

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

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In the Matter of:

THE INVESTIGATION OF THE
 USAIR, INC., FLIGHT 427,
 A BOEING 737-300, N513AU
 ALIQUIPPA, PENNSYLVANIA,
 SEPTEMBER 8, 1994

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DOCKET NO. SA-510

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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

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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

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VALENCIA, CALIFORNIA

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

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

3 CHAIRMAN HALL: Please be seated.

4 Good morning and welcome. We will convene
5 this public hearing that is being held in connection
6 with the investigation of the aircraft accident
7 involving USAir, Inc. flight 427, a Boeing 737-300,
8 tail number N513AU, that occurred on September 8th,
9 1994 at Aliquippa, Pennsylvania.

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

13 Today we are reopening our public hearing
14 concerning the accident that occurred on September 8,
15 1994 at Aliquippa, Pennsylvania, involving USAir, Inc.
16 flight 427, which resulted in the loss of all 132 souls
17 on board.

18 The hearing is being held for the purpose of
19 supplementing the facts, conditions and circumstances
20 discovered during the on-scene investigation. This

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1 process will assist the Safety Board in determining the
2 probable cause and in making any recommendations to
3 prevent similar accidents.

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

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

19 In January we conducted four and one-half
20 days of public hearings in Pittsburgh, Pennsylvania,

1 receiving testimony on such issues as the Boeing 737
2 lateral and directional control systems design,
3 certification and service history; flight crew training
4 for recovery from unusual attitudes; management and FAA
5 oversight of USAir flight operations; manufacturers'
6 service difficulty programs and continuing
7 airworthiness standards and practices; and standards
8 for enhanced flight data recorder parameters.

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

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

20 However, I saw an item in Newsweek magazine

1 some weeks ago that a prominent member of the aviation
2 bar said that we at the Safety Board know that the
3 rudder caused this accident; we were just not making it
4 public. Another lawyer was shown in the same article
5 holding up the servo valve for a rudder power control
6 unit, claiming to have discovered a defect in this
7 component.

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

18 I can only say that if we knew what caused
19 this accident, we would not be expending thousands of
20 hours a month on this investigation. We wouldn't have

1 spent a million dollars last month on a flight test.

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

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

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

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

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

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

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

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

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

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

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

20 Sitting to my right is Mr. William G. Laynor,

1 the Safety Board's Chief Technical Advisor. To my
2 left, Mr. Ron Schleede, the Deputy Director of the
3 Office of Aviation Safety. Again, to my right, Mr.
4 John Clark, Chief of the Vehicle Performance Division.
5 And finally, to my left, Mr. Michael Marx, Chief of
6 the Material Laboratory Division.

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

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

1 Board, Mr. Bob Francis.

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

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

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

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

20 All these members of the Safety Board are

1 paid by the taxpayers, work for the general public and
2 are available to be responsive to you and try to answer
3 any questions or concerns you may have at any of the
4 breaks.

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

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

19 The Safety Board's rules provide for the
20 designation of parties to a public hearing. In

1 accordance with these rules, those persons,
2 governmental agencies, companies and associations whose
3 participation in the hearing is deemed necessary in the
4 public interest and whose special knowledge will
5 contribute to the development of pertinent evidence are
6 designated as parties. The parties assisting the
7 Safety Board in this hearing have been designated in
8 accordance with these rules.

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

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

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

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

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

9 The Air Line Pilots Association. Captain?

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

15 Seated with me are Captain John Cox, who is
16 the central Air Safety Chairman for USAir-Alpha;
17 Captain Dan Sicchio, the Chief Accident Investigator
18 for USAir-Alpha; Mr. Jim Johnson, counsel for the Air
19 Line Pilots Association; Captain Robert Sumwalt, an
20 investigator on the Human Factors Group on the 427

1 accident; Mr. Keakini Kaulia, Engineer Staff with our
2 staff in Washington.

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

5 USAir, Inc. General?

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

16 CHAIRMAN HALL: Thank you very much for your
17 participation.

18 Boeing Commercial Airplane Group?

19 MR. PURVIS: Good morning, Mr. Chairman. I'm
20 John Purvis. I'm Director of Air Safety Investigation

1 for the Boeing Commercial Airplane Group. Seated at
2 our table are the following people: Rick Howes, who
3 has been the coordinator for this accident ever since
4 day one. He works for me. Jean McGrew who is our 737
5 Chief Project Engineer. Dick Kullberg, who will be a
6 witness later on. He's a 737 Hydraulics and Flight
7 Controls Engineer and also a designated engineering
8 representative. And two counsel; Tom McLaughlin and
9 Bruce Campbell.

10 CHAIRMAN HALL: Thank you for your
11 participation.

12 The Monsanto Company?

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

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

19 MR. JAKSE: Is it on now?

20 CHAIRMAN HALL: Yes. Thank you.

1 MR. JAKSE: I'm sorry.

2 My name is Frank Jakse.

3 CHAIRMAN HALL: Well, it's on. I guess just
4 if you could get a little closer to the microphone,
5 please.

6 MR. JAKSE: How about that? Is that better?

7 CHAIRMAN HALL: Can people hear in the
8 audience? It's difficult to tell here.

9 Yes. Please go ahead.

10 MR. JAKSE: Okay. I'm sorry. I'll start
11 over.

12 My name is Frank Jakse. I'm Technical
13 Service Manager for the Sky-draw Aviation Hydraulic
14 Fluid. To my left is Mr. Jim Siegel. He's Business
15 Manager for Aviation Fluids. To my right is Mr. John
16 Cowden, Legal Counsel.

17 CHAIRMAN HALL: Thank you very much.

18 Parker Hannifin, Incorporated.

19 MR. WEIK: Good morning, Mr. Chairman. My
20 name is Steve Weik, representing the Parker Hannifin

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

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

7 CHAIRMAN HALL: Thank you.

8 And the Association of Machinists and
9 Aerospace Workers?

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

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

18 Thank you.

19 CHAIRMAN HALL: I want to at this time
20 publicly thank all the parties for the assistance and

1 cooperation they have displayed during the course of
2 this investigation.

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

11 Copies of the witness list developed at the
12 prehearing conference are available at the press table.

13 There are numerous exhibits to be used in this
14 proceeding. Copies of the exhibits are also at the
15 press table for review.

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

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

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

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

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

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

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

13 CFM International, Mr. Paul Mingler. Thank
14 you.

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

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

19 The Association of Flight Attendants, Ms.
20 Nancy Gilmer.

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

3 Mr. Chee from Singapore Airlines.

4 Mr. Chan with the Civil Aviation Authority of
5 Singapore.

6 Mr. Dave King, with the AIB of the United
7 Kingdom.

8 And Rich Mercadonte of the Senate Aviation
9 Committee.

10 Finally, and most importantly, I want to
11 recognize and welcome the family members of the
12 individuals who lost their lives in the crash of flight
13 427.

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

17 (Witness testimony continues on the next
18 page.)

19

1 THOMAS E. HAUETER, INVESTIGATOR-IN-CHARGE AND SENIOR
2 ACCIDENT INVESTIGATOR, NATIONAL TRANSPORTATION
3 SAFETY BOARD, WASHINGTON, D. C.
4

5 Whereupon,

6 THOMAS E. HAUETER,
7 was called as a witness by and on behalf of the NTSB,
8 and, after having been duly sworn, was examined and
9 testified on his oath as follows:

10 THE WITNESS: Good morning.

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

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

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

19 THE WITNESS: For approximately 11 years.

20 MR. SCHLEEDE: Could you briefly describe

1 your education and background that qualifies you for
2 your present position?

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

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

11 THE WITNESS: Thank you.

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

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

1 Chicago, Illinois, to the Pittsburgh International
2 Airport.

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

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

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

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

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

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

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

20 The team made 27 recommendations intended to

1 enhance the safety of the B-737 and other transport
2 category airplanes through design, maintenance and
3 operational means. However, the team did not identify
4 any specific design deficiency or failure mode that
5 would result in an uncommanded flight control
6 deflection of the magnitude necessary to explain the
7 427 accident.

8 During the week of September 5, 1995, the
9 airplane performance group conducted a series of tests
10 that collected real world data on the effects of a B-
11 737 entering the wake vortices of a B-727. The tests
12 used a highly instrumented USAir 737 and the FAA's 727,
13 which had been equipped with smoke generators.

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

18 A thorough evaluation of all this data has
19 not yet been completed by the Aircraft Performance
20 Group. However, based upon the initial findings of the

1 flight test, it was found that further refinement of
2 the 737 engineering simulator and kinematic studies is
3 required.

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

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

15 The systems group completed a detailed
16 dimensional analysis of the rudder power control unit
17 from flight 427. There were no discrepancies found.
18 Additionally, the group examined possible effects of a
19 locking up or restricting the motion of several hinge
20 points in the rudder PCU feedback loop and simulating a

1 jam of the input rod to the PCU. In all cases the unit
2 behaved as anticipated. The tests found that jamming
3 the input rod would not result in a runaway condition
4 when the yaw damper was exercised.

5 The systems group has identified a Boeing
6 737-200 series that is being removed from service and
7 provided to a museum. The systems group plans to use
8 this airplane to conduct several tests of the complete
9 rudder system. These tests will include back-driving
10 the rudder power control unit, cable cuts, dynamic
11 inputs and impulse loads to the rudder system.

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

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

20 The Human Performance group is examining all

1 possible pilot reactions to unexpected events, such as
2 severe roll, and unusual attitude recovery procedures.

3 There is considerable anecdotal information on these
4 issues but little factual or statistical information.

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

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

18 Additionally, the group has examined cockpit
19 voice recorder sounds from United 585, Colorado
20 Springs, Colorado and from several other cockpit voice

1 recorders from other 737's.

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

6 Additionally, on February 22, 1995, the
7 Safety Board issued recommendations to the FAA to
8 enhance the number to parameters recorded on Boeing
9 737's and other transport category airplanes. The FAA
10 and industry actions on this issue will be discussed at
11 this hearing.

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

20 A key part of the investigation is that the

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

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

16 (Witness excused.)

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

19 (Witness testimony continues on the next
20 page.)

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

3

4 Whereupon,

5 JAMES R. CASH,
6 was called as a witness by and on behalf of the NTSB,
7 and, after having been duly sworn, was examined and
8 testified on his oath as follows:

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

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

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

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

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

20 THE WITNESS: Approximately 13 years.

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

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

8 MR. SCHLEEDE: Thank you. You can proceed.

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

14 The cockpit voice recorder receives its
15 electrical power from the aircraft, so any time there
16 is power in the aircraft the voice recorder is running.

17 The unit is an endless loop recorder, constantly
18 erasing the older information, recording the newer
19 information.

20 When electrical power is removed from the

1 unit or after the airplane crashes, the recorder
2 contains information from this point back, usually 30
3 minutes.

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

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

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

14 (Pause.)

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

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

20 (Pause.)

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

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

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

17 On this aircraft the two crew members were
18 wearing individual headset microphones. These are
19 hired hot to the CVR recorder. This hot term means
20 that whenever sounds were picked up by the crew

1 headsets, microphones were recorded directly on the
2 individual audio tracks of the CVR.

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

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

16 THE WITNESS: Yes, sir.

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

20 THE WITNESS: The cockpit voice recorder is a

1 crash protected unit which is usually -- in this
2 airplane it is actually mounted in the aft cargo
3 compartment. It's designed to, again, record 30 minutes
4 of audio information, in addition to the flight data
5 recorder, which is another recorder that looks very
6 similar to it.

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

16 The sound information arrives at various
17 microphones via several methods. The first and most
18 predominant method is by airborne sound waves in which
19 the sound energy is transmitted via the air to the
20 microphones in the cockpit. This is the main

1 transmission mode for the sounds recorded on the CVR.

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

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

16 By knowing the speed that sound travels
17 through the air, approximately a foot every 100th of a
18 second, and by measuring the time differences between
19 the arrival of the structure sound and the arrival of
20 the air sound, we are able to calculate the approximate

1 distance -- and the direction if we have multiple
2 microphones -- that the source of the sound was from
3 the microphone. Later in my presentation I have a
4 slide that depicts this event.

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

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

18 Because of the nature of the area microphone,
19 the same speech found on the crew channels, if he says
20 it loud enough, will appear on the area microphone and,

1 if it's reasonably loud, it will even appear on the
2 jumpseat microphone of the CVR.

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

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

17 On the area microphone channel we have what
18 are characterized on the CVR transcript as three
19 thumps, and that's these little guys right here.
20 Again, they're on the -- it's probably too little for

1 most people to see, but they are down here on the
2 jumpseat channel also. The same thumps appear here,
3 here and here on the jumpseat channel. There's a
4 louder thump here which is pretty predominant on the
5 jumpseat channel, too.

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

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

14 When you look at the frequency plot, ~~several~~
15 different additional pieces of information become
16 apparent. The constant frequency trace shown in the
17 red, which is -- can you move that up a little higher?

18 It's hard to see but it's this constant line here.

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

1 AUDIENCE: Your microphone, please.

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

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

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

20 It is not apparent from this slide but if I

1 were to increase the scale, two separate traces can be
2 observed. These two traces are due to the fact that
3 the two engines were operated at a few tenths of a
4 speed different from each other.

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

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

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

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

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

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

1 followed several hundredths of a second later by the
2 arrival of the air sound.

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

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

19 As a result of the tests, we were able to
20 verify both the direction the sounds came from, as well

1 as the approximate distance the source was from the
2 microphone. By using the same technique, we were able
3 to determine the approximate distance and the direction
4 that the thumps on the accident CVR are coming from.

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

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

18 Again, this is the cockpit area microphone,
19 the jumpseat microphone. This plot goes with this guy
20 and the bottom one goes with the jumpseat microphone.

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

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

12 We calculated the source of the thump sounds
13 to be approximately 20 feet towards the rear of the
14 aircraft from the area microphone. This places the
15 sound source approximately in the vicinity of first
16 class rows 1 and 2 of the airplane. The frequency
17 composition of these thump sounds on the accident
18 airplane were very similar to the ground test rubber
19 mallet strikes. This is not totally unexpected because
20 the frequency composition of the recorded sounds have

1 more to do with the sound transmission characteristics
2 of the aircraft, the metal skin of the aircraft, than
3 they do with the initiating event.

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

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

1 (Whereupon, a videotape presentation was
2 shown.)

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

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

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

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

17 I have another view which is the tail view of
18 the aircraft. The camera was mounted high on the
19 vertical tail. This gives you some idea of what the --
20 this is not the same test but earlier that day. Gives

1 you some idea of what the wake looks like from kind of
2 a back view.

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

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

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

14 The pilots initially reported on the first
15 day that some of the wake encounters did make a
16 distinct sound in the cockpit. The sounds they heard,
17 though, are not reported as being identical to the
18 recording to the sounds on the accident recorder. When
19 we reviewed their cockpit voice recorder after the
20 flight, the wake encounters did sound identical to the

1 ones found in the accident aircraft. Again, this is
2 due to the structure sounds being added to the air
3 sounds that the crew was hearing because they're only
4 hearing the air sounds.

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

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

16 As I mentioned before, an unexplained
17 increase in the amplitude of the noise of the engines
18 were heard on the accident aircraft. Again, that's
19 that red line that changes intensity here and again in
20 here. It actually gets louder here. Comes from almost

1 nothing and gets pretty loud and then fades away and
2 gets louder.

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

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

19 During these tests, using both left and right
20 rudder input, the engine sounds were noted as getting

1 louder when a rudder input from between 7 and 14
2 degrees was made. This level of increase was very
3 similar to the increase noted on the accident aircraft.

4 On this plot I have plotted the actual
5 intensity of the engine sounds. I extracted the engine
6 noise from the spectrum plots and plotted the increase
7 of engine. The top one that you see is from the wake
8 turbulence test with the left rudder input. The middle
9 one is the right rudder input and the bottom one is the
10 427 accident.

11 As you can see the intensity increase with
12 the rudder input, a little more on the right and left.

13 And the accident airplane increased intensity, leveled
14 off, decreased and then increased again.

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

1 degrees.

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

8 CHAIRMAN HALL: Thank you, Mr. Cash.

9 (Witness excused.)

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

12 MR. HAUETER: Yes, they have.

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

17 Mr. Schleede will swear the witness in.

18 (Witness testimony continues on the next
19 page.)

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1 MS. ANNE EVANS, SENIOR INSPECTOR OF AIR ACCIDENTS
2 (ENGINEERING) AIR ACCIDENT INVESTIGATION BRANCH
3 FARNBOROUGH, ENGLAND
4

5 Whereupon,

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

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

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

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

20 THE WITNESS: Okay.

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

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

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

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

11 MR. SCHLEEDE: Thank you.

12 Mr. Jacky will proceed.

13 MR. JACKY: Thank you.

14 Good morning, Ms. Evans.

15 THE WITNESS: Good morning.

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

1 THE WITNESS: Yes. I have it here.

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

6 Before we discuss the ~~at~~a search program,
7 could you, please --

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

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

15 CHAIRMAN HALL: Fine. Yes.

16 THE WITNESS: Okay. A quick access recorder
17 is a recorder, an additional data recorder, fitted for
18 maintenance and monitoring purposes. It's function is
19 basically similar to a flight data recorder, except the
20 recording medium is generally a cassette of magnetic

1 tape or it can be an optical drive. And this is easily
2 removable from the recorder itself post-flight.

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

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

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

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

20 THE WITNESS: The QAR is not designed for

1 accident investigation. The cassette is not crash
2 protected and it's not designed to survive an accident.

3 The airline fits a QAR because they have an interests
4 in actually utilizing the data for monitoring purposes.

5 And that can be engine health monitoring or, as a case
6 in study we do, operational monitoring.

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

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

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

19 THE WITNESS: The cassettes are removed on a
20 daily basis from each aircraft and processed through a

1 very large computing department.

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

4 THE WITNESS: Yes. Every airplane.

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

7 THE WITNESS: Yes.

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

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

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

20 THE WITNESS: Not normally. They wouldn't

1 replay the data recorder. It's a totally automatic
2 process using the cassettes alone.

3 MR. JACKY: Thank you.

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

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

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

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

19 MR. JACKY: So that if the airline noticed
20 that certainly some sort of event was happening over

1 and over they could add a program to look for that
2 specific event?

3 THE WITNESS: Yes, they can.

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

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

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

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

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

17 THE WITNESS: I think in the case of an
18 incident where the QAR was undamaged, our first course
19 would be to replay the QAR because it records much more
20 information than the FDR. Once we've satisfied

1 ourselves that that data is valid, we wouldn't then
2 need to replay the FDR. And it also gives us much more
3 information on previous flights, for example. We have
4 a number of cassettes which we are able to use for that
5 aircraft and indeed the whole fleet.

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

8 THE WITNESS: I'm sorry?

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

11 THE WITNESS: The airline would. Yes.

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

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

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

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

6 MR. JACKY: And where were these airlines
7 located?

8 THE WITNESS: Within Europe.

9 MR. JACKY: Could you explain, please, ~~hat~~
10 are the objectives of the program?

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

18 So we're doing a statistical analysis of what
19 is actually happening to the rudder and the yaw damper
20 movement and we're also looking for events which are

1 disagreements between the rudder pedal and the rudder
2 panel position as we have defined, and also looking for
3 lateral acceleration events above a certain level which
4 could be indicative of a yaw.

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

9 THE WITNESS: At the moment it's looking at
10 737-400 aircraft.

11 MR. JACKY: And how many airplanes are
12 involved?

13 THE WITNESS: Twenty-five aircraft.

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

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

20 MR. JACKY: Is it easy for the airline to

1 accomplish those changes?

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

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

7 THE WITNESS: Yes. I have it.

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

11 THE WITNESS: A histogram is a way of
12 presenting statistically data. And what we're looking
13 at here is a variety of rudder positions from minus 5-
14 1/2 degrees to 5 degrees, and dividing time intervals
15 and logging how long is spent at each rudder position.

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

19 THE WITNESS: Okay. Rudder position is shown
20 here and the data was divided into various flight

1 phases: takeoff and climb; climb, cruise and descent;
2 and approach and landing. We show here time in each
3 phase. You'll see most of the time has been spent
4 obviously in the climb, cruise and descent phase.

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

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

14 THE WITNESS: That's right.

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

18 THE WITNESS: 5,000 feet. So, takeoff to
19 5,000 feet would be the first phase and above 5,000
20 feet would be the climb, cruise and descent phase.

1 MR. JACKY: Okay. Thank you.

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

4 THE WITNESS: Yes. I have that here.

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

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

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

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

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

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

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

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

20 MR. JACKY: In addition to the histograms

1 that we've talked about, there are additional specific
2 events that the program encompasses. Would you explain
3 what those are, please?

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

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

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

19 THE WITNESS: The largest one has been 3.2
20 degrees in a fairly turbulent approach. And as I said,

1 3.2 degrees is within the tolerance of the calculations
2 and the calibration of the aircraft.

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

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

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

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

14 MR. JACKY: The information that's ~~show~~ in
15 the histograms here -- or how do you get that
16 information and how is that translated back to the
17 NTSB?

18 THE WITNESS: As each cassette is replayed,
19 the program analyzes the data for time spent in each
20 rudder or yaw damper activity position. That data is

1 then logged in a database within the computer and we're
2 able to interrogate that periodically and get an
3 update. And at the moment, we've been transferring
4 that finally to the NTSB.

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

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

10 MR. JACKY: And when did the program start?

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

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

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

20 MR. JACKY: Has the airline expressed any

1 interest in the program?

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

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

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

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

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

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

19 THE WITNESS: It's very dependent on the age
20 of the aircraft. For these particular aircraft, it is

1 not a requirement to record both pilot input and
2 surface position.

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

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

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

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

17 As you've seen from the histograms, usually
18 rudder position is around about zero, so we're going to
19 look for cases where there is an excess amount of
20 rudder being used, which obviously shouldn't be the

1 case unless you have an engine failure.

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

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

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

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

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

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

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

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

1 aircraft.

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

5 THE WITNESS: Yes. I have the exhibit here.

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

8 THE WITNESS: Item Number 50. Yes.

9 MR. JACKY: Okay. Recently the NTSB was
10 informed of an event that British Airways had on a 737-
11 200 airplane and I was wondering if you had any
12 knowledge of this event.

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

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

1 THE WITNESS: This incident is the subject of
2 an AAIB formal investigation and we are still
3 continuing that investigation.

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

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

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

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

1 increased.

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

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

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

9 THE WITNESS: I think the total number is
10 somewhere around 200.

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

13 CHAIRMAN HALL: Thank you, Mr. Jacky.

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

16 (No response.)

17 If not, we will at this time turn to the
18 parties. What I would like to do is what we did in
19 Pittsburgh. If you have an interest in asking a
20 question of this witness, if you would please have your

1 representative raise their hand and that would keep us
2 from having to go through the list every time to see.

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

5 (No response.)

6 If not, we will move to the Board of Inquiry.

7 Mr. Clark?

8 MR. CLARK: I have no questions.

9 CHAIRMAN HALL: Mr. Marx?

10 MR. MARX: No questions.

11 CHAIRMAN HALL: Mr. Schleede?

12 MR. SCHLEEDE: No questions.

13 CHAIRMAN HALL: Mr. Laynor?

14 MR. LAYNOR: No questions.

15 CHAIRMAN HALL: Well, the Chairman would just
16 like, Ms. Evans, to point out that in this
17 investigation we have sought out the international
18 assistance and international cooperation from around
19 the world and I want to note that the AAIB, which is
20 the British equivalent of the NTSB, I would like to

1 thank you and your organization for your support of
2 this investigation and your work with us, and note that
3 this has been done at the expense of your own
4 organization, which we greatly appreciate.

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

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

20 And we started, if I'm correct, in ~~October~~

1 with the recorder, quick access recorder, that gives us
2 the rudder -- what is it -- pedal and rudder panel. Is
3 that the correct description?

4 THE WITNESS: Yes.

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

7 And how long do we intend to monitor that?

8 THE WITNESS: For approximately six months.

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

11 THE WITNESS: Yes.

12 CHAIRMAN HALL: And basically, you've covered
13 this morning some information on the beginning of that.

14 And the reason we're doing that is that we hope that
15 we'll be able from that information to see if there are
16 any anomalies or rudder deflections that the Board --
17 that would assist us in this investigation.

18 Is that correct, Mr. Jacky?

19 MR. JACKY: That is correct.

20 CHAIRMAN HALL: Is there anything else that

1 the general public ought to know about what Ms. Evans
2 is doing and the work they're doing that would
3 contribute to the public understanding of what is a
4 fairly technical process?

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

13 CHAIRMAN HALL: Okay.

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

17 THE WITNESS: Thank you very much.

18 (Witness excused.)

19 CHAIRMAN HALL: Before we begin our next
20 witness, we will take a break for the benefit of all

1 involved for approximately 15 minutes. And we will
2 start this promptly at 10:45. So if you want to be
3 here, be ready in your seats at 10:45.

4 We stand in recess.

5 (Whereupon, a recess was taken.)

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

12 (Witness testimony continues on the next
13 page.)

14

15

1 MICHAEL ZIELINSKI, AEROSPACE ENGINEER, PROJECT OFFICER
2 CRITICAL DESIGN REVIEW TEAM LEADER, FEDERAL
3 AVIATION ADMINISTRATION, SEATTLE, WASHINGTON
4

5 Whereupon,

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

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

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

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

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

19 MR. SCHLEEDE: Ad you work for the FAA?

20 THE WITNESS: That's correct.

1 MR. SCHLEEDE: In what position?

2 THE WITNESS: I am an Aerospace Engineer
3 Project Officer within the Standardization Branch
4 within the Transport and Airplane Directorate.

5 MR. SCHLEEDE: Could you briefly describe
6 what your responsibilities are in the position?

7 THE WITNESS: My current responsibilities are
8 to monitor all transport category activity as far as
9 the Atlanta Certification Office and the LA -- that is
10 Los Angeles Aircraft Certification Office.

11 MR. SCHLEEDE: Would you give us a brief
12 description of your education and background that
13 qualifies you for your position?

14 THE WITNESS: I have a bachelor's degree in
15 aeronautical engineering. I've worked in industry 18
16 years, 10 of which have been as an FAA designated
17 engineering representative, flight analyst. I've been
18 employed at the FAA for the past 12 years.

19 MR. SCHLEEDE: Could you just briefly tell us
20 what a designated engineering representative does?

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

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

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

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

11 THE WITNESS: That is correct.

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

15 THE WITNESS: Yes.

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

20 THE WITNESS: Yes.

1 CHAIRMAN HALL: And I appreciate you being
2 here.

3 Mr. Phillips?

4 MR. PHILLIPS: Thank you.

5 Good morning, Mr. Zielinski?

6 THE WITNESS: Good morning.

7 MR. PHILLIPS: Can you hear me?

8 THE WITNESS: It's a little --

9 MR. PHILLIPS: Okay.

10 CHAIRMAN HALL: Is it on?

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

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

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

20 THE WITNESS: That's correct.

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

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

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

8 THE WITNESS: Both.

9 MR. PHILLIPS: Both. Okay.

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

12 THE WITNESS: That's correct.

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

17 THE WITNESS: Okay. The CDR, the critical
18 design review, was with respect to the 737 flight
19 controls and a charter was developed in October of '94
20 and it was felt that a team should take a fresh look at

1 the design of the flight control system on a 737 with
2 regard to possibly identifying any deficiencies that
3 might contribute to the ongoing accident investigation
4 with regard to the Pittsburgh accident.

5 There were eight to nine members at any given
6 time during that process, which went from October of
7 '94 through the end of April of '95. The document was
8 completed May 3rd of '95.

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

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

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

1 management?

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

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

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

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

1 THE WITNESS: Well, the idea for the effort
2 came out of the Seattle Aircraft Certification Office.

3 I believe Mr. Don Riggin, who is the Office Manager,
4 felt that something else had to be done and he thought
5 this was a possibility. He checked with upper
6 management as to the feasibility, considering the costs
7 and resources within the FAA, and it was decided that
8 this would be a worthwhile effort.

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

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

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

20 THE WITNESS: Well, certainly we are driven

1 by the accident -- accidents, I should say. And flight
2 controls was the area we wanted to focus. The decision
3 was made that the effort would be without any
4 inhibitions, inhibitions from the standpoint of the
5 probability of the occurrence. It was rather more of a
6 hazard assessment, a qualitative hazard assessment.

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

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

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

20 THE WITNESS: I'm sorry. The Colorado

1 Springs and the Pittsburgh events.

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

7 THE WITNESS: Yes, we did. The document,
8 that is the report on the critical design review,
9 contains our review of the initial certification of the
10 737-100-200 and the models 300, 400 and 500. It was to
11 give us a measure of where or what the certification
12 basis was for those airplanes with regard to today's
13 requirements.

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

17 THE WITNESS: An applicant, a manufacturer of
18 an aircraft, approaches the FAA with a design concept
19 and is requesting certification of the design. In this
20 case, a transport category airplane. And at that time

1 of application, we look at what is the current
2 amendment level within the certification rules. And
3 it's that level that's applicable to that particular
4 airplane.

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

7 THE WITNESS: That is correct.

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

13 THE WITNESS: Okay. A bit of background on
14 the 737, the various models. The airplane was
15 originally certified, I believe, in 1967. That is, the
16 100, 200. And beginning in '84, the other three
17 models, 300, 400 and 500, were certified against the
18 same type certification basis. And that is, that we
19 did not apply the -- directly apply the latest
20 amendments as they may exist say in 1984 against the

1 737-300, 400 and 500, except for those parts of the
2 airplane that had significant change.

