of any problem.

MR. JACKY: And was there any sort of determination of that sort?

THE WITNESS: Pardon me?

MR. JACKY: Was there any determination of that sort?

THE WITNESS: None at this point, no.

MR. JACKY: And have you taken any sort of follow-up action on these items beyond that?

THE WITNESS: Not so much on these items here. We are in the process of -- and we have developed a team and we're taking a look at -- we're gathering information from six airlines on the components removed from ATA's Chapter 22, which is the autoflight system and ATA Chapter 27, which is the flight control system for every component removed in the last five years to develop a database to see if we can come up with a common cause or commonality of any issues.

And we're doing this directly through the help and assistance of the principal inspectors since they're the ones that know the operators' program the most and how to defer the information that's set in their reliability program.

MR. JACKY: And you said this process has just begun?

THE WITNESS: Has begun, yes. We've already started it. We've already had meetings with the principal inspectors and they are now in the process of putting that information into the computer system so we can incorporate it into a mainframe.

MR. JACKY: And will this process be ongoing or is there some sort of end date?

THE WITNESS: Right now we've only projected to do the last five years of reliability data which is going to take quite some time to get all that information into the system. I would hope that we would continue it with -- everything's available where we can do that.

MR. JACKY: And is this just with the 737 airplane itself or is this encompassing all types of airplanes?

THE WITNESS: These are only the components on the 737 airplanes for certain operators.

MR. JACKY: The six airlines that you mentioned?

THE WITNESS: Six airlines. yes.

MR. JACKY: Are you at liberty to tell us what the names of those airlines are?

THE WITNESS: Pardon me?

MR. JACKY: Are you at liberty to tell us what the name of those airlines are?

THE WITNESS: We originally have been

requested by the airlines that we not use their information or their name in a report.

MR. JACKY: Understand.

And would this just be historical data or would it be starting time zero equal now and move on forward?

THE WITNESS: For the five years?

MR. JACKY: You're researching five years back?

THE WITNESS: Five years back. Yes.

MR. JACKY: And what will be the final product? Are you planning on issuing a report on your findings?

THE WITNESS: We plan on doing a report, on showing the components, the cause and the failures we've found on them and if there's any significant trend.

MR. JACKY: And have you made any sort of preliminary assessment as to any sort of significant trends?

THE WITNESS: Not at this point, no
MR. JACKY: In the process of going through your SDR reports, is the airplane manufacturer either -- or is the airplane manufacturer privy to your lists?
THE WITNESS: The list of the database we're putting together?
MR. JACKY: You said you received weekly updates on --
THE WITNESS: On the SDR's.
MR. JACKY: -- SDR's. Would an airline manufacturer have access to that same information?
THE WITNESS: I believe the manufacturers have the same access to the database that we do.
MR. JACKY: Do you do any sort of sharing at all of lists between -- any list that the manufacturer might have and what you might have?
THE WITNESS: When we do find a trend that we want to take a look at, we do contact the manufacturer and see what he has within his or whether he has other operators reporting. See, our database is only

servicing the U.S. certificated airplanes. The manufacturer would have the one that covers all the certificates airplanes for all the ones that they've sold, so they would have a larger -- most of the time they would have a larger database than we have, so we do contact them quite frequently to find out just what information they have and if they've done anything about them.

CHAIRMAN HALL: Mr. Newcombe, I'll go out of turn here and just ask what type of information do you have on these events from something that happened five years, four or five years ago? What type of information would you have that you'd be putting in this computer?

THE WITNESS: We'd have the -- that there was an incident or cause, what was removed, and sometimes we'll have what the fix for that unit was. That's what we're trying to get is -- with the SDR system we have what the cause was and what the failure was, what the replacement was. A lot of times we don't have what actually was fixed because a lot of times that's privileged information. That goes directly to the operator from the component.

CHAIRMAN HALL: But there is not an existing database on the 737 in regard to incidents like that that is maintained or --

THE WITNESS: No. Normally this is all pulled in by -- each individual operator has his own database, reliability database. We do not have one specifically for the '37. The manufacturer probably has one that he maintains.

CHAIRMAN HALL: Well, who would make the decision to set up a database?

THE WITNESS: Who would make the decision?

CHAIRMAN HALL: Yes.

THE WITNESS: It was --

CHAIRMAN HALL: And again, I'm asking you the obvious. You know, we had an accident in Colorado Springs. We had an accident in Pittsburgh. And what I'm hearing is we're just setting up a database now to track incidents, these incidents, and I was just wondering why.

THE WITNESS: Well, they've been tracking units separately all the time through the SDR system. Because of the incident or accident in Pittsburgh, the principal inspector there, who we've been in coordination with all the time, had done it with his operator. So we felt, well, this is good information that we should have from everybody -- from a limited source right now, six airlines, and then maybe eventually we'll try to get it from everybody.

So through discussion with him and showing what he's developed for his investigation, we felt it would be the same -- that we should do that. So through my superiors, we decided we would go ahead and do that and call the principals in to give us help in developing this.

CHAIRMAN HALL: And you've indicated that there's an engineer that has a responsibility that this information is reported to for the rudder system on the

737? Is there one engineer that has the responsibility in your department for tracking information or not?

THE WITNESS: I have all the responsibility for the 737's in the Aircraft Evaluation Group and we work with the engineers who have responsibility for their systems. There could be a bunch of them in the Certification Office.

CHAIRMAN HALL: I'm sorry, Mr. Jacky, for using my prerogative to butt in, but please proceed.

MR. JACKY: Thank you.

Back to the database that you were discussing and that you're putting together. Did you say that you would only be looking at the autopilot type events or are you talking about looking at all sorts of control upsets, events?

THE WITNESS: We're not looking at events so much. We're looking at the removals of the components and what was the cause of the failure of that component. So it's not so much -- well, we do take that into account so we can divide our database or we can sort our database to whether it's a rudder system, aileron system, whether it happened in takeoff crews, descent, approach.

So, we're trying to set it up so we can take a look at all different parameters and to get some information out of it.

MR. JACKY: And did I take it correctly that you asked all the PMI's to come in or principal maintenance inspectors to come in and talk about the setting up of this database?

THE WITNESS: We asked the principal inspectors of six airlines to get the reliability data from the operator for the last five years. The operators cooperated and gave this information to the principal inspectors, who then came to our meeting and we sat down and developed a form that we could use to incorporate all of the information because it's all different. So they have to be able to distinguish -- take information from one reliability program and be able to put it into one single form.

MR. JACKY: And this form that you've developed for the implementation to the database, that is different than the SDR form?

THE WITNESS: Yes, it is.

MR. JACKY: And at any time then, have you had any sort of review or meeting with representatives or engineers from operators more than just the six airlines that you've been referring to?

THE WITNESS: Not on this, no.

MR. JACKY: Thank you. I have no further questions.

CHAIRMAN HALL: Other questions from the Technical Panel?

Mr. Haueter?

MR. HAUETER: Yes. Just two brief ones.

I was curious on the SDR's. You mentioned they get flagged as they come in or you see something. Is that a manual flag? Is it done by computer? How do you keep track of all these SDR's and the things you find on them?

THE WITNESS: You mean -- 1 said they were flagged with the starts on them, you mean?

MR. HAUETER: Well, if you're looking for a specific trend, does that computer find it and pulls those out or how's that done?

THE WITNESS: No. I'm not sure if we're talking about two different things here. One was if it could be a safety issue, Oklahoma City would put a border around that one item. When we look at them, we look at every one of them pertaining to our airplane and we would look at the first ATA code and the probable cause or the removal of the incident, what caused the incident. And we would determine ourselves if we have a trend. But there's no computer generation for a trend.

MR. HAUETER: That's purely a manual search of going through all these things and reading them for each event?

THE WITNESS: Yes.

MR. HAUETER: How many people do that?

THE WITNESS: Pardon me?
MR. HAUETER: How many people do that? I mean, --
THE WITNESS: Well, right now we have --
MR. HAUETER: Just for 737's.
THE WITNESS: Just for the 737?
MR. HAUETER: Yes.
THE WITNESS: Just me.
MR. HAUETER: How many of these things do you look at a day? I'm kind of curious.
CHAIRMAN HALL: You're the only person? Is that what I heard? I'm sorry. The fan went on and I can't hear very well up here.
THE WITNESS: I'm the responsible MRB Chairman for the 737 fleet. We do have a backup person when I'm not in the office. However, when the SDR's come in, I'm the only person that actually looks at them and reviews each one to see if we have a trend or whatever.
And normally, --

CHAIRMAN HALL: How big a workload is that? How many would come in a day or a week? Do you know how many came in in the last year?

THE WITNESS: Well, like I mentioned earlier, we usually get a package each week and there may be anywhere from 10 up to 20 or 25 or so SDR reports. A lot of them are insignificant, like reading lights and stuff like that.

CHAIRMAN HALL: But you review all of those and at this point in time there's not a computer program you put them in other than here?

THE WITNESS: Right.

CHAIRMAN HALL: Fine. Okay.

MR. HAUETER: That's what I was getting at.

In looking at these, do you interact with the operations side on things that you may see in looking at SDR's to help out the operations group or is that done elsewhere?

THE WITNESS: We would. If we found something that we would need some discussion with them or we thought they should know about, then we would get our counterpart for the operations and the avionics person and discuss it with them to keep them informed.

MR. HAUETER: Are there any specific issues with the 737 that you're tracking or have a special flag on them now as far as your involvement?

THE WITNESS: Any flight control problem, any autopilot problem, we take a look at those mainly to see if -- because recently we keep track of every one of them so we usually have a lot of the information before the SDR gets to us. Because it goes from the operator to the principal inspector. Then it's sent to Oklahoma City who incorporates it into the system and then publishes the report and then sends it out.

MR. HAUETER: In going back once again and just clarifying, on Exhibit 13X-C, on the recent events, you mentioned that you normally wouldn't see these type of events? Did I misunderstand your response?

THE WITNESS: On uncommanded rolls and stuff?

MR. HAUETER: Right.

THE WITNESS: Yes. Some of the times some of these aren't classified as reportable through the regulations, so they wouldn't be reported under the SDR system.

MR. HAUETER: And so if there wasn't a component pulled, you may never even know that one of these events occurred?

THE WITNESS: Right. If it wasn't reported then we wouldn't know.

MR. HAUETER: Is there an operations counterpart of yourself that would pick up something like that through a different means?

THE WITNESS: Well, there again, the operations counterpart, if it was reported through the SDR, we would go to him and say, "Have you seen this," or whatever.

MR. HAUETER: But I mean, would your -- does your counterpart have a system similar to SDR's to find out about operational events? You may be the wrong person, but I just --

THE WITNESS: I don't --well, they have -- they still go through their principal inspectors, their principal operations inspectors for information coming from them, but for the ops side, there's nothing that's the same as the SDR for them getting information.

MR. HAUETER: Following up on the Chairman's comment and my own, could you use computerization to help you track all these SDR's and tag and trend them and things like that?

THE WITNESS: Could I?

MR. HAUETER: Yes.

THE WITNESS: Well, we are right now doing that.

MR. HAUETER: You're moving in that direction to --

THE WITNESS: Yes. We've taken the -- well, we developed the program we're going to use and the principal inspectors will be doing -- inserting most of that information at their place of location. They'll be sending me the disk or via the system, and I'll be inserting that into my computer as a main database. And then we'll be doing a track for that.

MR. HAUETER: Okay. Thank you.

That's all the questions I have.

CHAIRMAN HALL: Any other questions from the Technical Panel?

(No response.)

If not, we'll move to the parties. Do any of the parties have questions for this witness?

I see the hand of the FAA. Anyone else?

(No response.)

If not -- Mr. Donner.

MR. DONNER: Mr. Newcombe, just one point of clarification. All of these SDR's are computerized in Oklahoma City, are the not?

THE WITNESS: Yes, they are.

MR. DONNER: And they are available to you?

THE WITNESS: They are available to anyone in the FAA. Yes.

MR. DONNER: Thak you.

CHAIRMAN HALL: I guess, Mr. Donner, you're asking maybe what I'm -- if there's one database, does there need to be -- you're talking about creating a database out of a database; right? Information that comes out of Oklahoma City?

THE WITNESS: We're taking additional information that may not be in the database in Oklahoma City because we're going a little further. And like I said, the original SDR --

CHAIRMAN HALL: Where does that additional information come from?

THE WITNESS: Like I say, we were getting the principal inspectors to get that information from the operators. And one thing I forgot to point out. We have also contacted a couple of the OEM's to get their reliability data on that part for the last five years. And they've offered to do that, so --

CHAIRMAN HALL: That helps me. Okay.

We'll go to the table and Mr. Clark.

MR. CLARK: I have no questions.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Yes, sir.

I may have missed -- how does your office or you personally, how do you interact with the Boeing Company?

THE WITNESS: Well, I have -- as being the MRB Chairman, the initial -- and I might have to explain a little bit how the initial process is started as far as the maintenance program. When a manufacturer wishes to develop the design for an airplane, of course they have to have the instructions for continued airworthiness. So they would come up with -- normally it's about two years before the type certification of the airplane and say we have to develop a maintenance program for this airplane.

The industry steering committee is developed through the manufacturer, the operators, the engine and airframe manufacturer and appliance manufacturers. Once they develop that team then they would come to the FAA and say we're going to need to develop this maintenance program.

As me being the MRB Chairman, I would get together a team, and usually it's principal inspectors or other people in the Aircraft Evaluation Group. We develop the MRB team to help the manufacturer develop the initial maintenance requirements for that airplane before it's put into service so that the operator has a maintenance program before he gets the airplane.

So then once it's in service, then we work with the manufacturer to make sure that the instructions for continued airworthiness are maintained to the level of safety of original issuance.

MR. SCHLEEDE: Okay. I'm sorry. Really that's the part I was interested in, your day-to-day interaction with the Boeing Company.

THE WITNESS: Yes.

MR. SCHLEEDE: Do you have a certain office that you interact with or a person at Boeing on a daily basis?

THE WITNESS: It may not be on a daily basis. Depends on the occurrence. But we have several people in one office that we do discuss certain issues with and work with on an occasional basis whenever it's needed.

MR. SCHLEEDE: Do they provide -- does Boeing provide to you reports of 737 incidents outside of the U.S. on foreign registry?

THE WITNESS: If we were to request them, they will discuss them with us. Yes.

MR. SCHLEEDE: If you request them. So if there's a serious incident involving a 737 airworthiness overseas, how would you know about it?

THE WITNESS: Well, we would know about the incident as it happened and then we would contact our counterpart over there to see if they have any information.

MR. SCHLEEDE: Well, I'm trying to find out how your office would find out about it. Does Boeing report it to you or does the foreign authority report it to you?

THE WITNESS: Our counterparts do sometimes report to us that they've had an occurrence. Of course, again, we hear it through our public affairs system or a lot of times through the media that something had happened. So then that starts the ball rolling.