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

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

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

17 THE WITNESS: Well, the certification basis
18 is certainly set by the time of the application. If
19 it's an amendment to the type certification basis, our
20 current policy is to ask the applicant to assess the

1 opportunity to certify to the current amendment level,
2 although it's not a requirement, and to show how or why
3 that may not be appropriate, given the service
4 experience of the airplane and/or the inapplicability
5 of the new amendment level.

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

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

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

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

6 Within 25 -- that is, Advisory Circular
7 251309 are identified what are considerations as far as
8 the probability of failure and a degree of hazard
9 associated with that probability.

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

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

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

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

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

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

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

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

12 MR. PHILLIPS: So if it has a number of
13 251309, that means it's relative to that requirement or
14 regulation and that's a means of compliance?

15 THE WITNESS: That's correct.

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

1 THE WITNESS: That's fine.

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

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

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

18 We reviewed the AD history; that is,
19 Airworthiness Directive history on the 737 to tell us
20 if there were areas of particular concern, frequency of

1 failure, et cetera, which would give us focus as to any
2 considerations for possible recommendations on
3 corrective action.

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

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

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

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

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

3 THE WITNESS: Per the regulation.

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

8 THE WITNESS: That is the expectation.

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

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

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

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

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

12 THE WITNESS: Or the operator.

13 MR. PHILLIPS: Someone at the operator?
14 Okay.

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

18 THE WITNESS: SDR's are usually categorized
19 by ATA chapter and various numbers indicate elements
20 within, in this particular case, the flight control

1 system. And we interrogated that system for those ATA
2 chapters that affect flight controls.

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

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

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

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

20 We've also included in the appendix some

1 information with regard to service bulletins and
2 service letters that also were somewhat indicative of
3 the failure.

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

10 That's all referenced in those tables.

11 MR. PHILLIPS: I realize that.

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

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

19 MR. PHILLIPS: Sure can.

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

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

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

7 MR. PHILLIPS: Okay. Back to the ASRS issue.

8 Again, a brief description of what that is and who
9 maintains that database.

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

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

1 started about that time period.

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

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

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

9 THE WITNESS: That's correct.

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

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

1 assistance, with regard to the CDR.

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

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

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

14 THE WITNESS: No.

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

17 THE WITNESS: Right.

18 MR. PHILLIPS: As part of your work, I
19 believe you had a pilot with your group, at least one.
20 And you did some simulation work at Boeing. Could you

1 summarize that real briefly?

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

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

18 We looked at jams. We looked at failures.
19 We looked at jams, partial jams, full jams, from the
20 standpoint of using the example of the wheel. The

1 control wheel was jammed at 45 degrees, I believe, and
2 at a full throw. We looked at the consequent ability
3 with the remaining flight control to continue to fly
4 the airplane. And in some cases, we attempted to land
5 the airplane. Of course, all in the simulation.

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

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

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

14 THE WITNESS: That's right.

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

19 THE WITNESS: In our review of the failures
20 analyses, the question came up with regard to jam at

1 what position. Where does the flight control input
2 jam? And the FAA has a regulation, 25.671, that talks
3 about is normally encountered. And our investigation
4 as to what does that mean, we've come to a conclusion
5 there was no specific, meaning it was very subjective.

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

17 MR. PHILLIPS: Did you have any reason to
18 think that jams would occur only at a full travel
19 position or neutral position? Was there any basis from
20 your service history study of the SDR's that would

1 indicate you should be looking in those areas or was it
2 just thoroughness?

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

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

20 We're in the process of -- or we have, I

1 should say, developed an issue paper. An issue paper
2 is a document that identifies an FAA concern with
3 regard to compliance with a particular regulation.
4 It's a document that is developed in the process of
5 certification of an airplane. And within this
6 particular issue paper that I'm referring to, we are
7 attempting to identify criteria that should be used to
8 establish what normally encountered means.

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

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

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

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

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

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

17 I believe ultimately in our recommendation,
18 for instance with regard to the rudder, we did identify
19 failure of the modes consequences not shown to be
20 extremely improbable as those conditions that you would

1 not have to show controllability because of the
2 extremely improbable nature of the failure and a
3 consequence of being at say null rudder deflection.

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

6 THE WITNESS: To the FAA, it's as prescribed
7 in -- again, Advisory Circular 251309, revision 1A. It
8 identifies the probability, extremely improbable being
9 an event that is -- the potential for its occurrence
10 may be one in a billion. A billion flight hours, for
11 example, has not yet occurred with regard to the
12 operations certainly of the 737. It's on the order of
13 60-some million hours at this time.

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

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

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

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

10 THE WITNESS: No.

11 MR. PHILLIPS: Would it be --

12 THE WITNESS: Let me clarify. It was an
13 engineering judgment as to the hazard associated with
14 single multiple failures as opposed to a probabilistic
15 determination that the combination of events would be a
16 10 to the 9th or less.

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

20 THE WITNESS: Yes.

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

4 THE WITNESS: Yes.

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

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

17 And it was a judgment from the standpoint
18 that any event of occurrence that could pose a hazard,
19 there were alternate means or there was an action or a
20 response that could be elicited from the flight crew in

1 dealing with that failure.

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

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

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

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

13 THE WITNESS: Yes.

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

18 THE WITNESS: No. But there is another means
19 for dealing with issues. In the process of certifying
20 the airplane an assessment is made as to the hazards

1 associated with failures subsequent to the
2 certification of the airplane. We have what's called
3 the continued airworthiness -- continued operational
4 safety.

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

13 The Flight Standard service element of the
14 FAA contributes via its monitoring of the operation of
15 the airplane and the events occurring within that
16 particular operation. Those events, from the
17 standpoint of failures, component removals, et cetera,
18 that information is fed back to certification. That
19 is, Aircraft Certification Service. And the cumulative
20 information that is what comes from the operator, what

1 comes from the manufacturer, is accumulated within the
2 Aircraft Certification Office to determine whether or
3 not an airworthiness directive needs to be generated.

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

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

19 THE WITNESS: Are you talking about the
20 failure analysis?

1 MR. PHILLIPS: Failure analysis documents.

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

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

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

19 (Pause.)

20 You have to excuse me. I was going to make a

1 point. I can't recall. Repeat your question, please.

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

5 THE WITNESS: Okay. You asked engineering
6 judgment.

7 MR. PHILLIPS: Right.

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

18 CHAIRMAN HALL: Mr. Phillips, I'm just -- so
19 I can follow this now, is this -- the failure analysis
20 document is what you're saying, Mr. Zielinski, was

1 created in 1969 on this plane when it was originally
2 certified?

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

6 CHAIRMAN HALL: And that document is not
7 updated?

8 THE WITNESS: That's correct.

9 CHAIRMAN HALL: With each model that comes
10 along.

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

13 CHAIRMAN HALL: So the series, 100, 200, 300,
14 400, is that document updated or it stays the same?

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

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

20 THE WITNESS: For additional equipment, like

1 a change in the autopilot, the incorporation of other
2 design features modifications. Any time a significant
3 modification is introduced, the failure analysis needs
4 to be updated.

5 CHAIRMAN HALL: And you monitor that in your
6 shop?

7 THE WITNESS: It's a requirement.

8 CHAIRMAN HALL: Through that process?

9 THE WITNESS: Right.

10 CHAIRMAN HALL: Okay.

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

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

20 THE WITNESS: That's why our process, as far

1 as the CDR team. Just to emphasize, the people were
2 not necessarily familiar with the airplane but they
3 were expert in their particular area of specialty.
4 They were provided that familiarization. They were
5 privy to the analysis in support of the certification
6 of the airplane and then we looked at the service
7 history of the airplane in substantial or corroboration
8 of analyses and/or judgments that were provided as far
9 as failures and their associated hazard.

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

16 THE WITNESS: This is one of the advantages
17 of a fresh look at a design. The team began to ask
18 questions, simple questions with regard to sensitivity
19 of hydraulic components, with regard to contamination.
20 And as we explored that question, we also asked that

1 of Douglas as well, with regard to their approach
2 considerations.

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

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

20 And in this particular case, with response to

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

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

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

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

17 Did your work in this area result in any
18 recommendations?

19 THE WITNESS: Yes.

20 MR. PHILLIPS: And before we go into that a

1 whole lot, what I'd like to do is maybe in the end
2 summarize the recommendations. Right now, I'd just
3 like to stick with the area here.

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

6 THE WITNESS: Yes, we did.

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

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

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

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

20 THE WITNESS: Not that there are any

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

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

7 THE WITNESS: Yes.

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

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

15 THE WITNESS: Well, our intent initially was
16 to review the features and any potential concerns about
17 the flight control system on the 737. But in the
18 process, we identified a number of issues that were not
19 germane only to that airplane. And we began to see
20 that we had some internal problems with regard to

1 identification of policy and/or standards that should
2 be applied to airplanes of this category; that is, the
3 transport category.

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

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

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

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

20 Have you got that page there?

1 THE WITNESS: I have page 34.

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

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

9 THE WITNESS: Page 34?

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

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

14 MR. PHILLIPS: We need the actual exhibit.

15 CHAIRMAN HAL: It's page 39 of the exhibit;
16 right?

17 MR. SCHLEEDE: The handwritten 39.

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

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

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

5 CHAIRMAN HALL: Okay.

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

8 (Pause.)

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

16 THE WITNESS: That's right.

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

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

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

9 MR. PHILLIPS: Okay.

10 THE WITNESS: The --

11 MR. PHILLIPS: Go ahead.

12 THE WITNESS: The statement of sufficiency.

13 Is that what your concern; what does it mean?

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

16 THE WITNESS: I think I mentioned earlier our
17 concern about what normally encountered means and I
18 think that's what we're trying to say. That a
19 subjective approach to normally encountered is not
20 sufficient and we wanted a more specific criteria that

1 could be readily adapted to other airplanes, a
2 standardized approach to normally encountered.
3 Therefore, equal treatment with regard to certification
4 of this category of airplane.

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

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

18 MR. PHILLIPS: Okay. And under the area of
19 certification process, I see three recommendations.
20 Can you summarize those into a brief statement as to

1 the subject matter for those?

2 CHAIRMAN HALL: Which three?

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

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

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

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

19 What we found in our review was that this
20 expected response or action item didn't have a good

1 trail from the standpoint of implementation.

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

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

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

17 Now, in our discussion of this particular
18 recommendation with Flight Standards Service personnel
19 within the FAA, the belief was that to a degree it did
20 exist, but it was not a formal exercise where -- here's

1 a document that says this is the response of the flight
2 crew and this is how it's been disposed of.

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

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

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

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

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

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

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

18 So, although our sample is limited in the
19 case of only having looked at the 737 and the DC-9/MD-
20 80 series, I believe this is an internal issue within

1 the FAA as well. And that's why a recommendation
2 looked to Advisory Circular 251309.1A and subsequent
3 revisions to clarify. Action items consequent to a
4 failure analysis need to be dealt with, and any
5 recommendation for how that process should occur.

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

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

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

19 You're asking the SACO, which is the Seattle
20 Aircraft Certification Office, to carry out this

1 recommendation. Is there something in your studies
2 that indicated that the lateral control system could
3 not provide adequate directional control throughout the
4 airplane operating envelope?

5 That's the first part of that recommendation.

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

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

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

10 And what I mean by controllability is that
11 not only can I continue to fly the airplane but I can
12 maneuver the airplane to a successful safe landing.
13 And so we didn't feel that in our review of the failure
14 analyses that this was occurring. And I must say again
15 that having looked at another airplane series, the DC-
16 9/MD-80, there was a similar situation where it was not
17 demonstrated with regard to the controllability and
18 continued safe flight of the airplane was demonstrated
19 apart from a failure analysis says that it's okay.

20 And that having looked at some conditions, it

1 wasn't necessary to look at all conditions.

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

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

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

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

17 THE WITNESS: That's correct.

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

1 part?

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

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

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

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

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

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

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

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

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

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

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

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

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

7 THE WITNESS: No. We have not formalized
8 that.

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

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

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

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

3 MR. PHILLIPS: And his office is in Seattle?

4 THE WITNESS: That's correct.

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

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

19 And the reason for the elimination of the
20 pitch axis, and I think we've identified that in our

1 report, was it didn't appear to be implicated in the
2 referenced accidents. Although we did become familiar
3 with it, we chose not to spend the amount of effort
4 necessary to review that thoroughly.

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

12 I feel secure in that judgment still at this
13 time. The resources that we had I believe were
14 adequate. The level of expertise I believe was
15 adequate. You could always do more possibly. In
16 retrospect, I think I would have loved to spend more
17 time on a probabilistic analysis as opposed to
18 relegating the consequence review of that to somebody
19 else. I would have liked to have had the team spend
20 more time, having looked at the hazard assessment, the

1 qualitative approach to spend more time looking at the
2 quantitative analysis and to make some determinations
3 relative to that.

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

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

14 THE WITNESS: I think any comprehensive in
15 depth review of an airplane's design, especially let's
16 say an airplane that's been in service for a number of
17 years, the subsequent experience of that aircraft is of
18 value. It not only reveals any deficiencies that we
19 might have in process but also things that may have
20 been overlooked. And the closer you are to a project,

1 possibly the more apt you are to not spend the time and
2 look at some of the details of events, whereas an
3 outside group as say the CDR team was, I believe that
4 process does give you might say a second set of eyes
5 reviewing the same information and possibly identifying
6 issues that have been overlooked and should be
7 considered.

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

17 MR. PHILLIPS: I guess you almost answered my
18 final question but I'll ask it anyway. Did your review
19 find anything that would indicate a probable cause for
20 this accident or a lack of -- from what you've heard in

1 earlier testimony and your reviews of our materials, a
2 lack of direction or understanding in finding the
3 accident cause for either accident, Colorado Springs or
4 Pittsburgh?

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

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

20 MR. PHILLIPS: That's all the questions I

1 have right now unless you have something you'd like to
2 add as a closing comment or something that I may have
3 forgotten to ask that you'd like to answer.

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

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

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

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

1 the parties.

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

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

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

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

11 THE WITNESS: That's correct.

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

16 THE WITNESS: That's correct.

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

1 THE WITNESS: I have a copy of it.

2 MR. PURVIS: I think it's near the end.

3 Anyway, it's listed in the corner as Slide 10. I don't
4 think those pages are actually numbered.

5 CHAIRMAN HALL: No, they aren't.

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

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

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

12 CHAIRMAN HALL: Yes. There's no problem.

13 MR. PURVIS: Okay.

14 CHAIRMAN HALL: You want to put it up, put it
15 up. This is Exhibit Number 9X-N. It's in the docket
16 as SA-510. It's a Critical Design Review Executive
17 Summary and we have up on the viewgraph one of 12
18 slides that are with this presentation. This is Slide
19 10.

20 MR. PURVIS: First of all, my question would

1 be did the CDR team also prepare the Executive Summary?

2 THE WITNESS: Yes, it did.

3 MR. PURVIS: On that slide there are some of
4 the points you've talked about. The first one: The
5 737 meets all certification requirements. And I guess
6 you can read them down, about some that you just talked
7 about.

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

11 And earlier you talked about: No scenarios
12 identified that would explain either of the accidents.

13 I think you touched on that, at least on 427.

14 Do you agree with those?

15 THE WITNESS: Yes, I do.

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

20 Is that agreed to by the team also?

1 THE WITNESS: Yes.

2 MR. PURVIS: I have no further questions.

3 CHAIRMAN HALL: Verywell. We'll move to the
4 Air Line Pilots Association.

5 Captain?

6 MR. LeGROW: Thank you, Mr. Chairman.

7 I guess it's afternoon. Good afternoon, Mr.
8 Zielinski.

9 THE WITNESS: Good afternoon.

10 MR. LeGROW: Just a couple of questions.

11 First of all, in your testimony, you
12 testified the Boeing 737 and its derivatives were
13 certified in 1967. Is that correct?

14 THE WITNESS: No, it's not. The 737-100, 200,
15 I believe, was 1967. The 300 and on, 400 and 500
16 airplanes, began certification in '84. Boeing could
17 clarify the specific dates.

18 MR. LeGROW: But they used the same criteria
19 as the 100?

20 THE WITNESS: It wasn't identical. From the

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

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

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

20 THE WITNESS: Capability?

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

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

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

11 And of course, there were some changes to the
12 leading and trailing edge on the 300 relative to the
13 100 or 200 airplane.

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

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

20 THE WITNESS: I was not involved in that

1 certification.

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

4 CHAIRMAN HALL: Is that exhibit page 17?

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

7 THE WITNESS: This is the Critical Design
8 Review?

9 MR. LeGROW: Yes, sir.

10 THE WITNESS: Okay.

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

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

1 at a high altitude and speed.

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

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

10 THE WITNESS: Where is the word precise pilot
11 control?

12 MR. LeGROW: It would be the last --

13 THE WITNESS: Oh, okay.

14 MR. LeGROW: -- sentence in paragraph 2.

15 THE WITNESS: The slow and required precise
16 pilot control. Okay. I was the observer -- was an
17 observer of the exercise, not being in a cockpit but
18 outside the cockpit as far as the simulation. We had
19 two FAA pilots that were exercising the test plan and
20 my best recollection as to what they meant by precise

1 pilot control is with regard to the pitch and not
2 utilizing the pitch axis much in the recovery. That
3 is, pulling the stick back too far.

4 MR. LeGROW: Okay. Thank you.

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

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

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

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

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

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

12 THE WITNESS: Yes.

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

16 THE WITNESS: The Advisory Circular 251309.1A
17 speaks to the extremely improbable event as one times
18 10 to the 9th negative. So that you're looking at the
19 potential of one in a billion flight hours, for
20 example, of something occurring. And our

1 recommendation with regard to the demonstration of the
2 jams, failures, et cetera, not shown to be extremely
3 improbable is along the lines of -- and considering
4 that if it is extremely improbable or if it's not
5 likely to occur in one in a billion, considering where
6 the fleet is today, that it's not an issue.

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

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

13 THE WITNESS: No.

14 MR. LeGROW: Thank you.

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

18 THE WITNESS: Well, we initiated our exercise
19 in October of '94. I believe it was prior to Christmas
20 that we had the exercise in the simulator. The

1 document may have a date in it.

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

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

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

13 THE WITNESS: That's correct.

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

16 CHAIRMAN HALL: Thank you, Captain.

17 Mr. Donner, with the Federal Aviation
18 Administration.

19 MR. DONNER: Thank you, Mr. Chairman.

20 Just two questions, Mr. Zielinski.

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

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

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

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

19 THE WITNESS: Yes.

20 MR. DONNER: Back at the beginning of your

1 testimony you asked for a date on Advisory Circular
2 251309.1A. The current date that I have on yours is
3 6/21/88.

4 Thank you, sir.

5 CHAIRMAN HALL: Thank you.

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

10 MR. HAUETER: Thank you, sir.

11 Just a couple of clarifications. When the
12 300 series was certified, was a probability assessment
13 done of the lateral or directional control systems?

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

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

18 THE WITNESS: Let's see. There was a change
19 to the hydraulic system as far as A and B and the
20 pumps, engine driven pumps and electrical pumps. I

1 don't recall that that had any impact on the analysis.

2 I guess I'd have to ask Boeing if that recollection's
3 correct.

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

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

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

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

15 THE WITNESS: This was an interesting one.
16 We felt very concerned about this issue of directional
17 control versus lateral control. And to us, it was not
18 sufficient to do things how we'd done it in the past.
19 And we felt that -- and that's why this rigorous
20 methodology available and the note following that made

1 reference to a methodology that was used as it applies
2 to the thrust reversers and concerns that we had with
3 regards to failure assessments of thrust reversers.
4 And we felt that was a good example of the approach
5 that ought to be taken.

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

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

17 So, enough said.

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

1 methodology available?

2 THE WITNESS: Well, my hope is that it would.

3 I think the experience of what we've been through --
4 and it's been a lot with regard to the '37 and trying
5 to identify cause -- that we feel we must be more
6 thorough in our approach to failure analysis, and
7 particularly as it affects the flight control of the
8 airplane.

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

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

20 I believe it certainly behooves us to assure

1 ourselves that any new data doesn't cause any more
2 concern. At least to that extent we should do that.
3 That's my personal opinion.

4 MR. HAUETER: Thank you, sir.

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

7 Mr. Clark?

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

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

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

18 THE WITNESS: No.

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

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

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

13 THE WITNESS: When I was at Boeing?

14 MR. CLARK: Yes.

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

1 apart from stall characteristics.

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

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

9 MR. CLARK: The rudder PCU.

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

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

20 THE WITNESS: Oh, we had heaps and gobs of

1 discussion about the dual servo valve. First off,
2 understanding how it works, trying to get that under
3 our belt. And then the potentials for any kind of jam
4 or failure mode that could subsequently with the next
5 failure result in an uncommitted rudder.

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

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

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

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

8 MR. CLARK: You say it was?

9 THE WITNESS: Was. Is.

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

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

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

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

14 We feel we've made a fairly legitimate review
15 of the envelope with regard to flight control.

16 MR. CLARK: Okay. Thank you.

17 CHAIRMAN HALL: Mr. Marx?

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

19 I understand that the review was done on the
20 standby rudder components also and that you had made a

1 recommendation dealing with galling that occurs in the
2 bearing?

3 THE WITNESS: That's correct.

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

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

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

11 What is your understanding of the --

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

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

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

1 that?

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

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

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

20 THE WITNESS: Right. And one of our

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

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

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

18 This, I believe, is identified in our
19 document from the standpoint of if there's no alternate
20 means for flight control, there should be a concerted

1 effort to make sure that it works and that the
2 resulting utilization of that control is acceptable.

3 MR. MARX: Thank you.

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

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

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

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

18 THE WITNESS: It freezes, then it unfreezes?

19 MR. MARX: Yes.

20 THE WITNESS: I think the duration for which

1 that would be undetected is fairly short because there
2 would be -- again, either Boeing or Mr. Koch could
3 further expand upon that. As far as the impact on
4 flight crew making an input, certainly the yaw damper
5 could continue to function but as far as flight crew
6 trying to make an input, they would certainly be
7 impacted by grounding of the standby rudder.

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

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

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

17 THE WITNESS: Well, let's clarify that. I
18 think it's immediate corrective action. What that
19 means is that the defect that we see is a safety issue
20 that must be corrected now. And the way to do that is

1 to write an airworthiness directive that says if we
2 found that galling was indeed a safety issue that could
3 cause -- would prohibit continued safe flight and
4 landing, that an AD would come out the door
5 immediately. But we do not see that in this category.

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

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

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

15 THE WITNESS: I believe --

16 MR. MARX: This is dealing with
17 Recommendation 15.

18 THE WITNESS: Uh-huh. See, Boeing provided a
19 response, I believe mid-October. Said that no mandatory
20 action is required. But I believe they are initiating

1 an effort to correct the problem.

2 MR. MARX: I have no further questions.

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

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

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

14 THE WITNESS: That's correct.

15 CHAIRMAN HALL: Okay.

16 Mr. Schleede?

17 MR. SCHLEEDE: Yes, sir.

18 Mr. Phillips asked you questions, several
19 questions, regarding the 1960's failure analysis that
20 was used as a basis for the certification of the

1 airplane and I want to follow up on one of the
2 questions he asked.

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

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

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

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

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

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

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

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

18 In my hesitation, you might ~~de~~ct -- does
19 this guy know what he's talking about. But my
20 recollection of the team member that had the

1 responsibility to review the action items was that --
2 and those action items that we did review, there was no
3 connect between the failure analysis and the
4 documentation that says it's intuitive or it's
5 incorporated into an operations manual or a flight
6 manual.

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

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

18 THE WITNESS: No, we did not. We identified
19 the issue. We told -- in our documentation. We asked
20 Flight Standards to review flight crew training

1 requirements in consideration of the failure analysis
2 and action items. And we asked that the Transport
3 Directorate consider the incorporation of 251309 a
4 requirement to develop a process.

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

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

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

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

1 THE WITNESS: That's correct.

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

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

17 The fact that the crew does or doesn't take
18 that action, I think is one that involves a number of
19 elements, operations and engineering to assess. First
20 off, there's a lot of responses from flight crew

1 relative to failures. That is not a training issue.
2 And somebody has to make a judgment that the crew will
3 or will not do this particular action, in this
4 particular environment for this particular
5 configuration, flight, et cetera. And having made that
6 judgment then and asserting that it's not an intuitive
7 response then, and if it's important to accepting the
8 analysis, if the flight crew does not accomplish this
9 action, does this result in a -- is there a safety of
10 flight issue.

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

1 in their failure analysis.

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

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

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

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

20 Those are the only two I see closure at this

1 time.

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

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

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

18 MR. SCHLEEDE: Thank you very much, sir.

19 CHAIRMAN HALL: Mr. Laynor?

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

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

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

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

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

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

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

18 We looked at every failure analysis
19 documented by the Boeing Company in support of the
20 certification of the airplane. I don't recall any

1 failure mode where we identified the lack of any
2 analysis, other than the need for a probability
3 assessment of the rudder as opposed to a qualitative
4 assessment.

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

8 THE WITNESS: A probablistic assessment at
9 the time?

10 MR. LAYNOR: A probability assessment.

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

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

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

15 And we've lived that way for a long time in
16 the construction and development of airplanes. It was
17 a lot based on what engineering judgment resulted in.
18 Consequently, we've learned a lot of things. Our
19 database has grown with regard to transport category
20 airplanes. And we now can approach it more rigorously

1 from the standpoint of probability of failure. But
2 that's not to discount the use of engineering judgment.

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

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

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

18 We have some considerations for certain
19 mechanisms that although they're shown to be extremely
20 improbable, we still would like the failure to occur

1 and look at the consequent result.

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

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

15 THE WITNESS: Okay. Let me try ~~aga~~.

16 MR. LAYNOR: Well, --

17 THE WITNESS: It's both. Okay?

18 MR. LAYNOR: Okay.

19 THE WITNESS: An analysis was made, a
20 qualitative assessment made. There may or may not have

1 been an alternate means of flying the airplane. But
2 because of the remote nature or the improbable
3 occurrence of this failure coupled with that in the
4 judgment of the people that have the responsibility for
5 making the judgment, said it was okay. In some cases,
6 there is no alternative. In other cases, there are.

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

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

14 MR. LAYNOR: A little bit.

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

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

1 improbable during the point of certification?

2 THE WITNESS: Not improbable.

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

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

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

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

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

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

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

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

1 THE WITNESS: What those differences are?

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

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

7 MR. LAYNOR: In considering recovery by
8 alternative flight controls, I think one of your
9 recommendations is need for a better definition for
10 what kind of pilot response would be considered. Am I
11 interpreting that correctly? Do you feel like there's
12 a -- your team felt like there had to be a better
13 definition for a pilot response that would be
14 acceptable response to a flight control system failure?

15 THE WITNESS: I wonder if you could be a
16 little more specific. There's a couple of things we've
17 said about pilot response in various recommendations
18 but it's more implicit than it is explicit.

19 MR. LAYNOR: I don't have the recommendation
20 number right at hand but I thought that one of the

1 recommendations that I saw in here was the need to --
2 number 2? Is this recommendation 2 that you're talking
3 about?

4 THE WITNESS: Yes. A better definition.

5 CHAIRMAN HALL: That's Recommendation 2 on
6 page 39 of the exhibit.

7 THE WITNESS: Okay. This recommendation must
8 be taken in context with Recommendation Number 1,
9 alternate means of flying the airplane. I believe the
10 driver in this particular case was the lateral control
11 system.

12 Any event that there is a jam of aileron in
13 consideration of what's normal, normally encountered --
14 here we go again, you know, what's normally encountered
15 -- that when utilizing the alternate means, in this
16 case it would be continue to control the airplane
17 laterally through the aileron transfer mechanism.

18 And depending upon the degree, that is, how
19 much of a jam there is, therefore, how much aileron has
20 been deflected, would dictate how much control force

1 requirement is on a pilot that is now using the aileron
2 transfer mechanism.

3 In this case we, in our simulator exercise,
4 did look at a number of scenarios where the jam
5 occurred half full wheel and therefore the need to fly
6 the airplane through this mechanism. And the force
7 required was high. And we wanted to make sure that all
8 the folks, that is, the certification people, were
9 aware that these mechanisms, these alternate devices as
10 a general category, as opposed to specifically the
11 transfer mechanism in the case of the 737, that when
12 using an alternate means for flying the airplane it
13 shall not require exceptional pilot skill and strength.

14 And we believe -- did make some reference to
15 FAR Part 25.143 as far as the temporary and prolonged
16 forces as a measure of what might be considered
17 something beyond what a normal pilot might be expected
18 to provide.

19 MR. LAYNOR: So there are response times and
20 how much of an unusual attitude that could develop

1 before response is taken. That's all taken into
2 consideration there?

3 THE WITNESS: Well, in this particular
4 recommendations, the response time wasn't so much an
5 issue as much as it was pilot strength and skill. The
6 response time, I think, is later on in Recommendation
7 19. That's on page 45, where we are recommending that
8 in this particular case, the 37 flight crew training
9 program ensure the use of proper procedures for
10 recovery from flight path upsets and flight crew
11 awareness regarding loss of airplane performance due to
12 flight control system malfunctions.

13 What's behind that is the proper procedure is
14 a time issue. Recognition is an issue of the failure
15 event proper responses and this awareness of loss of
16 airplane performance. What's behind that is in our
17 exercise in the simulator, we looked at spoiler stuck
18 up and a failure mode where that might occur and the
19 consequent loss of airplane performance was rather
20 dramatic. And I think what we're seeing here is that

1 that realization of that loss of performance is of
2 significance. And if that were to occur, the flight
3 crew should be aware of the high sink rates that may be
4 associated with it.