MR. SCHLEEDE: Is there any requirement that Boeing report that to your office, any kind of a serious event like that?

THE WITNESS: Not on the flight standards side. Only on the certification side Boeing has to report certain stuff.

MR. SCHLEEDE: Do you know roughly how long it takes from the time an event that generates an SDR gets in the system and will get to your office?

THE WITNESS: I couldn't say for sure. It could be sometimes two weeks, maybe three weeks.

MR. SCHLEEDE: Thank you.
CHAIRMAN HALL: Mr. Laynor?
MR. LAYNOR: No questions.
CHAIRMAN HALL: Well, first, an administrative announcement.
Mr. Haueter, you'd better tell the hotel that as soon as I conclude here they can take the back of the ballroom.
MR. HAUETER: They're ready.
CHAIRMAN HALL: They're ready to go? Okay. So just -- when we take our break here after this, we will be giving up the back portion of the ballroom, so anyone that's sitting back there has any belongings, please collect them. There should be adequate seating, looking at the crowd, on the area that we'll have left.
Mr. Newcombe, so I can put this in context in my mind, would you tell me exactly what an SDR is? It's a service --
THE WITNESS: Service difficulty report.
CHAIRMAN HALL: And that's referenced

somewhere. But in as much layman's language as you can, could you tell me what that report is that comes to you from the airline through Oklahoma City?

THE WITNESS: What it does it it's an occurrence of a malfunction of something that has to be reported by the airline to the principal inspector. And normally it's a flight interruption or a damage or something to a primary flight control or whatever.

CHAIRMAN HALL: And in almost all cases or all cases a component would be involved and that would be pulled for examination and a report made on it or not?

THE WITNESS: If it's in a component -- well, normally -- usually it's a component of some kind. Like I say, it can range from an aircraft seat, a reading light, to a flap.

CHAIRMAN HALL: So you would get an airplane seat reading light component report as one of those 25, as well as maybe something involving the flight control system?

THE WITNESS: Flight control system or
emergency light. Yes.

CHAIRMAN HALL: Things of that nature. Now,
that information then comes to you. And on the 737,
how long has that service difficulty report system been
in place?

THE WITNESS: Ever since I've been in the
agency, so I'm not sure.

CHAIRMAN HALL: So on the 737, you have
information going back to 1967 essentially?

Is that when, John, it started?

When it started in '67 with certification and
went into service shortly thereafter, do you have the
information back to '67?

THE WITNESS: I'm not sure how long the
information is maintained at Oklahoma City. I know
after a certain period of time it's put in the archives
which is still available if we need to go back. But
I'm not sure just exactly. I've never had to go back
to '67 or whatever to get information like that.

CHAIRMAN HALL: Well, how long have you been in this specific -- in the position that you presently hold?

THE WITNESS: I've been with the Aircraft Evaluation Group since 1987. I was in the Standards staff originally and then I moved down to the Aircraft Evaluation Group and took over responsibility for the 737. So I've had the 737 for two years.

CHAIRMAN HALL: For two years?

THE WITNESS: Yes.

CHAIRMAN HALL: And who had it previous to that?

THE WITNESS: Mr. Fred Duval.

CHAIRMAN HALL: Is he still with the organization?

THE WITNESS: Yes, he is.

CHAIRMAN HALL: And still in he office?

THE WITNESS: He's still in the office. He would have normally kept this airplane, however, with the development of the 600, 700 and 800, and him being close to retirement age, they wanted somebody to be put into that position who would be able to continue the full process.

CHAIRMAN HALL: Well, in reviewing all these service difficulty reports over a two year period of time is there anything that we have not done in this investigation that you would recommend we do?

THE WITNESS: No. I think everything's been done.

CHAIRMAN HALL: Nothing that's come to your attention that you think needs further examination?

THE WITNESS: Not as far as maintenance practices, no.

CHAIRMAN HALL: Again, I guess there were 53 items, is that correct -- incidents, that are -- events. What's the proper terminology here? Events, flight events, that are listed here. And I counted just roughly about 17 of them occurred outside the United States airspace.

Are you aware of a1117 and have you -- would you have information on those to follow up on what Mr. Schleede had asked?

THE WITNESS: I'm not aware of all 17 that happened outside the United States. Only the ones that we get within U.S. certificated operators.

CHAIRMAN HALL: Do you think it would be important to you in performing your responsibilities for the FAA and the American public if this information, since many of these aircraft operate internationally, that this information was somehow maintained and brought together?

THE WITNESS: I do. And we're in the process right now. We have mailed out the CDR report to all of the principal inspectors. We're now going to the international field offices with a copy. And also, we're getting a listing of all of the foreign regulatory authorities so we can give them a copy so that they can go in and evaluate the information contained in the CDR report.

And we also are in the process of developing a flight standards information bulletin for airworthiness which is normally controlled out of AFS 300 in Washington that will be going to pretty much all of the people I just mentioned. That will be requesting certain information and giving them certain information of this nature.

CHAIRMAN HALL: You also do the ATR series of airplanes?

THE WITNESS: Yes, I do.

CHAIRMAN HALL: I guess my last question. Do you have on any of these incidents, does flight data recorder information come to you?

THE WITNESS: There's been a couple that the principal inspector has provided. However, myself, I didn't have the expertise to read it and know what was in it, so I had to get with the appropriate people to find out just what it all actually meant and what occurred at certain points in time and everything.

CHAIRMAN HALL: Well, Mr. Newcombe, we certainly appreciate your testimony and your being here. And unless here are other questions, you will be excused.

(Witness excused.)

CHAIRMAN HALL: We will take a 15 minute break and come back promptly for the next witness at -- well, we'll make it an 18 minute break -- at 10 minutes to the hour.

We'll stand in recess.

(Whereupon, a recess was taken.)

CHAIRMAN HALL: We will reconvene this Board of Inquiry and to a smaller setting. It's nice to see the audience up closer. We might have to try this at my church.

So, the next witness we will call is Mr. Richard Kullberg. Mr. Kullberg, if you could please come forward.

Mr. Kullberg is the Designated Engineering Representative for the Boeing 737 Hydraulics/Flight Control Engineer with the Boeing Commercial Airplane Group in Seattle, Washington.

(Witness testimony continues on the next page.)

RICHARD KULLBERG, DESIGNATED ENGINEERING
REPRESENTATIVE, B-737 HYDRAULICS/FLIGHT CONTROL
ENGINEER,BOEING COMMERCIAL AIRPLANE GROUP,
SEATTLE, WASHINGTON

Whereupon,

RICHARD KULLBERG,

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. SCHLEEDE: Mr. Kullberg, please give us your full name and business address?

THE WITNESS: Richard Kullberg, the Boeing Company, Seattle, Washington.

MR. SCHLEEDE: And your position at Boeing?

THE WITNESS: I'm a Senior Principal Engineer working on the analysis, certification and testing of the 737, 757 flight control systems.

MR. SCHLEEDE: And how long have you worked at Boeing?

THE WITNESS: Approximately 30 years.

MR. SCHLEEDE: Would you briefly describe your education and background that brings you to your present position?

THE WITNESS: I've a bachelor's degree from the University of Minnesota and worked numerous flight control type areas with the Boeing Company, starting with 747 and SST and on through the 700. I'm also, for approximately the last year and a half, I've also worked the 737.

MR. SCHLEEDE: And you're listed on our list as a designated engineering representative or DER. Could you briefly describe what your duties are or what a DER is and what your duties are as a DER?

THE WITNESS: The primary duty is to find compliance with the FAR's, to review design changes, verify that they meet the FAR's, production changes, service bulletins. Also, to prove certification data.

MR. SCHLEEDE: And who gives you that designation, the FAA?

THE WITNESS: Correct.
MR. SCHLEEDE: And so when you're working in that function, are you working on behalf of the FAA?
THE WITNESS: That's correct.
MR. SCHLEEDE: Okay. Thank you.
Mr. Phillips will continue.
MR. PHILLIPS: Good afternoon. A little follow-up to Mr. Schleede's question about the DER responsibilities.
What would you be required to do as a DER? Do you sign engineering drawings and specifications or do you advise as to design guidelines? What would be a typical duty of a DER?
THE WITNESS: I don't sign detailed drawings. I sign the top drawing which is part of the certification process for each individual airplane. When I do that, I'm basically making a finding that airplane, as far as the flight control systems go, meet the FAR requirements.
MR. PHILLIPS: Does every drawing have to

meet your approval? Does it have to be signed by you?

THE WITNESS: Not every drawing. The top -- the drawing tree system feeds into the top drawing, so in essence, by signing a top drawing I'm approving the drawings underneath it for my area.

MR. PHILLIPS: Is the top drawing an installation drawing, an assembly drawing, a detailed drawing?

THE WITNESS: It's one single drawing that pulls everything together for the whole airplane.

MR. PHILLIPS: Okay.

THE WITNESS: But also, other than that, I would approve by qualification testing, any type of certification, a function that requires FAA approval. And I would make -- either approve it or recommend approval to the FAA.

MR. PHILLIPS: And in doing this job for the FAA while you're an employee at Boeing, do you share any other management or -- any other management responsibilities for any other areas? For instance, you said you were involved with the 757 program. Do you still work in that program as a DER right now?

THE WITNESS: That's correct.

MR. PHILLIPS: And the reason behind the 757 is because that's a natural grouping for the Renton Division manufacturing?

THE WITNESS: Yes.

MR. PHILLIPS: Along those lines, we've gotten noted for your testimony today some discussions of the 737 rudder system design. We've had extensive testimony in the proceeding hearing by several people on the detail design. I'd like to very generally touch on that this afternoon.

And to start off, I'd like to ask what are the primary differences between the 737 and 757 designs with relationship to specifically the directional control system?

THE WITNESS: The principal difference is in the surface actuation system. 757 was -- 757/767 were the first airplanes to eliminate mass balance weights from the rudder control surface. As part of this, what allows this elimination is the actuators on the surface provide stiffness, which provide damping, and therefore take the place of the mass balance weights.

The '37 airplane surface is mass balanced so that to begin with, the '57 started with this multiple actuator configuration to get the redundancy for flutter suppression. The individual actuators on the '57 are all single load path valve jam protection. Instead of being provided by dual valve, it's provided by the multiple actuators.

If we were to have say a valve jam on a 757, there would be some back driving of the rudder surface until the field system broke out some shear outs and allowed the other two to overcome it.

MR. PHILLIPS: How many actuators are there on the 757 driving the rudder?

THE WITNESS: There's three.

MR. PHILLIPS: Three.

THE WITNESS: With three full-time hydraulic systems. The 737 has one dualized actuator and it's a tandem actuator so it has two hydraulic systems sparring it. And then the standby actuator is just that. It does not operate until you've had a failure of a hydraulic system.

MR. PHILLIPS: Or commanded by the pilot at his option? You don't have to have a failure to activate the standby, do you?

THE WITNESS: No. You need to have a failure. Procedurally, you would not turn on the standby until you've had one failure.

MR. PHILLIPS: In the 767, is it similar to the 757 in design with three actuators?

THE WITNESS: Nearly identical. Yes. As far as the architecture.

MR. PHILLIPS: How about the 777?

THE WITNESS: That's also three parallel actuators. The difference is it's fly by wire.

MR. PHILLIPS: And by fly by wire, you mean that the signals to the actuator are electrically

commanded?
THE WITNESS: Electrically commanded. Correct.
MR. PHILLIPS: The surfaces on the 73-5-6 and triple 7 are all single surface rudders; am I correct?
THE WITNESS: Correct.
MR. PHILLIPS: There's no balance tabs? And you mentioned that there was mass balance on the 737 but not on the 75. Is that same carried through to the 67 and triple 7?
THE WITNESS: That's correct. Yes.
MR. PHILLIPS: And you mentioned flutter suppression as part of the design criteria for using multiple packages. Is that an active flutter suppression system? Does it respond to some dynamic input?
What drives the flutter suppression system on those airplanes?
THE WITNESS: It's basically the stiffness and damping of the actuator, so it's a passive damping

system.

MR. PHILLIPS: So it isn't actively driven for flutter purposes. It's these as a mass balance in its body itself?

THE WITNESS: Right. If you maintain enough stiffness in the actuators, you don't get flutter.

MR. PHILLIPS: Let's drop back one digit there on the 727. That rudder has a different design concept, too. Could you tell me a little bit about it?

THE WITNESS: The 727 has split rudders. Each rudder is powered by a single actuator. One of the rudders has a standby actuator but essentially identical to the '37 standby actuator.

MR. PHILLIPS: And the 747, I think one we've left out?

THE WITNESS: It's got split rudders It has dual tandem actuator on each rudder. '47 is a little bit unique in that it has four hydraulic systems.

MR. PHILLIPS: So we've got two airplanes, the '27 and '47 have split rudders, and then the rest of the Boeing -- the current manufactured series airplanes have single panel rudders?

THE WITNESS: Right. And also the 707.

MR. PHILLIPS: 707?

THE WITNESS: Single panel.

MR. PHILLIPS: And that's a single panel? And how many actuators?

THE WITNESS: It's got one dual tandem actuator and it also has manual reversion capability.

MR. PHILLIPS: Is that dual tandem actuator in the 707 or was it similar to the 737 design?

THE WITNESS: I'm not sure what the similarities are. Architecturally it's very similar. It's got a yaw damper that's integral to the actuator. It's got dual concentric valve, dual load path linkage.

MR. PHILLIPS: In the yaw damper sections of the airplanes we've discussed, we heard earlier Mr. Koch describe an integrated package where the yaw damper was a component of the PCU. Do your other aircraft designs integrate the yaw damper into a component package such as the rudder PCU?

THE WITNESS: The '27, '07, '37, '47 have integrated actuators. '57, '67 the actuators are separated. Partly because you have -- '57, '67 has two yaw dampers that have to drive three main actuators, so integrating them would be -- well, you couldn't integrate them for that situation.

MR. PHILLIPS: In the description of the series of the rudder actuators and the rudder surface configurations, does the 737 stand out in your mind as being different than the others for a Boeing design?

THE WITNESS: Philosophically, it's very similar. It's completely dual load path from the aft quadrant through the whole actuation system, so it's designed to be fault tolerant as far as any single disconnect, for example, would have no affect on the pilot control of the rudder. And that's pretty much -- however you implement it, that's the philosophy.

MR. PHILLIPS: And what drove the design to a dual load path single unit versus a multiple configuration?

THE WITNESS: Well, at the time of the 737 design, that I think was the most common practice. There was -- we really first started looking at multiple actuators on the SST because of mass balance removal and there were a lot of concerns about synchronizing multiple actuators if they have a large force bite or if you have failure modes, for instance, where one actuator doesn't want to track the others, you can get into problems. So it took quite a while to actually develop this parallel actuation system.

MR. PHILLIPS: Speaking of failure modes, what could you describe as a failure mode which would cause an uncommanded rudder deflection? What conditions would have to be set up to have that?

Without a pilot input, what would have to happen to get a rudder deflect to its limit in the 737?

THE WITNESS: Well, fundamentally, you'd need a control valve that would be open that could not be closed. I've talked about dual valve jams. There are linkage jams that you could hypothesize if you leave the valve open.

MR. PHILLIPS: And linkage jams, would those be external to the unit or internal or --

THE WITNESS: In the feedback linkage itself. And that was covered by the CDR team and we've done a -- submitted a very extensive failure analysis looking at all these types of failures and looking at whether or not they're reasonable failures. That's all been submitted to the FAA now.

MR. PHILLIPS: Okay. Let's talk a little bit about the CDR. Were you involved in the -- while the CDR was in work, while the group was formed, were you involved in any meetings with that team to educate them or describe the systems to them?

THE WITNESS: Right. We went over the descriptions of the systems with them to familiarize them with the systems. We went over the failure analysis with them, provided technical data to them.

MR. PHILLIPS: Did the team provide you a list of requirements for data that they wanted to look at or did you just offer up what you thought they needed for the review?

THE WITNESS: A little bit of both, but in real life the needs of the CDR team, as you would expect, comes really as a part of the discussion. A subject comes up, triggers something and then they ask for data.

MR. PHILLIPS: And in that data, you provided a failure analysis, I would assume, of the rudder system that we discussed this morning.

Were you involved in that formulation of that failure analysis back when it was originally done in the '6Os?

THE WITNESS: No, I wasn't.

MR. PHILLIPS: Have you been involved in any failure analysis from the '57 or any of the newer aircraft?

THE WITNESS: Yes. I was involved with --

quite heavily with the failure analysis of the '57.
MR. PHILLIPS: Does the '57 -- is it certified to the newer standard, post-amendment 23 to Part 25 that requires in I believe it's 25 -- well, in the newer certification standard where we consider the probability of failure extremely improbable, is the '57 certified for those standards?
THE WITNESS: Yes, it is.
MR. PHILLIPS: And is that because of the date that it was originally certified?
THE WITNESS: Right. That requirement would start as a special condition on the 747 and was formally incorporated into the FAR sometime after that.
MR. PHILLIPS: And I would assume the '67 and triple 7 all have met the newer standard?
THE WITNESS: That's correct.
MR. PHILLIPS: In your -- go ahead.
THE WITNESS: I was just going to make a comment that the CDR team, in my opinion, conducted their design review looking at those requirements, the

latest requirements.

MR. PHILLIPS: Their original charter asked them to look at the airplane independent of the certification basis. Is that correct?

THE WITNESS: Right.

MR. PHILLIPS: And in doing that, they didn't need to consider whether it was extremely improbable or -- that wasn't a factor in their evaluations?

THE WITNESS: No. It was a factor.

MR. PHILLIPS: It was a factor?

THE WITNESS: Whether or not something is extremely improbable? Yes, that was a factor. And a factor in our submittal to the FAA, the recent submittal that's been mentioned here.

MR. PHILLIPS: That submittal that you've mentioned, is that a response to the recommendations from the CDR?

THE WITNESS: The CDR recommendations, as far as the design areas, which is the only thing I'm really talking about here, went to the Seattle Certification

Office. They then asked us to provide analysis and data to allow them to make a judgment on the systems.

MR. PHILLIPS: So the Seattle Certification Office to respond to the recommendations needed an input from you?

THE WITNESS: Correct.

MR. PHILLIPS: And what form did -- what was done to provide that input to the CDR or to the ACO?

THE WITNESS: Well, we basically responded to 15 of the recommendations that dealt with design areas. Part of that was we conducted pilot simulations. We did failure analysis work. We constructed fault tree analysis that you heard mentioned, latent failures. The way that we -- in today's certification atmosphere, the way we address those is through fault trees, so we provided fault trees for all the latent failures.

The fault trees are designed to show how these latent failures enter into the probability of a critical flight condition or critical failure condition.

MR. PHILLIPS: Had you ever done any of this type of analysis prior to your CDR requirements?

MR. PHILLIPS: Not for the basic flight control systems. I think it's been mentioned we did it for the autopilot because we made some autopilot changes. We did it for some of the other systems that were changed but we did not do it for the systems in general.

MR. PHILLIPS: The response that you provided to the FAA, is that a discussion item now that's open for the FAA to come back and ask for further clarification or more work to be done?

THE WITNESS: That's correct. Yes.

MR. PHILLIPS: Have they done that at this point?

THE WITNESS: No, they haven't.

MR. PHILLIPS: Were you involved in any flight testing to provide this analysis back to the FAA?

THE WITNESS: No. We didn't do flight

testing. It was -- the testing that we did was simulations, simulators.

MR. PHILLIPS: Aircraft simulators? Did you put any components on the test bench and do any systems testing?

THE WITNESS: No, we didn't.

MR. PHILLIPS: Is part of that response to consider the areas of contamination or silting or jamming of the servo control valve?

THE WITNESS: Could you repeat that?

MR. PHILLIPS: Was part of the response, did any of the response to the recommendations involve discussions involving jamming or silting of the main rudder control valve?

THE WITNESS: Silting, no. Jamming, I guess not directly. The NTSB testing that we were talking about earlier is kind of the -- you might say the definitive thing as far as the effects of -- or what it takes to jam a valve.

MR. PHILLIPS: That would be the chip shear testing we talked about earlier?

THE WITNESS: Correct.

MR. PHILLIPS: And you said silting -- not silting.

THE WITNESS: I think silting is something that's been brought up relatively recently. It's gotten a lot of attention recently. The CDR, I think, was really pretty much done by the time silting became an issue.

MR. PHILLIPS: Okay. So it wouldn't have been expected that that would have been part of the response for your CDR report?

THE WITNESS: Right.

MR. PHILLIPS: While we're on the subject of silting, did the definition we heard this morning agree with your definition of what silting is? Do you have a different viewpoint?

THE WITNESS: I don't disagree with what was said. I do have a -- I'm prepared to make a little more detailed explanation, if anyone's interested.

MR. PHILLIPS: I certainly would like to hear that and spend a little time talking about that.

THE WITNESS: It's number 6.

MR. PHILLIPS: Were's looking for what? Page 6 of 9X-K?

THE WITNESS: Right.

CHAIRMAN HALL: Can everybody see?

Mr. Benson, or somebody that can handle the magic of the lights being dimmed.

You can pull that microphone out.

THE WITNESS: Okay. This figure is designed to show the relative size of the underlap of the primary control valve on the '37 rudder and give you an idea of what's going on.

The particles that are shown are typical of the maximum particle size that would be able to get through the filter. There's a filter, 10 micron nominal filter on the inlet to the PCU. The maximum particle size getting through is on the order of 25 microns. So those would be indicative then of particles that would be coming through.

This distance here is what we refer to as the underlap in the control valve. It's about a maximum of about 22 thousandths on the '37 rudder. The '37 rudder itself is really not very susceptible to silting. As you can see, the particles are bigger than the opening and would typically just flow through the opening.

Some of the other Boeing valvesyou could take the '57 as an example, are underlapped on that. The actuator is only about 10 percent of what it is on the '37 and the filters themselves on the '57 are about four times more coarse. On the '57, I know the testing I was involved with on the original development of the actuators, we started out with the net lap and you could definitely see the effects of silting on that.

And the effect of silting was basically you plug up that opening. If you were to observe the return flow from the actuator, you'd see it slowly dry up. The problem we ran into on the '57 was simply that the positional accuracy was affected slightly by the silting. Never saw anything that would indicate high friction forces.

The '57/'67 airplanes are designed such that if you do get a partial valve jam or excessive friction in the valve, you would get some surface motion. The way it's designed, the field systems would eventually stop the surface motion but in my experience I've never heard anything -- of any problems on these airplanes of any surface motion that would be associated with silting.

I can finish my explanation on the next slide, Number 7.

MR. PHILLIPS: Dick, before you go on to that, could you give us a brief description of the differences between an underlap and an overlap? What is that?

THE WITNESS: The next slide actually I think I can illustrate it better.

This schematic shows what -- it's an exaggerated amount of underlap but this is underlap there and there. Maybe I should go through the actuator first.

The hydraulic flow would come in through this port. It then would with the valve at neutral, the flow would be into the cylinder port, back out through return on one side. The same thing on the other side.

If you commanded the actuator, you'd move the valve. You would move the valve this way. You can see that you open up pressure to this side, which then would flow into the cylinder, causing the actuator to extend. The feedback would come along, and it would close the valve again.

If you had a net lap, this would be no space there at all. If there were an overlap, it would be -- the valve spool would extend past this edge.

One thing that's been hypothesized with silting is that you could silt up say this side. If that were to silt up, then the pressure would no longer be able to act on the cylinder. The cylinder would still be open to return, so its pressure would drop.

The actuator would then move -- in this case, extend. The feedback would come along and start to close off this. And normally you would expect the silt, as the valve moved the silt, to pass on through it. But if that didn't happen, the valve couldn't move until it's just touched that edge.

Once that's happened, then there's no further motion of the actuator. Both pressure ports are cut off. The cylinder pressure bleeds back to return, which is no differential pressure. Then both C-l and C-2 would be at 50 psi, which is the return pressure nominal.

So, I've just kind of concocted the worst case situation where the maximum actuator motion would be such as to just close the valve on this side. That would, on the '37 rudder, it would be the 25 thousandths that I mentioned. Excuse me. Twenty-two ten thousandths. And that equates to roughly about .05 degrees of surface motion.

So you could get -- in theory, you could get some surface motion but it would be extremely small.

Other questions, or --

MR. PHILLIPS: Well, I want to follow along the line here a little bit.

So is silting -- is silting only problem at near neutral condition or position in the valve?

THE WITNESS: If the valve is open, it literally -- the opening is too big to silt. It just rushes right through.

MR. PHILLIPS: Okay. So we would only be concerned about silting in periods where the valve stayed fairly near neutral or the underlap condition or the clearance between the two lands would be --

THE WITNESS: Right. You'd have to get particles that literally won't fit through the valve orifice.

MR. PHILLIPS: As soon as the orifice is made larger, the particles flow through; correct?

THE WITNESS: That's correct. After they've built up a bit, you might have to make it -- the orifice might have to open up more than the individual particles, but it doesn't have to open a great deal and it will just go right through.

MR. PHILLIPS: So any movement of the valve off of that neutral and null position would tend to clear the valve?

THE WITNESS: That's correct. And that's -- 1 believe some of the theories would involve the valve says perfect stationary. In that case, the silt can built up. But once you have block off the ports, there's no longer any flow and the silt stops building up.

MR. PHILLIPS: Is this based on your theoretical knowledge or your experience or have you actually seen tests to validate this?

THE WITNESS: My experience with the development of the 757, both rudder and elevator PCU's to me validates it. As I said, initially we had more hysteresis than we wanted.

You know, you're talking here a tenth of a degree or .05 degrees of surface motion as far as the hysteresis. After a bunch of testing, we determined that it was silting and we opened up the underlap to ensure that we had a positive underlap and problems went away.

MR. PHILLIPS: By hysteresis, you mean the ability of the surface to return to the original position?

THE WITNESS: Correct.

MR. PHILLIPS: Is there a test -- specifically now to the 737 PCU, is there a functional test that would indicate the presence of silting in an operational sense? Could a pilot or mechanic tell whether he had an installed PCU that was being affected by silting?

THE WITNESS: The pilot would never -- no. Any effects would be much too small to detect.

MR. PHILLIPS: Would you have any estimate as to the level of force that we would see increase as a result of silting if it was possible?

THE WITNESS: I've never seen an force increase. I really can't comment on that.

MR. PHILLIPS: We had some discussion this morning about --

THE WITNESS: The vendor --

MR. PHILLIPS: Go ahead.

THE WITNESS: I was just going to say the vendors, I think Parker is going to be on later. They might have more experience on that.

MR. PHILLIPS: Are there any tests that could be done? We talked about that this morning, but testing we could attempt to measure the forces resulting from silting?

THE WITNESS: I would think that a test of the type that Werner Koch brought would -- it seems reasonable to me. I'm not -- you know, I can't think of anything beyond that.

MR. PHILLIPS: Do you have any plans or do you know of any plans to do a test like that at Boeing?

THE WITNESS: No. We don't at Boeing. No.

MR. PHILLIPS: Have you ever done a test like that for the '67 or '57?

THE WITNESS: No, not specifically to look at silting.

MR. PHILLIPS: Have you ever done chip shear tests for your valves?

THE WITNESS: Not in the time that I've been at Boeing, other than the NTSB test.

MR. PHILLIPS: There's been a recent 747 chip shear test, hasn't there? Are you aware of that? Since the accident investigation activity?

THE WITNESS: Not vaguely aware.

MR. PHILLIPS: Yes. That's about the limit of my knowledge, too.

CHAIRMAN HALL: Just so I understand, that's not on the fault tree, then. Is that correct?

THE WITNESS: The --

CHAIRMAN HALL: The chip shear test or the silting?

THE WITNESS: No.

MR. PHILLIPS: Along those lines, in your
hazard assessment, are you aware that -- well,
certainly jamming was a consideration but have you ever
considered the effects of silting in your failure
analysis?

THE WITNESS: No, we haven't.

MR. PHILLIPS: So it's safe to say that
silting is a fairly recent thing that's came into
discussion in this investigation and also it's fairly
recent to your experiences at Boeing?

THE WITNESS: That's correct. I mean, we've
never seen any problems associated with silting on any
of our airplanes, so no, we haven't done anything.

MR. PHILLIPS: On the disassembly of a part
that's had some silting, would you expect to see any
erosion in the lands or marking or anything that would
indicate the valve had been operated in silting
conditions?

THE WITNESS: Not at normal contaminant
levels. When we did our Boeing contamination test, in

there we had massive amounts of particulates and there we did see a lot of erosion. But again, you might want to ask that question of Parker or someone that regularly would inspect valves.

MR. PHILLIPS: Right. Along the lines of that contamination test, would you expect that a test like that with a very high level of contaminants, would that represent silting condition or much worse than silting?

THE WITNESS: Well, as far as the effects on valve friction, I'd say it's much worse than silting. I'm sure it's much worse than silting.

MR. PHILLIPS: So you believe the larger particulates would increase the forces faster than the small particles -- than a bunch of small particles?

THE WITNESS: Only on the basis that in my experience we haven't yet.

CHAIRMAN HALL: What is worse than silting? I'm sorry.

MR. PHILLIPS: The original question was

about contamination tests that Boeing ran at the end of the year last year where they took a PCU and ran high levels of contaminants through. The question was would big particles, a bunch of big particles be worse than a bunch of little particles.

CHAIRMAN HALL: And that's worse than silting? I apologize, again. When this fan's going, it's very difficult to hear up here.

THE WITNESS: As I was about to say, I would say the answer is yes, only because in my experience I haven't seen any high friction forces or anything due to silting other than just the direct effect that I was referring to on hysteresis.