5 Does that help?

6 MR. LAYNOR: Yes, sir. Thank you. And in
7 considering such response or standards for
8 certification based on pilot response, do you believe
9 that operation on the autopilot at the initial event
10 should be considered?

11 THE WITNESS: The operation of the autopilot
12 as a --

13 MR. LAYNOR: As it might mask an initial
14 recognition of an event?

15 THE WITNESS: Well, it's certainly a
16 consideration, without a doubt.

17 MR. LAYNOR: Let me ask one last question,
18 and it happens to be the next recommendation,
19 Recommendation 20 on page 46. You don't have to refer
20 to it but it discusses the overhaul of flight control

1 components by persons other than the PMA and original
2 part certificate holder.

3 Can you briefly summarize what the team's
4 findings and concerns were regarding replacement of
5 flight control system components by people other than
6 the original manufacturer?

7 THE WITNESS: Okay. Let's take 20 and 21
8 together. I'll speak to both of them.

9 There are elements within the flight control
10 system that we've let say put into the category of
11 primary. That is, if these elements were not properly
12 maintained, repaired and returned to service, we'd have
13 some real concerns. What's going on here is that we
14 certainly do allow a construction of parts, that is,
15 PMA can produce parts for replacement into flight
16 control systems but there's also an opportunity for
17 others to possibly create these parts as part of their
18 SFAR 36 authority in the repair of, in this case, say a
19 primary control unit or part control unit.

20 Our concern was that if it's other than the

1 PMA that is providing a replacement part, we must
2 ensure ourselves that the replacement part is indeed
3 equivalent and we've identified that there is an
4 opportunity for that equivalence to not necessarily
5 occur.

6 That doesn't mean that it's an unsafe
7 condition but we felt, considering the critical nature
8 of some of these parts, that we need to be better
9 assured that when that part is constructed and
10 installed, that there's no compromise as to the
11 performance function and safety of that particular
12 element in the flight control system.

13 We are taking steps to make sure that when
14 something like that is done, that is, a repair of a
15 primary element in a flight control system is
16 conducted, that the construction of that repair element
17 is done with the assurance that it's design performance
18 is equivalent to what was originally certified.

19 And to make sure that happens, it's our
20 effort to require that an Aircraft Certification Office

1 that is monitoring an SFAR 36 operation, that when they
2 repair primary control elements, flight control
3 elements, that the design fabrication of the repair
4 part or the part that's to be installed as part of the
5 repair meets the same standards as was expected for the
6 original certification.

7 For that to occur, let's say for example Los
8 Angeles is monitoring or is providing surveillance
9 supervision of an SFAR 36 approval, that that office
10 will coordinate with say the Seattle Aircraft
11 Certification Office to assure itself that it has the
12 latest information with regard to design, any
13 associated tooling, any acceptance test procedures, so
14 that we are assured that the consequent function of the
15 repaired part is equivalent to the original
16 certification.

17 That's a lot. It's a lot of words, I know.
18 Maybe it's babble to a lot of people. But the point is
19 that there's stuff out there that we want to make
20 doubly sure that we have not compromised the safety of

1 design.

2 MR. LAYNOR: Okay. Thank you very much.

3 CHAIRMAN HALL: Mr. Zielinski, you have been
4 up here a good amount of time and I am the last person
5 that will ask you questions. But let me say at the
6 beginning I appreciate very much the time you've taken
7 in responding to the questions of the Board of Inquiry.

8 And let me thank you for the work of the
9 Critical Design Review Team. Obviously, that's I think
10 important work and important recommendations. And I'm
11 sure, given your background and qualifications, you're
12 to be complimented for being selected to head that
13 team.

14 I would like to just get into some sort of
15 basic matters. Who or what initiated this team being
16 formed?

17 THE WITNESS: I think fundamentally it's the
18 frustration of not being able to find cause with the
19 Pittsburgh accident.

20 CHAIRMAN HALL: I guess -- was it the

1 Administrator or was it someone else in the
2 organization that said we need to form this team, go
3 form it?

4 THE WITNESS: The original suggestion came
5 out of the Manager of the Seattle Aircraft
6 Certification Office.

7 CHAIRMAN HALL: Very good. And the team was
8 organized and you were selected, nine individuals, and
9 given a charter. And I believe you said earlier that
10 you all had not become familiar with the accidents and
11 one of the things that you, if you had to do the
12 process over, and we all -- hindsight is always 20/20,
13 that you would have wanted to become more familiar with
14 the accidents.

15 And that just kind of left a question in my
16 mind because it seemed to me that if this was really
17 initiated because of these two accidents, why you all
18 weren't more focused on those accidents.

19 THE WITNESS: Okay. Let me put it in
20 perspective. The reason for the separation was so that

1 if you eliminated certain elements, that would follow
2 suit. If the accident investigation said this is not a
3 consideration, don't bother with it, so therefore, why
4 continue to do the CDR in this area. But that wasn't
5 our charter. There still might be deficiencies. They
6 may not be causal to the accident but they still would
7 be deficiencies relative to the flight control system
8 design.

9 So we wanted to at least start that process
10 where we were not part of the accident investigation.
11 We were looking at the design of the airplane
12 independent of that. But at some point in time, I
13 think now that we've completed the majority of our
14 work, now look at what has been gained out of the
15 accident investigation to find out if there's another
16 strategy or other approaches that should be taken.

17 So it was to prevent a premature elimination
18 of areas of investigation on our part that we kept the
19 two activities separate.

20 CHAIRMAN HALL: Now, whose decision was that?

1 Was that the team's decision or was that the direction
2 that you received?

3 THE WITNESS: That's the direction that we
4 undertook the project.

5 CHAIRMAN HALL: Very well. Now, on page 38
6 of this Exhibit 9X-A, it says, as a result of having
7 conducted the Boeing -- and let me ask first to lay the
8 groundwork for this. What date did you all complete
9 and this document was submitted?

10 THE WITNESS: I'm sorry?

11 CHAIRMAN HALL: What date did you complete
12 your report and it was published? Was it April?

13 THE WITNESS: This document was completed
14 May 3rd, '95.

15 CHAIRMAN HALL: May 3rd?

16 THE WITNESS: That's correct.

17 CHAIRMAN HALL: And it says here, "As a
18 result of having conducted the Boeing 737 flight
19 control system critical design review, the team
20 believes there are a number of action items that should

1 be addressed by the Seattle Aircraft Certification
2 Office, the Transport Airplane Directorate Standards
3 staff, the Aircraft Engineering Division or Flight
4 Standards Service, as may be appropriate to any
5 particular or all models of the Boeing 737."

6 And I think you then came up with ~~wha--~~
7 some 27 recommendations, as you say, that are made to
8 enhance an already safe design of the Boeing 737 and
9 improve the certification process.

10 Now, this material has been in the hands of
11 those offices since May. When will we get a report
12 from them on the action they're going to take in regard
13 to your recommendations and who's the individual in the
14 FAA, if you do not know, that we could address that
15 question to?

16 THE WITNESS: I believe the end responsible
17 person is the Transport Airplane Directorate Manager,
18 Mr. Ron Wojnar. The --

19 CHAIRMAN HALL: But some of these
20 organizations are not under his control.

1 THE WITNESS: No. But at the same time, all
2 these issues emanated from his request, as far as the
3 charter of the organization and responsibility.
4 Although recommendations may have been an action item
5 for Flight Standards, they are still aware of the
6 responsibility to respond to Mr. Wojnar.

7 CHAIRMAN HALL: Well, do you expect as the
8 head of this team to get a written response to your
9 report or what type of response are you expecting to
10 get in regard to the recommendations that this team has
11 made?

12 THE WITNESS: My expectation is not for a
13 report to me. My expectation is that the Aircraft
14 Certification Office, as managed by Don Riggan, will
15 respond to Mr. Wojnar as far as the disposition of the
16 recommendations.

17 CHAIRMAN HALL: Well, Mr. Haueter, let's see
18 if we can't get hold of this gentleman while this
19 hearing is going on and see if he can tell us when
20 there will be a response to these recommendations.

1 MR. HAUETER: Okay.

2 CHAIRMAN HALL: Or, if Mr. McSweeny, who is
3 testifying later, can give us that information.

4 First of all, I applaud your work. This
5 investigation has consumed thousands of taxpayer
6 dollars and thousands of dollars that are being
7 contributed by the parties in this investigation. And
8 if work is found, I think the public needs to know when
9 the work -- you know, if these recommendations have
10 been made, when we're going to see a report on the
11 recommendations.

12 Just a couple of other things. You also said
13 that you all didn't look at the operational history in
14 regard to what the pilots I guess do. And yet in your
15 charter, it states here that you're supposed to, in
16 developing the analysis, the team should assume the
17 worst case reaction of the crew to any malfunction.

18 Can you in layman's terms tell me what that
19 means and how you were able to determine what was the
20 worst case reaction?

1 THE WITNESS: Worst case reaction is a
2 judgment from the standpoint of delaying the response
3 to an upset condition or in the event of, for example,
4 a feel spring as part of the feel system in the rudder.
5 We identified the potential for a spring being a
6 latent failure. Now, that's arguable, in some cases,
7 that the pilot could detect spring failure, which would
8 mean that there's reduced force requirement on the
9 rudder pedals. But in some cases it would not be.

10 So we felt the worst case is that it would
11 not be. And therefore, qualified the spring failure as
12 a latent failure. And I must say that we were not
13 specific as far as degree of delay or how much of a
14 delay was taken in response to failure. What I'm
15 referring to are the exercises we conducted in the
16 simulator. Flight crew response to -- that is, the two
17 pilots, FAA pilots that we had and how they reacted to
18 a failure being introduced.

19 In the worst case, they looked -- approached
20 -- they, the two pilots, approached the failure

1 differently and it was the conservative approach that
2 we based our recommendations on.

3 Does that help?

4 CHAIRMAN HALL: I think that helps. It was
5 just curious to me that you wouldn't have looked at the
6 flight manual -- I mean, the pilot's manual for say
7 United and for USAir since those were the two accidents
8 that really initiated this special review in terms of
9 seeing what the pilots were trained to do.

10 THE WITNESS: You mean a possible wrongful
11 response relative to their training?

12 CHAIRMAN HALL: I'm sorry?

13 THE WITNESS: I guess I'm still trying to get
14 a clarification. Are you talking about a wrongful
15 response or -- a worst case response is not a wrongful
16 response.

17 CHAIRMAN HALL: Well, I guess -- and I'm not
18 an engineer. I'm not a technical person. But in order
19 to determine a wrong response, I'd think you'd first
20 want to know what the right response is. Does that

1 make sense or not?

2 Well, let's move on.

3 You stated that you felt that it was good
4 that you all did this review and it provided a fresh
5 look at the design. When was this plane originally
6 certified? Or can you tell me when the failure
7 analysis document, what was the date? When was that
8 generated initially on the 737?

9 THE WITNESS: I don't know the date of the
10 documentation. Boeing would have to provide that. But
11 it was prior to certification, without a doubt.

12 CHAIRMAN HALL: And you have mentioned that
13 you all didn't look that much at the accident scenario.
14 Is that correct?

15 THE WITNESS: Not initially.

16 CHAIRMAN HALL: I guess, again, when we talk
17 about all of this and the simulations of 190 degrees
18 flaps one, that was consistent with the USAir flight
19 427; correct?

20 THE WITNESS: Right.

1 CHAIRMAN HALL: And how was that selected?

2 THE WITNESS: That information was readily
3 available. We thought we -- in making sure that we're
4 covering the envelope, we certainly cover the event to
5 see if there are any anomalies there.

6 CHAIRMAN HALL: And this team is still
7 together?

8 THE WITNESS: As required, to review
9 disposition of the recommendations. Yes.

10 CHAIRMAN HALL: Have you all been asked to
11 review anything?

12 THE WITNESS: What do you mean? Subsequent
13 to our final documentation or something?

14 CHAIRMAN HALL: Since May?

15 THE WITNESS: Oh, yes. I've certainly looked
16 at all the responses to -- what Boeing has provided.
17 I've funnelled the responses back to some of the team
18 members. The one team member I have not worked with
19 has been the NTSB representative.

20 CHAIRMAN HALL: Well, one of the results that

1 was on Slide 10 states that no specific scenario is
2 identified that could explain either of the accidents.

3 Could you tell me how you come with that result
4 without looking specifically at the accidents?

5 THE WITNESS: Because the activity was so
6 closely you might say affiliated with the accident, we
7 asked ourselves the question; based on what we know,
8 what information that we've gotten, even though we
9 haven't been involved in the accident investigation,
10 per se, we did have some access to some of the
11 documentation. We did look at the flight data recorder
12 information. We had to ask ourselves are we seeking
13 anything.

14 Even though we weren't part of the
15 investigation, we felt we would be asked that question.

16 From what we knew at the time, even though we weren't
17 part of the investigation, formally a part of it, did
18 we see anything that might. And we felt we had to
19 answer that question.

20 CHAIRMAN HALL: Mr. Zielinski, I hope you

1 understand the inconsistency I'm having to deal with
2 here in my mind. And I think -- I know that you all
3 have done the best job that you could do and there are
4 nine able people. But if we come up with a result that
5 says no specific scenario is identified that can
6 explain either of the accidents, and then you say
7 earlier that you all wish you had become more familiar
8 with the accidents, that leads me to wonder how that
9 statement could be made. Because I think that
10 statement does provide some representation to the
11 public from the FAA that we've looked at this in light
12 of these accidents and we can't come up with a specific
13 scenario that could explain either of the accidents.

14 THE WITNESS: It's not to say that any of the
15 deficiencies we identified aren't the cause. I think
16 what we're saying is the failures we looked at from
17 what we knew at the time and let's say our last
18 snapshot of information was as of the end of April, we
19 couldn't identify anything that might be causal to the
20 accident, based on the information we had.

1 We felt we had to make the statement.

2 CHAIRMAN HALL: You did not identify any
3 failures of the system that the flight crew could not
4 recover from?

5 THE WITNESS: We have identified possible
6 failures where recovery is doubtful and I think we've
7 qualified that in the documentation.

8 CHAIRMAN HALL: And I assume that the team
9 would be willing to continue in light of the new
10 information that we have obtained from the wake vortex
11 tests? Obviously, I know everybody works for somebody
12 but the team would be glad, if their supervisors said
13 reassemble and go forward, to take a look at the
14 information that we got up in New Jersey?

15 THE WITNESS: Let me put it this way. The
16 team being exposed to the accident and being involved
17 in the CDR would very much like to be involved,
18 continue to be involved, without a doubt. We wish we
19 could have found the problem.

20 CHAIRMAN HALL: Well, the Chairman wants

1 anybody to be involved that feels like they can help
2 identify and put closure to this matter. And certainly
3 if we could have a conversation with I guess Mr.
4 McSweeny when he's here and see if there's a continued
5 role that you all might need to play as a result of the
6 extensive work that you have done.

7 Well, we have kept you up here a long time,
8 Mr. Zielinski, and I appreciate, again, the work that
9 the team did. I think it's important. I appreciate
10 your candid and forthright presentation and response to
11 the questions.

12 We have run to 1:30 and that's past dinner
13 time in Tennessee. And so we'll take an hour and come
14 back at 2:30.

15 (Witness excused.)

16 (Whereupon, the luncheon recess was taken at
17 1:30 p.m.)

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1 AFTERNOON SESSION

2 (Time noted: 2:40 p.m.)

3 CHAIRMAN HALL: We will reconvene this Board
4 of Inquiry and would call the next witness, Mr. Werner
5 Koch, Mechanical Flight Systems Engineer, the Aircraft
6 Certification Office, Federal Aviation Administration's
7 Southwest Region, Dallas-Fort Worth, Texas.

8 Thank you, Mr. Koch.

9 (Witness testimony continues on the next
10 page.)

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1 WERNER KOCH, MECHANICAL FLIGHT SYSTEMS ENGINEER
2 AIRCRAFT CERTIFICATION OFFICE, FAA-SOUTHWEST
3 REGION, DALLAS-FORT WORTH, TEXAS
4

5 Whereupon,

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

10 MR. SCHLEEDE: Mr. Koch, give us your full
11 name and business address, please?

12 THE WITNESS: My name is Werner Koch. I'm
13 located in Fort Worth at the FAA Regional Office on
14 Meacham Boulevard.

15 MR. SCHLEEDE: And your position with the
16 FAA?

17 THE WITNESS: A certification mechanical
18 systems engineer there in the Airplane Certification
19 Office.

20 MR. SCHLEEDE: And briefly, what are your

1 duties and responsibilities in that position?

2 THE WITNESS: Is to review mechanical systems
3 type data, approve that kind of activity with regard to
4 type certification projects, STC's, supplement type
5 certification projects, type changes and so forth.

6 MR. SCHLEEDE: Could you briefly describe
7 your educational background that qualifies you for your
8 position?

9 THE WITNESS: My educational background is I
10 have a B.S. in ME from the University of Texas and a
11 M.S. in ME from the University of Southern California.

12 MR. SCHLEEDE: Thank you very much.

13 Mr. Phillips will proceed.

14 MR. PHILLIPS: Good afternoon, Mr. Koch.

15 THE WITNESS: Good afternoon.

16 MR. PHILLIPS: B.S. in ME, that's bachelor of
17 science in mechanical engineering?

18 THE WITNESS: Yes, sir.

19 MR. PHILLIPS: And master of science in
20 mechanical engineering?

1 THE WITNESS: Yes, sir.

2 MR. PHILLIPS: How long have you been with
3 the FAA?

4 THE WITNESS: I've been with the FAA
5 approximately five years.

6 MR. PHILLIPS: And prior to that, what did
7 you do?

8 THE WITNESS: Prior to that, the previous 16
9 years I was with Bell Helicopter in the Hydraulic
10 Design Group. I led that group for about eight years.

11 I was an FAA designated engineering representative for
12 about 13 of those years. And prior to that, I was with
13 E Systems as a design engineer for component suppliers,
14 hydraulic component suppliers.

15 MR. PHILLIPS: So is it safe to say most of
16 your career you've been involved in hydraulic component
17 design?

18 THE WITNESS: I believe that's right.

19 MR. PHILLIPS: In your duties with Bell
20 before you came to the FAA, did you ever have specific

1 design responsibility for hydraulic control valves,
2 actuation systems?

3 THE WITNESS: Yes. The Hydraulic Design
4 Group that I was either in or led for a number of years
5 had that responsibility to provide the hydraulic
6 systems for the helicopters.

7 MR. PHILLIPS: And in that job you were
8 involved with testing of hydraulic systems and
9 procurement specifications, things like that?

10 THE WITNESS: Yes. Design and the testing
11 qualifications.

12 MR. PHILLIPS: How about certification? Have
13 you been involved in certification of any aircraft?

14 THE WITNESS: Yes, sir. Yes, sir.

15 MR. PHILLIPS: For Bell?

16 THE WITNESS: Yes. For our commercial
17 vehicles.

18 MR. PHILLIPS: When you were selected for the
19 CDR team, I realize that you came somewhere after the
20 program began. Could you tell us the time when you

1 started and circumstances where you came into the
2 group?

3 THE WITNESS: I was asked to join the group,
4 oh, 50 percent or better through the activity, to aid
5 or supplement the hydraulic component and specifically,
6 actuator experience on the team.

7 MR. PHILLIPS: So did you consider that you
8 were called in as an expert for hydraulics design for
9 the purpose of this review?

10 THE WITNESS: I was added to the team to
11 augment or supplement the experience of the team in
12 that area. Yes.

13 MR. PHILLIPS: Within that team, did any of
14 the other members have any specific hydraulic design
15 experience?

16 THE WITNESS: I don't believe so.

17 MR. PHILLIPS: Did any of them have, to the
18 best of your knowledge, any prior experience in flight
19 control certification design?

20 THE WITNESS: I can't answer that.

1 MR. PHILLIPS: Okay. That's fair.

2 We've heard quite a bit of testimony this
3 morning from Mr. Zielinski. We don't want to repeat
4 that. But what I would like to do is go into some
5 detail your role on the CDR team in relationship to
6 your expertise in hydraulic system components.

7 And to start that off, I'd like to ask what
8 kind of materials did you have to review the hydraulic
9 system design or flight controls design for the review?

10 THE WITNESS: I had some training material, I
11 guess, that was provided by Boeing. I think I had some
12 training material that was from one of the airlines in
13 both the flight controls and hydraulics. I was
14 provided some background from Mike, of course, and
15 other team members to bring me up to speed. Plus folks
16 at the ACO in Seattle were very helpful, as well as, of
17 course, Boeing people in flight controls and hydraulics
18 that were helpful.

19 MR. PHILLIPS: Did you review any failure
20 analysis or documents provided by Boeing for failure

1 analysis?

2 THE WITNESS: I did go over some of the
3 failure analysis but I tried to limit my effort in the
4 hydraulic componentry area.

5 MR. PHILLIPS: Mr. Zielinski testified this
6 morning that engineering judgment is an important part
7 of failure analysis. Fundamentals, anyway.

8 In your engineering judgment, were those
9 analyses that you looked at adequate to explain or did
10 they represent a reasonable failure analysis of that
11 component?

12 THE WITNESS: I believe so. In general, I
13 believe that's the case. Yes, sir.

14 MR. PHILLIPS: And are we speaking
15 specifically of the main rudder power control unit or
16 the rudder control system?

17 THE WITNESS: The analysis that was provided.
18 And there've been some subsequent analysis provided as
19 a result of Boeing's response to our recommendations.
20 I've reviewed those. Just started to review those.

1 And I know that's the Seattle ACO's responsibility to
2 address those initially, but I have started to look at
3 those. But I guess I haven't studied them enough to
4 totally absorb it all.

5 MR. PHILLIPS: Is there a requirement for you
6 to study those and get back with someone on what you
7 see?

8 THE WITNESS: I guess I've been asked to
9 review those and I intend to do that. I don't know. I
10 have not been asked to respond to those officially.

11 MR. PHILLIPS: So you were part of the team
12 that made recommendations in the package --

13 THE WITNESS: Yes, sir.

14 MR. PHILLIPS: -- that happened near the end
15 of the work?

16 THE WITNESS: Yes, sir.

17 MR. PHILLIPS: In reviewing the materials for
18 the team's work, did you -- were you provided any test
19 data from Boeing or from any other manufacturers as to
20 performance on any of these components?

1 THE WITNESS: Are you talking about the
2 qualification or certification type or acceptance
3 testing on a unit to unit basis?

4 MR. PHILLIPS: That would be part. More
5 specifically I'd like to know was there any testing
6 done specifically at the request of your group? Did
7 you review any data for that?

8 THE WITNESS: I don't know that we -- that I
9 reviewed any data that we specifically requested of
10 tests to conduct.

11 MR. PHILLIPS: § there were some engineering
12 simulations or flight simulations done but the group
13 didn't ask for any other lab work to be done on any
14 hydraulic components or systems?

15 THE WITNESS: I don't believe so.

16 MR. PHILLIPS: In your review, did you use
17 any materials from the accident investigation? Any
18 factual reports, anything like that?

19 THE WITNESS: Yes. I did review some of the
20 material. I guess the report that addressed some of

1 the testing that was done at Parker and at Boeing
2 facilities.

3 MR. PHILLIPS: Did you participate or watch
4 any of the testing that was done for the Pittsburgh
5 accident at Parker or at Boeing?

6 THE WITNESS: Yes. At Boeing.

7 MR. PHILLIPS: And what specific test was
8 that?

9 THE WITNESS: The chip shearing test that was
10 conducted there sometime in December or January.

11 MR. PHILLIPS: And under whose direction was
12 that testing being done? Do you recall?

13 THE WITNESS: I believe that was under your
14 direction at that time.

15 MR. PHILLIPS: I recall that.

16 As you watched that test setup, what did you
17 believe the intent of that test was at the time, the
18 purpose?

19 THE WITNESS: To determine the ability of
20 that valve in the rudder PCU to shear the largest chip

1 that you could inject into that valve.

2 MR. PHILLIPS: Why were we concerned about
3 that?

4 THE WITNESS: Well, that particular actuator,
5 the control valve in that particular actuator has a
6 limiting aspect to it with regard to how much force you
7 can apply to clear a jam or shear a chip. And it was a
8 concern I guess not only of the team, of the CDR team,
9 but other principals also in the investigation, that
10 perhaps that might be a limiting condition. That is,
11 the force available to shear a chip might be less than
12 what it would actually require to shear a chip of the
13 largest magnitude that you could ship into this valve.

14 MR. PHILLIPS: So, did you see -- let's talk
15 a little bit about that limitation to the chip shear
16 capability.

17 Can you briefly describe to us what you
18 understand creates that limitation?

19 THE WITNESS: Yes. The rudder PCU is what we
20 term in industry an integrated actuator. That is, it

1 accepts both mechanical inputs from the pilot's pedal
2 as well as electrical inputs from the yaw system. And
3 as a result of that, there's summing linkage in that
4 unit and springs associated with this for redundancy
5 and also for just implementation of it.

6 Consequently, when a pilot input is applied
7 that exceeds a certain level, these springs back off
8 and the energy actually goes into compressing a spring
9 rather than moving the valve.

10 So it's the unique design. It's not -- the
11 rudder PCU, I don't want to give the impression that
12 it's a unique design, but it is a design. Because it's
13 typical of many other integrated actuator packages that
14 have been designed and they're successfully being used.

15 But the implementation of that is such in that unit
16 that at a certain level you do limit the amount of
17 force you can apply to clear a jam in the main valve.

18 MR. PHILLIPS: Would that be a design
19 consideration for the manufacturers or the engineers to
20 specify a minimum amount of chip shear capability?

1 THE WITNESS: I would think that would be the
2 customary way you would control that. Yes.

3 MR. PHILLIPS: Do you know if this package
4 has such a requirement in any of its drawings or
5 specifications?

6 THE WITNESS: I don't know that.

7 MR. PHILLIPS: In chip shear, you observed
8 the testing. Do you recall the test setup
9 specifically?

10 THE WITNESS: Yes, sir.

11 MR. PHILLIPS: Could you give us a rundown
12 exactly what that test, bench test looked like?

13 THE WITNESS: It was basically the actuator
14 setup with the valve modified to be able to insert
15 various materials into the orifice. The input was
16 powered with a pneumatic cylinder through a force
17 transducer. I don't recall exactly how that pneumatic
18 system was set up. I think they had -- this was
19 conducted in a Boeing -- I forget the name of the lab
20 there. But anyway, in a Boeing facility.

1 MR. PHILLIPS: The ~~EA~~ lab?

2 THE WITNESS: Yes. But the pneumatic
3 actuator was used to apply force through the force
4 gauge to the input, and consequently into the valve.

5 MR. PHILLIPS: Did the fact that the
6 pneumatic force was driving that chip shear test, would
7 that have been any different -- the outcome been any
8 different if it had been a hydraulic force or
9 electrical force?

10 THE WITNESS: Not in my mind. No.

11 MR. PHILLIPS: And I think, if you recall, we
12 -- during the testing, we held the secondary spool
13 fixed and then we inserted a portion through to the
14 primary and then sheared it with the primary.

15 Would holding the secondary spool in the
16 fixed position affect the outcome of being able to
17 determine the effects of a chip sheared in the primary
18 and secondary interface?

19 THE WITNESS: I don't believe so.

20 MR. PHILLIPS: Did you see any attempt to

1 look at the secondary servo valve housing interface
2 chip shear capability in that test setup?

3 THE WITNESS: No.

4 MR. PHILLIPS: As far as the selection of
5 materials to shear, did you see the process or how the
6 chips were selected or manufactured?

7 THE WITNESS: I think the selection of a
8 material was made prior to my joining the team but they
9 were -- just observing while the pieces were inserted,
10 it seemed a correct and reasonable way to do that to
11 me.

12 MR. PHILLIPS: How did they insert these
13 chips into the orifice? Do you recall?

14 THE WITNESS: Mechanically with -- by hand or
15 tweezers, I believe. The orifices are small and
16 consequently the material that was inserted into these
17 orifices was of a small nature.

18 MR. PHILLIPS: Do you recall what the results
19 were of inserting these various chips into the orifices
20 and shearing them?

1 THE WITNESS: In general, yes, sir.

2 MR. PHILLIPS: And specifically, did you see
3 the valve -- did you see it not shear or shear pieces
4 of material?

5 THE WITNESS: There was one material that --
6 well, to back off just a little bit. The idea was to
7 apply up to 40 pounds or 44 pounds. And if it didn't
8 shear at that level, we would back off. And only one
9 of some 10 or so -- there was only one of those 10 or
10 so specimens that didn't shear in less than the 40 or
11 44 pounds.

12 MR. PHILLIPS: Was there any effort to
13 examine the interfaces to see if there were markings
14 for proof that a jam had existed or markings?

15 THE WITNESS: Yes. The valves were examined
16 after the chip was sheared after each one of the tests.
17 These were individual tests that were designed to
18 shear these individual specimen material. And in all
19 cases, I believe, we were able to detect obvious
20 rollover of the land where the shearing took place.

1 MR. PHILLIPS: So based on your engineering
2 experience and judgment, would you consider this test a
3 valid indicator of the chip shear capability of the
4 servo valve assembly?

5 THE WITNESS: For the configuration that we
6 tested. Yes.

7 MR. PHILLIPS: Let's talk a little bit about
8 -- while we're talking about the servo valves and the
9 spools, let's talk a little bit about a phenomenon
10 called silting.

11 Are you familiar with the term silting?

12 THE WITNESS: Yes, sir.

13 MR. PHILLIPS: Could you describe it for me,
14 please?

15 THE WITNESS: Well, in an engineering
16 environment, I guess, we use the term silting as it
17 applies to small particle,; perhaps sub-micron
18 particles as opposed to the large pieces that we've
19 tested in our previous discussion here.

20 These small micron -- small sub-micron

1 particles tend to or can tend to be driven if a
2 condition is such by differential pressure across the
3 annulus of a spool and sleeves valve and can cause,
4 depending on what the clearance is in this valve,
5 depending on the pressure, differential pressure across
6 the land, for instance, can cause some increase in
7 friction of this valve.

8 MR. PHILLIPS: That's silting? Okay.

9 THE WITNESS: Yes. That's my crude
10 definition of silting. Yes. It has a lot of -- it can
11 happen in a lot of ways but that's certainly one way
12 and probably one of the more frequent ways that silting
13 does occur.

14 MR. PHILLIPS: Okay. So if I back up a
15 little bit and simplified it, maybe we could call it
16 small particles. You said sub-micron small particles
17 in fluid that a lot of them build up and do something
18 to the valve and increase the friction or forces on the
19 valve at the land face?

20 THE WITNESS: Yes, sir.

1 MR. PHILLIPS: At the land edge.

2 Is silting generally evident in your
3 experience in valves? Can you disassemble a valve,
4 test a valve, to indicate that silting has been a
5 factor in that valve's operation?

6 THE WITNESS: Whether it has been a factor?

7 MR. PHILLIPS: Has been.

8 THE WITNESS: I can't say that positively.
9 No, sir.

10 MR. PHILLIPS: Do you know of any test that
11 can be done that would indicate a valve's been silting
12 or operating in silting conditions?

13 THE WITNESS: Whether it has previously been
14 involved in a silting condition?

15 MR. PHILLIPS: Yes.

16 THE WITNESS: I don't know off hand. No,
17 sir.

18 MR. PHILLIPS: In silting, in the fact that
19 it affects the friction forces as you've described them
20 in the spools, the interfaces of the spools, is the

1 manufacturer of the spools, the lands, critical to
2 whether silting is a problem or could be a problem?

3 In other words, the underlap and overlap
4 conditions?

5 THE WITNESS: I believe, and just based on my
6 engineering judgment and my limited experience, I
7 believe that an overlap valve might have more of an
8 increase in friction resulting from silting than an
9 underlap configuration.

10 MR. PHILLIPS: And why would that be? In an
11 underlap valve, then, if you have a small gap that
12 exists at the neutral position, does the flow around
13 the land allow that to clear itself?

14 THE WITNESS: In an underlap condition -- in
15 an underlap valve. Yes, sir.

16 MR. PHILLIPS: Do we have underlap or overlap
17 conditions in this spools of this servo valve of the
18 main PCU?

19 THE WITNESS: Yes. I believe the
20 specification requires a slight underlap on the primary

1 valve and then a slight overlap of 2-1/2 thousandths on
2 the secondary.

3 MR. PHILLIPS: So on one part of the system
4 it's underlapped and the other part it's overlapped?

5 THE WITNESS: Yes, sir.

6 MR. PHILLIPS: Would it be evident and based
7 on your knowledge of this package, would it be evident
8 to a mechanic or to a pilot that a valve has -- silting
9 has happened or it's caused friction forces to increase
10 between the spools?

11 THE WITNESS: Not to my knowledge, I don't
12 believe.

13 MR. PHILLIPS: Did you make any
14 recommendations in your report in regards to the
15 operation or the design of the servo valve
16 specifically?

17 THE WITNESS: I believe we made mention of
18 the limited jam clearing capability of this actuator
19 and that's included in one of the tables, I believe.
20 And I believe it's Recommendation 4. And also 12 and

1 13 addresses it.

2 MR. PHILLIPS: In your engineering judgment
3 and your review with the CDR team, could you have
4 recommended to the CDR team any additional testing to
5 add to your recommendations or clarify the work that
6 you've done after the fact with some hindsight?

7 THE WITNESS: I believe that in hindsight I
8 might have recommended some additional testing with
9 regard to this silting activity. And part of that,
10 Greg, is simply because we haven't found the smoking
11 gun. And I think that my philosophy is that you've got
12 to do some testing.

13 MR. PHILLIPS: So you've got some concerns
14 about the potential for silting? You think it needs to
15 be looked at?

16 THE WITNESS: I believe so. And it's partly
17 as a result of we haven't found anything else. I think
18 that might be one of the logical steps to proceed with
19 further.

20 MR. PHILLIPS: Okay. We'll move along from

1 that right now.

2 In your review we heard some discussion
3 earlier today about galling relative to the standby
4 rudder power control unit and the input shaft and
5 bearing. Did you examine galling or the effects of
6 galling on the system in the CDR?

7 THE WITNESS: Yes.

8 MR. PHILLIPS: Did you make any
9 determinations as to how it would affect the system?

10 THE WITNESS: Yes, I think we did. We
11 observed that, and as a result of that galling, what
12 the effect might be. Yes, sir.

13 MR. PHILLIPS: And what do you think the
14 effect would be if you found a galled input shaft
15 bearing?

16 THE WITNESS: We're talking about the standby
17 actuator?

18 MR. PHILLIPS: The standby. Yes.

19 THE WITNESS: Well, there are any number of
20 scenarios, I guess, Greg. Certainly one condition is

1 that it simply galls at the surface neutral position.
2 And if that's the case, there's very little effect
3 other than increase in pilot pedal force with regard to
4 a mechanical input.

5 Now with regard to a yaw input, that's a
6 different story. Now the surface is going to move.
7 And how much it moves depends on what the amplitude of
8 the yaw damper signal is.

9 MR. PHILLIPS: Do you have any kind of
10 feeling whether or not a galled standby rudder input
11 shaft could cause a full rudder deflection in this
12 airplane?

13 THE WITNESS: I believe it's possible if the
14 pilot doesn't react. I think the analysis that Boeing
15 provided indicates that it takes pilot reaction in
16 terms of a fairly significant amount of pedal force to
17 prevent that.

18 MR. PHILLIPS: Was this analysis provided
19 after the CDR recommendation or was it before or --

20 THE WITNESS: I believe there was some

1 provided prior to, but it was my understanding at the
2 time -- and again, I entered the activity on this team
3 rather late, but in retrospect, it turns out that
4 Boeing had done -- I thought initially it was just an
5 analysis and I was concerned about that. But it turns
6 out that they had conducted some test prior to that and
7 established what the spring rate in that system was
8 that would allow the pilot to overcome an issue of that
9 type.

10 MR. PHILLIPS: Do you know of any other
11 conditions that would cause the rudder on this airplane
12 to fully deflect with or without a pilot command?
13 Let's do the without a pilot command to start with.

14 THE WITNESS: Any other being beside a rudder
15 jam?

16 MR. PHILLIPS: That would be one.

17 THE WITNESS: I mean a standby rudder jam.

18 MR. PHILLIPS: Right.

19 THE WITNESS: Well, of course, the dual
20 concentric valve, a jam in both of those in one

1 direction.

2 MR. PHILLIPS: Would jam in either one
3 individually cause it to run away hardover?

4 THE WITNESS: No, no. Not with the pilot's
5 input.

6 MR. PHILLIPS: As part of the flight 427
7 accident investigation, the systems group conducted
8 some testing relative to positioning primary and
9 secondary spools of the servo valves at extreme limits
10 of their travel. Are you aware of that testing?

11 THE WITNESS: Yes, sir.

12 MR. PHILLIPS: Have you looked at that data?

13 THE WITNESS: Yes, sir.

14 MR. PHILLIPS: Could you briefly describe
15 what you saw as the intent of that test?

16 THE WITNESS: I'm not sure what the intent of
17 the test was. I wasn't a party to that. I just
18 observed the results in the report.

19 MR. PHILLIPS: And to refresh your memory
20 just a little bit, I believe that the tests were

1 conducted by holding the primary and secondary
2 independently or at different times at full travel
3 positions, or estimated at full travel positions,
4 measured full travel positions and then measuring the
5 residual pressure differential. What would that tell
6 an engineer? What would that test mean?

7 THE WITNESS: Well, it told me that the
8 orifices that were available under those conditions
9 were not equal between the primary and the secondary
10 and the differential pressure or residual pressure that
11 was measured was simply the resulting pressure when
12 you're looking at -- running fluid at 3,000 psi through
13 a series of orifices and you pick off the pressure at
14 these various junctures.

15 MR. PHILLIPS: What would the result be to
16 the rudder or to the pilot?

17 THE WITNESS: I believe there was one
18 condition where it would -- I guess this was with the
19 secondary position hardover where there was a
20 significant amount of residual pressure which would

1 tend to offset the rudder.

2 MR. PHILLIPS: Did the CDR team do any
3 testing or do any kind of review of residual pressure
4 differential tests or anything?

5 THE WITNESS: No, sir.

6 MR. PHILLIPS: Was there any discussion of
7 that in any of the failures analysis that you reviewed?

8 THE WITNESS: No, sir.

9 MR. PHILLIPS: Is it a valid engineering
10 practice to look at things like that? Have you done it
11 before or seen people do that?

12 THE WITNESS: I personally haven't looked at
13 that specific issue. I've worked with dual concentric
14 tandem control valves but they were always of a
15 slightly different nature. This issue didn't quite
16 apply.

17 MR. PHILLIPS: Is this servo valve unique in
18 any way to a dual tandem concentric servo that you've
19 seen before?

20 THE WITNESS: It's different than what we use

1 at Bell Helicopter, for instance, but it's not
2 different than what's used other places in the industry
3 but I'm personally not familiar with them.

4 MR. PHILLIPS: As part of your CDR team work,
5 I see that you made some field trips; one to Parker?

6 THE WITNESS: Yes, sir.

7 MR. PHILLIPS: Could you tell me a little bit
8 about that visit and what you learned on that trip?

9 THE WITNESS: It was primarily to gain first
10 hand information on the details of that actuator since
11 I was thought to be the expert on that effort with
12 regard to the CDR team, to get the first hand
13 information, talk to the designers, exactly how the
14 design was arrived, who did the design and exactly how
15 it worked, the various ratios to determine -- one of
16 the things that I wanted to determine for sure was what
17 the jam clearing capability was precisely.

18 And then also, observed the manufacturing of
19 this control valve. It was a familiarization trip
20 primarily.

1 MR. PHILLIPS: Did you look at any valves
2 being tested that had been returned from manufactures -
3 - or operators?

4 THE WITNESS: Yes, sir.

5 MR. PHILLIPS: And could you -- do you recall
6 the test methods that were used?

7 THE WITNESS: Parker has an ATP. It's an
8 approved ATP which they use.

9 MR. PHILLIPS: And an ATP is a --

10 THE WITNESS: Acceptance test procedure.
11 It's a test procedure generated by the OEM and probably
12 approved by Boeing, but that each serial number, each
13 delivered unit or each overhauled unit is tested to.

14 MR. PHILLIPS: And the rudder PCU assembly is
15 tested separate from the servo valve. Did you see the
16 two separate tests being conducted?

17 THE WITNESS: I believe I -- yes, I did
18 witness parts of this, yes. Certainly not the whole
19 thing. I didn't spent a great deal of time, but enough
20 to convince myself that I thought the OEM was doing an

1 effective job of providing acceptable units.

2 MR. PHILLIPS: Is Parker the only
3 manufacturer for the main rudder power control unit?

4 THE WITNESS: To the best of my knowledge
5 they're the only -- I guess Boeing approved
6 manufacturer.

7 MR. PHILLIPS: Do you know if other people
8 have the authority to overhaul or repair the main
9 rudder power control unit?

10 THE WITNESS: Yes, sir.

11 MR. PHILLIPS: And who would that be?

12 THE WITNESS: The one I'm familiar with and
13 that I've visited the facilities is Fortner
14 Manufacturing and Engineering in Glendale.

15 MR. PHILLIPS: Glendale, California?

16 THE WITNESS: Yes, sir.

17 MR. PHILLIPS: And what do they do to the
18 part or what can they do to the part?

19 THE WITNESS: They overhauled the servo
20 valve. They were in a position to do that based on

1 their delegation by the FAA, I believe.

2 MR. PHILLIPS: So an operator can send his
3 servo valve to Fortner for repair and have it returned
4 to service and it would be an FAA approved part then?

5 THE WITNESS: Correct. And what?

6 MR. PHILLIPS: It would be an FAA approved
7 part if they had been authorized to work on it?

8 THE WITNESS: I believe that's correct.

9 MR. PHILLIPS: The CDR report talks in some
10 detail and we mentioned it briefly this morning,
11 Recommendations 20, 21 and 22, I guess, on page 46 of
12 Exhibit 9-A, 9X-A. And in regards to PMA approval of
13 non-OEM, non-original manufacturers, is that a standard
14 in hydraulics design? In your experience, is approval
15 of non-OEM manufacturers normal, standard, expected?

16 THE WITNESS: I'm not sure.

17 MR. PHILLIPS: Are you aware that this servo
18 valve does have matched primary and secondary spools?

19 THE WITNESS: Yes, sir.

20 MR. PHILLIPS: And would an OEM or would an

1 SFAR 36 PMA approved facility have approval then to
2 manufacture or remanufacture a set of spools?

3 THE WITNESS: I believe that they did have.
4 Yes, sir.

5 MR. PHILLIPS: Back on the subject of failure
6 analysis for just a little bit, in conducting failure
7 analysis based on probablistic materials, how does a
8 hydraulic designer when he initiates a new design, how
9 does he know how to calculate the chip shear capability
10 that he needs and how would you start out with a blank
11 sheet of paper in doing the right thing the first time?

12 THE WITNESS: I guess if I were doing it and
13 had to determine what I wanted for jam clearing or chip
14 shearing -- I like to use the term jam clearing because
15 that's more generic, I would indicate a force level
16 that I thought was sufficient to -- you know, based on
17 my experience and industry experience was sufficient to
18 clear jams.

19 MR. PHILLIPS: But if your valve design
20 required two jams to happen, would that change your

1 approach to that? Would you lower the level because
2 the probability of second jam would be less?

3 THE WITNESS: Again, my personal experience
4 or my personal preference, I guess, would be that would
5 not affect the level because of common cause failures.

6 MR. PHILLIPS: We've talked about a number
7 somewhere around 40 pounds for this particular valve.
8 Do you have a feeling of what's an adequate or more
9 adequate number for chip shear capability?

10 THE WITNESS: Again, it's very subjective.
11 This configuration has flown 67 million flight hours
12 where I've been told that that has not been a problem,
13 so I guess I can take that as a fact. But I guess I
14 feel that's still a marginal level of force to be able
15 to clear a jam.

16 MR. PHILLIPS: Does that operational
17 experience then, does that weigh heavily into this
18 engineering judgment criteria?

19 THE WITNESS: Well, it weighs in. Yes.

20 MR. PHILLIPS: Could the possibility exist

1 that there have been jams that have just been
2 undetected or haven't been found or commented on?

3 THE WITNESS: I don't know that.

4 MR. PHILLIPS: Who would know that? Would
5 that be -- how would we find out if wanted to ask that
6 question to the best source?

7 THE WITNESS: I guess somebody that has that
8 experience or has conducted a test to that effect. And
9 I guess that might even be a recommendation to do that.

10 MR. PHILLIPS: Could we rely on operators who
11 have overhaul capabilities and approvals to feedback to
12 us and let us know when they've seen jams? Would that
13 be a valid source or would we need to go back to Parker
14 and Boeing?

15 THE WITNESS: Well, certainly anyone who's
16 had that experience in the problem is getting some
17 reliable data.

18 MR. PHILLIPS: And just a couple of things
19 here in closing. From your observations of the CDR
20 team, did you find the effort worthwhile?

1 THE WITNESS: Oh, yes, sir.

2 MR. PHILLIPS: Very productive?

3 THE WITNESS: Yes, sir. I thought it was
4 very productive. Yes, sir.

5 MR. PHILLIPS: Have you ever been involved
6 with any other CDR efforts?

7 THE WITNESS: No.

8 MR. PHILLIPS: This is the first for you?

9 THE WITNESS: Yes, sir.

10 MR. PHILLIPS: Would you recommend that CDR's
11 be done on other airplanes without the benefit of an
12 accident leading you into it?

13 THE WITNESS: A CDR or something to that
14 effect if budget is available, I think would be
15 helpful. Yes, sir.

16 MR. PHILLIPS: Were you satisfied with the
17 makeup of the team? Did you feel like you needed
18 another hydraulics expert or fluids expert or anything
19 like that?

20 THE WITNESS: I thought the makeup of the

1 team was adequate. Yes, sir.

2 MR. PHILLIPS: And did you ever feel the need
3 to have any more support from the accident
4 investigations? Did you need data that you weren't
5 provided or asked for?

6 THE WITNESS: No. I thought that we were
7 provided with ample data, as a matter of fact. It was
8 sometimes more than ample.

9 MR. PHILLIPS: Do you have any
10 recommendations for continuing the investigation that
11 you can make to the systems group as far as additional
12 areas you'd like to see based on your experience in the
13 CDR report? Anything you'd like to have us take a look
14 at?

15 THE WITNESS: Only in the area of continued
16 testing, perhaps, of that valve arrangement with regard
17 to silting. And again, it's -- you know, it's somewhat
18 of a long shot but that might be a place to look next.

19 MR. PHILLIPS: I have nothing else unless you
20 have something you'd like to add.

1 THE WITNESS: I don't have anything else.

2 MR. PHILLIPS: Thank you.

3 CHAIRMAN HALL: Any other questions from the
4 Technical Panel?

5 Mr. Haueter?

6 MR. HAUETER: Excuse me just a second. A
7 couple.

8 If there were a jam of one of the servo
9 valves, how could the pilot detect that or how would
10 you know the one valve had jammed?

11 THE WITNESS: Again, it depends on the
12 position of the jam, whether it's in neutral or
13 hardover. If it's in neutral, might be a little
14 difficult for the pilot to detect because he would
15 simply detect a difference in max rate. In other
16 words, if with both valves operating properly the rate
17 is full stroke in two seconds, with one jam at null,
18 the rate, max rate would be full stroke in two second.

19 MR. HAUETER: What if it jammed at someplace
20 off null? Would that --

1 THE WITNESS: Okay. If it's -- I guess the
2 other extreme. If it's jammed hardover in one
3 direction, if the primary is jammed hardover in one
4 direction, then he simply has to counter that with a
5 hardover in the other direction to neutralize the
6 effect and allow the surface to trail, basically,
7 probably.

8 MR. HAUETER: But what you're saying is
9 neutral jams could occur basically with very little
10 indication or being known?

11 THE WITNESS: Well, it might be difficult for
12 a pilot to detect because it's only the max rate that's
13 affected. If he tries to apply a max rate, he would
14 see a difference. Now, whether he would detect -- you
15 know, whether it would register on him or not, I don't
16 know.

17 MR. HAUETER: You mentioned that this dual
18 concentric servo valve is not a unique design but it's
19 different than the helicopter industry. Can you
20 describe what the differences might be?

1 THE WITNESS: Well, in the 737 rudder PCU,
2 the valve is a dual tandem concentric but both the
3 primary and the secondary are used in normal operation.

4 In the helicopters or the ones that I'm familiar with
5 at Bell Helicopter, the secondary was essentially a
6 bypass configuration so that if, for instance, you had
7 a jam in the primary one, you used the secondary one to
8 bypass the effect of the first one.

9 MR. HAUETER: Okay. Thank you very much.

10 That's all I have, sir.

11 CHAIRMAN HALL: Questions from the parties?

12 I see the hand of the Air Line Pilots
13 Association. Anyone else?

14 Very well, captain.

15 MR. LeGROW: Thank you, Mr. Chairma

16 Good afternoon, Mr. Koch.

17 THE WITNESS: Good afternoon.

18 MR. LeGROW: Just a couple of quick questions
19 along the same line that Mr. Haueter was on.

20 You said that if you had a jam of one spool,

1 that the crew would only detect it or it could only be
2 detected with a full throw. Would you elaborate on
3 that a little bit?

4 In your view, would that be something that a
5 pilot in normal flight would be able to recognize?

6 THE WITNESS: I guess I'm limited in my
7 ability to respond to that properly, Captain, because
8 not being a pilot. I can only tell you what I believe
9 would be the distinguishing characteristics. That if
10 he did try to move it at full rate, that is as fast as
11 you can, that that rate would be limited after a
12 primary valve jam at neutral.

13 MR. LeGROW: Okay. Thank you.

14 In Mr. Phillips' questioning you said that
15 there were some silting tests that were done, and in
16 your view and hindsight that perhaps more testing could
17 have been done or should have been done.

18 And my question is how much input did the
19 members of this CDR team have in the tests that were
20 conducted?

1 THE WITNESS: No. I don't believe there were
2 any silting tests conducted, number one. I think I
3 said that in hindsight -- if I said there were silting
4 tests conducted, I misspoke.

5 MR. LeGROW: I misspoke the question. I'm
6 sorry.

7 THE WITNESS: Okay. What I did say, that in
8 hindsight and after all this time has passed and we
9 still haven't found the golden nugget, so to speak, it
10 may be time to get into areas like silting and do some
11 testing.

12 MR. LeGROW: And my question is how much
13 input were the members of the CDR team given in the
14 tests that were conducted? In other words, were the
15 team members -- did they have input in exactly what
16 tests would be conducted or would not be conducted or
17 is this something that was given to the members before
18 the --

19 THE WITNESS: I think most of that was done
20 in parallel with the CDR team effort. The accident

1 investigation was done sort of in parallel. And I'm
2 not sure just how much input the team members had to
3 identify what tests should be done and how they should
4 be done but there was some, obviously.

5 MR. LeGROW: Along the same lines, sir, it's
6 my understanding that everybody that participated in
7 the CDR were government employees, either the U.S. or
8 Canada. Is that correct?

9 THE WITNESS: I believe that's correct.

10 MR. LeGROW: Do you think in just your
11 opinion that it may have been valuable to have people
12 from the private sector participating in the CDR?

13 THE WITNESS: I think that's not for me to --
14 I don't have any response to that. I was just simply
15 picked as a member by management.

16 MR. LeGROW: Were you here for Mr.
17 Zielinski's testimony this morning?

18 THE WITNESS: Yes, sir.

19 MR. LeGROW: And Mr. Zielinski testified that
20 he felt it would be helpful to participate in the

1 accident investigation. I guess my question -- do you
2 think in your view that it would have been helpful to
3 have accident investigators participating in the CDR?

4 THE WITNESS: I think so. And we did ~~hav~~
5 one member of the NTSB on our team.

6 MR. LeGROW: But he was a government
7 employee. He wasn't from the private sector.

8 THE WITNESS: That's correct.

9 MR. LeGROW: Thank you very much.

10 I have no further questions.

11 CHAIRMAN HALL: No other questions from the
12 parties?

13 We'll move to Mr. Clark.

14 MR. CLARK: I think you said that you were
15 present when some of the chip shear tests were done or
16 you witnessed the results?

17 THE WITNESS: Yes, sir.

18 MR. CLARK: Have you participated in that
19 kind of event before in your design work to do chip
20 shears, look for witness marks?

1 THE WITNESS: Yes, sir.

2 MR. CLARK: How extensive is your experience
3 in that area?

4 THE WITNESS: Limited.

5 MR. CLARK: One or two designs? One design?

6 THE WITNESS: Yes. Yes. Where we at Bell
7 Helicopter -- this is something that -- just to
8 elaborate a little bit -- that's been done by several
9 companies to establish a chip shear capability.

10 MR. CLARK: From what you saw and what you
11 observed, would there be any changes or additions to
12 those tests that you would recommend or were you
13 satisfied with the extent of those tests?

14 THE WITNESS: I believe I was pretty well
15 satisfied with the extent of those tests. As I
16 indicated, I think those tests were valid for the test
17 conditions, for the hardware that we were using. I
18 think we had some real good valid results.

19 MR. CLARK: They all made sense to you?

20 THE WITNESS: Yes, sir.

1 MR. CLARK: Okay. Thank you.

2 CHAIRMAN HALL: Mr. Marx?

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

4 You were mentioning silting and I would like
5 to get your opinion on what you would expect to find if
6 you could look at those valves at very, very high
7 magnifications, what effect silting would have on the
8 valve?

9 THE WITNESS: I don't know.

10 MR. MARX: Any physical changes?

11 THE WITNESS: I don't know.

12 MR. MARX: Marks or --

13 THE WITNESS: I don't know.

14 MR. MARX: And also, you mentioned something
15 about -- I didn't quite follow when you were talking
16 about galling in the neutral position, it would have no
17 effect. Would it have an effect if it was outside of
18 the neutral position? This is on a standby.

19 THE WITNESS: Yes. I believe I stated that
20 if the standby actuator was galled at neutral, there

1 would be virtually no effect from the mechanical inputs
2 from the pilot and he would feel some additional force.

3 Whether that would be detectable or not, I don't know.

4 But there would be an effect from yaw damper inputs
5 and the degree is questionable. I'm not sure I fully
6 understand what would happen but we believe that it
7 would not be a major catastrophic effect.

8 MR. MARX: Thank you.

9 CHAIRMAN HALL: Mr. Schleede?

10 MR. SCHLEEDE: No questions.

11 CHAIRMAN HALL: Mr. Laynor?

12 MR. LAYNOR: Just one, Mr. Koch.

13 When you were addressing the subject of
14 silting, it's effect on the servo valve performance,
15 can you speculate based on your experience of how the
16 yaw damper activity would effect the performance
17 change?

18 THE WITNESS: I'm not sure I understand the
19 gist of your question, sir.

20 MR. LAYNOR: Well, the gist of my question is

1 if you have yaw damper activity in this valve, would
2 you not have more or less frequent cyclic motion of the
3 valve spools within the housing?

4 THE WITNESS: Yaw damper activity would tend
5 to neutralize silting effects. Yes, sir. Is that what
6 you're asking? Yaw damper inputs would cause the valve
7 to cycle at whatever rate the yaw damper was applying
8 that signal and would tend to alleviate silting
9 effects.

10 MR. LAYNOR: Have you looked at any -- the
11 recording traces of Boeing 737 rudder activity to make
12 an assessment whether you think that would have an
13 effect on the --

14 THE WITNESS: No, I haven't. No, I haven't.

15 MR. LAYNOR: Okay. Thank you, sir.

16 CHAIRMAN HALL: Mr. Koch, it's nice to have a
17 witness whose accent I can understand very well.

18 (Laughter.)

19 Let me --

20 THE WITNESS: Thank you.

1 CHAIRMAN HALL: Let me just ask you a
2 question or two. You came on the team you say late?
3 And the individual you replaced, was he a hydraulics
4 person?

5 THE WITNESS: I believe that's correct.

6 CHAIRMAN HALL: The silting, you said the
7 silting needs to be looked at. How would you do that?

8 THE WITNESS: I haven't thought that out
9 thoroughly. I think I indicated that as a result of
10 the impasse or the lack of a smoking gun, I think that
11 might be a logical place to look next. And just how
12 you would implement that I'm not sure.

13 I believe I would try to set up a situation
14 with that actuator or with oil from an operational
15 aircraft and leave it some sort of a static condition
16 with it at full pressure, 3,000 psi, and let that
17 silting effect occur. That may occur for some period
18 of time. And then look at the forces it takes to undo
19 that silting effect. And do this a number of times
20 just to get the feel of it.

1 There may even be some serendipitous results
2 as a result of this or -- and you'd go on from there.
3 As you learn from the initial test, then you would
4 proceed to the next step of it.

5 CHAIRMAN HALL: Mr. Phillips, is that
6 something we can do?

7 MR. PHILLIPS: Yes, it is.

8 CHAIRMAN HALL: Well, let's do it then.

9 Let me ask you one more question then. Is
10 galling and silting is that something that goes
11 together?

12 THE WITNESS: No, sir.

13 CHAIRMAN HALL: That's two different things?

14 THE WITNESS: There could be a relationship
15 but that's normally not -- the two don't normally
16 occur.

17 CHAIRMAN HALL: Okay. But you did say that
18 galling could cause the rudder to fully deflect?

19 THE WITNESS: No.

20 CHAIRMAN HALL: No? Okay. Well tell me what

1 galling can do then to the rudder in your opinion.
2 That got my attention because I believed there was
3 galling on both Colorado Springs and the Pittsburgh
4 actuators; right? So I'm just wanting to understand
5 that.

6 THE WITNESS: The effect -- I guess just in
7 summary, the effect of this galling, sir, can be
8 overcome by the pilot, is effectively the answer.

9 CHAIRMAN HALL: With a pedal movement or --

10 THE WITNESS: Pedal pressure and movement.
11 Yes, sir.

12 CHAIRMAN HALL: And how much pressure?

13 THE WITNESS: I don't have those numbers. I
14 think there are some initial witnesses to that.

15 CHAIRMAN HALL: Is that where we get into the
16 40 pounds you referred to being -- no?

17 THE WITNESS: No.

18 CHAIRMAN HALL: Okay. We'll get into that
19 later.

20 THE WITNESS: Yes, sir.

1 CHAIRMAN HALL: But I wanted to clarify that
2 in my mind. I have the advantage up here of not having
3 a technical background so I'm trying to interpret all
4 this.

5 But I think unless there are other questions
6 from the table or the technical staff, that we thank
7 you very much for your testimony and also your service
8 on the CDR team.

9 Let me just before I excuse you, ask you do
10 you think that there is any reason that this team
11 should continue its work or any value to that?

12 THE WITNESS: Just my personal opinion?

13 CHAIRMAN HALL: Yes, sir. You may be
14 furloughed so you might be able to give that. I don't
15 know.

16 THE WITNESS: I think there would be a
17 benefit, certainly.

18 CHAIRMAN HALL: Thank you very much.

19 THE WITNESS: Thank you.

20 (Witness excused.)