MR. PHILLIPS: Were you involved in that contamination test last year in setting up the test or witnessing it?

THE WITNESS: Yes. I was involved in setting up the requirements for the test.

MR. PHILLIPS: Did you believe that was a representative test to provide valid data for understanding the effects of contaminants in the PCU?

THE WITNESS: Well, it was purposely made much, much worse than anything in service, so in the sense that it was an absolute worst case, yes.

MR. PHILLIPS: And you took the filters out of the PCU so you could purposely get more large particles in than you normally would expect?

THE WITNESS: Right. I think it was on the order of about 50 times what we would expect to be worst case.

MR. PHILLIPS: Would you have expected the results to have been any different if you used a smaller particulate over a longer period of time? I guess I'm asking you to extrapolate data here, but --

THE WITNESS: Well, what we used was a wide variety of sizes. I mean, we purposely selected the sizes to be the full range of what's possible.

MR. PHILLIPS: And when you cycled the spools in the servo valve, did you have a program or a method of how those spools were cycled; rate or distance?

THE WITNESS: Say that again?

MR. PHILLIPS: During the testing when you moved the servo valve spools, did you have a purpose or a plan that set a rate or a positional travel requirement on moving the spools during the test? Did you hold them fixed at near null for a period of time, then opened them a little bit and hold them, to duplicate a flight profile or a nominal surface profile?

THE WITNESS: Well, no. They were pretty much cycled continuously. At the time we set up the test, it was before this latest theory, so we were really trying to duplicate the yaw damper motion.

MR. PHILLIPS: Do we understand the yaw damper moves these valves frequently?

THE WITNESS: Almost continuously in flight. On the ground there is no yaw damper input, so no input of any kind. So that when an airplane is sitting on the ground, the valve would be sitting at null for a long period. Well, as long as the hydraulic systems are pressurized, which would vary quite a bit. It might be a few minutes. It might be an extended period of time. And then the pilot would do his controls check.

So for that situation, we do have a case of the valve sitting basically still and then the pilot given an opportunity to see if anything is abnormal at that point. That's just -- every flight has this situation to some extent.

MR. PHILLIPS: Have you looked at the data that indicates the health of the 737 fleet flight control system recently? Are you familiar with yaw damper events and roll events we've talked about previously today?

THE WITNESS: Not intimately familiar. The yaw damper and autopilot are not part of the area that I cover. I am ware of the events but only from a somewhat peripheral standpoint.

MR. PHILLIPS: Well, my next question is that in this list of events that -- you've had several different numbers subject to interpretation, but do you believe we could be seeing the effects of silting or contaminants in any of these events? Have we researched them far enough to even make a statement along those lines?

THE WITNESS: I don't think that we are, but I don't know of any conditions where that would be the most logical explanation.

MR. PHILLIPS: Could we have characterized the failure as a yaw damper coupler failure when in effect it could have been something else? If we don't find a fault with the cutout we removed, does that indicate it could be something else?

THE WITNESS: If we get FDR data and it indicates that the upset corresponds to a three degree rudder input, then to me it's the yaw damper problem. It's not a silting problem.

I don't know of any cases -- again, I haven't studied each one, but I don't know of any cases where silting would make sense.

MR. PHILLIPS: I'd like to change directions here a little bit and to go the standby rudder actuator.

Are you familiar with that component in the system?

THE WITNESS: Yes.

MR. PHILLIPS: And one of the things we've discussed today and at the last hearing also was galling, which is the transfer of material between the input bearing and the shaft.

Have you seen this galling condition? Have you seen the parts?

THE WITNESS: No. I've seen a lot of photographs.

MR. PHILLIPS: And you're aware that both the Colorado Springs and Pittsburgh aircraft had what we considered galling on those shafts?

THE WITNESS: Right.

MR. PHILLIPS: Have we had any other occurrences in service airplanes of galling that you're aware of?

THE WITNESS: I know we've had on the order of four or five specific occurrences of galling. Yes. And if you were to include very, very minor galling, then we've probably had lots of cases of very, very minor galling.

MR. PHILLIPS: What generally is the effect of this galling to the airplane?

THE WITNESS: If it becomes severe enough, generally it's picked up as a yaw damper problem. I think we've had cases where it was enough for the pilot to feel. But these four or five worst case problems I'm talking about, they've all been picked up before they've caused any upset or anything like that.

MR. PHILLIPS: Were they found on the ground then or during testing?

THE WITNESS: Well, if it affects yaw damper performance, that would be in the air. The pilot could pick it up during a controls check, also.

MR. PHILLIPS: Is there any other way to

detect galling in the standby actuator other than the control check? Is there any maintenance action that would indicate that galling may be present?

THE WITNESS: Yes. And I'm not sure what the time frame was when we did it, exactly, but right now in our maintenance manuals, if we have a yaw damper problem, that's one of the things that the airlines would be asked to check if they were following maintenance manual procedures. That wasn't always in the maintenance manuals. It's been the last couple of years that we've had that coverage.

MR. PHILLIPS: Have you considered the case of a standby rudder actuator, galled in the worst possible condition in either direction, what the result to the airplane would be as far as rudder deflection and controllability?

THE WITNESS: Well,if you were to have a complete seizure of the linkage and it occurred right when the autopilot -- or excuse me -- when the yaw damper was putting in a full three degree command, it could get about 7-l/2 degrees of rudder.

MR. PHILLIPS: Have there been any tests to validate that or is that based on analysis?

THE WITNESS: The testing that was done was done during the original certification. It's what we call iron bird testing. It's a ground type -- on ground working mock-up of the flight controls. And from that we've gotten enough data to make calculations where -- but the actual numbers, the number that I quoted, for example, is a calculated number.

MR. PHILLIPS: Have there been any iron bird tests done in recent history or does it go back to the original certification of the airplane?

THE WITNESS: It goes back to the original certification.

MR. PHILLIPS: Has there been any discussion as to the potential requirement for doing additional testing in light of the concern in this area?

THE WITNESS: Yes. We are considering doing a test of the standby actuator where we'd basically install it to where it would freeze the input lever.

MR. PHILLIPS: Is this a Boeing test?

THE WITNESS: Excuse me. That would be mainly just to validate our analysis.

MR. PHILLIPS: Is this test planned by Boeing or is it in response to investigation activities?

THE WITNESS: It's at least partly in response to the NTSB concerns.

MR. PHILLIPS: Along those lines, there was -- in the last hearing, we heard some testimony about design changes to the input bearing and opening clearances to reduce galling. Are there any new changes planned for the standby PCU in light of the fact that galling is still a concern?

THE WITNESS: Yes. We are planning on putting in a design change that would put roller bearing on the input shaft. That's what I believe was mentioned at the last hearing that we were considering that.

MR. PHILLIPS: Did this result from the CDR recommendation or was it more prior to the CDR findings or --

THE WITNESS: Well, we've been looking at it for some time. It's kind of a combination of events, I think.

MR. PHILLIPS: Do you have anything to help describe that? Do you have a chart on that, the design change?

THE WITNESS: Yes. Number 4.

CHAIRMAN HALL: Am I correct, this is in response to a CDR recommendation or not?

MR. PHILLIPS: Say again, please?

CHAIRMAN HALL: Is this change in response to the CDR team's recommendation or something Boeing --

MR. PHILLIPS: We could ask Mr. Kullberg. I think his answer was that it was in work or in discussion and it just fell in line, I guess.

THE WITNESS: It's been a concern on the part of the NTSB. It was a concern on the part of the CDR team. So all those go into making a judgment as to whether or not to make a design change.

Okay. This shows the -- this is the input shaft. This is the housing manifold of the actuator. The current configuration, this bearing and this bearing, are not there. It's basically just a bushing. And the galling that we're talking about occurs between the shaft and the bushing right here.

So all that we're doing then is to redo this piece to accommodate these bearings. This design would make it similar to what we would do on most other control surface actuators.

MR. PHILLIPS: Does the galling result from side loads on this shaft? How do we get the loads into this to create the galling?

THE WITNESS: It's mainly a lack of clearance between the shaft and the bushing. I don't know that it's necessarily a direct function of load. The problems that we've had in the past have been -- I know at least most of them have been due to very tight clearances. In some cases we found them slightly out of drawing tolerance. They were a little tighter than drawing tolerances would normally allow.

We've also -- we've made design changes in the past to open up the clearance in what we call the drive part so that the actual wear surfaces are lubricated by the fluid inside the actuator. The actuators that we have with this modification, the galling has been very, very limited but it still is there. You can still see some galling. So we're taking a final step, basically.

MR. PHILLIPS: You mentioned that you use a design similar to this in other applications. Could you tell us what those are? Other standby actuators or other --

THE WITNESS: No. I mean the use of these types of bearings to support the shaft.

MR. PHILLIPS: Okay. How do you plan to implement this change or what's the plan for implementation on the 737 fleet?

THE WITNESS: I'm not sure if that's been decided but I assume that we will -- the vendor will put out a service bulletin that would give rework instructions to make the modification.

MR. PHILLIPS: So at this stage, this is an engineering proposal that hasn't been approved?

THE WITNESS: It's been approved but the scheduling hasn't been done.

MR. PHILLIPS: Has there been any discussion at Boeing about the criticality of this change? What level of service bulletin you would recommend that it be?

THE WITNESS: It hasn't gotten that far yet.

MR. PHILLIPS: Just on the spot assessment, it would just be a mandatory or --

THE WITNESS: Well, my guess at this time, it would be a normal service bulletin.

MR. PHILLIPS: So by that, the operator would have the option of either doing it or not as he desired?

THE WITNESS: Right. We would recommend it but we don't consider it a safety of flight item.

MR. PHILLIPS: Have you had any discussions with the FAA that would indicate that they may consider this to be an airworthiness directive service bulletin?

THE WITNESS: No. I think that the FAA has indicated that they're going to consider making it mandatory but we haven't had detailed discussions with them at this point.

MR. PHILLIPS: How would you have discussions with them once the decision was made to make an AD? Would you get involved in the process of negotiating compliance dates or schedules or anything like that?

THE WITNESS: Yes.

MR. PHILLIPS: Your slide says the 300, 400, 500 airplanes. Could this also be used on the 100, 200 airplanes?

THE WITNESS: Yes.

MR. PHILLIPS: Would you expect that it would also apply to them, too?

THE WITNESS: Yes.

MR. PHILLIPS: One other question in the area of the standby, more on the function than on galling on this design change. How would the standby function if -- could the standby actuator function if both A and B systems were pressurized? Is there a failure mechanism that would allow the standby actuator to be energized?

THE WITNESS: You could have failures that would cause it to be energized. In fact, that was a failure mode that was brought up by the CDR team and we did do analysis to look at that. This is not -- if it were to pressurize with the other two, you would have a potential or you could exceed limit load, but you would exceed it only by a small margin. You still would maintain an adequate margin to ultimate load, the margin that's required for a failure.

It's been looked at fairly thoroughly.

MR. PHILLIPS: Okay. Could you describe limit load versus ultimate load? How does that apply?

THE WITNESS: I'm not a structural engineer, but fundamentally the limit load tends to be the maximum operating load and the ultimate load is usually 50 percent higher.

MR. PHILLIPS: So the effect of the standby being pressurized with both systems pressurized would cause a structural load to be imposed on the airplane?

THE WITNESS: If the pilot were to put in maximum rudder input all the way to the blow down limit, then he would not maintain the margins that you would normally have, the structural margins that you would normally have.

MR. PHILLIPS: And those margins are in the rudder structure itself or the system attachment structure?

THE WITNESS: That's out of my area.

MR. PHILLIPS: Okay. No problem.

In this failure assessment or analysis that you've done for the FAA for the CDR response, can you characterize any changes that you foresee in the airplane? Was there any significant findings that you presented to them that you can tell us about here today that lead you to believe that changes need to be made to the airplane?

THE WITNESS: We've already discussed the standby PCU. In addition to that, we are planning on looking at what can be done to improve the reliability of the yaw damper and we haven't gotten to the point yet of saying what would be redesigned, but we will do something to improve its reliability.

MR. PHILLIPS: Do you see that reliability issue as a safety of flight issue?

THE WITNESS: For the yaw damper? No. It's I think discussed that the yaw damper is limited to three degrees and we talked earlier about this program to look for something that's more than three degrees. But where we have had incidents and we have been able to get flight data recorders, I don't think there's any case where it would look like a yaw damper has gone beyond three degrees.

MR. PHILLIPS: Are you aware of any plans by Boeing to significantly redesign the rudder system main power control unit or standby unit, other than what you've described?

THE WITNESS: No.

MR. PHILLIPS: Is there any activity at Boeing to do any additional failure analysis or hazard assessment work as follow-up to the things you've already provided? Any new areas of exploration or concern?

THE WITNESS: None that I -- no. There may be things that come up as we have our discussions with the FAA. They may want more data or testing.

MR. PHILLIPS: I think that's all I have for now. If you have any comments you'd like to add, I'd certainly give you the opportunity.

THE WITNESS: No.

MR. PHILLIPS: Okay. Thank you.

CHAIRMAN HALL: Other questions from the Technical Panel?

(No response.)

If not, we'll move to the parties. Would any of the parties have questions for this witness?

I see the hands of the Boeing Airline Group, the Air Line Pilots Association, USAir, the FAA.

Mr. Donner?

MR. DONNER: I haven't even read the questions.

Mr. Kullberg, do you agree with Mr. Koch that an active yaw damper would reduce the probability for silting?

THE WITNESS: Yes. The valve as it moves is self-cleansing.

MR. DONNER: Did you hear Ms. Evans' testimony this morning?

THE WITNESS: Yes.

MR. DONNER: Based upon the yaw damper activity shown by Ms. Evans, would you care to comment on the effect of this activity on silting?

THE WITNESS: On silting?

MR. DONNER: Yes. On the activity that she showed for the yaw damper?

THE WITNESS: I wouldn't expect to have silting. But then, again, like I mentioned with the amount of underlap and the filters that we have on the actuator, I really wouldn't expect much of an effect on silting under any circumstances.

MR. DONNER: Thank you very much.

CHAIRMAN HALL: USAir? General?

GENERAL ARMSTRONG: Thank you, sir.

If you would, please refer to Exhibit 9X-A, page 21 in the references, the top of the page, "Single Failures - Rudder." The second sentence says: Failures suggest there are a number of ways where loss of rudder control and potential for a sustained rudder hardover may occur.

Do you concur with that?

THE WITNESS: Yes.

GENERAL ARMSTRONG: And this is in the Critical Design Review report?

THE WITNESS: Yes. By a number of ways it certain is. It's a very limited number of ways but a number.

GENERAL ARMSTRONG: Butit is possible. Okay. Thank you.

CHAIRMAN HALL: The Air Line Pilots Association. Captain?

MR. LeGROW: Thank you, Mr. Chairman.

Good afternoon, Mr. Kullberg. I just have one question.