1 CHAIRMAN HALL: Now I guess we'll continue
2 and maybe take a -- we will call Mr. Thomas A.
3 Newcombe, Aviation Safety Inspector for Airworthiness
4 with the Seattle Aircraft Evaluation Group, FAA,
5 Seattle, Washington.

6 (Witness testimony continues on the next
7 page.)

8

9

1 THOMAS A. NEWCOMBE, AVIATION SAFETY INSPECTOR-
2 AIRWORTHINESS, SEATTLE AIRCRAFT EVALUATION GROUP
3 FAA, SEATTLE, WASHINGTON
4

5 Whereupon,

6 THOMAS A. NEWCOMBE,
7 was called as a witness by and on behalf of the NTSB,
8 and, after having been duly sworn, was examined and
9 testified on his oath as follows:

10 MR. SCHLEEDE: Mr. Newcombe, please give us
11 your full name and business address.

12 THE WITNESS: My name is Thomas Allen
13 Newcombe with the Aircraft Evaluation Group of the FAA,
14 Seattle, Washington.

15 MR. SCHLEEDE: And what is your position at
16 the Aircraft Evaluation Group?

17 THE WITNESS: My position is the Aviation
18 Safety Inspector-Airworthiness, MRB Chairman on the 737
19 airplane and ATR airplanes.

20 MR. SCHLEEDE: How long have you worked for

1 the FAA?

2 THE WITNESS: I've been with the FAA nine
3 years.

4 MR. SCHLEEDE: And would you give us a brief
5 description of your education and background that
6 qualifies you for your position?

7 THE WITNESS: I have an airframe and power
8 plant rating, acquired at the Institute of Technology
9 in Inglewood, California, and commercial airplane
10 rating with instrument, multi-engine. I have 20 years
11 of industry experience with different airlines, leading
12 from mechanic, lead mechanic, to special projects
13 engineer.

14 I was co-owner of a general aviation business
15 with a fixed base operation and also a co-
16 owner/operator of a flight charter service out of
17 Hawthorne, California.

18 MR. SCHLEEDE: Thank you.

19 I think Mr. Phillips is going to get into
20 asking you questions about the AEG and your

1 responsibilities.

2 Thank you.

3 MR. PHILLIPS: Thank you, and good afternoon.

4 Mr. Newcombe, as Mr. Schleede just mentioned,
5 you come from the Aircraft Evaluation Group?

6 THE WITNESS: Yes, I do.

7 MR. PHILLIPS: Could you tell us what that is
8 and what they do?

9 THE WITNESS: The Aircraft Evaluation Group
10 is kind of like the liaison between the Certification
11 Offices and the Flight Standards District Offices. We
12 interact with both in assuring that the instructions
13 for continued airworthiness are initially developed and
14 maintained to the level of safety of the initial
15 certification.

16 MR. PHILLIPS: So what is -- before we get
17 into that, you used the initials MRB Chairman. Is that
18 Material Review Board?

19 THE WITNESS: No. That's the Maintenance
20 Review Board.

1 MR. PHILLIPS: Maintenance Review Board.

2 Okay. And what do you do in that function?

3 THE WITNESS: There again, on the initial --
4 we develop or help develop the initial maintenance
5 inspection requirements to be done for the instructions
6 for continued airworthiness, which eventually go to the
7 operator of the airplane to develop his initial
8 maintenance program.

9 MR. PHILLIPS: Other than maintenance, do you
10 get involved in any other initial certification design
11 activities?

12 THE WITNESS: Not too much on the initial
13 design activity. Only if there's some airplanes in
14 service and only with the maintenance program
15 beforehand.

16 MR. PHILLIPS: Do you use failure analysis or
17 hazard assessments as part of your normal job?

18 THE WITNESS: No.

19 MR. PHILLIPS: Were you part of the CDR team?

20 THE WITNESS: No, I was not.

1 MR. PHILLIPS: Have you read the CDR report?

2 THE WITNESS: Yes, I have.

3 MR. PHILLIPS: I'd like to talk a little bit
4 about the section entitled Continued Operational Safety
5 Issues. And you've said that's an area that the AEG is
6 involved with.

7 Can you tell me what Continued Operational
8 Safety Issues is or what would fit into that category?

9 THE WITNESS: Well, that in my opinion would
10 be one that has already had an issue established on it
11 that the design or the maintenance feature maintains an
12 adequate level of safety or the initial level of
13 safety.

14 MR. PHILLIPS: So would part of that process
15 involve writing AD's? Would you be involved with
16 writing an AD or issuing an AD?

17 THE WITNESS: I wouldn't be involved in
18 writing it. I would be involved in reviewing it to
19 make sure if there's any maintenance implications, that
20 they can be followed through by the Flight Standards

1 District people in the field.

2 MR. PHILLIPS: Are you part of any process to
3 review service bulletins or service letters from the
4 manufacturers before they're released?

5 THE WITNESS: No.

6 MR. PHILLIPS: Do you have anything to do
7 with determining whether they should be -- I guess if
8 you don't review them, you don't determine whether they
9 should be made mandatory or anything like that then.

10 I answered my own question.

11 THE WITNESS: No, I don't.

12 MR. PHILLIPS: In the CDR report there's a
13 group of recommendations, 16, 17 and 18 on page 39 --
14 I'm sorry. On page 44, I guess, and 45 of the report.
15 This is Exhibit 9X-A.

16 And one of the discussions is on the adequacy
17 of maintenance task and associated intervals. Could
18 you refer to that page, 44 of 9X-A?

19 THE WITNESS: 44, 9-A. Right.

20 MR. PHILLIPS: 9X-A.

1 THE WITNESS: Uh-huh. Which recommendation?

2 MR. PHILLIPS: We'll start with 16 but I want
3 to begin with the opening paragraph there.

4 The CDR team recognized that maintenance
5 tasks and the intervals of maintenance was a critical -
6 -

7 CHAIRMAN HALL: Recommendation 16?

8 MR. PHILLIPS: Yes.

9 CHAIRMAN HALL: And that's page 44?

10 MR. PHILLIPS: Page 44.

11 CHAIRMAN HALL: Yes. Let's just be sure if
12 we're referring to the exhibits we identify the page
13 for the benefit of the audience.

14 MR. PHILLIPS: Yes, sir.

15 As part of this ongoing operational safety,
16 maintenance inspection intervals and tasks and the
17 definition of those were addressed in the CDR report.
18 Could you tell us on Recommendation 16, could you just
19 discuss that recommendation for us briefly?

20 It says -- I'll read it. The recommendation

1 is to review and revise as appropriate the 737
2 inspection tasks associated with latent failures
3 identified in Tables 3 and 4 in Section 10 in
4 accordance with MSG-3.

5 And a couple of questions there. First of
6 all, what's MSG-3?

7 THE WITNESS: It stands for Maintenance
8 Steering Group and that's a document that was developed
9 by the Air Transport Association of America.

10 MR. PHILLIPS: Is that specific to the 737
11 and for all types?

12 THE WITNESS: All airplanes.

13 MR. PHILLIPS: And what would be in that
14 document generally?

15 THE WITNESS: It's a logic process to come up
16 with the initial maintenance inspection requirements
17 for the systems and structures.

18 MR. PHILLIPS: Is the consideration of latent
19 failures an important part of a maintenance program?

20 THE WITNESS: We don't consider latent

1 failures. Certification does, however. We do consider
2 hidden failures. So it's a little bit different. It's
3 a little different process.

4 MR. PHILLIPS: Could you briefly describe the
5 differences between latent and hidden?

6 THE WITNESS: Well, what we consider a hidden
7 failure would be hidden to the flight crew during the
8 performance of their normal duties. And considered
9 normal duties is when they're sitting in their seat for
10 takeoff. So if it's in the latent failure, discussed
11 earlier, was what Mike had read in the 251309 which we
12 consider the opposite of -- not opposite, but we
13 consider a hidden failure to the flight crew and not to
14 the design of the airplane.

15 MR. PHILLIPS: Are you familiar enough with
16 the design of this airplane and this CDR report to
17 describe to us any potential latent failures in this
18 airplane's flight control system?

19 THE WITNESS: I would not want to do that.
20 That's not my expertise, latent failures.

1 MR. PHILLIPS: On Recommendation 18 on page
2 45 of Exhibit 9X-A, the team recommended that the MRB
3 and PD inspection task description be revised. Could
4 you briefly describe what the intent of this
5 recommendation is?

6 THE WITNESS: Well, we're going to -- along
7 with the Boeing maintenance and ground operations
8 services, we're going to develop -- and this is a
9 normal process used in the development of a maintenance
10 program or the maintenance requirement is that you
11 develop a team consisting of the operators,
12 manufacturer of the airframe engine and any appliance
13 that may be involved. And through that team, you get
14 together and you go through the MSG-3 analysis to see
15 if a task and an interval is required.

16 And what we'll do is we'll take the same
17 process, develop what they call a policy and procedures
18 handbook, and this is the guidance that will be given
19 to the team on how they're going to do the analysis and
20 come up with an interval, if appropriate, and then what

1 to do after that.

2 MR. PHILLIPS: Could you tell us what a 1C,
3 3C, 1A interval is?

4 THE WITNESS: When you're doing the
5 inspection requirements and develop the maintenance
6 program, it's normally broken down into levels of
7 inspection or intervals. A C check could range
8 anywhere from 2500 hours up to a certain other number
9 with 1C would be a normal check. Usually they're done
10 in multiples of these. You'd have 1C and 2C until
11 you'd get up to maybe a D check. And that breaks down
12 to also the A checks. You'd have multiples of A checks
13 until you got to the level of a C check. And that's
14 where you would stop the multiples of A.

15 MR. PHILLIPS: So what's the most
16 comprehensive level of check? Is that an A or a C or
17 D?

18 THE WITNESS: The most common?

19 MR. PHILLIPS: Comprehensive, most thorough.

20 THE WITNESS: The most comprehensive is a D

1 or someone doing many multiples of a D, which is the
2 most comprehensive. Then it goes down to the C, and
3 the A being usually a weekly check with minor things to
4 check.

5 MR. PHILLIPS: And so on Recommendation~~18~~ on
6 this page 45, the last element in this table is a
7 standby hydraulic system, including a rudder function.
8 This is less than or equal to a 1A check. That's the
9 recommended inspection interval.

10 Does that mean that this check should be done
11 less than once a week or once a week? How would I
12 interpret that?

13 THE WITNESS: Should be done. Yes.

14 MR. PHILLIPS: Do you know if there's a
15 requirement to do that?

16 THE WITNESS: Pardon me?

17 MR. PHILLIPS: Do you know today if there
18 exists a requirement to do that check at the 1A level?

19 THE WITNESS: I believe on most -- let me
20 clarify something. When we establish the maintenance

1 requirements, this is the initial one that goes to the
2 operators. Once the operator gets the Maintenance
3 Review Board report, of course they have to implement
4 normally all of the items that are in the MRB report.

5 Through their reliability program and through
6 their experience and everything, they can through their
7 local authority have items escalated. So initially,
8 every airplane would start out with a 1A check.

9 MR. PHILLIPS: Do you, in doing your job, do
10 you use service difficulty reports?

11 THE WITNESS: Yes, we do.

12 MR. PHILLIPS: And how do those get to you?
13 Do you have a computer system there? Are they hard
14 copy papers or --

15 THE WITNESS: We have a computer system, the
16 ASOS system where we can access limited -- we have a
17 contact in Oklahoma City that we can call or get a
18 message to to get a more advanced or more complicated
19 search. Then they would send that information normal
20 mail.

1 MR. PHILLIPS: Based on your experiences and
2 your position, how effective are the SDR's in reporting
3 the maintenance issues in the fleet?

4 THE WITNESS: I think they're very effective.
5 We get indication of what is failing. A lot of times,
6 like we say, we don't get the full information of what
7 the failed part was or what actually failed on that
8 part but we know what it was. And then through our
9 office we do, if we consider it a safety issue or could
10 project into a safety issue, we would go further and
11 get more information on it and contact additional
12 people.

13 MR. PHILLIPS: How do you determine that it's
14 a safety issue? I would assume on an SDR you'd have a
15 part number and some description. Can just looking at
16 that one form tell you that there's a safety issue
17 involved? Is there any system that codes the SDR's as
18 critical or non-critical?

19 THE WITNESS: There's only -- sometimes in
20 the SDR system they do have a star border around it

1 which is a highlight that it could be safety issue.
2 Otherwise, we would take it into account with our
3 experience determine whether this possible unit could
4 affect the safety of the aircraft.

5 MR. PHILLIPS: In reviewing this SDR's are
6 you segregated by ATA codes? Do you have one person
7 who looks at flight controls, another person who looks
8 at structures or how do you divide the workload?

9 THE WITNESS: Well, in our group we train to
10 one airplane so we do the whole thing. And we do
11 separate the SDR's through the ATA code system.

12 MR. PHILLIPS: So you having the
13 responsibility for the 737 fleet at sometime or other
14 the SDR's should come across your desk and you should
15 have a look at it?

16 THE WITNESS: Normally, I'd have all '37.
17 And at least once a week a pamphlet is sent out through
18 Oklahoma City or from Oklahoma City to our office and
19 each one in the office reviews his particular airplanes
20 for the items that are in there.

1 MR. PHILLIPS: Do you recall any significant
2 trends in the SDR activity or SDR reports concerning
3 any of the 737 systems? Any common failures, problem
4 areas?

5 THE WITNESS: No.

6 MR. PHILLIPS: And this is looked at -- did
7 you say weekly or monthly or occasional?

8 THE WITNESS: Normally, weekly. And it
9 depends on the input, how much information is in there.

10 MR. PHILLIPS: I think we had a comment
11 earlier in the day that there's additional information
12 available behind these SDR's. Is there a way to
13 contact the person who wrote it to get more detail if
14 you need to know more about that SDR?

15 THE WITNESS: Yes. We normally have daily
16 contact with the principal maintenance inspectors for
17 the operators that are assigned or that have our
18 particular airplane. So if we find something that we
19 need more information on then we will contact the
20 principal inspector and have him either research his

1 current database or he will go to the operator and get
2 the information.

3 Very seldom do we ourselves deal with the
4 operator. We try to leave that up to the principal
5 inspector.

6 MR. PHILLIPS: Are the operators required by
7 law to write an SDR?

8 THE WITNESS: On certain things, yes.

9 MR. PHILLIPS: And what would be an example
10 of something they would be required to write an SDR on?

11 THE WITNESS: Any problem with the flight
12 controls. The regulations usually state the items that
13 they're required to report on. Some of them report
14 almost everything any more.

15 MR. PHILLIPS: Do some operators write more
16 SDR's than others?

17 THE WITNESS: No. They only write an SDR
18 when they have a problem so it all depends on when
19 there's a problem.

20 MR. PHILLIPS: I guess a better question is

1 do you believe that every problem is recorded on an
2 SDR?

3 THE WITNESS: Pardon me?

4 MR. PHILLIPS: Do you believe every problem
5 is recorded on an SDR?

6 THE WITNESS: No.

7 MR. PHILLIPS: Recently, we've been -- the
8 NTSB has been following a series of events involving
9 737 flight controls. I say recently. It's actually
10 been over a period of years. And other aircraft, too.

11 But would your office have responsibility for
12 following in-flight events or upset events? Is there
13 any reporting process that's required to the AEG?

14 THE WITNESS: Not so much a reporting
15 process. However, we are involved in the incidents
16 through the principal inspector. So we do get that
17 information and we do a follow-up.

18 MR. PHILLIPS: I think along those lines, Mr.
19 Jacky would like to ask some questions about some in-
20 flight events, so we'll pass the baton here.

1 MR. JACKY: The exhibit to which Mr. Phillips
2 was referring to is Exhibit Number 13X-C, if you could
3 refer to that, please. And specifically, pages 4 and
4 5.

5 Mr. Phillips sort of hinted at what -- or
6 took a couple of my questions, I guess. I'm wondering
7 in the process of -- in your work when you see the list
8 of SDR's, is there any sort of way of going back and
9 looking at any sort of particular either flight control
10 system or some sort of upset that would -- or to look
11 at them categorically by type of system? Would that be
12 the ATA code?

13 THE WITNESS: Yes, it would.

14 MR. JACKY: And is there any sort of process
15 within your group that if any one such code kept coming
16 up X amount of times that it would raise a red flag or
17 something?

18 THE WITNESS: Normally that's what we -- we'd
19 take a look at see -- we'd find a trend. If that
20 code's coming up all the time, then we would normally

1 gather those and go to the Aircraft Certification
2 Office and discuss it with the engineer who has
3 responsibility for the system.

4 MR. JACKY: And on these SDR's, are they
5 coded by airline at all?

6 THE WITNESS: Coded by what?

7 MR. JACKY: Airline.

8 THE WITNESS: Aileron?

9 MR. JACKY: No. Airline. By air carrier.

10 THE WITNESS: Yes, they are.

11 MR. JACKY: And in the process of going
12 through the SDR's, if one air carrier came up more than
13 others, would that throw a red flag?

14 THE WITNESS: It would. And we would contact
15 the principal inspector.

16 MR. JACKY: In looking at this list on page
17 number 4, the items that I would like to reference you
18 to are events that have been referred to the NTSB as
19 being uncommanded rolls.

20 CHAIRMAN HALL: We don't believe he has the

1 exhibit. See if you can assist, Mr. Schleede. It's
2 13X-C.

3 THE WITNESS: Okay.

4 MR. JACKY: And starting on page 5, Item
5 Number 32, and on down through the rest of the page are
6 several uncommanded roll events. And I'm wondering if
7 in the process of the last few months if you or anyone
8 in your group have noticed any sort of increase in
9 SDR's or anything that might hint at a type of problem
10 like this?

11 THE WITNESS: On these incidents in here we
12 haven't. The SDR reports would not have been entered
13 into the ASOS system and out to the field -- out to us.
14 However, we have continued contact with the principal
15 inspectors on all of these items and we have been doing
16 the follow up with those.

17 MR. JACKY: And what have been the type of
18 follow ups that you've been doing?

19 THE WITNESS: On the items that were removed
20 from the airplane due to either response by the

1 operator themselves or the NTSB or the FAA for
2 recommendation of removal and items sent to the
3 original aircraft manufacturer for teardown, we would -
4 - and I've been to most of them -- go to the facility
5 where they're going to do the testing and evaluate --
6 not evaluate the test but witness the testing and see
7 if there's anything that came out of the testing that
8 we could use in our determination of any problem.

9 MR. JACKY: And was there any sort of
10 determination of that sort?

11 THE WITNESS: Pardon me?

12 MR. JACKY: Was there any determination of
13 that sort?

14 THE WITNESS: None at this point, no.

15 MR. JACKY: And have you taken any sort of
16 follow-up action on these items beyond that?

17 THE WITNESS: Not so much on these items
18 here. We are in the process of -- and we have
19 developed a team and we're taking a look at -- we're
20 gathering information from six airlines on the

1 components removed from ATA's Chapter 22, which is the
2 autoflight system and ATA Chapter 27, which is the
3 flight control system for every component removed in
4 the last five years to develop a database to see if we
5 can come up with a common cause or commonality of any
6 issues.

7 And we're doing this directly through the
8 help and assistance of the principal inspectors since
9 they're the ones that know the operators' program the
10 most and how to defer the information that's set in
11 their reliability program.

12 MR. JACKY: And you said this process has
13 just begun?

14 THE WITNESS: Has begun, yes. We've already
15 started it. We've already had meetings with the
16 principal inspectors and they are now in the process of
17 putting that information into the computer system so we
18 can incorporate it into a mainframe.

19 MR. JACKY: And will this process be ongoing
20 or is there some sort of end date?

1 THE WITNESS: Right now we've only projected
2 to do the last five years of reliability data which is
3 going to take quite some time to get all that
4 information into the system. I would hope that we
5 would continue it with -- everything's available where
6 we can do that.

7 MR. JACKY: And is this just with the 737
8 airplane itself or is this encompassing all types of
9 airplanes?

10 THE WITNESS: These are only the components
11 on the 737 airplanes for certain operators.

12 MR. JACKY: The six airlines that you
13 mentioned?

14 THE WITNESS: Six airlines. yes.

15 MR. JACKY: Are you at liberty to tell us
16 what the names of those airlines are?

17 THE WITNESS: Pardon me?

18 MR. JACKY: Are you at liberty to tell us
19 what the name of those airlines are?

20 THE WITNESS: We originally have been

1 requested by the airlines that we not use their
2 information or their name in a report.

3 MR. JACKY: Understand.

4 And would this just be historical data or
5 would it be starting time zero equal now and move on
6 forward?

7 THE WITNESS: For the five years?

8 MR. JACKY: You're researching five years
9 back?

10 THE WITNESS: Five years back. Yes.

11 MR. JACKY: And what will be the final
12 product? Are you planning on issuing a report on your
13 findings?

14 THE WITNESS: We plan on doing a report, on
15 showing the components, the cause and the failures
16 we've found on them and if there's any significant
17 trend.

18 MR. JACKY: And have you made any sort of
19 preliminary assessment as to any sort of significant
20 trends?

1 THE WITNESS: Not at this point, no

2 MR. JACKY: In the process of going through
3 your SDR reports, is the airplane manufacturer either -
4 - or is the airplane manufacturer privy to your lists?

5 THE WITNESS: The list of the database we're
6 putting together?

7 MR. JACKY: You said you received weekly
8 updates on --

9 THE WITNESS: On the SDR's.

10 MR. JACKY: -- SDR's. Would an airline
11 manufacturer have access to that same information?

12 THE WITNESS: I believe the manufacturers
13 have the same access to the database that we do.

14 MR. JACKY: Doyou do any sort of sharing at
15 all of lists between -- any list that the manufacturer
16 might have and what you might have?

17 THE WITNESS: When we do find a trend that we
18 want to take a look at, we do contact the manufacturer
19 and see what he has within his or whether he has other
20 operators reporting. See, our database is only

1 servicing the U.S. certificated airplanes. The
2 manufacturer would have the one that covers all the
3 certificates airplanes for all the ones that they've
4 sold, so they would have a larger -- most of the time
5 they would have a larger database than we have, so we
6 do contact them quite frequently to find out just what
7 information they have and if they've done anything
8 about them.

9 CHAIRMAN HALL: Mr. Newcombe, I'll go out of
10 turn here and just ask what type of information do you
11 have on these events from something that happened five
12 years, four or five years ago? What type of
13 information would you have that you'd be putting in
14 this computer?

15 THE WITNESS: We'd have the -- that there was
16 an incident or cause, what was removed, and sometimes
17 we'll have what the fix for that unit was. That's what
18 we're trying to get is -- with the SDR system we have
19 what the cause was and what the failure was, what the
20 replacement was. A lot of times we don't have what

1 actually was fixed because a lot of times that's
2 privileged information. That goes directly to the
3 operator from the component.

4 CHAIRMAN HALL: But there is not an existing
5 database on the 737 in regard to incidents like that
6 that is maintained or --

7 THE WITNESS: No. Normally this is all
8 pulled in by -- each individual operator has his own
9 database, reliability database. We do not have one
10 specifically for the '37. The manufacturer probably
11 has one that he maintains.

12 CHAIRMAN HALL: Well, who would make the
13 decision to set up a database?

14 THE WITNESS: Who would make the decision?

15 CHAIRMAN HALL: Yes.

16 THE WITNESS: It was --

17 CHAIRMAN HALL: And again, I'm asking you the
18 obvious. You know, we had an accident in Colorado
19 Springs. We had an accident in Pittsburgh. And what
20 I'm hearing is we're just setting up a database now to

1 track incidents, these incidents, and I was just
2 wondering why.

3 THE WITNESS: Well, they've been tracking
4 units separately all the time through the SDR system.
5 Because of the incident or accident in Pittsburgh, the
6 principal inspector there, who we've been in
7 coordination with all the time, had done it with his
8 operator. So we felt, well, this is good information
9 that we should have from everybody -- from a limited
10 source right now, six airlines, and then maybe
11 eventually we'll try to get it from everybody.

12 So through discussion with him and showing
13 what he's developed for his investigation, we felt it
14 would be the same -- that we should do that. So
15 through my superiors, we decided we would go ahead and
16 do that and call the principals in to give us help in
17 developing this.

18 CHAIRMAN HALL: And you've indicated that
19 there's an engineer that has a responsibility that this
20 information is reported to for the rudder system on the

1 737? Is there one engineer that has the responsibility
2 in your department for tracking information or not?

3 THE WITNESS: I have all the responsibility
4 for the 737's in the Aircraft Evaluation Group and we
5 work with the engineers who have responsibility for
6 their systems. There could be a bunch of them in the
7 Certification Office.

8 CHAIRMAN HALL: I'm sorry, Mr. Jacky, for
9 using my prerogative to butt in, but please proceed.

10 MR. JACKY: Thank you.

11 Back to the database that you were discussing
12 and that you're putting together. Did you say that you
13 would only be looking at the autopilot type events or
14 are you talking about looking at all sorts of control
15 upsets, events?

16 THE WITNESS: We're not looking at events so
17 much. We're looking at the removals of the components
18 and what was the cause of the failure of that
19 component. So it's not so much -- well, we do take
20 that into account so we can divide our database or we

1 can sort our database to whether it's a rudder system,
2 aileron system, whether it happened in takeoff crews,
3 descent, approach.

4 So, we're trying to set it up so we can take
5 a look at all different parameters and to get some
6 information out of it.

7 MR. JACKY: And did I take it correctly that
8 you asked all the PMI's to come in or principal
9 maintenance inspectors to come in and talk about the
10 setting up of this database?

11 THE WITNESS: We asked the principal
12 inspectors of six airlines to get the reliability data
13 from the operator for the last five years. The
14 operators cooperated and gave this information to the
15 principal inspectors, who then came to our meeting and
16 we sat down and developed a form that we could use to
17 incorporate all of the information because it's all
18 different. So they have to be able to distinguish --
19 take information from one reliability program and be
20 able to put it into one single form.

1 MR. JACKY: And this form that you've
2 developed for the implementation to the database, that
3 is different than the SDR form?

4 THE WITNESS: Yes, it is.

5 MR. JACKY: And at any time then, have you
6 had any sort of review or meeting with representatives
7 or engineers from operators more than just the six
8 airlines that you've been referring to?

9 THE WITNESS: Not on this, no.

10 MR. JACKY: Thank you. I have no further
11 questions.

12 CHAIRMAN HALL: Other questions from the
13 Technical Panel?

14 Mr. Haueter?

15 MR. HAUETER: Yes. Just two brief ones.

16 I was curious on the SDR's. You mentioned
17 they get flagged as they come in or you see something.

18 Is that a manual flag? Is it done by computer? How
19 do you keep track of all these SDR's and the things you
20 find on them?

1 THE WITNESS: You mean -- I said they were
2 flagged with the starts on them, you mean?

3 MR. HAUETER: Well, if you're looking for a
4 specific trend, does that computer find it and pulls
5 those out or how's that done?

6 THE WITNESS: No. I'm not sure if we're
7 talking about two different things here. One was if it
8 could be a safety issue, Oklahoma City would put a
9 border around that one item. When we look at them, we
10 look at every one of them pertaining to our airplane
11 and we would look at the first ATA code and the
12 probable cause or the removal of the incident, what
13 caused the incident. And we would determine ourselves
14 if we have a trend. But there's no computer generation
15 for a trend.

16 MR. HAUETER: That's purely a manual search
17 of going through all these things and reading them for
18 each event?

19 THE WITNESS: Yes.

20 MR. HAUETER: How many people do that?

1 THE WITNESS: Pardon me?

2 MR. HAUETER: How many people do that? I
3 mean, --

4 THE WITNESS: Well, right now we have --

5 MR. HAUETER: Just for 737's.

6 THE WITNESS: Just for the 737?

7 MR. HAUETER: Yes.

8 THE WITNESS: Just me.

9 MR. HAUETER: How many of these things do you
10 look at a day? I'm kind of curious.

11 CHAIRMAN HALL: You're the only person? Is
12 that what I heard? I'm sorry. The fan went on and I
13 can't hear very well up here.

14 THE WITNESS: I'm the responsible MRB
15 Chairman for the 737 fleet. We do have a backup person
16 when I'm not in the office. However, when the SDR's
17 come in, I'm the only person that actually looks at
18 them and reviews each one to see if we have a trend or
19 whatever.

20 And normally, --

1 CHAIRMAN HALL: How big a workload is that?
2 How many would come in a day or a week? Do you know
3 how many came in in the last year?

4 THE WITNESS: Well, like I mentioned earlier,
5 we usually get a package each week and there may be
6 anywhere from 10 up to 20 or 25 or so SDR reports. A
7 lot of them are insignificant, like reading lights and
8 stuff like that.

9 CHAIRMAN HALL: But you review all of those
10 and at this point in time there's not a computer
11 program you put them in other than here?

12 THE WITNESS: Right.

13 CHAIRMAN HALL: Fine. Okay.

14 MR. HAUETER: That's what I was getting at.

15 In looking at these, do you interact with the
16 operations side on things that you may see in looking
17 at SDR's to help out the operations group or is that
18 done elsewhere?

19 THE WITNESS: We would. If we found
20 something that we would need some discussion with them

1 or we thought they should know about, then we would get
2 our counterpart for the operations and the avionics
3 person and discuss it with them to keep them informed.

4 MR. HAUETER: Are there any specific issues
5 with the 737 that you're tracking or have a special
6 flag on them now as far as your involvement?

7 THE WITNESS: Any flight control problem, any
8 autopilot problem, we take a look at those mainly to
9 see if -- because recently we keep track of every one
10 of them so we usually have a lot of the information
11 before the SDR gets to us. Because it goes from the
12 operator to the principal inspector. Then it's sent to
13 Oklahoma City who incorporates it into the system and
14 then publishes the report and then sends it out.

15 MR. HAUETER: In going back once again and
16 just clarifying, on Exhibit 13X-C, on the recent
17 events, you mentioned that you normally wouldn't see
18 these type of events? Did I misunderstand your
19 response?

20 THE WITNESS: On uncommanded rolls and stuff?

1 MR. HAUETER: Right.

2 THE WITNESS: Yes. Some of the times some of
3 these aren't classified as reportable through the
4 regulations, so they wouldn't be reported under the SDR
5 system.

6 MR. HAUETER: And so if there wasn't a
7 component pulled, you may never even know that one of
8 these events occurred?

9 THE WITNESS: Right. If it wasn't reported
10 then we wouldn't know.

11 MR. HAUETER: Is there an operations
12 counterpart of yourself that would pick up something
13 like that through a different means?

14 THE WITNESS: Well, there again, the
15 operations counterpart, if it was reported through the
16 SDR, we would go to him and say, "Have you seen this,"
17 or whatever.

18 MR. HAUETER: But I mean, would your -- does
19 your counterpart have a system similar to SDR's to find
20 out about operational events? You may be the wrong

1 person, but I just --

2 THE WITNESS: I don't --well, they have --
3 they still go through their principal inspectors, their
4 principal operations inspectors for information coming
5 from them, but for the ops side, there's nothing that's
6 the same as the SDR for them getting information.

7 MR. HAUETER: Following up on the Chairman's
8 comment and my own, could you use computerization to
9 help you track all these SDR's and tag and trend them
10 and things like that?

11 THE WITNESS: Could I?

12 MR. HAUETER: Yes.

13 THE WITNESS: Well, we are right now doing
14 that.

15 MR. HAUETER: You're moving in that direction
16 to --

17 THE WITNESS: Yes. We've taken the -- well,
18 we developed the program we're going to use and the
19 principal inspectors will be doing -- inserting most of
20 that information at their place of location. They'll

1 be sending me the disk or via the system, and I'll be
2 inserting that into my computer as a main database.
3 And then we'll be doing a track for that.

4 MR. HAUETER: Okay. Thank you.

5 That's all the questions I have.

6 CHAIRMAN HALL: Any other questions from the
7 Technical Panel?

8 (No response.)

9 If not, we'll move to the parties. Do any of
10 the parties have questions for this witness?

11 I see the hand of the FAA. Anyone else?

12 (No response.)

13 If not -- Mr. Donner.

14 MR. DONNER: Mr. Newcombe, just one point of
15 clarification. All of these SDR's are computerized in
16 Oklahoma City, are they not?

17 THE WITNESS: Yes, they are.

18 MR. DONNER: And they are available to you?

19 THE WITNESS: They are available to anyone in
20 the FAA. Yes.

1 MR. DONNER: Thank you.

2 CHAIRMAN HALL: I guess, Mr. Donner, you're
3 asking maybe what I'm -- if there's one database, does
4 there need to be -- you're talking about creating a
5 database out of a database; right? Information that
6 comes out of Oklahoma City?

7 THE WITNESS: We're taking additional
8 information that may not be in the database in Oklahoma
9 City because we're going a little further. And like I
10 said, the original SDR --

11 CHAIRMAN HALL: Where does that additional
12 information come from?

13 THE WITNESS: Like I ~~sa~~, we were getting the
14 principal inspectors to get that information from the
15 operators. And one thing I forgot to point out. We
16 have also contacted a couple of the OEM's to get their
17 reliability data on that part for the last five years.
18 And they've offered to do that, so --

19 CHAIRMAN HALL: That helps me. Okay.
20 We'll go to the table and Mr. Clark.

1 MR. CLARK: I have no questions.

2 CHAIRMAN HALL: Mr. Marx?

3 MR. MARX: No questions.

4 CHAIRMAN HALL: Mr. Schleede?

5 MR. SCHLEEDE: Yes, sir.

6 I may have missed -- how does your office or
7 you personally, how do you interact with the Boeing
8 Company?

9 THE WITNESS: Well, I have -- as being the
10 MRB Chairman, the initial -- and I might have to
11 explain a little bit how the initial process is started
12 as far as the maintenance program. When a manufacturer
13 wishes to develop the design for an airplane, of course
14 they have to have the instructions for continued
15 airworthiness. So they would come up with -- normally
16 it's about two years before the type certification of
17 the airplane and say we have to develop a maintenance
18 program for this airplane.

19 The industry steering committee is developed
20 through the manufacturer, the operators, the engine and

1 airframe manufacturer and appliance manufacturers.
2 Once they develop that team then they would come to the
3 FAA and say we're going to need to develop this
4 maintenance program.

5 As me being the MRB Chairman, I would get
6 together a team, and usually it's principal inspectors
7 or other people in the Aircraft Evaluation Group. We
8 develop the MRB team to help the manufacturer develop
9 the initial maintenance requirements for that airplane
10 before it's put into service so that the operator has a
11 maintenance program before he gets the airplane.

12 So then once it's in service, then we work
13 with the manufacturer to make sure that the
14 instructions for continued airworthiness are maintained
15 to the level of safety of original issuance.

16 MR. SCHLEEDE: Okay. I'm sorry. Really
17 that's the part I was interested in, your day-to-day
18 interaction with the Boeing Company.

19 THE WITNESS: Yes.

20 MR. SCHLEEDE: Do you have a certain office

1 that you interact with or a person at Boeing on a daily
2 basis?

3 THE WITNESS: It may not be on a daily basis.

4 Depends on the occurrence. But we have several people
5 in one office that we do discuss certain issues with
6 and work with on an occasional basis whenever it's
7 needed.

8 MR. SCHLEEDE: Do they provide -- does Boeing
9 provide to you reports of 737 incidents outside of the
10 U.S. on foreign registry?

11 THE WITNESS: If we were to request them,
12 they will discuss them with us. Yes.

13 MR. SCHLEEDE: If you request them. So if
14 there's a serious incident involving a 737
15 airworthiness overseas, how would you know about it?

16 THE WITNESS: Well, we would know about the
17 incident as it happened and then we would contact our
18 counterpart over there to see if they have any
19 information.

20 MR. SCHLEEDE: Well, I'm trying to find out

1 how your office would find out about it. Does Boeing
2 report it to you or does the foreign authority report
3 it to you?

4 THE WITNESS: Our counterparts do sometimes
5 report to us that they've had an occurrence. Of
6 course, again, we hear it through our public affairs
7 system or a lot of times through the media that
8 something had happened. So then that starts the ball
9 rolling.

10 MR. SCHLEEDE: Is there any requirement that
11 Boeing report that to your office, any kind of a
12 serious event like that?

13 THE WITNESS: Not on the flight standards
14 side. Only on the certification side Boeing has to
15 report certain stuff.

16 MR. SCHLEEDE: Do you know roughly how long
17 it takes from the time an event that generates an SDR
18 gets in the system and will get to your office?

19 THE WITNESS: I couldn't say for sure. It
20 could be sometimes two weeks, maybe three weeks.

1 MR. SCHLEEDE: Thank you.

2 CHAIRMAN HALL: Mr. Laynor?

3 MR. LAYNOR: No questions.

4 CHAIRMAN HALL: Well, first, an
5 administrative announcement.

6 Mr. Haueter, you'd better tell the hotel that
7 as soon as I conclude here they can take the back of
8 the ballroom.

9 MR. HAUETER: They're ready.

10 CHAIRMAN HALL: They're ready to go? Okay.
11 So just -- when we take our break here after this, we
12 will be giving up the back portion of the ballroom, so
13 anyone that's sitting back there has any belongings,
14 please collect them. There should be adequate seating,
15 looking at the crowd, on the area that we'll have left.

16 Mr. Newcombe, so I can put this in context in
17 my mind, would you tell me exactly what an SDR is?
18 It's a service --

19 THE WITNESS: Service difficulty report.

20 CHAIRMAN HALL: And that's referenced

1 somewhere. But in as much layman's language as you
2 can, could you tell me what that report is that comes
3 to you from the airline through Oklahoma City?

4 THE WITNESS: What it does it it's an
5 occurrence of a malfunction of something that has to be
6 reported by the airline to the principal inspector.
7 And normally it's a flight interruption or a damage or
8 something to a primary flight control or whatever.

9 CHAIRMAN HALL: And in almost all cases or
10 all cases a component would be involved and that would
11 be pulled for examination and a report made on it or
12 not?

13 THE WITNESS: If it's in a component -- well,
14 normally -- usually it's a component of some kind.
15 Like I say, it can range from an aircraft seat, a
16 reading light, to a flap.

17 CHAIRMAN HALL: So you would get an airplane
18 seat reading light component report as one of those 25,
19 as well as maybe something involving the flight control
20 system?

1 THE WITNESS: Flight control system or
2 emergency light. Yes.

3 CHAIRMAN HALL: Things of that nature. Now,
4 that information then comes to you. And on the 737,
5 how long has that service difficulty report system been
6 in place?

7 THE WITNESS: Ever since I've been in the
8 agency, so I'm not sure.

9 CHAIRMAN HALL: So on the 737, you have
10 information going back to 1967 essentially?

11 Is that when, John, it started?

12 When it started in '67 with certification and
13 went into service shortly thereafter, do you have the
14 information back to '67?

15 THE WITNESS: I'm not sure how long the
16 information is maintained at Oklahoma City. I know
17 after a certain period of time it's put in the archives
18 which is still available if we need to go back. But
19 I'm not sure just exactly. I've never had to go back
20 to '67 or whatever to get information like that.

1 CHAIRMAN HALL: Well, how long have you been
2 in this specific -- in the position that you presently
3 hold?

4 THE WITNESS: I've been with the Aircraft
5 Evaluation Group since 1987. I was in the Standards
6 staff originally and then I moved down to the Aircraft
7 Evaluation Group and took over responsibility for the
8 737. So I've had the 737 for two years.

9 CHAIRMAN HALL: For two years?

10 THE WITNESS: Yes.

11 CHAIRMAN HALL: And who had it previous to
12 that?

13 THE WITNESS: Mr. Fred Duval.

14 CHAIRMAN HALL: Is he still with the
15 organization?

16 THE WITNESS: Yes, he is.

17 CHAIRMAN HALL: And still in he office?

18 THE WITNESS: He's still in the office. He
19 would have normally kept this airplane, however, with
20 the development of the 600, 700 and 800, and him being

1 close to retirement age, they wanted somebody to be put
2 into that position who would be able to continue the
3 full process.

4 CHAIRMAN HALL: Well, in reviewing all these
5 service difficulty reports over a two year period of
6 time is there anything that we have not done in this
7 investigation that you would recommend we do?

8 THE WITNESS: No. I think everything's been
9 done.

10 CHAIRMAN HALL: Nothing that's come to your
11 attention that you think needs further examination?

12 THE WITNESS: Not as far as maintenance
13 practices, no.

14 CHAIRMAN HALL: Again, I guess there were 53
15 items, is that correct -- incidents, that are --
16 events. What's the proper terminology here? Events,
17 flight events, that are listed here. And I counted
18 just roughly about 17 of them occurred outside the
19 United States airspace.

20 Are you aware of all 17 and have you -- would

1 you have information on those to follow up on what Mr.
2 Schleede had asked?

3 THE WITNESS: I'm not aware of all 17 that
4 happened outside the United States. Only the ones that
5 we get within U.S. certificated operators.

6 CHAIRMAN HALL: Do you think it would be
7 important to you in performing your responsibilities
8 for the FAA and the American public if this
9 information, since many of these aircraft operate
10 internationally, that this information was somehow
11 maintained and brought together?

12 THE WITNESS: I do. And we're in the process
13 right now. We have mailed out the CDR report to all of
14 the principal inspectors. We're now going to the
15 international field offices with a copy. And also,
16 we're getting a listing of all of the foreign
17 regulatory authorities so we can give them a copy so
18 that they can go in and evaluate the information
19 contained in the CDR report.

20 And we also are in the process of developing

1 a flight standards information bulletin for
2 airworthiness which is normally controlled out of AFS
3 300 in Washington that will be going to pretty much all
4 of the people I just mentioned. That will be
5 requesting certain information and giving them certain
6 information of this nature.

7 CHAIRMAN HALL: You also do the ATR series of
8 airplanes?

9 THE WITNESS: Yes, I do.

10 CHAIRMAN HALL: I guess my last question. Do
11 you have on any of these incidents, does flight data
12 recorder information come to you?

13 THE WITNESS: There's been a couple that the
14 principal inspector has provided. However, myself, I
15 didn't have the expertise to read it and know what was
16 in it, so I had to get with the appropriate people to
17 find out just what it all actually meant and what
18 occurred at certain points in time and everything.

19 CHAIRMAN HALL: Well, Mr. Newcombe, we
20 certainly appreciate your testimony and your being

1 here. And unless here are other questions, you will be
2 excused.

3 (Witness excused.)

4 CHAIRMAN HALL: We will take a 15 minute
5 break and come back promptly for the next witness at --
6 well, we'll make it an 18 minute break -- at 10 minutes
7 to the hour.

8 We'll stand in recess.

9 (Whereupon, a recess was taken.)

10 CHAIRMAN HALL: We will reconvene this Board
11 of Inquiry and to a smaller setting. It's nice to see
12 the audience up closer. We might have to try this at
13 my church.

14 So, the next witness we will call is Mr.
15 Richard Kullberg. Mr. Kullberg, if you could please
16 come forward.

17 Mr. Kullberg is the Designated Engineering
18 Representative for the Boeing 737 Hydraulics/Flight
19 Control Engineer with the Boeing Commercial Airplane
20 Group in Seattle, Washington.

1 (Witness testimony continues on the next
2 page.)

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1 RICHARD KULLBERG, DESIGNATED ENGINEERING
2 REPRESENTATIVE, B-737 HYDRAULICS/FLIGHT CONTROL
3 ENGINEER, BOEING COMMERCIAL AIRPLANE GROUP,
4 SEATTLE, WASHINGTON

5

6 Whereupon,

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

11 MR. SCHLEEDE: Mr. Kullberg, please give us
12 your full name and business address?

13 THE WITNESS: Richard Kullberg, the Boeing
14 Company, Seattle, Washington.

15 MR. SCHLEEDE: And your position at Boeing?

16 THE WITNESS: I'm a Senior Principal Engineer
17 working on the analysis, certification and testing of
18 the 737, 757 flight control systems.

19 MR. SCHLEEDE: And how long have you worked
20 at Boeing?

1 THE WITNESS: Approximately 30 years.

2 MR. SCHLEEDE: Would you briefly describe
3 your education and background that brings you to your
4 present position?

5 THE WITNESS: I've a bachelor's degree from
6 the University of Minnesota and worked numerous flight
7 control type areas with the Boeing Company, starting
8 with 747 and SST and on through the 700. I'm also, for
9 approximately the last year and a half, I've also
10 worked the 737.

11 MR. SCHLEEDE: And you're listed on our list
12 as a designated engineering representative or DER.
13 Could you briefly describe what your duties are or what
14 a DER is and what your duties are as a DER?

15 THE WITNESS: The primary duty is to find
16 compliance with the FAR's, to review design changes,
17 verify that they meet the FAR's, production changes,
18 service bulletins. Also, to prove certification data.

19 MR. SCHLEEDE: And who gives you that
20 designation, the FAA?

1 THE WITNESS: Correct.

2 MR. SCHLEEDE: And so when you're working in
3 that function, are you working on behalf of the FAA?

4 THE WITNESS: That's correct.

5 MR. SCHLEEDE: Okay. Thank you.

6 Mr. Phillips will continue.

7 MR. PHILLIPS: Good afternoon. A little
8 follow-up to Mr. Schleede's question about the DER
9 responsibilities.

10 What would you be required to do as a DER?
11 Do you sign engineering drawings and specifications or
12 do you advise as to design guidelines? What would be a
13 typical duty of a DER?

14 THE WITNESS: I don't sign detailed drawings.

15 I sign the top drawing which is part of the
16 certification process for each individual airplane.
17 When I do that, I'm basically making a finding that
18 airplane, as far as the flight control systems go, meet
19 the FAR requirements.

20 MR. PHILLIPS: Does every drawing have to

1 meet your approval? Does it have to be signed by you?

2 THE WITNESS: Not every drawing. The top --
3 the drawing tree system feeds into the top drawing, so
4 in essence, by signing a top drawing I'm approving the
5 drawings underneath it for my area.

6 MR. PHILLIPS: Is the top drawing an
7 installation drawing, an assembly drawing, a detailed
8 drawing?

9 THE WITNESS: It's one single drawing that
10 pulls everything together for the whole airplane.

11 MR. PHILLIPS: Okay.

12 THE WITNESS: But also, other than that, I
13 would approve by qualification testing, any type of
14 certification, a function that requires FAA approval.
15 And I would make -- either approve it or recommend
16 approval to the FAA.

17 MR. PHILLIPS: And in doing this job for the
18 FAA while you're an employee at Boeing, do you share
19 any other management or -- any other management
20 responsibilities for any other areas? For instance,

1 you said you were involved with the 757 program. Do
2 you still work in that program as a DER right now?

3 THE WITNESS: That's correct.

4 MR. PHILLIPS: And the reason behind the 757
5 is because that's a natural grouping for the Renton
6 Division manufacturing?

7 THE WITNESS: Yes.

8 MR. PHILLIPS: Along those lines, we've
9 gotten noted for your testimony today some discussions
10 of the 737 rudder system design. We've had extensive
11 testimony in the proceeding hearing by several people
12 on the detail design. I'd like to very generally touch
13 on that this afternoon.

14 And to start off, I'd like to ask what are
15 the primary differences between the 737 and 757 designs
16 with relationship to specifically the directional
17 control system?

18 THE WITNESS: The principal difference is in
19 the surface actuation system. 757 was -- 757/767 were
20 the first airplanes to eliminate mass balance weights

1 from the rudder control surface. As part of this, what
2 allows this elimination is the actuators on the surface
3 provide stiffness, which provide damping, and therefore
4 take the place of the mass balance weights.

5 The '37 airplane surface is mass balanced so
6 that to begin with, the '57 started with this multiple
7 actuator configuration to get the redundancy for
8 flutter suppression. The individual actuators on the
9 '57 are all single load path valve jam protection.
10 Instead of being provided by dual valve, it's provided
11 by the multiple actuators.

12 If we were to have say a valve jam on a 757,
13 there would be some back driving of the rudder surface
14 until the field system broke out some shear outs and
15 allowed the other two to overcome it.

16 MR. PHILLIPS: How many actuators are there
17 on the 757 driving the rudder?

18 THE WITNESS: There's three.

19 MR. PHILLIPS: Three.

20 THE WITNESS: With three full-time hydraulic

1 systems. The 737 has one dualized actuator and it's a
2 tandem actuator so it has two hydraulic systems
3 sparring it. And then the standby actuator is just
4 that. It does not operate until you've had a failure
5 of a hydraulic system.

6 MR. PHILLIPS: Or commanded by the pilot at
7 his option? You don't have to have a failure to
8 activate the standby, do you?

9 THE WITNESS: No. You need to have a
10 failure. Procedurally, you would not turn on the
11 standby until you've had one failure.

12 MR. PHILLIPS: In the 767, is it similar to
13 the 757 in design with three actuators?

14 THE WITNESS: Nearly identical. Yes. As far
15 as the architecture.

16 MR. PHILLIPS: How about the 777?

17 THE WITNESS: That's also three parallel
18 actuators. The difference is it's fly by wire.

19 MR. PHILLIPS: And by fly by wire, you mean
20 that the signals to the actuator are electrically

1 commanded?

2 THE WITNESS: Electrically commanded.

3 Correct.

4 MR. PHILLIPS: The surfaces on the 73-5-6 and
5 triple 7 are all single surface rudders; am I correct?

6 THE WITNESS: Correct.

7 MR. PHILLIPS: There's no balance tabs? And
8 you mentioned that there was mass balance on the 737
9 but not on the 75. Is that same carried through to the
10 67 and triple 7?

11 THE WITNESS: That's correct. Yes.

12 MR. PHILLIPS: And you mentioned flutter
13 suppression as part of the design criteria for using
14 multiple packages. Is that an active flutter
15 suppression system? Does it respond to some dynamic
16 input?

17 What drives the flutter suppression system on
18 those airplanes?

19 THE WITNESS: It's basically the stiffness
20 and damping of the actuator, so it's a passive damping

1 system.

2 MR. PHILLIPS: So it isn't actively driven
3 for flutter purposes. It's these as a mass balance in
4 its body itself?

5 THE WITNESS: Right. If you maintain enough
6 stiffness in the actuators, you don't get flutter.

7 MR. PHILLIPS: Let's drop back one digit
8 there on the 727. That rudder has a different design
9 concept, too. Could you tell me a little bit about it?

10 THE WITNESS: The 727 has split rudders.
11 Each rudder is powered by a single actuator. One of
12 the rudders has a standby actuator but essentially
13 identical to the '37 standby actuator.

14 MR. PHILLIPS: And the 747, I think one we've
15 left out?

16 THE WITNESS: It's got split rudders It has
17 dual tandem actuator on each rudder. '47 is a little
18 bit unique in that it has four hydraulic systems.

19 MR. PHILLIPS: So we've got two airplanes,
20 the '27 and '47 have split rudders, and then the rest

1 of the Boeing -- the current manufactured series
2 airplanes have single panel rudders?

3 THE WITNESS: Right. And also the 707.

4 MR. PHILLIPS: 707?

5 THE WITNESS: Single panel.

6 MR. PHILLIPS: And that's a single panel?

7 And how many actuators?

8 THE WITNESS: It's got one dual tandem
9 actuator and it also has manual reversion capability.

10 MR. PHILLIPS: Is that dual tandem actuator
11 in the 707 or was it similar to the 737 design?

12 THE WITNESS: I'm not sure what the
13 similarities are. Architecturally it's very similar.
14 It's got a yaw damper that's integral to the actuator.
15 It's got dual concentric valve, dual load path
16 linkage.

17 MR. PHILLIPS: In the yaw damper sections of
18 the airplanes we've discussed, we heard earlier Mr.
19 Koch describe an integrated package where the yaw
20 damper was a component of the PCU. Do your other

1 aircraft designs integrate the yaw damper into a
2 component package such as the rudder PCU?

3 THE WITNESS: The '27, '07, '37, '47 have
4 integrated actuators. '57, '67 the actuators are
5 separated. Partly because you have -- '57, '67 has two
6 yaw dampers that have to drive three main actuators, so
7 integrating them would be -- well, you couldn't
8 integrate them for that situation.

9 MR. PHILLIPS: In the description of the
10 series of the rudder actuators and the rudder surface
11 configurations, does the 737 stand out in your mind as
12 being different than the others for a Boeing design?

13 THE WITNESS: Philosophically, it's very
14 similar. It's completely dual load path from the aft
15 quadrant through the whole actuation system, so it's
16 designed to be fault tolerant as far as any single
17 disconnect, for example, would have no affect on the
18 pilot control of the rudder. And that's pretty much --
19 however you implement it, that's the philosophy.

20 MR. PHILLIPS: And what drove the design to a

1 dual load path single unit versus a multiple
2 configuration?

3 THE WITNESS: Well, at the time of the 737
4 design, that I think was the most common practice.
5 There was -- we really first started looking at
6 multiple actuators on the SST because of mass balance
7 removal and there were a lot of concerns about
8 synchronizing multiple actuators if they have a large
9 force bite or if you have failure modes, for instance,
10 where one actuator doesn't want to track the others,
11 you can get into problems. So it took quite a while to
12 actually develop this parallel actuation system.

13 MR. PHILLIPS: Speaking of failure modes,
14 what could you describe as a failure mode which would
15 cause an uncommanded rudder deflection? What
16 conditions would have to be set up to have that?

17 Without a pilot input, what would have to
18 happen to get a rudder deflect to its limit in the 737?

19 THE WITNESS: Well, fundamentally, you'd need
20 a control valve that would be open that could not be

1 closed. I've talked about dual valve jams. There are
2 linkage jams that you could hypothesize if you leave
3 the valve open.

4 MR. PHILLIPS: And linkage jams, would those
5 be external to the unit or internal or --

6 THE WITNESS: In the feedback linkage itself.
7 And that was covered by the CDR team and we've done a
8 -- submitted a very extensive failure analysis looking
9 at all these types of failures and looking at whether
10 or not they're reasonable failures. That's all been
11 submitted to the FAA now.

12 MR. PHILLIPS: Okay. Let's talk a little bit
13 about the CDR. Were you involved in the -- while the
14 CDR was in work, while the group was formed, were you
15 involved in any meetings with that team to educate them
16 or describe the systems to them?

17 THE WITNESS: Right. We went over the
18 descriptions of the systems with them to familiarize
19 them with the systems. We went over the failure
20 analysis with them, provided technical data to them.

1 MR. PHILLIPS: Did the team provide you a
2 list of requirements for data that they wanted to look
3 at or did you just offer up what you thought they
4 needed for the review?

5 THE WITNESS: A little bit of both, but in
6 real life the needs of the CDR team, as you would
7 expect, comes really as a part of the discussion. A
8 subject comes up, triggers something and then they ask
9 for data.

10 MR. PHILLIPS: And in that data, you provided
11 a failure analysis, I would assume, of the rudder
12 system that we discussed this morning.

13 Were you involved in that formulation of that
14 failure analysis back when it was originally done in
15 the '60s?

16 THE WITNESS: No, I wasn't.

17 MR. PHILLIPS: Have you been involved in any
18 failure analysis from the '57 or any of the newer
19 aircraft?

20 THE WITNESS: Yes. I was involved with --

1 quite heavily with the failure analysis of the '57.

2 MR. PHILLIPS: Does the '57 -- is it
3 certified to the newer standard, post-amendment 23 to
4 Part 25 that requires in I believe it's 25 -- well, in
5 the newer certification standard where we consider the
6 probability of failure extremely improbable, is the '57
7 certified for those standards?

8 THE WITNESS: Yes, it is.

9 MR. PHILLIPS: And is that because of the
10 date that it was originally certified?

11 THE WITNESS: Right. That requirement would
12 start as a special condition on the 747 and was
13 formally incorporated into the FAR sometime after that.

14 MR. PHILLIPS: And I would assume the '67 and
15 triple 7 all have met the newer standard?

16 THE WITNESS: That's correct.

17 MR. PHILLIPS: In your -- go ahead.

18 THE WITNESS: I was just going to make a
19 comment that the CDR team, in my opinion, conducted
20 their design review looking at those requirements, the

1 latest requirements.

2 MR. PHILLIPS: Their original charter asked
3 them to look at the airplane independent of the
4 certification basis. Is that correct?

5 THE WITNESS: Right.

6 MR. PHILLIPS: And in doing that, they didn't
7 need to consider whether it was extremely improbable or
8 -- that wasn't a factor in their evaluations?

9 THE WITNESS: No. It was a factor.

10 MR. PHILLIPS: It was a factor?

11 THE WITNESS: Whether or not something is
12 extremely improbable? Yes, that was a factor. And a
13 factor in our submittal to the FAA, the recent
14 submittal that's been mentioned here.

15 MR. PHILLIPS: That submittal that you've
16 mentioned, is that a response to the recommendations
17 from the CDR?

18 THE WITNESS: The CDR recommendations, as far
19 as the design areas, which is the only thing I'm really
20 talking about here, went to the Seattle Certification

1 Office. They then asked us to provide analysis and
2 data to allow them to make a judgment on the systems.

3 MR. PHILLIPS: So the Seattle Certification
4 Office to respond to the recommendations needed an
5 input from you?

6 THE WITNESS: Correct.

7 MR. PHILLIPS: And what form did -- what was
8 done to provide that input to the CDR or to the ACO?

9 THE WITNESS: Well, we basically responded to
10 15 of the recommendations that dealt with design areas.

11 Part of that was we conducted pilot simulations. We
12 did failure analysis work. We constructed fault tree
13 analysis that you heard mentioned, latent failures.
14 The way that we -- in today's certification atmosphere,
15 the way we address those is through fault trees, so we
16 provided fault trees for all the latent failures.

17 The fault trees are designed to show how
18 these latent failures enter into the probability of a
19 critical flight condition or critical failure
20 condition.

1 MR. PHILLIPS: Had you ever done any of this
2 type of analysis prior to your CDR requirements?

3 MR. PHILLIPS: Not for the ~~ls~~ac flight
4 control systems. I think it's been mentioned we did it
5 for the autopilot because we made some autopilot
6 changes. We did it for some of the other systems that
7 were changed but we did not do it for the systems in
8 general.

9 MR. PHILLIPS: The response that you provided
10 to the FAA, is that a discussion item now that's open
11 for the FAA to come back and ask for further
12 clarification or more work to be done?

13 THE WITNESS: That's correct. Yes.

14 MR. PHILLIPS: Have they done that at this
15 point?

16 THE WITNESS: No, they haven't.

17 MR. PHILLIPS: Were you involved in any
18 flight testing to provide this analysis back to the
19 FAA?

20 THE WITNESS: No. We didn't do flight

1 testing. It was -- the testing that we did was
2 simulations, simulators.

3 MR. PHILLIPS: Aircraft simulators? Did you
4 put any components on the test bench and do any systems
5 testing?

6 THE WITNESS: No, we didn't.

7 MR. PHILLIPS: Is part of that response to
8 consider the areas of contamination or silting or
9 jamming of the servo control valve?