In Mr. Phillips' questioning he talked about a severely galled standby actuator. And it's my understanding that your answer or your statement was that the yaw damper would then give you seven or 7-l/2 degrees authority?

THE WITNESS: That's correct. The scenario would be basically that the yaw damper has gone full over all the way to the full three degrees. It then jams the yaw damper then comes back to zero. For that situation with an absolutely hard jam, that you would get about 7-l/2 degrees of rudder offset. So that's a very severe situation.

MR. LeGROW: So the yaw damper would have to be jammed also?

THE WITNESS: No, no. The situation is that the yaw damper, for whatever reason, has but in a full command. So there's extreme turbulence. It's gone all the way to it's limit. That particular moment in time you were to then suddenly lock up the standby actuator, so it's rigidly attached at that point to the manifold, a hard jam. At that point, nothing has happened except the three degree of yaw damper.

Now if you were then to take the yaw damper command, bring it back to zero, that would result in about a 7-l/2 offset.

MR. LeGROW: Okay. I understand now. Thank you.

Thank you, Mr. Chairman.

CHAIRMAN HALL: Mr. Purvis, Boeing Commercial Airplane Group.

MR. PURVIS: Thank you.

First, I want to go back to his -- without using the viewfoils. He was turned this way while he was describing certain things and I'm not sure it got through to this direction to the audience.

First of all, talking about underlap and overlap, in particular, the underlap condition, can you equate that to a gap or something simple like that in the opening on the sides?

Let's say an underlap. Can that be equated to a gap?

THE WITNESS: If you have underlap, then the primary spool land is narrower than the orifice that it's covering up so that there's a gap on either side of the land.

MR. PURVIS: With the valve in neutral?

THE WITNESS: With the valve in neutral. Correct. Yes.

MR. PURVIS: In your opinion, is silting like to occur on a 737? And if not, can you explain what would keep it from happening? I think you've done a little bit of that previously.

THE WITNESS: Yes. The fluid coming into the PCU is filtered. It's filtered down to say 25 micron type of particle. The gap in the valve is several times bigger than that, so it would be very difficult for it to silt.

MR. PURVIS: And can you explain again the effect of the yaw damper action on that, on silting?

THE WITNESS: Well, the motion of the control valve from the pilot or the yaw damper tends to clear any silt that would accumulate momentarily. So that that's why Werner Koch, for instance said, well, let's run a test with no input to the valve.

I agree with him. That would be more severe for silting. But as long as the airplane is flying, the yaw damper, unless it were switched off, would be putting an input into the valve.

MR. PURVIS: Once again, you were facing the screen when you were describing that. If in some hypothetical case silting did occur, how much -- in the worst case scenario, how much surface rudder motion would you actually get until it flushed or it cleared?

THE WITNESS: It would be on the order of .05 degrees. Basically, it should be minuscule.

MR. PURVIS: .05?

THE WITNESS: A tiny, tiny amount. Yes.

MR. PURVIS: So that's what? A tenth of a half a degree; right?

Going back to the exhibit that -- I think it's 9X-A, 21. Is that the pages that was referred to just previously? Do you have that open again?

THE WITNESS: Yes.

MR. PURVIS: And the failures, the sentence that was quoted, the failures suggest there are a number of ways where loss of rudder control and potential for sustained --

THE WITNESS: Yes. Can I make a comment?

MR. PURVIS: Yes.

THE WITNESS: Because in re-reading this, the term failures, I think the CDR team here was referring to jams. Sometimes you think of failures as only being disconnects. An example of what they were talking about, if you were to look into the report, is say you were to get a cable jam and a cable jam were to occur at a full pilot input. That would result in a sustained rudder hardover and that's where we really don't think it's reasonable to have a jam, combined with a rudder deflection that really would only occur if you had some type of emergency situation.

We saw in the -- read at the very beginning the histograms of rudder deflection and my recollection is that rudder deflections were less than five degrees out of 134 flights.

MR. PURVIS: Are these -- in doing a FMEA or something, would these be considered highly improbable events?

THE WITNESS: A jam combined with a large rudder input would definitely be considered extremely improbable.

MR. PURVIS: On galling, did you say you had seen photographs from the USAir 427 event on the galling from the standby unit?

THE WITNESS: Yes, I have.

MR. PURVIS: Would you characterize the amount of galling as -- I'll let you say.

THE WITNESS: It was quite severe. Excuse me. You said the United Airlines?

MR. PURVIS: No. USAir 427.

THE WITNESS: Oh, excuse me. I was -- excuse me. I was talking about the United Airlines case. The USAir one, the ones I've seen, galling was quite minor.

MR. PURVIS: And on the United one, do you want to talk about that one, too?

THE WITNESS: Well, I wasn't working in this area at the time but the reports I've read is that the galling was relatively severe on that airplane.

I think -- well, quite a bit of testing was done to determine what the effect of galling was for that situation. The NTSB test report which is basically where I'm coming from on that is that the galling wouldn't have really been applicable, in that the retainer for the shaft was loosened. So at the time of the crash, the input linkage would have been free.

MR. PURVIS: So the effect of the galling was what?

THE WITNESS: That it loosened the retainer.

MR. PURVIS: And then it was free to move? Is that what you're saying?

THE WITNESS: That's correct. But again, my input is basically what I read in the NTSB report.

MR. PURVIS: And the last question. If in fact you had a hardover, if you want to call it that, from a galled standby, would the pilot lose control?

THE WITNESS: No. The situation would always be controllable. For the relatively severe case that I mentioned, if you did get the 7-l/2 degrees, the pilot could easily get the rudder back to neutral.

MR. PURVIS: Thank you, Mr. Chairman. I have no further questions.

CHAIRMAN HALL: Thank you.

Mr. Clark?

MR. CLARK: We've been talking about the galling and the three degree yaw damper input and a seven degree effect from a fully galled or a fully bound up input lever to the standby. You mentioned earlier that part of that number or that seven degree calculation or whatever, came from the iron bird test during the original certification.

Was that particular problem specifically addressed in the iron bird test?

THE WITNESS: No. The iron bird test I'm referring to was -- 1 need to give a little background. Initially there was a shear out that was intended to protect against those jams. When they ran the iron bird test, they found that they could get the rudder back to zero with a pedal force that was less than the shear-out force, so that as a result of that, they removed the shear-outs. In other words, the shear-out wasn't needed because it took less force to get the rudder back to neutral than it would have taken to shear it out.

And that testing was done before my time, obviously, during the original certification. But the test itself has allowed us to do some calculations of other scenarios that people can hypothesize.

MR. CLARK: The data from that you can extrapolate to other scenarios?

THE WITNESS: Right.

MR. CLARK: Where was the shear-out going to be placed in the system? Where was it placed?

THE WITNESS: I'm not sure exactly. It was basically in the input linkage.

MR. CLARK: To the main PCU or to the standby?

THE WITNESS: To the standby.

MR. CLARK: To the standby.

You mentioned that you're planning some changes -- well, let me back it up. I'll come to this in a minute.

We earlier talked about the chip shear

requirements in this unit. That basically we can get a maximum of somewhere around 40 pounds into the servo valve and some units carry 100 pounds. What's the limiting factor in this unit that holds us at 40 pounds?

THE WITNESS: That's what we call the walking beam linkage, which is a link that allows the yaw damper to make an input to the linkage. It provides a centering function and it's kind of a remnant of when we had two yaw dampers. If you have two yaw dampers, in order for them to operate one at a time, you have to have what amounts to a spring loaded link. And that's -- the force that spring loaded link puts in is what limits the chip shear to the valve.

MR. CLARK: So if I were to somehow try to load 40 pounds into the valve, at that point the breakout starts moving?

THE WITNESS: Correct.

MR. CLARK: Is there any reason to have that in there now?

THE WITNESS: Only that it would take a pretty complete redesign of the actuator to eliminate it.

MR. CLARK: Could you stiffen the spring to drive that force up?

THE WITNESS: Something like that.

MR. CLARK: Functionally, other than an effort to go through the redesign, there's no reason to have the breakout in there, or the breakout portion of the walking beam?

THE WITNESS: I believe that's correct.

Now, one other comment on the chip shear force. We have been looking at the chip shear capability of the valve, and 40 pounds or 42 pounds is really kind of a minimum capability that if you were to get two valve jams, for example, both the primary and secondary were to jam, which is the situation that we'd be concerned about, it's probable that you could get significantly more than 42 pounds. But we -- at this time, we don't have test data to validate that.

So the 42 pounds that's been mentioned is kind of a minimum chip shear capability.

MR. CLARK: You're saying that if you had the inner valve jammed to the outer valve and the outer valve jammed to the body, you could end up requiring much more than the 42 pounds to break that out?

THE WITNESS: Not requiring, but you potentially could get in a greater chip shear force than the 42 pounds. We were just talking about the walking beam limiting the chip shear force. Part of the reason it's limiting it is because of compliance in the linkage. The primary linkage has more compliance. In other words, it's less stiff than the secondary, so that it appears that if you were to jam the secondary, that you could get more than the 42 pounds.

That's a little bit of an aside, but the 42 pounds that we mentioned is basically a minimum level.

MR. CLARK: That would still come down to a -- well, let me ask it this way then. If we were dealing with that combination that gave us greater than

42 pounds, each jam could be contributing less than --

THE WITNESS: Oh, no, no. Each jam would get that full 42 pounds. It's just that it may be possible to get even more than 42 pounds. But you'd have the same force being applied to each valve slide, so in order to jam both of them you would somehow have to get -- let's say a chip into each valve, neither one of which could be sheared out with 42 pounds.

So when you start looking at the likelihood of being able to get a chip in there based upon the test data, a chip into each valve slide that is stronger than that 42 pounds, it's really, really remote.

MR. CLARK: But even at that, if a contaminate that caused that, at least for the testing today, would that leave a witness mark on the edge of the opening?

THE WITNESS: Yes. And the test that was referred to earlier, the one case that it shifted and not sheared, it did leave a witness mark. And I think that the witness marks were left for the majority of chips that were sheared.

MR. CLARK: I'm still not clear. We talked to Mr. Zielinski earlier and asked him about the certification basis of this rudder unit, this PCU, in the context of assuming that there could be a rudder hardover.

How did Boeing determine that that's a safe situation? Either that scenario could not happen or could be controlled or whatever. What's the certification basis in that regard or the determination that a rudder hardover is not a problem?

THE WITNESS: I don't know exactly what went on in the original certification but in our analysis that we've done as a result of the CDR, we've concluded that the hardover is extremely improbable.

MR. CLARK: Okay. That's the way it is now?

THE WITNESS: That's correct.

MR. CLARK: And was that based on the CDR or the flight test or both that bought into question the controllability issue?

THE WITNESS: It's based upon our analysis that was done as a result of the CDR but subsequent to it. This is part of the submittal that we made to the FAA on October 2nd.

MR. CLARK: Back at the original certification -- let me ask it this way. The original basis was that the lateral authority was greater than the directional authority in the event of a rudder hardover?

THE WITNESS: No. If you read the failure analysis, it kind of mentions both. The writing of the original failure analysis it's simply not clear enough to be able to determine exactly how it was certified. Normally you write the failure analysis and submit it to the FAA. There's discussion that goes on with the FAA. And I don't know how the final determination was based or what it was based on.

MR. CLARK: I guess the thing that throws me is that Mr. Zielinski said earlier that he felt that it was both. Both within that original certification the issue of the airplane could be controlled if this event happened, and also that the probability was very low.

THE WITNESS: It could well be both. My understanding is the airplane is controllable for most of the flight envelope and not every corner of the envelope, though. So it does -- if you start doing a qualitative judgment, you do take both factors into account.

MR. CLARK: Okay. Are there any changes -- well, you've talked about changes that have been planned for the standby unit and the yaw dampers itself. Are there any changes being planned for the PCU itself?

THE WITNESS: No.

MR. CLARK: So based on the design as is, Boeing's comfortable with that design?

THE WITNESS: That's correct.

MR. CLARK: Okay. Thank you.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: I just have a few questions here.
I want to follow up on this walking beam. Is there any way to keep the walking beam from walking? Like freeze it, weld it to keep it --
THE WITNESS: No. In order for the yaw damper to function as it is now, you have to be able to move the walking beam. Whenever the yaw damper ma- piston, the little yaw damper piston, whenever that moves to make an input it has to be able to move the walking beam. If it didn't, it would be locked in place.
MR. MARX: But I mean the so-called breakaway. My understanding of the walking beam is that it folds or causes --
THE WITNESS: One end of the linkage is grounded. The middle of it is attached to the walking beam. The other end is attached to the piston so that this walking beam gets upset as the piston moves.
MR. MARX: So there isn't any --
THE WITNESS: You couldn't do it like that.

No. You'd have to relocate the ma-piston so it's directly in line with the summing lever.

MR. MARX: Without the walking beam there, what would be the force be? We're talking about 42 as a minimum with the walking beam. If you didn't have that --

THE WITNESS: I'm not exactly sure if the -- it would be substantially higher, though.

MR. MARX: And you also --

MR. CLARK: Let me clarify. The walking beam has to be there. We're talking about the breakout portion, the bending of the walking beam. The walking beam always has to be there and move by the current design.

THE WITNESS: You mean stiffen it? Then you get into structural problems with the linkage itself. So I'm not an expert on that but you would get into strength problems.

MR. CLARK: Okay. Thank you.

MR. MARX: You also were talking about the case where we would somehow freeze the standby shaft and the bearing from galling or some other -- mainly galling mechanism. You talked about a 7-l/2 degree rudder deflection. Does that take into account blowdown? I mean, is that 7-l/2 degrees at say 190 knots, would that still be able to move the rudder 7-1/2 degrees?

THE WITNESS: Yes. At 190 knots you're on the order of about 20 degrees from blowdown, so that's less than halfway to blowdown.

CHAIRMAN HALL: Mr. Marx, you might tell us what blowdown is, or one of you.

MR. MARX: Well, I think the witness would be much better to explain blowdown.

THE WITNESS: Okay. The actuator has obviously a finite force capability. If you put in a maximum command to the actuator, it generates a full 3,000 psi. The inner load is going to stop the rudder when you hit a force balance, and that we commonly call blowdown.

MR. MARX: In other events that would be suspected of some kind of uncommanded yaw or yaw damper anomalies, have they checked the standby shaft bearing -- so-called bearing? It's actually called a bearing -- for galling in these instances?

THE WITNESS: Yes. That's part of the troubleshooting procedure for yaw damper problems.

MR. MARX: How do they do that?

THE WITNESS: They disconnect the input linkage and measure the force required to move the input linkage.

MR. MARX: No. Have they ever disassembled it to find out if there's galling, if it's still there?

THE WITNESS: I'm sure they haven different occasions. I can't say specifically though.

MR. MARX: So mainly they're just measuring the force on the lever arm to see if there is a frozen condition?

THE WITNESS: Well, there's a requirement that it be less than one pound. So if it's within the one pound operating limit, they typically would not remove the actuator. No.