10 THE WITNESS: Could you repeat that?

11 MR. PHILLIPS: Was part of the response, did
12 any of the response to the recommendations involve
13 discussions involving jamming or silting of the main
14 rudder control valve?

15 THE WITNESS: Silting, no. Jamming, I guess
16 not directly. The NTSB testing that we were talking
17 about earlier is kind of the -- you might say the
18 definitive thing as far as the effects of -- or what it
19 takes to jam a valve.

20 MR. PHILLIPS: That would be the chip shear

1 testing we talked about earlier?

2 THE WITNESS: Correct.

3 MR. PHILLIPS: And you said silting -- not
4 silting.

5 THE WITNESS: I think silting is something
6 that's been brought up relatively recently. It's
7 gotten a lot of attention recently. The CDR, I think,
8 was really pretty much done by the time silting became
9 an issue.

10 MR. PHILLIPS: Okay. So it wouldn't have
11 been expected that that would have been part of the
12 response for your CDR report?

13 THE WITNESS: Right.

14 MR. PHILLIPS: While we're on the subject of
15 silting, did the definition we heard this morning agree
16 with your definition of what silting is? Do you have a
17 different viewpoint?

18 THE WITNESS: I don't disagree with what was
19 said. I do have a -- I'm prepared to make a little
20 more detailed explanation, if anyone's interested.

1 MR. PHILLIPS: I certainly would like to hear
2 that and spend a little time talking about that.

3 THE WITNESS: It's number 6.

4 MR. PHILLIPS: Were's looking for what? Page
5 6 of 9X-K?

6 THE WITNESS: Right.

7 CHAIRMAN HALL: Can everybody see?

8 Mr. Benson, or somebody that can handle the
9 magic of the lights being dimmed.

10 You can pull that microphone out.

11 THE WITNESS: Okay. This figure is designed
12 to show the relative size of the underlap of the
13 primary control valve on the '37 rudder and give you an
14 idea of what's going on.

15 The particles that are shown are typical of
16 the maximum particle size that would be able to get
17 through the filter. There's a filter, 10 micron
18 nominal filter on the inlet to the PCU. The maximum
19 particle size getting through is on the order of 25
20 microns. So those would be indicative then of

1 particles that would be coming through.

2 This distance here is what we refer to as the
3 underlap in the control valve. It's about a maximum of
4 about 22 thousandths on the '37 rudder. The '37 rudder
5 itself is really not very susceptible to silting. As
6 you can see, the particles are bigger than the opening
7 and would typically just flow through the opening.

8 Some of the other Boeing valves you could
9 take the '57 as an example, are underlapped on that.
10 The actuator is only about 10 percent of what it is on
11 the '37 and the filters themselves on the '57 are about
12 four times more coarse. On the '57, I know the testing
13 I was involved with on the original development of the
14 actuators, we started out with the net lap and you
15 could definitely see the effects of silting on that.

16 And the effect of silting was basically you
17 plug up that opening. If you were to observe the
18 return flow from the actuator, you'd see it slowly dry
19 up. The problem we ran into on the '57 was simply that
20 the positional accuracy was affected slightly by the

1 silting. Never saw anything that would indicate high
2 friction forces.

3 The '57/'67 airplanes are designed such that
4 if you do get a partial valve jam or excessive friction
5 in the valve, you would get some surface motion. The
6 way it's designed, the field systems would eventually
7 stop the surface motion but in my experience I've never
8 heard anything -- of any problems on these airplanes of
9 any surface motion that would be associated with
10 silting.

11 I can finish my explanation on the next
12 slide, Number 7.

13 MR. PHILLIPS: Dick, before you go on to
14 that, could you give us a brief description of the
15 differences between an underlap and an overlap? What
16 is that?

17 THE WITNESS: The next slide actually I think
18 I can illustrate it better.

19 This schematic shows what -- it's an
20 exaggerated amount of underlap but this is underlap

1 there and there. Maybe I should go through the
2 actuator first.

3 The hydraulic flow would come in through this
4 port. It then would with the valve at neutral, the flow
5 would be into the cylinder port, back out through
6 return on one side. The same thing on the other side.

7 If you commanded the actuator, you'd move the
8 valve. You would move the valve this way. You can see
9 that you open up pressure to this side, which then
10 would flow into the cylinder, causing the actuator to
11 extend. The feedback would come along, and it would
12 close the valve again.

13 If you had a net lap, this would be no space
14 there at all. If there were an overlap, it would be --
15 the valve spool would extend past this edge.

16 One thing that's been hypothesized with
17 silting is that you could silt up say this side. If
18 that were to silt up, then the pressure would no longer
19 be able to act on the cylinder. The cylinder would
20 still be open to return, so its pressure would drop.

1 The actuator would then move -- in this case, extend.
2 The feedback would come along and start to close off
3 this. And normally you would expect the silt, as the
4 valve moved the silt, to pass on through it. But if
5 that didn't happen, the valve couldn't move until it's
6 just touched that edge.

7 Once that's happened, then there's no further
8 motion of the actuator. Both pressure ports are cut
9 off. The cylinder pressure bleeds back to return,
10 which is no differential pressure. Then both C-1 and
11 C-2 would be at 50 psi, which is the return pressure
12 nominal.

13 So, I've just kind of concocted the worst
14 case situation where the maximum actuator motion would
15 be such as to just close the valve on this side. That
16 would, on the '37 rudder, it would be the 25
17 thousandths that I mentioned. Excuse me. Twenty-two
18 ten thousandths. And that equates to roughly about .05
19 degrees of surface motion.

20 So you could get -- in theory, you could get

1 some surface motion but it would be extremely small.

2 Other questions, or --

3 MR. PHILLIPS: Well, I want to follow along
4 the line here a little bit.

5 So is silting -- is silting only a problem at
6 near neutral condition or position in the valve?

7 THE WITNESS: If the valve is open, it
8 literally -- the opening is too big to silt. It just
9 rushes right through.

10 MR. PHILLIPS: Okay. So we would only be
11 concerned about silting in periods where the valve
12 stayed fairly near neutral or the underlap condition or
13 the clearance between the two lands would be --

14 THE WITNESS: Right. You'd have to get
15 particles that literally won't fit through the valve
16 orifice.

17 MR. PHILLIPS: As soon as the orifice is made
18 larger, the particles flow through; correct?

19 THE WITNESS: That's correct. After they've
20 built up a bit, you might have to make it -- the

1 orifice might have to open up more than the individual
2 particles, but it doesn't have to open a great deal and
3 it will just go right through.

4 MR. PHILLIPS: So any movement of the valve
5 off of that neutral and null position would tend to
6 clear the valve?

7 THE WITNESS: That's correct. And that's --
8 I believe some of the theories would involve the valve
9 says perfect stationary. In that case, the silt can
10 built up. But once you have block off the ports,
11 there's no longer any flow and the silt stops building
12 up.

13 MR. PHILLIPS: Is this based on your
14 theoretical knowledge or your experience or have you
15 actually seen tests to validate this?

16 THE WITNESS: My experience with the
17 development of the 757, both rudder and elevator PCU's
18 to me validates it. As I said, initially we had more
19 hysteresis than we wanted.

20 You know, you're talking here a tenth of a

1 degree or .05 degrees of surface motion as far as the
2 hysteresis. After a bunch of testing, we determined
3 that it was silting and we opened up the underlap to
4 ensure that we had a positive underlap and problems
5 went away.

6 MR. PHILLIPS: By hysteresis, you mean the
7 ability of the surface to return to the original
8 position?

9 THE WITNESS: Correct.

10 MR. PHILLIPS: Is there a test --
11 specifically now to the 737 PCU, is there a functional
12 test that would indicate the presence of silting in an
13 operational sense? Could a pilot or mechanic tell
14 whether he had an installed PCU that was being affected
15 by silting?

16 THE WITNESS: The pilot would never -- no.
17 Any effects would be much too small to detect.

18 MR. PHILLIPS: Would you have any estimate as
19 to the level of force that we would see increase as a
20 result of silting if it was possible?

1 THE WITNESS: I've never seen an force
2 increase. I really can't comment on that.

3 MR. PHILLIPS: We had some discussion this
4 morning about --

5 THE WITNESS: The vendor --

6 MR. PHILLIPS: Go ahead.

7 THE WITNESS: I was just going to say the
8 vendors, I think Parker is going to be on later. They
9 might have more experience on that.

10 MR. PHILLIPS: Are there any tests that could
11 be done? We talked about that this morning, but
12 testing we could attempt to measure the forces
13 resulting from silting?

14 THE WITNESS: I would think that a test of
15 the type that Werner Koch brought would -- it seems
16 reasonable to me. I'm not -- you know, I can't think of
17 anything beyond that.

18 MR. PHILLIPS: Do you have any plans or do
19 you know of any plans to do a test like that at Boeing?

20 THE WITNESS: No. We don't at Boeing. No.

1 MR. PHILLIPS: Have you ever done a test like
2 that for the '67 or '57?

3 THE WITNESS: No, not specifically to look at
4 silting.

5 MR. PHILLIPS: Have you ever done chip shear
6 tests for your valves?

7 THE WITNESS: Not in the time that I've been
8 at Boeing, other than the NTSB test.

9 MR. PHILLIPS: There's been a recent 747 chip
10 shear test, hasn't there? Are you aware of that?
11 Since the accident investigation activity?

12 THE WITNESS: Not vaguely aware.

13 MR. PHILLIPS: Yes. That's about the limit
14 of my knowledge, too.

15 CHAIRMAN HALL: Just so I understand, that's
16 not on the fault tree, then. Is that correct?

17 THE WITNESS: The --

18 CHAIRMAN HALL: The chip shear test or the
19 silting?

20 THE WITNESS: No.

1 MR. PHILLIPS: Along those lines, in your
2 hazard assessment, are you aware that -- well,
3 certainly jamming was a consideration but have you ever
4 considered the effects of silting in your failure
5 analysis?

6 THE WITNESS: No, we haven't.

7 MR. PHILLIPS: So it's safe to say that
8 silting is a fairly recent thing that's came into
9 discussion in this investigation and also it's fairly
10 recent to your experiences at Boeing?

11 THE WITNESS: That's correct. I mean, we've
12 never seen any problems associated with silting on any
13 of our airplanes, so no, we haven't done anything.

14 MR. PHILLIPS: On the disassembly of a part
15 that's had some silting, would you expect to see any
16 erosion in the lands or marking or anything that would
17 indicate the valve had been operated in silting
18 conditions?

19 THE WITNESS: Not at normal contaminant
20 levels. When we did our Boeing contamination test, in

1 there we had massive amounts of particulates and there
2 we did see a lot of erosion. But again, you might want
3 to ask that question of Parker or someone that
4 regularly would inspect valves.

5 MR. PHILLIPS: Right. Along the lines of
6 that contamination test, would you expect that a test
7 like that with a very high level of contaminants, would
8 that represent silting condition or much worse than
9 silting?

10 THE WITNESS: Well, as far as the effects on
11 valve friction, I'd say it's much worse than silting.
12 I'm sure it's much worse than silting.

13 MR. PHILLIPS: So you believe the larger
14 particulates would increase the forces faster than the
15 small particles -- than a bunch of small particles?

16 THE WITNESS: Only on the basis that in my
17 experience we haven't yet.

18 CHAIRMAN HALL: What is worse than silting?
19 I'm sorry.

20 MR. PHILLIPS: The original question was

1 about contamination tests that Boeing ran at the end of
2 the year last year where they took a PCU and ran high
3 levels of contaminants through. The question was would
4 big particles, a bunch of big particles be worse than a
5 bunch of little particles.

6 CHAIRMAN HALL: And that's worse than
7 silting? I apologize, again. When this fan's going,
8 it's very difficult to hear up here.

9 THE WITNESS: As I was about to say, I would
10 say the answer is yes, only because in my experience I
11 haven't seen any high friction forces or anything due
12 to silting other than just the direct effect that I was
13 referring to on hysteresis.

14 MR. PHILLIPS: Were you involved in that
15 contamination test last year in setting up the test or
16 witnessing it?

17 THE WITNESS: Yes. I was involved in setting
18 up the requirements for the test.

19 MR. PHILLIPS: Did you believe that was a
20 representative test to provide valid data for

1 understanding the effects of contaminants in the PCU?

2 THE WITNESS: Well, it was purposely made
3 much, much worse than anything in service, so in the
4 sense that it was an absolute worst case, yes.

5 MR. PHILLIPS: And you took the filters out
6 of the PCU so you could purposely get more large
7 particles in than you normally would expect?

8 THE WITNESS: Right. I think it was on the
9 order of about 50 times what we would expect to be
10 worst case.

11 MR. PHILLIPS: Would you have expected the
12 results to have been any different if you used a
13 smaller particulate over a longer period of time? I
14 guess I'm asking you to extrapolate data here, but --

15 THE WITNESS: Well, what we used was a wide
16 variety of sizes. I mean, we purposely selected the
17 sizes to be the full range of what's possible.

18 MR. PHILLIPS: And when you cycled the spools
19 in the servo valve, did you have a program or a method
20 of how those spools were cycled; rate or distance?

1 THE WITNESS: Say that again?

2 MR. PHILLIPS: During the testing when you
3 moved the servo valve spools, did you have a purpose or
4 a plan that set a rate or a positional travel
5 requirement on moving the spools during the test? Did
6 you hold them fixed at near null for a period of time,
7 then opened them a little bit and hold them, to
8 duplicate a flight profile or a nominal surface
9 profile?

10 THE WITNESS: Well, no. They were pretty
11 much cycled continuously. At the time we set up the
12 test, it was before this latest theory, so we were
13 really trying to duplicate the yaw damper motion.

14 MR. PHILLIPS: Do we understand the yaw
15 damper moves these valves frequently?

16 THE WITNESS: Almost continuously in flight.
17 On the ground there is no yaw damper input, so no
18 input of any kind. So that when an airplane is sitting
19 on the ground, the valve would be sitting at null for a
20 long period. Well, as long as the hydraulic systems

1 are pressurized, which would vary quite a bit. It
2 might be a few minutes. It might be an extended period
3 of time. And then the pilot would do his controls
4 check.

5 So for that situation, we do have a case of
6 the valve sitting basically still and then the pilot
7 given an opportunity to see if anything is abnormal at
8 that point. That's just -- every flight has this
9 situation to some extent.

10 MR. PHILLIPS: Have you looked at the data
11 that indicates the health of the 737 fleet flight
12 control system recently? Are you familiar with yaw
13 damper events and roll events we've talked about
14 previously today?

15 THE WITNESS: Not intimately familiar. The
16 yaw damper and autopilot are not part of the area that
17 I cover. I am ware of the events but only from a
18 somewhat peripheral standpoint.

19 MR. PHILLIPS: Well, my next question is that
20 in this list of events that -- you've had several

1 different numbers subject to interpretation, but do you
2 believe we could be seeing the effects of silting or
3 contaminants in any of these events? Have we
4 researched them far enough to even make a statement
5 along those lines?

6 THE WITNESS: I don't think that we are, but
7 I don't know of any conditions where that would be the
8 most logical explanation.

9 MR. PHILLIPS: Could we have characterized
10 the failure as a yaw damper coupler failure when in
11 effect it could have been something else? If we don't
12 find a fault with the cutout we removed, does that
13 indicate it could be something else?

14 THE WITNESS: If we get FDR data and it
15 indicates that the upset corresponds to a three degree
16 rudder input, then to me it's the yaw damper problem.
17 It's not a silting problem.

18 I don't know of any cases -- again, I haven't
19 studied each one, but I don't know of any cases where
20 silting would make sense.

1 MR. PHILLIPS: I'd like to change directions
2 here a little bit and to go the standby rudder
3 actuator.

4 Are you familiar with that component in the
5 system?

6 THE WITNESS: Yes.

7 MR. PHILLIPS: And one of the things we've
8 discussed today and at the last hearing also was
9 galling, which is the transfer of material between the
10 input bearing and the shaft.

11 Have you seen this galling condition? Have
12 you seen the parts?

13 THE WITNESS: No. I've seen a lot of
14 photographs.

15 MR. PHILLIPS: And you're aware that both the
16 Colorado Springs and Pittsburgh aircraft had what we
17 considered galling on those shafts?

18 THE WITNESS: Right.

19 MR. PHILLIPS: Have we had any other
20 occurrences in service airplanes of galling that you're

1 aware of?

2 THE WITNESS: I know we've had on the order
3 of four or five specific occurrences of galling. Yes.
4 And if you were to include very, very minor galling,
5 then we've probably had lots of cases of very, very
6 minor galling.

7 MR. PHILLIPS: What generally is the effect
8 of this galling to the airplane?

9 THE WITNESS: If it becomes severe enough,
10 generally it's picked up as a yaw damper problem. I
11 think we've had cases where it was enough for the pilot
12 to feel. But these four or five worst case problems
13 I'm talking about, they've all been picked up before
14 they've caused any upset or anything like that.

15 MR. PHILLIPS: Were they found on the ground
16 then or during testing?

17 THE WITNESS: Well, if it affects yaw damper
18 performance, that would be in the air. The pilot could
19 pick it up during a controls check, also.

20 MR. PHILLIPS: Is there any other way to

1 detect galling in the standby actuator other than the
2 control check? Is there any maintenance action that
3 would indicate that galling may be present?

4 THE WITNESS: Yes. And I'm not sure what the
5 time frame was when we did it, exactly, but right now
6 in our maintenance manuals, if we have a yaw damper
7 problem, that's one of the things that the airlines
8 would be asked to check if they were following
9 maintenance manual procedures. That wasn't always in
10 the maintenance manuals. It's been the last couple of
11 years that we've had that coverage.

12 MR. PHILLIPS: Have you considered the case
13 of a standby rudder actuator, galled in the worst
14 possible condition in either direction, what the result
15 to the airplane would be as far as rudder deflection
16 and controllability?

17 THE WITNESS: Well, if you were to have a
18 complete seizure of the linkage and it occurred right
19 when the autopilot -- or excuse me -- when the yaw
20 damper was putting in a full three degree command, it

1 could get about 7-1/2 degrees of rudder.

2 MR. PHILLIPS: Have there been any tests to
3 validate that or is that based on analysis?

4 THE WITNESS: The testing that was done was
5 done during the original certification. It's what we
6 call iron bird testing. It's a ground type -- on
7 ground working mock-up of the flight controls. And
8 from that we've gotten enough data to make calculations
9 where -- but the actual numbers, the number that I
10 quoted, for example, is a calculated number.

11 MR. PHILLIPS: Have there been any iron bird
12 tests done in recent history or does it go back to the
13 original certification of the airplane?

14 THE WITNESS: It goes back to the original
15 certification.

16 MR. PHILLIPS: Has there been any discussion
17 as to the potential requirement for doing additional
18 testing in light of the concern in this area?

19 THE WITNESS: Yes. We are considering doing
20 a test of the standby actuator where we'd basically

1 install it to where it would freeze the input lever.

2 MR. PHILLIPS: Is this a Boeing test?

3 THE WITNESS: Excuse me. That would be
4 mainly just to validate our analysis.

5 MR. PHILLIPS: Is this test planned by Boeing
6 or is it in response to investigation activities?

7 THE WITNESS: It's at least partly in
8 response to the NTSB concerns.

9 MR. PHILLIPS: Along those lines, there was -
10 - in the last hearing, we heard some testimony about
11 design changes to the input bearing and opening
12 clearances to reduce galling. Are there any new
13 changes planned for the standby PCU in light of the
14 fact that galling is still a concern?

15 THE WITNESS: Yes. We are planning on
16 putting in a design change that would put roller
17 bearing on the input shaft. That's what I believe was
18 mentioned at the last hearing that we were considering
19 that.

20 MR. PHILLIPS: Did this result from the CDR

1 recommendation or was it more prior to the CDR findings
2 or --

3 THE WITNESS: Well, we've been looking at it
4 for some time. It's kind of a combination of events, I
5 think.

6 MR. PHILLIPS: Do you have anything to help
7 describe that? Do you have a chart on that, the design
8 change?

9 THE WITNESS: Yes. Number 4.

10 CHAIRMAN HALL: Am I correct, this is in
11 response to a CDR recommendation or not?

12 MR. PHILLIPS: Say again, please?

13 CHAIRMAN HALL: Is this change in response to
14 the CDR team's recommendation or something Boeing --

15 MR. PHILLIPS: We could ask Mr. Kullberg. I
16 think his answer was that it was in work or in
17 discussion and it just fell in line, I guess.

18 THE WITNESS: It's been a concern on the part
19 of the NTSB. It was a concern on the part of the CDR
20 team. So all those go into making a judgment as to

1 whether or not to make a design change.

2 Okay. This shows the -- this is the input
3 shaft. This is the housing manifold of the actuator.
4 The current configuration, this bearing and this
5 bearing, are not there. It's basically just a bushing.

6 And the galling that we're talking about occurs
7 between the shaft and the bushing right here.

8 So all that we're doing then is to redo this
9 piece to accommodate these bearings. This design would
10 make it similar to what we would do on most other
11 control surface actuators.

12 MR. PHILLIPS: Does the galling result from
13 side loads on this shaft? How do we get the loads into
14 this to create the galling?

15 THE WITNESS: It's mainly a lack of clearance
16 between the shaft and the bushing. I don't know that
17 it's necessarily a direct function of load. The
18 problems that we've had in the past have been -- I know
19 at least most of them have been due to very tight
20 clearances. In some cases we found them slightly out

1 of drawing tolerance. They were a little tighter than
2 drawing tolerances would normally allow.

3 We've also -- we've made design changes in
4 the past to open up the clearance in what we call the
5 drive part so that the actual wear surfaces are
6 lubricated by the fluid inside the actuator. The
7 actuators that we have with this modification, the
8 galling has been very, very limited but it still is
9 there. You can still see some galling. So we're taking
10 a final step, basically.

11 MR. PHILLIPS: You mentioned that you use a
12 design similar to this in other applications. Could
13 you tell us what those are? Other standby actuators or
14 other --

15 THE WITNESS: No. I mean the use of these
16 types of bearings to support the shaft.

17 MR. PHILLIPS: Okay. How do you plan to
18 implement this change or what's the plan for
19 implementation on the 737 fleet?

20 THE WITNESS: I'm not sure if that's been

1 decided but I assume that we will -- the vendor will
2 put out a service bulletin that would give rework
3 instructions to make the modification.

4 MR. PHILLIPS: So at this stage, this is an
5 engineering proposal that hasn't been approved?

6 THE WITNESS: It's been approved but the
7 scheduling hasn't been done.

8 MR. PHILLIPS: Has there been any discussion
9 at Boeing about the criticality of this change? What
10 level of service bulletin you would recommend that it
11 be?

12 THE WITNESS: It hasn't gotten that far yet.

13 MR. PHILLIPS: Just on the spot assessment,
14 it would just be a mandatory or --

15 THE WITNESS: Well, my guess at this time, it
16 would be a normal service bulletin.

17 MR. PHILLIPS: So by that, the operator would
18 have the option of either doing it or not as he
19 desired?

20 THE WITNESS: Right. We would recommend it

1 but we don't consider it a safety of flight item.

2 MR. PHILLIPS: Have you had any discussions
3 with the FAA that would indicate that they may consider
4 this to be an airworthiness directive service bulletin?

5 THE WITNESS: No. I think that the FAA has
6 indicated that they're going to consider making it
7 mandatory but we haven't had detailed discussions with
8 them at this point.

9 MR. PHILLIPS: How would you have discussions
10 with them once the decision was made to make an AD?
11 Would you get involved in the process of negotiating
12 compliance dates or schedules or anything like that?

13 THE WITNESS: Yes.

14 MR. PHILLIPS: Your slide says the 300, 400,
15 500 airplanes. Could this also be used on the 100, 200
16 airplanes?

17 THE WITNESS: Yes.

18 MR. PHILLIPS: Would you expect that it would
19 also apply to them, too?

20 THE WITNESS: Yes.

1 MR. PHILLIPS: One other question in the area
2 of the standby, more on the function than on galling on
3 this design change. How would the standby function if
4 -- could the standby actuator function if both A and B
5 systems were pressurized? Is there a failure mechanism
6 that would allow the standby actuator to be energized?

7 THE WITNESS: You could have failures that
8 would cause it to be energized. In fact, that was a
9 failure mode that was brought up by the CDR team and we
10 did do analysis to look at that. This is not -- if it
11 were to pressurize with the other two, you would have a
12 potential or you could exceed limit load, but you would
13 exceed it only by a small margin. You still would
14 maintain an adequate margin to ultimate load, the
15 margin that's required for a failure.

16 It's been looked at fairly thoroughly.

17 MR. PHILLIPS: Okay. Could you describe
18 limit load versus ultimate load? How does that apply?

19 THE WITNESS: I'm not a structural engineer,
20 but fundamentally the limit load tends to be the

1 maximum operating load and the ultimate load is usually
2 50 percent higher.

3 MR. PHILLIPS: So the effect of ~~the~~ standby
4 being pressurized with both systems pressurized would
5 cause a structural load to be imposed on the airplane?

6 THE WITNESS: If the pilot were to put in
7 maximum rudder input all the way to the blow down
8 limit, then he would not maintain the margins that you
9 would normally have, the structural margins that you
10 would normally have.

11 MR. PHILLIPS: And those margins are in the
12 rudder structure itself or the system attachment
13 structure?

14 THE WITNESS: That's out of my area.

15 MR. PHILLIPS: Okay. ~~No~~ problem.

16 In this failure assessment or analysis that
17 you've done for the FAA for the CDR response, can you
18 characterize any changes that you foresee in the
19 airplane? Was there any significant findings that you
20 presented to them that you can tell us about here today

1 that lead you to believe that changes need to be made
2 to the airplane?

3 THE WITNESS: We've already discussed the
4 standby PCU. In addition to that, we are planning on
5 looking at what can be done to improve the reliability
6 of the yaw damper and we haven't gotten to the point
7 yet of saying what would be redesigned, but we will do
8 something to improve its reliability.

9 MR. PHILLIPS: Do you see that reliability
10 issue as a safety of flight issue?

11 THE WITNESS: For the yaw damper? No. It's
12 I think discussed that the yaw damper is limited to
13 three degrees and we talked earlier about this program
14 to look for something that's more than three degrees.
15 But where we have had incidents and we have been able
16 to get flight data recorders, I don't think there's any
17 case where it would look like a yaw damper has gone
18 beyond three degrees.

19 MR. PHILLIPS: Are you aware of any plans by
20 Boeing to significantly redesign the rudder system main

1 power control unit or standby unit, other than what
2 you've described?

3 THE WITNESS: No.

4 MR. PHILLIPS: Is there any activity at
5 Boeing to do any additional failure analysis or hazard
6 assessment work as follow-up to the things you've
7 already provided? Any new areas of exploration or
8 concern?

9 THE WITNESS: None that I -- no. There may
10 be things that come up as we have our discussions with
11 the FAA. They may want more data or testing.

12 MR. PHILLIPS: I think that's all I have for
13 now. If you have any comments you'd like to add, I'd
14 certainly give you the opportunity.

15 THE WITNESS: No.

16 MR. PHILLIPS: Okay. Thank you.

17 CHAIRMAN HALL: Other questions from the
18 Technical Panel?

19 (No response.)

20 If not, we'll move to the parties. Would any

1 of the parties have questions for this witness?

2 I see the hands of the Boeing Airline Group,
3 the Air Line Pilots Association, USAir, the FAA.

4 Mr. Donner?

5 MR. DONNER: I haven't even read the
6 questions.

7 Mr. Kullberg, do you agree with Mr. Koch that
8 an active yaw damper would reduce the probability for
9 silting?

10 THE WITNESS: Yes. The valve as it moves is
11 self-cleansing.

12 MR. DONNER: Did you hear Ms. Evans'
13 testimony this morning?

14 THE WITNESS: Yes.

15 MR. DONNER: Based upon the yaw damper
16 activity shown by Ms. Evans, would you care to comment
17 on the effect of this activity on silting?

18 THE WITNESS: On silting?

19 MR. DONNER: Yes. On the activity that she
20 showed for the yaw damper?

1 THE WITNESS: I wouldn't expect to have
2 silting. But then, again, like I mentioned with the
3 amount of underlap and the filters that we have on the
4 actuator, I really wouldn't expect much of an effect on
5 silting under any circumstances.

6 MR. DONNER: Thank you very much.

7 CHAIRMAN HALL: USAir? General?

8 GENERAL ARMSTRONG: Thank you, sir.

9 If you would, please refer to Exhibit 9X-A,
10 page 21 in the references, the top of the page, "Single
11 Failures - Rudder." The second sentence says: Failures
12 suggest there are a number of ways where loss of rudder
13 control and potential for a sustained rudder hardover
14 may occur.

15 Do you concur with that?

16 THE WITNESS: Yes.

17 GENERAL ARMSTRONG: And this is in the
18 Critical Design Review report?

19 THE WITNESS: Yes. By a number of ways it
20 certain is. It's a very limited number of ways but a

1 number.

2 GENERAL ARMSTRONG: But it is possible.

3 Okay. Thank you.

4 CHAIRMAN HALL: The Air Line Pilots
5 Association. Captain?

6 MR. LeGROW: Thank you, Mr. Chairman.

7 Good afternoon, Mr. Kullberg. I just have
8 one question.

9 In Mr. Phillips' questioning he talked about
10 a severely galled standby actuator. And it's my
11 understanding that your answer or your statement was
12 that the yaw damper would then give you seven or 7-1/2
13 degrees authority?

14 THE WITNESS: That's correct. The scenario
15 would be basically that the yaw damper has gone full
16 over all the way to the full three degrees. It then
17 jams the yaw damper then comes back to zero. For that
18 situation with an absolutely hard jam, that you would
19 get about 7-1/2 degrees of rudder offset. So that's a
20 very severe situation.