MR. MARX: That brings me to the question of what is normal wear and tear on these standby bearings? For instance, do we know what type of galling we would expect to have on a bearing that's been in service for so many years? Has there been any tests or examinations that are done on these particular components to get the norm as to what type of wear and tear is actually occurring?

THE WITNESS: I don't know of any specific studies on that. I think as part of the United Airlines Colorado Springs that they did some testing but I wasn't a party to that.

MR. MARX: You were talking about silting between the primary and the secondary and that the underlap in this case would be less probable of having silting. Between the secondary and the housing, isn't there an overlap?

THE WITNESS: That's correct.

MR. MARX: And would that be more prone then to silting?

THE WITNESS: Well, there's no flow so if you don't have flow bringing the particles in, then I don't really understand how you'd get silting.

MR. MARX: Okay. So the real silting problem would be right around the net lap?

THE WITNESS: Right.

MR. MARX: I have no further questions.

Thanks.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Yes, sir.

I'm going to belabor a couple of points, Mr. Kullberg.

First of all, in the galling of the standby input arm, has any consideration been given to what the effect would be if the standby system were pressurized?

THE WITNESS: If it were pressurized full-time?

MR. LAYNOR: Yes, sir. Well, if it were pressurized for any reason during the flight and this galling condition existed.

THE WITNESS: Well, the effect would be very similar to what it would be when it's not pressurized, in that -- well, excuse me.

MR. LAYNOR: Would you be able to null out the servo valve in the standby PCU?

THE WITNESS: You would have to apply a force that would overcome the galling in order to center the valve. But there's also a large dead zone in the valve so that you normally, when you pressurized it, you'd be within the dead zone of the valve. So you'd also, I believe, by having thought about this in advance, I think you'd have to be outside of that dead zone.

MR. LAYNOR: Well, do you agree that it's possible that that could be a more serious situation, given the pressurization of the standby system if it's galled out in neutral, out of null?

THE WITNESS: You'd first have to lose two hydraulic systems before the standby would actually overcome. And also, the standby system is verified. The actuator is verified at each seat check.

MR. LAYNOR: And getting back to the walking beam and a breakout in the main PCU from the standpoint of chip shear, has Boeing established that it's not possible or it is designed such that it's not possible through progressive pedal movement and force to get beyond the breakout, so to speak? Beyond the limitations of the breakout?

In other words, can you -- if you continue to apply force, can you exceed the 40 pounds?

THE WITNESS: That's what I was -- eventually, the walking beam bottoms out but it bottoms out about the same time you hit the valve stops. But that's what I'm talking about. You may have some extra capability for the dual jam case.

MR. LAYNOR: Okay. So that would come about by progressive force?

THE WITNESS: By bottoming out the walking beam and then you can then apply some more force.

MR. LAYNOR: And this goes back to a discussion you had with Mr. Phillips, but I was wondering if you might clarify for me from your viewpoint as a DER, in particular, what the essential difference would be in the certification requirements for that rudder power control unit and the control system by today's standards compared to what it was in 1965, the primary major differences.

THE WITNESS: Primary differences would be with multiple failures. In '65, '67, they did not address multiple failures. And that's one of the things that the CDR team did address. That's where the fault tree analysis comes in to try to predict the probability of critical events.

MR. LAYNOR: All right. So by -- I'm not sure I understand, but by 1965 standards a single failure which could not be tolerated by the airplane would be acceptable to the certification team?

THE WITNESS: No. I touched on this just briefly, but there are no single disconnects on a '37 rudder that can cause uncommanded motion. Where you get into the issue is the current 671 says that you must be good for any single failure excluding jams, if they can be shown to be extremely improbable.

So even under the current regulations, you can certainly use the argument that a jam is extremely improbable. So you would look at what does it really take to cause the jam and is it reasonable or is it an unreasonable type of situation.

MR. LAYNOR: Do you know what the philosophy was in the dual concentric servo valve compared to say a tandem servo valve spool or just a single valve?

THE WITNESS: The dual concentric valve is designed to be tolerant of a single jam, whereas a single spool obviously is not.

MR. LAYNOR: And that was a design criteria in 1965?

THE WITNESS: Well, it was -- at least it was a Boeing criteria that you be able to neutralize a jam.

MR. LAYNOR: Has Boeing given any consideration with the knowledge that they have today on any pressure reduction or any changes, modifications to the hydraulic system itself rather than the PCU, to accommodate the total flight envelope and controllability?

THE WITNESS: When you say consideration, we've looked at it. But when you do something like that, you make sacrifices in other areas. The rudder power is there for reasons, and when you start -- something like a pressure reducer does degrade the overall capability of the rudder.

MR. LAYNOR: Do you have any such logic in any of your other airplanes for structural considerations?

THE WITNESS: Yes. We do do pressure limiting on other airplanes and we do do ratio changes on other airplanes. They are there for structural reasons.

MR. LAYNOR: All right. Thank you, Mr. Kullberg.

CHAIRMAN HALL: Thank you, Mr. Kullberg, for your testimony. I have just a few questions for you.

Could you explain as succinctly as you can what is a designated engineering representative?

THE WITNESS: He's basically in play if, in this case, a manufacturer that has demonstrated certain capabilities, integrity type of thing to the FAA, and the FAA has authorized him to make certain findings of compliance with the FAR's and to prove certain types of data.

CHAIRMAN HALL: Is this a position you volunteer for or you are selected for?

THE WITNESS: No. It's both. I mean, in order to become a DER, you have to demonstrate, like I said, a number of things both to the Boeing Company and to the FAA.

CHAIRMAN HALL: I guess my point is how did you become a DER on this airplane? Did the airline select you? Did the FAA select you? I mean, the airplane group?

THE WITNESS: Well, Boeing presents you as a candidate and then the FAA either accepts or rejects you.

CHAIRMAN HALL: And who has the responsibility of accepting or rejecting you?

THE WITNESS: The FAA Seattle Certification Office in this case.

CHAIRMAN HALL: In Seattle, the Aircraft Certification Office?

THE WITNESS: Correct.

CHAIRMAN HALL: So to the extent that you report to anyone, you are supervised by that entity?

THE WITNESS: Whenever I'm acting as a DER, I'm really reporting to the FAA.

CHAIRMAN HALL: And how long have you been a DER on the 737 for hydraulics/flight control?

THE WITNESS: On the '37 for about a year and a half. Previous to that I was DER and currently am a

DER for the 757. That's about 10 years now.
CHAIRMAN HALL: So you've been the DER on both planes for some period of time then?
THE WITNESS: Well, I just recently took over the '37.
CHAIRMAN HALL: So you were not the designated engineering representative at the time of the Colorado Springs accident?
THE WITNESS: That's correct.
CHAIRMAN HALL: The recommendations that you looked at of the 20 -- is it 7 or 9 -- 27 recommendations, how many of those have you been responsible for responding to or been involved in responding to?
THE WITNESS: Well, within the 737 engineering, we've responded to -- I believe it's 15 recommendations.
CHAIRMAN HALL: 15. Has that been done in writing?
THE WITNESS: That's correct.

CHAIRMAN HALL: And when was that done?

THE WITNESS: We submitted it -- I believe it was October 2nd of this year.

CHAIRMAN HALL: October 2nd. So you received that I guess in May and you have given your response in writing. Have you completed your work? Has Boeing completed its work on the response to those recommendations?

THE WITNESS: Yes.

CHAIRMAN HALL: So there's no further work that's in progress in terms of responding to those recommendations?

THE WITNESS: That's correct. But once the FAA has done their analysis, I would not be surprised to be requested more data.

CHAIRMAN HALL: Are there any actions that you all anticipate that have been generated as a result of those recommendations inside Boeing?

THE WITNESS: Just what I've talked about on the standby PCU and the yaw damper.

CHAIRMAN HALL: Two items?

THE WITNESS: Well, of those 15, yes.

CHAIRMAN HALL: And what is your understanding of the report you submitted to the FAA? What will become of that report?

THE WITNESS: My assumption is that the -- well, I know that the FAA is currently evaluating it. I would expect to start hearing from them very shortly.

I'd like to correct one thing. Also, one of the recommendations was regarding cable inspections. That one's been closed out and we did make changes to the maintenance manuals on that.

CHAIRMAN HALL: Well, just on, for example, Recommendation Number 12, was that one that you all -- where it says require the failure analysis of the Boeing 737 yaw damper identified components and any relevant tests be conducted to identify all failure modes, malfunctions and potential jam conditions of these vital elements. Have you completed work on that one and did you conduct tests as recommended here?

THE WITNESS: We didn't do any specific testing. We did very extensive analysis.

CHAIRMAN HALL: And would you anticipate, in light of this recommendation, that the FAA would come back and ask you to conduct any tests?

THE WITNESS: It's certainly possible that they could. I can't say that I would anticipate that they would, but it's possible.

CHAIRMAN HALL: The fault tree. Is that something that is updated from time to time or is that something that exists -- you know, once it's created, is static?

THE WITNESS: We would not normally update the fault trees for the whole of a system. The FAA may request us to update them for specific concerns that they might have.

CHAIRMAN HALL: Where there any changes that you were aware of in the fault tree as a result of either the Pittsburgh or the Colorado Springs accidents?

THE WITNESS: On the '37, the first time that we submitted fault trees was just very recently as a result of the CDR recommendations. We did not submit fault trees in the original --

CHAIRMAN HALL: I just apologize, Mr. Kullberg. I can't hear with that fan going on. Would you mind repeating that again, please?

THE WITNESS: The fault trees that I've referred to, those fault trees were just submitted in October. We did not previous to that submit fault trees except I believe for some autopilot design changes. So the fault tree submittal is basically brand new.

CHAIRMAN HALL: All right. The subject of silting and if I try to follow your testimony and the question Mr. Donner came up with is that that yaw damper moves and therefore that would remove the silt. Is that what you're saying essentially?

THE WITNESS: That's correct. If it did silt, it would.

CHAIRMAN HALL: Do you still think we need to do a silting test? And if so, why?

THE WITNESS: No. I don't think that we need to do one. I simply stated that I didn't have any objection to doing it. I don't think that we would learn a whole lot but if it would put people's concerns to rest, then I wouldn't have any objection.

CHAIRMAN HALL: Well, that's understandable.

In your 18 months and your previous experience as a DER on Boeing products, is there anything else that we should be looking at that Boeing has not already addressed or things that come to your attention, tests that should be done? Anything else that you think we ought to be doing on this investigation?

THE WITNESS: No. I think to my mind the investigation has been very, very thorough. We still are talking about possibly running some other tests. We mentioned the standby actuator testing. Again, I don't think it's directly applicable to the accidents but I'm at a loss to come up with anything that would make sense that hasn't already been done.

CHAIRMAN HALL: All right. Well, Mr. Kullberg, we appreciate your testimony and you are -- may step down.

(Witness excused.)

CHAIRMAN HALL: Before we call the next witness, I would just like to bring to the attention of the audience and the news media, because the question has been brought to my attention, that at the Pittsburgh hearing on January 27th, at the close of that hearing, I made the following statement. And I'm going to read from the transcript:

The Board welcomes any information or recommendations from the parties or the public which may assist in its efforts to ensure the safe operation of commercial aircraft. Any such recommendations should be sent to the National Transportation Safety Board, Washington, D. C. 20594, to Mr. Tom Haueter's direction. That's Mr. Haueter right there.

And Mr. Haueter patiently responded to many, many letters that we have gotten from the general public and others in regard to information or recommendations that they present.

And I want to say today the Board welcomes any information from the public. And I again will read into the record again, nine months later, that if anyone has anything useful, of course we want to see it. Tom Haueter is the investigator-in-charge. His phone number is 382-6830. So if you don't want to call him -- write him, you can call him.

This leads me to say that obviously I would question the motives of anyone who would sit on the cause of this accident and not submit it to the scrutiny or to objective testing. Anyone who would wait to the day of the hearing, of a hearing that has been planned for two months, I would have to come to the conclusion that the purpose of that individual is to manipulate the processes of this hearing for private motives.

Therefore, again, I say anyone who knows the cause of this accident has a public duty to come forward and you can reach Mr. Haueter at 382-6830, area code 202.

I'd like to call now our next witness, Mr. Paul Knerr, the Vice President, Engineering, at Canyon Engineering, Society of Automotive Engineers. He's the A6 Committee Member and he's come here from Valencia, California.

(Witness testimony continues on the next page.)

PAUL KNERR, VICE-PRESIDENT, ENGINEERING, CANYON
ENGINEERING, SOCIETY OF AUTOMOTIVE ENGINEERS,
A6 COMMITTEE MEMBER, VALENCIA, CALIFORNIA

Whereupon,

PAUL KNERR,

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. SCHLEEDE: Mr. Knerr, could you give us your full name and business address for our record, please?

THE WITNESS: My name is Paul Knerr and I work for Canyon Engineering in Valencia, California.

MR. SCHLEEDE: And what is your position at Canyon Engineering?

THE WITNESS: I'm Vice President of Engineering.

MR. SCHLEEDE: Could you give us a brief description of your background and education that bring you to your present position?

THE WITNESS: I've worked for Canyon for 10 years. And prior to that, I worked for the Lee Company in Connecticut for 11 years. During this period of time, I've designed products for aircraft and also worked with the SAE Committee for 15 years in contamination and filtration.

MR. SCHLEEDE: Thank you. Mr. Phillips will proceed.

MR. PHILLIPS: Good evening, Mr. Knerr.

First of all, I'd like to talk a little bit about your responsibilities as Vice President of Engineering of Canyon Engineering. What does Canyon Engineering do?

THE WITNESS: Canyon Engineering is a small business that builds primarily valves, flow control valves, relief valves, check valves, for hydraulic systems. We built nozzles and that sort of thing for fuel systems and we build some lube systems also.

We're a secondary or sub tier supplier to

Parker Hannifin and other companies like that.

MR. PHILLIPS: Do you build parts for Boeing?

THE WITNESS: We don't build the parts directly for Boeing.

MR. PHILLIPS: Have you manufactured any part of the 737 main power control unit?

THE WITNESS: Not to my knowledge.

MR. PHILLIPS: How about the standby rudder actuator?

THE WITNESS: Not to my knowledge.

MR. PHILLIPS: Have you ever been involved in any testing of either one of those two components?

THE WITNESS: No, I haven't.

MR. PHILLIPS: Anyone at your company that you know of?

THE WITNESS: No.

MR. PHILLIPS: How big is your company? Number of people.

THE WITNESS: We're 42 people.

MR. PHILLIPS: And do you do original design work or do you do modifications of original design?

THE WITNESS: We do design OEM products to specification to companies, again, like Parker. We also build to their prints.

MR. PHILLIPS: And that's where they supply you he drawings and you manufacture the parts?

THE WITNESS: That's correct. I'd like to also say that we do the complete testing and assembly of those parts to acceptance test procedures that are supplied by those companies.

MR. PHILLIPS: Do you participate in the development of acceptance test procedures in your design work?

THE WITNESS: We generally write our own acceptance test procedure that details our detailed procedures to testing those parts. Those are based on the company's ATP's but are further modified for our own needs.

MR. PHILLIPS: I'd like to talk for just a minute about the SAE. The Chairman asked us in a meeting a few weeks ago what was the SAE and exactly what's the organization all about.

Could you give us a few sentences about the SAE and about your committee in general?

THE WITNESS: Okay. The SAE is the Society of Automotive Engineers. The terminology is somewhat misleading in that when it was originally conceived in 1909 the word automotive meant any kind of automotive product, whether it be on land, sea or air.

Right now, they handle standards and recommended procedures for both aircraft and ground vehicles and seagoing vehicles, too.

My involvement there has been for about 15 years. The way that the SAE runs, it's a volunteer organization made up of individuals who have an interest or an area of expertise in the areas that they're writing standards on. And I became involved with the contamination and filtration panel and also more recently with the components panel.

MR. PHILLIPS I've had some discussions

prior to the hearing with the SAE headquarters, I guess you could call it. And I think this is the place to make the point that Mr. Knerr isn't speaking or isn't testifying on behalf of the SAE. He's testifying on behalf of his experiences at Canyon Engineering and his professional experience, so I'll make that clear, although we recognize your affiliation and we want to have a little bit more discussion about that.

You said you were at Lee for quite a while. Can you tell me a little bit about what Lee does?

THE WITNESS: Lee builds similar components. They're smaller, generally, micro hydraulics. They're used in flight controls as well. My role there was first as project engineer and then chief engineer in charge of valves.

MR. PHILLIPS: So for your whole career you've been involved with hydraulic valves and components?

THE WITNESS: Before that I was with Hamilton Standard and before that with NASA.

MR. PHILLIPS: And what did you do for NASA?
THE WITNESS: Basically, an engineering trainee during the Apollo days.
MR. PHILLIPS: So would you consider yourself an expert in hydraulic component design, hydraulic systems?
THE WITNESS: Yes, I would.
MR. PHILLIPS: I'd agree.
CHAIRMAN HALL: And that's why we have him here, right?
MR. PHILLIPS: Certainly is.
CHAIRMAN HALL: And we appreciate you being present because you are an expert in hydraulics and we appreciate you being here, sir.
MR. PHILLIPS: You mentioned that the SAE has a committee that looks into filtration and contamination. Can you tell me how that subdivision of a committee or group of people were formed and why?
THE WITNESS: The SAE A6 Committee deals with all aspects of aircraft hydraulics. There are

committees that are broken down into various areas, flight controls being one, servo actuators being one. A number of other committees. This just happens to be one of the ways that they broke it down.

Considering the filtration and contamination is an important part of the hydraulic area, they developed a committee. A committee is about 15 individuals right now.

MR. PHILLIPS: Do you attempt to define standards for filtration for hydraulic systems?

THE WITNESS: Yes, we do.

MR. PHILLIPS: And who uses those standards?

THE WITNESS: These standards are AIR's, Aerospace Information Reports; ARP's, which are recommended procedures; and AS's, which are standards of components. The aerospace industry, both the military and commercial people, use those standards.

MR. PHILLIPS: The Committee, the A6 Committee, do companies such as Parker or Boeing have participants on those committees?

THE WITNESS: Yes, sir, they do.

MR. PHILLIPS: Does the FAA or other government agencies have people on those committees?

THE WITNESS: Yes. Werner is on the committee.

MR. PHILLIPS: Werner Koch is a member of the A6 Committee?

THE WITNESS: Yes, he is.

MR. PHILLIPS: How are people selected for the committees? Are they volunteers or --

THE WITNESS: It's strictly volunteer. To become a member, one has to just show a particular interest and work on standards documents.

MR. PHILLIPS: You mentioned ARP. That's an Aerospace Recommended Practice?

THE WITNESS: Yes, it is.

MR. PHILLIPS: And also, one of the -- in the previous hearing we discussed an NAS, which is a National Aerospace Standard 1638 which applies to contamination. Are you familiar with those documents?

THE WITNESS: Yes, I am.

MR. PHILLIPS: Okay. 1638 and ARP 219. Are you familiar with that document?

THE WITNESS: Right.

MR. PHILLIPS: Could you briefly describe what ARP 219 is?

THE WITNESS: ARP 219 is a document which addresses the issue of testing for contamination sensitivity of components. It's a rather old document. It was recently -- or is going through the process of cancellation for various reasons.

MR. PHILLIPS: Is that document used by manufacturers as a guideline for their contamination concerns for design?

THE WITNESS: One of the reasons it's being cancelled is because very few companies have used it. To just characterize it, it's a rather severe test of components using AC fine test dust and the feeling generally is that it's much more severe than anything that could occur in an aircraft hydraulic system.

MR. PHILLIPS: How was an original standard set that missed the point?

THE WITNESS: I think the intent was more to compare one valve design or one pump design for another and it does that. It's a comparative sort of a document. However, it doesn't relate to how long an in-service vehicle would last. And generally, it's pretty hard on the component. You can wear out a valve or a pump in a very short amount of time and not know how that relates to in-service times.

However, it was good for comparing one valve against another.

MR. PHILLIPS: Is there any kind of requirement for a manufacturer to use ARP 219?

THE WITNESS: There have been some specifications issued by companies that require 219.

MR. PHILLIPS: Do you know if ARP 219 testing was required in any of the 737 flight control components?

THE WITNESS: I don't know that. No.

MR. PHILLIPS: NAS 1638. Could you briefly describe that document?

THE WITNESS: That's a document that establishes the classifications of cleanliness for hydraulic fluids, broken down into a number of different classes. Each class doubles in particulate count and that is further broken down into size of particles, the first size being 5 to 15 micron and on up to 100 micron.

There is also an SAE document which expands on that. It's AS 4059, which is a more recent document that includes 2 micron particles and further expands on the document.

MR. PHILLIPS: Which document would be used -- would be currently used to categorize particulate contamination of hydraulic fluid?

THE WITNESS: NAS 1638 has been used for years and that's the one that I've seen in most areas.

MR. PHILLIPS: Okay. Are you familiar with any hydraulic fluid sampling that was done in the process of this investigation of flight 427?

THE WITNESS: Yes, I am. There was a report that the NTSB put out which I reviewed and did my own analysis of.

MR. PHILLIPS: I'd like to take a little bit of time and talk about your analysis of that work that we've done. In the NTSB report you referenced, do you generally recall what the report was about?

THE WITNESS: The report was to look at the in-service airplanes, 737's. There were 21 airplanes involved and 104 samples. And the intent was to randomly look at the three airlines that were involved and the 21 airplanes that were involved and see what kind of fluid contamination existed -- this is particulate contamination -- existed in the typical fleet.

MR. PHILLIPS: Could you tell us a little bit about the findings -- your analysis of the findings in that report?

THE WITNESS: To briefly summarize, about 22 percent of the airplanes that were surveyed exhibited particulate contamination greater than a Class 8, Class 8 being the normal military level for hydraulic contamination. That is established in a mill spec, both for components and for systems.

And I think speaking for the rest of us in the SAE, Class 8 is a pretty typical level that we would expect a fairly dirty hydraulic system to go to and would not exceed.

MR. PHILLIPS: So in your opinion, a Class 8 would be the upper limit of acceptable according to NAS 1638?

THE WITNESS: Not according to NAS 1638. It doesn't establish any levels. It's simply a classification of those levels. To my knowledge, there is no general commercial limit. However, the different airlines range from 7 to 9. I'm sorry. The different airframe manufacturers range from 7 to 9.

MR. PHILLIPS: So the manufacturers impose a requirement for NAS 1638 limits of 7 to 9?

THE WITNESS: All except Boeing. Boeing does not have an in-service limit.

MR. PHILLIPS: And there is no requirement at Boeing. Who would be responsible then for a Boeing airplane for setting the standard for hydraulic cleanliness?

THE WITNESS: Boeing uses the philosophy that it establishes the filter change time intervals based on A, B and C checks and then leaves it up to the user to determine if they take samples and what level of cleanliness the aircraft will achieve.

MR. PHILLIPS: As a follow-on, I believe you prepared a chart here that gives a relative description of these classifications. Could we take a look at that? It's page 2 of the exhibit.

And Rick, I think it will look like a 1 on a piece of paper.

CHAIRMAN HALL: Which exhibit?

MR. PHILLIPS: It's page 2. 9M.

CHAIRMAN HALL: M as in Mike or N as in

November.

MR. PHILLIPS: M as in Mike.

THE WITNESS: I don't know how well you can see this but in trying to describe what these contamination levels look like, if you can visualize a one gallon drum on the left-hand size with the particles suspended in that drum, and then in the next picture in the middle, if all of the particles were to settle to the bottom of that drum, about a five inch diameter disk. And then you were to magnify it greatly, you would look at these three classes.

The little one on the top there is Class 6. The little worm in the middle of the page is just for reference. That's a 100 micron hair which is a typical human hair. And the particles that are shown are only the 50 micron particles.

There would be only four particles on that patch for Class 6. There would be many more particles for Class 12, as you can see. And Class 18, which represents about the level that Boeing did their test at, is shown at the bottom.

MR. PHILLIPS: By the Boeing test, you're referencing the contamination test done late last year?

THE WITNESS: Yes.

MR. PHILLIPS: We were talking about requirements for cleanliness standards. Are you aware of any requirements by the FAA placed on the manufacturers?

THE WITNESS: I'm not aware of any requirements. No.

MR. PHILLIPS: What kind of level do most manufacturers maintain in their testing equipment?

THE WITNESS: Our ATP's that we receive from most of our customers require a Class 6 or less. We maintain our test stands to approximately Class 4. We've seen them go up to Class 6.

MR. PHILLIPS: Are you aware of any testing that's done at higher contaminate levels are part of a certification process or part of the approval process?

THE WITNESS: Nothing specific. I have heard of tests being run on specific components where contamination might have been an issue. Back at the Lee Company we ran some tests of sensitivity of small valves to contamination. This was generally following somewhat of the Boeing procedure where we put massive amounts of Arizona road dust into the components.

MR. PHILLIPS: And what is Arizona road dust?

THE WITNESS: AC fine test dust. That's a calibrated test dust that's used to calibrate particle counters. There are several other test dusts that are also used, but that's fairly common.

MR. PHILLIPS: Is it common to place other materials as contaminants in solution like pieces of metal or Teflon?

THE WITNESS: Yes. I haven't personally done this but I known of other companies that have mixed contaminants. The Boeing test was a mixed contaminant test where metal particles and Teflon particles and sand particles were put in.

MR. PHILLIPS: Do you know what the basis would be for calculating the mix or finding percentages?

THE WITNESS: Not specifically. I understand that Boeing used in-flight sampling to match their contaminant load with.

MR. PHILLIPS: You've described several classes of contaminants. And this is based on particulate count and excluding any chemical contamination. Could you briefly describe the sources of high particulate count in fluid samples?

THE WITNESS: There are a number of sources of generation of particulate. The pump probably being the primary generator of small flakes of metal; built-in contaminants from the assembly procedures or from breaks in the line for servicing.

The contaminants that get by the wiper seals on actuators are brought into the system. The actuators themselves generate particulate, both the seals and the metal surfaces. These are some of the kinds of sources.

In addition, the filters themselves do pass contaminants. Filters are not specifically blocking out all contaminants of a particular size but they're sort of playing catch-up with the generation, and then they do shed some particles also.

MR. PHILLIPS: On the subject of filtration, can you give us some general guidance in how hydraulic systems are filtered?

THE WITNESS: In most cases of aircraft systems, there's three primary filters. There's a pressure filter which takes the pressure from the pump and goes out to the system. That's what's feeding the hydraulic actuators. There's a return filter which collects the debris from the system and there's generally a case drain filter which is a smaller filter that takes the case drain flow from the pump and feeds it back into the system.

MR. PHILLIPS: What about filters on individual components on the inlet lines?

THE WITNESS: There are also what we

generally refer to as last chance filters or smaller filters in front of the PDU, in front of other critical components. These are generally coarser than the nominal filtration rating of the system filter.

The pressure and return filters on the 737 are 15 microns nominal. And again, that doesn't mean it traps all 15 micron particles. That's just the generic way of stating a filtration rate.

The case drain I believe is 20 microns. And as was mentioned before, the inlet PDU filter is 25 microns.

MR. PHILLIPS: What drives the filter sizing in the component? How's the 25 micron filter selected?

THE WITNESS: I can't answer that. That's a system design problem.

MR. PHILLIPS: Okay. That's fair.

As filters get saturated or they trap particles, does that affect their ability to filter and continue to do the job they're supposed to do?

THE WITNESS: Yes, it does. The more heavily a filter is loaded, the more it will shed.

MR. PHILLIPS: Going back to the SAE committee that you're a part of, you mentioned a little there today but in previous discussions we've had that as a result of some recent activity there is a new committee forming or new group. Could you please give us a description of that?

THE WITNESS: At the last meeting in San Antonio in October of this year, the FAA approached the SAE to respond to some of the recommendations from the CDR in regards to contamination. Those issues are being addressed by 16 volunteers within the overall committee. The Committee, by the way, is about 300 engineers and maintenance people. And those volunteers are from filter companies, from airlines, from valve manufacturers, like myself, and other places.

We intend to meet in January to address the issues that the FAA were asking us to address. Those issues regard both particulate contamination and also chemical contamination, such as water and chlorine.

And to address the issue of valve sensitivity testing and tip shear limits, as well as limits to the overall contamination class for an aircraft.

MR. PHILLIPS: Is one of the tasks of this group to discuss the fact that Boeing doesn't have an in-service requirement for particulate?

THE WITNESS: I think it's more to standardize the requirement across the board. If it's going to be a Class 8 like it is in the military, then there should be a standard written that says that.

Boeing does have a limit to a shipped new aircraft, which is Class 9. And several other airframers do say Class 9 is a better number. And that's what the effort would be, to establish a number for everybody to use.

CHAIRMAN HALL: Mr. Phillips, at this point -- how did that request come to you, verbally or in writing?

THE WITNESS: It was in writing from the Seattle office.

CHAIRMAN HALL: Could we make that a part of the exhibits? Any problem?

MR. PHILLIPS: We'll look into it.

THE WITNESS: I have a copy of it here.

MR. PHILLIPS: So the attempt is to standardize a NAS 1638 class among all manufacturers that is generally agreed upon. Is that correct?

THE WITNESS: That's correct.

MR. PHILLIPS: In your experience working with -- in valves over these years, could you describe to us what you've seen along the lines of jamming? And I want to start specifically with spool valves, sliding spool valves.

Is it your belief that the indications of jamming are normally readily apparent on those parts?

THE WITNESS: On aircraft parts where the clearance is generally around one to six microns, I have no experience whatsoever in particle jamming.

In larger clearance high pressure valves, we have seen some cases of jamming. However, these are generally not aircraft valves. They're industrial valves in highly contaminated areas and the leakage flow is completely through the clearance and the forces are fairly low.

MR. PHILLIPS: Did this jam leave any visible mark on the valve?

THE WITNESS: Yes, it did.

MR. PHILLIPS: Have you ever seen a dual concentric valve, a two spool valve, where both spools jammed?

THE WITNESS: No. I've never seen a dual concentric valve.

MR. PHILLIPS: Have you ever heard of one?

THE WITNESS: I've heard of them, but no, we have never -- 1 have never personally operated with any of the dual concentric valves.

MR. PHILLIPS: Do you have any more details specifically of the one that you've heard of?

THE WITNESS: I think relative to the silting question, I think that's a big question in my mind as to whether any kind of major hysteresis can occur. And I think that's based primarily on the nature of the contaminant.

If, for example, you use natural contaminants generated from the aircraft which are usually very small sliver metal particles, it is conceivable that enough of those could get together and cause some hysteresis in a valve. Whether that could cause a jam that was greater than 42 pounds, I doubt. But again, it's still a question in my mind.

MR. PHILLIPS: So would you follow Mr. Koch's statement and you'd like to see some additional testing done along those lines?

THE WITNESS: Yes, I would. I have to say that the testing would be very difficult. It think it would have to follow a procedure that's been set up in various circles that talks about engineering experiments, where we would take a number of parameters of the valve and vary them and create a matrix of experiments and then look at the nature of the hysteresis or friction increase based on all of those parameters.

The approach that Boeing took was certainly the most direct way and that is to introduce some very hard particles and a great number of them to see if the actuator can withstand that kind of an environment. However, we're working with something that is sort of a very random nature and I think we'd have to do some trending by these experiments to determine whether there's a probability on a very rare occurrence.

MR. PHILLIPS: Do I understand your concern is more for hysteresis rather than a total blockage or jamming or inability to move the valve?

THE WITNESS: Yes. I think that if we were to test this system and include all of the system; that is, include the filters in the PDU and then allow the natural contamination to build up within the pumping system by simply going to coarser system filters, let that build up to about a Class 12 and do some design experiments. By design experiments, I mean change surface features of the valves, surface finishes. Perhaps taper on some of the spools and other parameters like that. Very small parameters, indeed, but change those in a systematic way and then look for a build up in friction at about a Class 12 of natural contaminants.

That's the way I'd run the test.

MR. PHILLIPS: That sounds to me like a test that would -- the goal would be to design a standard for the shape of the spools and that. Specifically, in this accident investigation, if we were wanting to -- NTSB was wanting to determine that silting was an issue, would you recommend a test, the same test?

THE WITNESS: That kind of rambled on. Could you explain what you're asking?

MR. PHILLIPS: Yes. Everybody's laughing. That's bad. I'll probably get my pilot's license taken away.

Specifically, in the course of investigating this accident as a step that we're looking into and we've discussed today, would you recommend a silting test where we introduce a Class 12 fluid with the intent to see if we can change the valve or make it fail? Or could we never have it happen? Would it have to go for a long time?

THE WITNESS: Well, that's why I'm saying we'd have to use this particular statistical approach to determining whether there are trends towards increasing friction by changing a number of parameters at the same time. That sounds like it's against the normal experimental method but that has been a proven way to get at a solution a lot faster and doing a lot less tests.

If, for example, we determined that a slight amount of taper and a particular clearance produced the worst hysteresis in a Class 12 natural environment, then perhaps we can use that information to project what may occur in a statistical improbable situation.

MR. PHILLIPS: In your experiences, can normally tell? Can you look at a valve and tell that a valve has been operating in contaminated fluid?

THE WITNESS: Can I look at a valve and determine whether it can operate?

MR. PHILLIPS: Visual observation.

THE WITNESS: There are a number of guidelines that engineers use to prevent contamination being a problem or locking up a valve. One, for example, is to have very sharp spool lands. Any radiusing or rounding or tapering of those spool lands will make the valve much more susceptible to jamming.

MR. PHILLIPS: Have you looked at this valve that we're talking about, the main rudder power control unit, the servo valve?

THE WITNESS: No, I haven't, but I've seen valves that are similar to it. I'm sure that the edges are very sharp, as originally manufactured. One of the concerns that we might have with high particle counts is that the erosion of the valves goes up very quickly with high particle counts, which will round off the edges of the spool and thereby create a situation where jamming would be more probable.

MR. PHILLIPS: Are there any other processes that can be done to the spools to raise the chip shear capability or protect against jamming other than sharp edges?

THE WITNESS: Certainly lack of taper. These are generally ground and honed spools. But I can conceive of ways in which taper could occur in the manufacture of the parts and any kind of taper would cause severe problems.

MR. PHILLIPS: Do you agree with the testimony we've heard earlier today that an underlapped valve generally is less susceptible to silting?

THE WITNESS: Yes, I do, but I think I'd rather reserve judgment until I could see what the actual configuration looked like. If those inlet ports were completely annular, then I do agree. If, however, there are multiple inlets or some kind of land that the particles can jam in radially around the valve, then I would question that.

MR. PHILLIPS: Is radial jamming a common occurrence? Do you see that often?

THE WITNESS: No, but any time you have a differential pressure across a clearance is where the problem can occur.

MR. PHILLIPS: Have you read the FAA's CDR report?

THE WITNESS: Yes, I have.

MR. PHILLIPS: Do you have any observations or comments as to the areas that address the areas of your expertise?

THE WITNESS: No. I thought it was a very well written report and I appreciate the FAA coming to the SAE and asking them to look into these things.

MR. PHILLIPS: So was there any correlation or was there any connection with the SAE while the CDR was in work or did it come after the report was completed?

THE WITNESS: It came after the report was written.

MR. PHILLIPS: I think that's about all I have. Do you have anything else you'd like to add or say?

THE WITNESS: No, not at this time.

CHAIRMAN HALL: Any other questions from the Technical Panel?

(No response.)

The parties?

(No response.)

I see no hands from the parties. Very well.

Mr. Clark?

MR. CLARK: No questions.

CHAIRMAN HALL: I'm sorry?

MR. CLARK: No questions.

CHAIRMAN HALL: Mr. Purvis, with the Boeing Commercial Airplane Group?

MR. PURVIS: You were talking about a test just now and using -- 1 think you said Class 12 fluid. How would you confirm that Class 12 is actually present in the valve?

THE WITNESS: There are a number of methods for determining particle contamination. At a Class 12, I doubt if an automatic particle counter would be valid, so I'd use ARP 598 which is a microscopic count method; take patches, and verify that that was in fact in the valve.

MR. PURVIS: And why did you choose Class 12?

THE WITNESS: Each class doubles in particulate so this is 16 times more than the level that we would expect to be normal in an aircraft hydraulic system. It is also the level that was approached and in one case exceeded on the 21 airplane sampling that we saw.

So I think it would be typical of a fairly dirty airplane. We could of course go to Class 18 or even higher but I think what we're looking for is with a typical operating system is is everything functioning okay.

MR. PURVIS: On the samples that you reviewed, those 21 samples, is there any chance that say contamination from say poor sampling techniques maybe contaminated the sample?

THE WITNESS: Very definitely. That was the immediate reaction of the SAE panel was that those samples that were well above the norm were due to sampling error. And I agree that that is a very real possibility.

I had another viewgraph that showed that this was out of the normal distribution. The two datapoints were way up there around Class 13 were out of the normal distribution, which would tend to make you believe that it was not a normal sampling. However, the normal distribution does allow the level to go up quite high.

MR. PURVIS: What was the normal distribution on those airplanes?

THE WITNESS: The average of the 21 samples was about a Class 7. The extension of the Bell curve or the normal distribution went up to about a Class 11.

MR. PURVIS: I guess the question still begs the question why use Class 12, given the considerations of the various possibilities of contamination and the distribution?

THE WITNESS: Well, you want to get a high enough level to try to simulate some kind of fault or at least some kind of trend. So I think you have to be up to a level that at least will perhaps show something. However, I don't want to be up at the kind of levels that would mask the results. And I think going beyond 12 would be impractical.

It seems clear to me that if the results of the sampling of the 21 airplanes is due totally -- or at the extremes is due totally to sampling error, then perhaps we can go lower. But I'm not convinced that it's due totally to sampling error.

I'm looking right now at some more sample data that was furnished by another fluid company and there's considerably more data there. And the Bell curve is just as wide, if not wider.

MR. PURVIS: In the data that was in the

report, did you observe that some of those actually had two samples taken from the same place with widely different results?

THE WITNESS: Yes. And I pointed that out to a -- I presented this data to the SAE committee back in April of this year and one of the sources of error other than sampling -- I'm sorry -- including sampling, showed two datapoints that were five classes apart taken by the same operator at the same point. And therefore, it was very evident to me that at least that one sample was in error. However, I don't know which one was in error.

It's more likely for the dirtier sample to be in error, but I don't know conclusively which one was in error.

MR. PURVIS: The tests you described were quite extensive, I'm sure. They sounded that to me. We've got something like 150 million hours on the Boeing fleet. Does that give you -- and without any particular problems that we know of. Does that give you a feeling of sufficient effects of silting or the lack of effects of silting?

THE WITNESS: I fly Boeing 737's all the time and I have no problem whatsoever with the safety of the airplanes. What we're looking for here though is something less than one in a billion chance and something more than one in a million chance, an occurrence. That's something that's very difficult to find, but I think this design of experiments may help us at least to go in that direction.

MR. PURVIS: No other questions, sir.

CHAIRMAN HALL: Any other questions from the parties?

(No response.)

If not, we'll go to Mr. Clark?

MR. CLARK: I have no questions.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HALL: Mr. Knerr, what motivates you to serve on this committee? It's volunteer; right?

THE WITNESS: Yes, sir. The same thing that I guess motivates all 300 of us, and that is to establish standards for the industry, both for safety reasons and for establishing just general procedures.

CHAIRMAN HALL: Well, I applaud you for that and I think the American public probably knows very little about the excellent work the Society of Automotive Engineers does. And I've been trying to get up to speed on it myself. I was extremely impressed.

You mentioned, however, there were no standards of cleanliness in this area. Is that correct?

THE WITNESS: That's correct. At least for commercial vehicles.

CHAIRMAN HALL: And is this an area that there should be standards since your committee sets standards or is it an area that you didn't feel standards were important or --

THE WITNESS: Well, let me categorize that a little bit.

CHAIRMAN HALL: I understand you recommend standards. Mr. Schleede has corrected me.

THE WITNESS: There are standards within individual documents. For example, AS 490 is a servo valve standard. And in it, it formerly had indicated that the level be Class 6. We have recently changed that to Class 8 because we feel those servo valves can withstand at least that level.

The problem as it appears to me as a component manufacturer is that if I'm designing a valve to a spec that says Class 6 and yet it's being used in a Class 10, then we should at least know what the component does. So we need to do some testing to establish that.

Either we have to set the limits for the system or we have to change the testing to be more in line with what the aircraft we're flying.

CHAIRMAN HALL: Is there anyone from the Boeing Commercial Airplane Group on one of these committees, on the committee you serve on?

THE WITNESS: I believe, yes, Boeing is represented.

CHAIRMAN HALL: I would think so.

But again, just so I'm clear and I don't leave any confusion, you are like the NTSB. You can only recommend.

THE WITNESS: That's correct.

CHAIRMAN HALL: But your standards are fairly well accepted in the industry?

THE WITNESS: Yes, they are. If Boeing, for example, wants to use an ARP or AIR in the specification to a contractor, then those become part of the contract.

CHAIRMAN HALL: Well, I appreciate your being here.

Mr. Phillips, when we -- after Pittsburgh, I started saying we'd find the best hydraulics experts in the country and I believe he has done that.

Now is there anybody else that isn't on your committee that ought to be involved in this voluntary effort that the FAA has requested you to do?

THE WITNESS: We would much like to see more airlines involved. They used to be back 20 years ago and we would like to see more airline involvement.

CHAIRMAN HALL: Well, possibly, could we send a letter to the airlines? I'll ask Mr. McSweeny, and see if they wouldn't get involved with this process. And January is the earliest you can begin this process?

THE WITNESS: We've begun the process. Manny Runkle from Dowdy Aerospace is leading the team, and he has prepared some paperwork for us all to review. It's just that January is our first combined meeting.

CHAIRMAN HALL: Well, we are trying to pursue any possibility, just as far as we can go. And anything we can do to support your committee's work -- and I'm sure you'll receive a positive response from the airlines -- we want to do. And I really appreciate your leadership on this voluntary standards group and your attendance here today.

Thank you very, very much.

THE WITNESS: Can I offer one more thing that I forgot to mention?

CHAIRMAN HALL: Yes, sir, please. Anything that you think.

THE WITNESS: I had initiated a program to instrument a 737 at the pressure filter outlet with an automatic particle counter. We tried to do that for about a year and Boeing did cooperate in doing that. That was the airplane that we were going to use for the vortex test. We were going to piggyback this little test on it.

But due to circumstances beyond everybody's control, we were unable to do that. I think the reason that it's important to find out the level of contamination that's coming out of the main pressure filter in real flight time because the filters tend to change their behavior due to vibration and shock loads and changing flow and that sort of things, for a component manufacturer to know that that level varies widely is very important in our analysis of a valve design. We have an ongoing effort to do this perhaps with the FAA 727 and just wanted to mention that we're trying to do that.

CHAIRMAN HALL: Thank you. And you've kind of triggered my mind. Do you think this FAA letter requesting you to look at some of these recommendations, how long do you think it would take you to provide a response?

THE WITNESS: We're trying to get together a response within six months from October, whatever that makes it. Sometime in April, I guess. Just how definitive that response will be, I don't know. That's what we need to work on for the next couple of months.

CHAIRMAN HALL: Well, again, thank you very much. I appreciate your being here and providing these views.

(Witness excused.)

CHAIRMAN HALL: I assume we should quit for the day or should we continue?

Mr. Haueter?

MR. HAUETER: I think I need to go back and start answering phone calls in my office, so --

(Laughter.)

CHAIRMAN HALL: Okay. Well, you'll have to find out of Dr. Loeb authorized voice mail for the office yet.

We will continue this Board of Inquiry in the morning, beginning with Mr. Walter Walz, who is a Customer Service Representative for Parker Hannifin, followed by Mr. Tom McSweeny who is the Director of the Aircraft Certification Service for the FAA, and then continue as far as we can go.

We're scheduled, Mr. Haueter, to begin at 9:00 a.m., again?

I appreciate everyone has an interest in this who's spending their time to be here. Again, appreciate the witnesses that came forward to present testimony today.

And with that, we will stand in recess until 9:00 o'clock tomorrow morning.

(Whereupon, the proceedings were adjourned at 7:35 p.m., to be reconvened on Thursday, November 16, 1995 at 9:00 a.m. in he same place.)