1 MR. LeGROW: So the yaw damper would have to
2 be jammed also?

3 THE WITNESS: No, no. The situation is that
4 the yaw damper, for whatever reason, has but in a full
5 command. So there's extreme turbulence. It's gone all
6 the way to it's limit. That particular moment in time
7 you were to then suddenly lock up the standby actuator,
8 so it's rigidly attached at that point to the manifold,
9 a hard jam. At that point, nothing has happened except
10 the three degree of yaw damper.

11 Now if you were then to take the yaw damper
12 command, bring it back to zero, that would result in
13 about a 7-1/2 offset.

14 MR. LeGROW: Okay. I understand now. Thank
15 you.

16 Thank you, Mr. Chairman.

17 CHAIRMAN HALL: Mr. Purvis, Boeing Commercial
18 Airplane Group.

19 MR. PURVIS: Thank you.

20 First, I want to go back to his -- without

1 using the viewfoils. He was turned this way while he
2 was describing certain things and I'm not sure it got
3 through to this direction to the audience.

4 First of all, talking about underlap and
5 overlap, in particular, the underlap condition, can you
6 equate that to a gap or something simple like that in
7 the opening on the sides?

8 Let's say an underlap. Can that be equated
9 to a gap?

10 THE WITNESS: If you have underlap, then the
11 primary spool land is narrower than the orifice that
12 it's covering up so that there's a gap on either side
13 of the land.

14 MR. PURVIS: With the valve in neutral?

15 THE WITNESS: With the valve in neutral.
16 Correct. Yes.

17 MR. PURVIS: In your opinion, is silting like
18 to occur on a 737? And if not, can you explain what
19 would keep it from happening? I think you've done a
20 little bit of that previously.

1 THE WITNESS: Yes. The fluid coming into the
2 PCU is filtered. It's filtered down to say 25 micron
3 type of particle. The gap in the valve is several
4 times bigger than that, so it would be very difficult
5 for it to silt.

6 MR. PURVIS: And can you explain again the
7 effect of the yaw damper action on that, on silting?

8 THE WITNESS: Well, the motion of the control
9 valve from the pilot or the yaw damper tends to clear
10 any silt that would accumulate momentarily. So that
11 that's why Werner Koch, for instance said, well, let's
12 run a test with no input to the valve.

13 I agree with him. That would be more severe
14 for silting. But as long as the airplane is flying,
15 the yaw damper, unless it were switched off, would be
16 putting an input into the valve.

17 MR. PURVIS: Once again, you were facing the
18 screen when you were describing that. If in some
19 hypothetical case silting did occur, how much -- in the
20 worst case scenario, how much surface rudder motion

1 would you actually get until it flushed or it cleared?

2 THE WITNESS: It would be on the order of .05
3 degrees. Basically, it should be minuscule.

4 MR. PURVIS: .05?

5 THE WITNESS: A tiny, tiny amount. Yes.

6 MR. PURVIS: So that's what? A tenth of a
7 half a degree; right?

8 Going back to the exhibit that -- I think
9 it's 9X-A, 21. Is that the pages that was referred to
10 just previously? Do you have that open again?

11 THE WITNESS: Yes.

12 MR. PURVIS: And the failures, the sentence
13 that was quoted, the failures suggest there are a
14 number of ways where loss of rudder control and
15 potential for sustained --

16 THE WITNESS: Yes. Can I make a comment?

17 MR. PURVIS: Yes.

18 THE WITNESS: Because in re-reading this, the
19 term failures, I think the CDR team here was referring
20 to jams. Sometimes you think of failures as only being

1 disconnects. An example of what they were talking
2 about, if you were to look into the report, is say you
3 were to get a cable jam and a cable jam were to occur
4 at a full pilot input. That would result in a
5 sustained rudder hardover and that's where we really
6 don't think it's reasonable to have a jam, combined
7 with a rudder deflection that really would only occur
8 if you had some type of emergency situation.

9 We saw in the -- read at the very beginning
10 the histograms of rudder deflection and my recollection
11 is that rudder deflections were less than five degrees
12 out of 134 flights.

13 MR. PURVIS: Are these -- in doing a FMEA or
14 something, would these be considered highly improbable
15 events?

16 THE WITNESS: A jam combined with a large
17 rudder input would definitely be considered extremely
18 improbable.

19 MR. PURVIS: On galling, did you say you had
20 seen photographs from the USAir 427 event on the

1 galling from the standby unit?

2 THE WITNESS: Yes, I have.

3 MR. PURVIS: Would you characterize the
4 amount of galling as -- I'll let you say.

5 THE WITNESS: It was quite severe. Excuse
6 me. You said the United Airlines?

7 MR. PURVIS: No. USAir 427.

8 THE WITNESS: Oh, excuse me. I was -- excuse
9 me. I was talking about the United Airlines case. The
10 USAir one, the ones I've seen, galling was quite minor.

11 MR. PURVIS: And on the United one, do you
12 want to talk about that one, too?

13 THE WITNESS: Well, I wasn't working in this
14 area at the time but the reports I've read is that the
15 galling was relatively severe on that airplane.

16 I think -- well, quite a bit of testing was
17 done to determine what the effect of galling was for
18 that situation. The NTSB test report which is
19 basically where I'm coming from on that is that the
20 galling wouldn't have really been applicable, in that

1 the retainer for the shaft was loosened. So at the
2 time of the crash, the input linkage would have been
3 free.

4 MR. PURVIS: So the effect of the galling was
5 what?

6 THE WITNESS: That it loosened the retainer.

7 MR. PURVIS: And then it was free to move?
8 Is that what you're saying?

9 THE WITNESS: That's correct. But again, my
10 input is basically what I read in the NTSB report.

11 MR. PURVIS: And the last question. If in
12 fact you had a hardover, if you want to call it that,
13 from a galled standby, would the pilot lose control?

14 THE WITNESS: No. The situation would always
15 be controllable. For the relatively severe case that I
16 mentioned, if you did get the 7-1/2 degrees, the pilot
17 could easily get the rudder back to neutral.

18 MR. PURVIS: Thank you, Mr. Chairman. I have
19 no further questions.

20 CHAIRMAN HALL: Thank you.

1 Mr. Clark?

2 MR. CLARK: We've been talking about the
3 galling and the three degree yaw damper input and a
4 seven degree effect from a fully galled or a fully
5 bound up input lever to the standby. You mentioned
6 earlier that part of that number or that seven degree
7 calculation or whatever, came from the iron bird test
8 during the original certification.

9 Was that particular problem specifically
10 addressed in the iron bird test?

11 THE WITNESS: No. The iron bird test I'm
12 referring to was -- I need to give a little background.

13 Initially there was a shear out that was intended to
14 protect against those jams. When they ran the iron
15 bird test, they found that they could get the rudder
16 back to zero with a pedal force that was less than the
17 shear-out force, so that as a result of that, they
18 removed the shear-outs. In other words, the shear-out
19 wasn't needed because it took less force to get the
20 rudder back to neutral than it would have taken to

1 shear it out.

2 And that testing was done before my time,
3 obviously, during the original certification. But the
4 test itself has allowed us to do some calculations of
5 other scenarios that people can hypothesize.

6 MR. CLARK: The data from that you can
7 extrapolate to other scenarios?

8 THE WITNESS: Right.

9 MR. CLARK: Where was the shear-out going to
10 be placed in the system? Where was it placed?

11 THE WITNESS: I'm not sure exactly. It was
12 basically in the input linkage.

13 MR. CLARK: To the main PCU or to the
14 standby?

15 THE WITNESS: To the standby.

16 MR. CLARK: To the standby.

17 You mentioned that you're planning some
18 changes -- well, let me back it up. I'll come to this
19 in a minute.

20 We earlier talked about the chip shear

1 requirements in this unit. That basically we can get a
2 maximum of somewhere around 40 pounds into the servo
3 valve and some units carry 100 pounds. What's the
4 limiting factor in this unit that holds us at 40
5 pounds?

6 THE WITNESS: That's what we call the walking
7 beam linkage, which is a link that allows the yaw
8 damper to make an input to the linkage. It provides a
9 centering function and it's kind of a remnant of when
10 we had two yaw dampers. If you have two yaw dampers,
11 in order for them to operate one at a time, you have to
12 have what amounts to a spring loaded link. And that's
13 -- the force that spring loaded link puts in is what
14 limits the chip shear to the valve.

15 MR. CLARK: So if I were to somehow try to
16 load 40 pounds into the valve, at that point the
17 breakout starts moving?

18 THE WITNESS: Correct.

19 MR. CLARK: Is there any reason to have that
20 in there now?

1 THE WITNESS: Only that it would take a
2 pretty complete redesign of the actuator to eliminate
3 it.

4 MR. CLARK: Could you stiffen the spring to
5 drive that force up?

6 THE WITNESS: Something like that.

7 MR. CLARK: Functionally, other than an effort to
8 go through the redesign, there's no reason to have the
9 breakout in there, or the breakout portion of the
10 walking beam?

11 THE WITNESS: I believe that's correct.

12 Now, one other comment on the chip shear
13 force. We have been looking at the chip shear
14 capability of the valve, and 40 pounds or 42 pounds is
15 really kind of a minimum capability that if you were to
16 get two valve jams, for example, both the primary and
17 secondary were to jam, which is the situation that we'd
18 be concerned about, it's probable that you could get
19 significantly more than 42 pounds. But we -- at this
20 time, we don't have test data to validate that.

1 So the 42 pounds that's been mentioned is
2 kind of a minimum chip shear capability.

3 MR. CLARK: You're saying that if you had the
4 inner valve jammed to the outer valve and the outer
5 valve jammed to the body, you could end up requiring
6 much more than the 42 pounds to break that out?

7 THE WITNESS: Not requiring, but you
8 potentially could get in a greater chip shear force
9 than the 42 pounds. We were just talking about the
10 walking beam limiting the chip shear force. Part of
11 the reason it's limiting it is because of compliance in
12 the linkage. The primary linkage has more compliance.

13 In other words, it's less stiff than the secondary, so
14 that it appears that if you were to jam the secondary,
15 that you could get more than the 42 pounds.

16 That's a little bit of an aside, but the 42
17 pounds that we mentioned is basically a minimum level.

18 MR. CLARK: That would still come down to a -
19 - well, let me ask it this way then. If we were
20 dealing with that combination that gave us greater than

1 42 pounds, each jam could be contributing less than --

2 THE WITNESS: Oh, no, no. Each jam would get
3 that full 42 pounds. It's just that it may be possible
4 to get even more than 42 pounds. But you'd have the
5 same force being applied to each valve slide, so in
6 order to jam both of them you would somehow have to get
7 -- let's say a chip into each valve, neither one of
8 which could be sheared out with 42 pounds.

9 So when you start looking at the likelihood
10 of being able to get a chip in there based upon the
11 test data, a chip into each valve slide that is
12 stronger than that 42 pounds, it's really, really
13 remote.

14 MR. CLARK: But even at that, if a
15 contaminate that caused that, at least for the testing
16 today, would that leave a witness mark on the edge of
17 the opening?

18 THE WITNESS: Yes. And the test that was
19 referred to earlier, the one case that it shifted and
20 not sheared, it did leave a witness mark. And I think

1 that the witness marks were left for the majority of
2 chips that were sheared.

3 MR. CLARK: I'm still not clear. We talked
4 to Mr. Zielinski earlier and asked him about the
5 certification basis of this rudder unit, this PCU, in
6 the context of assuming that there could be a rudder
7 hardover.

8 How did Boeing determine that that's a safe
9 situation? Either that scenario could not happen or
10 could be controlled or whatever. What's the
11 certification basis in that regard or the determination
12 that a rudder hardover is not a problem?

13 THE WITNESS: I don't know exactly what went
14 on in the original certification but in our analysis
15 that we've done as a result of the CDR, we've concluded
16 that the hardover is extremely improbable.

17 MR. CLARK: Okay. That's the way it is now?

18 THE WITNESS: That's correct.

19 MR. CLARK: And was that based on the CDR or
20 the flight test or both that brought into question the

1 controllability issue?

2 THE WITNESS: It's based upon our analysis
3 that was done as a result of the CDR but subsequent to
4 it. This is part of the submittal that we made to the
5 FAA on October 2nd.

6 MR. CLARK: Back at the original
7 certification -- let me ask it this way. The original
8 basis was that the lateral authority was greater than
9 the directional authority in the event of a rudder
10 hardover?

11 THE WITNESS: No. If you read the failure
12 analysis, it kind of mentions both. The writing of the
13 original failure analysis it's simply not clear enough
14 to be able to determine exactly how it was certified.
15 Normally you write the failure analysis and submit it
16 to the FAA. There's discussion that goes on with the
17 FAA. And I don't know how the final determination was
18 based or what it was based on.

19 MR. CLARK: I guess the thing that throws me
20 is that Mr. Zielinski said earlier that he felt that it

1 was both. Both within that original certification the
2 issue of the airplane could be controlled if this event
3 happened, and also that the probability was very low.

4 THE WITNESS: It could well be both. My
5 understanding is the airplane is controllable for most
6 of the flight envelope and not every corner of the
7 envelope, though. So it does -- if you start doing a
8 qualitative judgment, you do take both factors into
9 account.

10 MR. CLARK: Okay. Are there any changes --
11 well, you've talked about changes that have been
12 planned for the standby unit and the yaw dampers
13 itself. Are there any changes being planned for the
14 PCU itself?

15 THE WITNESS: No.

16 MR. CLARK: So based on the design as is,
17 Boeing's comfortable with that design?

18 THE WITNESS: That's correct.

19 MR. CLARK: Okay. Thank you.

20 CHAIRMAN HALL: Mr. Marx?

1 MR. MARX: I just have a few questions here.

2 I want to follow up on this walking beam. Is
3 there any way to keep the walking beam from walking?
4 Like freeze it, weld it to keep it --

5 THE WITNESS: No. In order for the yaw
6 damper to function as it is now, you have to be able to
7 move the walking beam. Whenever the yaw damper ma-
8 piston, the little yaw damper piston, whenever that
9 moves to make an input it has to be able to move the
10 walking beam. If it didn't, it would be locked in
11 place.

12 MR. MARX: But I mean the so-called
13 breakaway. My understanding of the walking beam is
14 that it folds or causes --

15 THE WITNESS: One end of the linkage is
16 grounded. The middle of it is attached to the walking
17 beam. The other end is attached to the piston so that
18 this walking beam gets upset as the piston moves.

19 MR. MARX: So there isn't any --

20 THE WITNESS: You couldn't do it like that.

1 No. You'd have to relocate the ma-piston so it's
2 directly in line with the summing lever.

3 MR. MARX: Without the walking beam there,
4 what would be the force be? We're talking about 42 as
5 a minimum with the walking beam. If you didn't have
6 that --

7 THE WITNESS: I'm not exadty sure if the --
8 it would be substantially higher, though.

9 MR. MARX: And you also --

10 MR. CLARK: Let me clarify. The walking beam
11 has to be there. We're talking about the breakout
12 portion, the bending of the walking beam. The walking
13 beam always has to be there and move by the current
14 design.

15 THE WITNESS: You mean stiffen it? Then you
16 get into structural problems with the linkage itself.
17 So I'm not an expert on that but you would get into
18 strength problems.

19 MR. CLARK: Okay. Thank you.

20 MR. MARX: You also were talking about the

1 case where we would somehow freeze the standby shaft
2 and the bearing from galling or some other -- mainly
3 galling mechanism. You talked about a 7-1/2 degree
4 rudder deflection. Does that take into account
5 blowdown? I mean, is that 7-1/2 degrees at say 190
6 knots, would that still be able to move the rudder 7-
7 1/2 degrees?

8 THE WITNESS: Yes. At 190 knots you're on
9 the order of about 20 degrees from blowdown, so that's
10 less than halfway to blowdown.

11 CHAIRMAN HALL: Mr. Marx, you might tell us
12 what blowdown is, or one of you.

13 MR. MARX: Well, I think the witness would be
14 much better to explain blowdown.

15 THE WITNESS: Okay. The actuator has
16 obviously a finite force capability. If you put in a
17 maximum command to the actuator, it generates a full
18 3,000 psi. The inner load is going to stop the rudder
19 when you hit a force balance, and that we commonly call
20 blowdown.

1 MR. MARX: In other events that would be
2 suspected of some kind of uncommanded yaw or yaw damper
3 anomalies, have they checked the standby shaft bearing
4 -- so-called bearing? It's actually called a bearing -
5 - for galling in these instances?

6 THE WITNESS: Yes. That's part of the
7 troubleshooting procedure for yaw damper problems.

8 MR. MARX: How do they do that?

9 THE WITNESS: They disconnect the input
10 linkage and measure the force required to move the
11 input linkage.

12 MR. MARX: No. Have they ever disassembled
13 it to find out if there's galling, if it's still there?

14 THE WITNESS: I'm sure they haven't had different
15 occasions. I can't say specifically though.

16 MR. MARX: So mainly they're just measuring
17 the force on the lever arm to see if there is a frozen
18 condition?

19 THE WITNESS: Well, there's a requirement
20 that it be less than one pound. So if it's within the

1 one pound operating limit, they typically would not
2 remove the actuator. No.

3 MR. MARX: That brings me to the question of
4 what is normal wear and tear on these standby bearings?
5 For instance, do we know what type of galling we would
6 expect to have on a bearing that's been in service for
7 so many years? Has there been any tests or
8 examinations that are done on these particular
9 components to get the norm as to what type of wear and
10 tear is actually occurring?

11 THE WITNESS: I don't know of any specific
12 studies on that. I think as part of the United
13 Airlines Colorado Springs that they did some testing
14 but I wasn't a party to that.

15 MR. MARX: You were talking about silting
16 between the primary and the secondary and that the
17 underlap in this case would be less probable of having
18 siltting. Between the secondary and the housing, isn't
19 there an overlap?

20 THE WITNESS: That's correct.

1 MR. MARX: And would that be more prone then
2 to silting?

3 THE WITNESS: Well, there's no flow so if you
4 don't have flow bringing the particles in, then I don't
5 really understand how you'd get silting.

6 MR. MARX: Okay. So the real silting problem
7 would be right around the net lap?

8 THE WITNESS: Right.

9 MR. MARX: I have no further questions.
10 Thanks.

11 CHAIRMAN HALL: Mr. Schleede?

12 MR. SCHLEEDE: No questions.

13 CHAIRMAN HALL: Mr. Laynor?

14 MR. LAYNOR: Yes, sir.

15 I'm going to belabor a couple of points, Mr.
16 Kullberg.

17 First of all, in the galling of the standby
18 input arm, has any consideration been given to what the
19 effect would be if the standby system were pressurized?

20 THE WITNESS: If it were pressurized full-

1 time?

2 MR. LAYNOR: Yes, sir. Well, if it were
3 pressurized for any reason during the flight and this
4 galling condition existed.

5 THE WITNESS: Well, the effect would be very
6 similar to what it would be when it's not pressurized,
7 in that -- well, excuse me.

8 MR. LAYNOR: Would you be able to null out
9 the servo valve in the standby PCU?

10 THE WITNESS: You would have to apply a force
11 that would overcome the galling in order to center the
12 valve. But there's also a large dead zone in the valve
13 so that you normally, when you pressurized it, you'd be
14 within the dead zone of the valve. So you'd also, I
15 believe, by having thought about this in advance, I
16 think you'd have to be outside of that dead zone.

17 MR. LAYNOR: Well, do you agree that it's
18 possible that that could be a more serious situation,
19 given the pressurization of the standby system if it's
20 galled out in neutral, out of null?

1 THE WITNESS: You'd first have to lose two
2 hydraulic systems before the standby would actually
3 overcome. And also, the standby system is verified.
4 The actuator is verified at each seat check.

5 MR. LAYNOR: And getting back to the walking
6 beam and a breakout in the main PCU from the standpoint
7 of chip shear, has Boeing established that it's not
8 possible or it is designed such that it's not possible
9 through progressive pedal movement and force to get
10 beyond the breakout, so to speak? Beyond the
11 limitations of the breakout?

12 In other words, can you -- if you continue to
13 apply force, can you exceed the 40 pounds?

14 THE WITNESS: That's what I was --
15 eventually, the walking beam bottoms out but it bottoms
16 out about the same time you hit the valve stops. But
17 that's what I'm talking about. You may have some extra
18 capability for the dual jam case.

19 MR. LAYNOR: Okay. So that would come about
20 by progressive force?

1 THE WITNESS: By bottoming out the walking
2 beam and then you can then apply some more force.

3 MR. LAYNOR: And this goes back to a
4 discussion you had with Mr. Phillips, but I was
5 wondering if you might clarify for me from your
6 viewpoint as a DER, in particular, what the essential
7 difference would be in the certification requirements
8 for that rudder power control unit and the control
9 system by today's standards compared to what it was in
10 1965, the primary major differences.

11 THE WITNESS: Primary differences would be
12 with multiple failures. In '65, '67, they did not
13 address multiple failures. And that's one of the
14 things that the CDR team did address. That's where the
15 fault tree analysis comes in to try to predict the
16 probability of critical events.

17 MR. LAYNOR: All right. So by --'m not
18 sure I understand, but by 1965 standards a single
19 failure which could not be tolerated by the airplane
20 would be acceptable to the certification team?

1 THE WITNESS: No. I touched on this just
2 briefly, but there are no single disconnects on a '37
3 rudder that can cause uncommanded motion. Where you
4 get into the issue is the current 671 says that you
5 must be good for any single failure excluding jams, if
6 they can be shown to be extremely improbable.

7 So even under the current regulations, you
8 can certainly use the argument that a jam is extremely
9 improbable. So you would look at what does it really
10 take to cause the jam and is it reasonable or is it an
11 unreasonable type of situation.

12 MR. LAYNOR: Do you know what the philosophy
13 was in the dual concentric servo valve compared to say
14 a tandem servo valve spool or just a single valve?

15 THE WITNESS: The dual concentric valve is
16 designed to be tolerant of a single jam, whereas a
17 single spool obviously is not.

18 MR. LAYNOR: And that was a design ~~criteria~~
19 in 1965?

20 THE WITNESS: Well, it was -- at least it was

1 a Boeing criteria that you be able to neutralize a jam.

2 MR. LAYNOR: Has Boeing given any
3 consideration with the knowledge that they have today
4 on any pressure reduction or any changes, modifications
5 to the hydraulic system itself rather than the PCU, to
6 accommodate the total flight envelope and
7 controllability?

8 THE WITNESS: When you say consideration,
9 we've looked at it. But when you do something like
10 that, you make sacrifices in other areas. The rudder
11 power is there for reasons, and when you start --
12 something like a pressure reducer does degrade the
13 overall capability of the rudder.

14 MR. LAYNOR: Do you have any such logic in
15 any of your other airplanes for structural
16 considerations?

17 THE WITNESS: Yes. We do do pressure
18 limiting on other airplanes and we do do ratio changes
19 on other airplanes. They are there for structural
20 reasons.

1 MR. LAYNOR: All right. Thank you, Mr.
2 Kullberg.

3 CHAIRMAN HALL: Thank you, Mr. Kullberg, for
4 your testimony. I have just a few questions for you.

5 Could you explain as succinctly as you can
6 what is a designated engineering representative?

7 THE WITNESS: He's basically in play if, in
8 this case, a manufacturer that has demonstrated certain
9 capabilities, integrity type of thing to the FAA, and
10 the FAA has authorized him to make certain findings of
11 compliance with the FAR's and to prove certain types of
12 data.

13 CHAIRMAN HALL: Is this a position you
14 volunteer for or you are selected for?

15 THE WITNESS: No. It's both. I mean, in
16 order to become a DER, you have to demonstrate, like I
17 said, a number of things both to the Boeing Company and
18 to the FAA.

19 CHAIRMAN HALL: I guess my point is how did
20 you become a DER on this airplane? Did the airline

1 select you? Did the FAA select you? I mean, the
2 airplane group?

3 THE WITNESS: Well, Boeing presents you as a
4 candidate and then the FAA either accepts or rejects
5 you.

6 CHAIRMAN HALL: And who has the
7 responsibility of accepting or rejecting you?

8 THE WITNESS: The FAA Seattle Certification
9 Office in this case.

10 CHAIRMAN HALL: In Seattle, the Aircraft
11 Certification Office?

12 THE WITNESS: Correct.

13 CHAIRMAN HALL: So to the extent that you
14 report to anyone, you are supervised by that entity?

15 THE WITNESS: Whenever I'm acting as a DER,
16 I'm really reporting to the FAA.

17 CHAIRMAN HALL: And how long have you been a
18 DER on the 737 for hydraulics/flight control?

19 THE WITNESS: On the '37 for about a year and
20 a half. Previous to that I was DER and currently am a

1 DER for the 757. That's about 10 years now.

2 CHAIRMAN HALL: So you've been the DER on
3 both planes for some period of time then?

4 THE WITNESS: Well, I just recently took over
5 the '37.

6 CHAIRMAN HALL: So you were not the
7 designated engineering representative at the time of
8 the Colorado Springs accident?

9 THE WITNESS: That's correct.

10 CHAIRMAN HALL: The recommendations that you
11 looked at of the 20 -- is it 7 or 9 -- 27
12 recommendations, how many of those have you been
13 responsible for responding to or been involved in
14 responding to?

15 THE WITNESS: Well, within the 737
16 engineering, we've responded to -- I believe it's 15
17 recommendations.

18 CHAIRMAN HALL: 15. Has that been done in
19 writing?

20 THE WITNESS: That's correct.

1 CHAIRMAN HALL: And when was that done?

2 THE WITNESS: We submitted it -- I believe it
3 was October 2nd of this year.

4 CHAIRMAN HALL: October 2nd. So you received
5 that I guess in May and you have given your response in
6 writing. Have you completed your work? Has Boeing
7 completed its work on the response to those
8 recommendations?

9 THE WITNESS: Yes.

10 CHAIRMAN HALL: So there's no further work
11 that's in progress in terms of responding to those
12 recommendations?

13 THE WITNESS: That's correct. But once the
14 FAA has done their analysis, I would not be surprised
15 to be requested more data.

16 CHAIRMAN HALL: Are there any actions that
17 you all anticipate that have been generated as a result
18 of those recommendations inside Boeing?

19 THE WITNESS: Just what I've talked about on
20 the standby PCU and the yaw damper.

1 CHAIRMAN HALL: Two items?

2 THE WITNESS: Well, of those 15, yes.

3 CHAIRMAN HALL: And what is your
4 understanding of the report you submitted to the FAA?
5 What will become of that report?

6 THE WITNESS: My assumption is that the --
7 well, I know that the FAA is currently evaluating it.
8 I would expect to start hearing from them very shortly.

9 I'd like to correct one thing. Also, one of
10 the recommendations was regarding cable inspections.
11 That one's been closed out and we did make changes to
12 the maintenance manuals on that.

13 CHAIRMAN HALL: Well, just on, for example,
14 Recommendation Number 12, was that one that you all --
15 where it says require the failure analysis of the
16 Boeing 737 yaw damper identified components and any
17 relevant tests be conducted to identify all failure
18 modes, malfunctions and potential jam conditions of
19 these vital elements. Have you completed work on that
20 one and did you conduct tests as recommended here?

1 THE WITNESS: We didn't do any specific
2 testing. We did very extensive analysis.

3 CHAIRMAN HALL: And would you anticipate, in
4 light of this recommendation, that the FAA would come
5 back and ask you to conduct any tests?

6 THE WITNESS: It's certainly possible that
7 they could. I can't say that I would anticipate that
8 they would, but it's possible.

9 CHAIRMAN HALL: The fault tree. Is that
10 something that is updated from time to time or is that
11 something that exists -- you know, once it's created,
12 is static?

13 THE WITNESS: We would not normally update
14 the fault trees for the whole of a system. The FAA may
15 request us to update them for specific concerns that
16 they might have.

17 CHAIRMAN HALL: Where there any changes that
18 you were aware of in the fault tree as a result of
19 either the Pittsburgh or the Colorado Springs
20 accidents?

1 THE WITNESS: On the '37, the first time that
2 we submitted fault trees was just very recently as a
3 result of the CDR recommendations. We did not submit
4 fault trees in the original --

5 CHAIRMAN HALL: I just apologize, Mr.
6 Kullberg. I can't hear with that fan going on. Would
7 you mind repeating that again, please?

8 THE WITNESS: The fault trees that I've
9 referred to, those fault trees were just submitted in
10 October. We did not previous to that submit fault
11 trees except I believe for some autopilot design
12 changes. So the fault tree submittal is basically brand
13 new.

14 CHAIRMAN HALL: All right. The subject of
15 silting and if I try to follow your testimony and the
16 question Mr. Donner came up with is that that yaw
17 damper moves and therefore that would remove the silt.
18 Is that what you're saying essentially?

19 THE WITNESS: That's correct. If it did
20 silt, it would.

1 CHAIRMAN HALL: Do you still think we need to
2 do a silting test? And if so, why?

3 THE WITNESS: No. I don't think that we need
4 to do one. I simply stated that I didn't have any
5 objection to doing it. I don't think that we would
6 learn a whole lot but if it would put people's concerns
7 to rest, then I wouldn't have any objection.

8 CHAIRMAN HALL: Well, that's understandable.

9 In your 18 months and your previous
10 experience as a DER on Boeing products, is there
11 anything else that we should be looking at that Boeing
12 has not already addressed or things that come to your
13 attention, tests that should be done? Anything else
14 that you think we ought to be doing on this
15 investigation?

16 THE WITNESS: No. I think ~~to~~ my mind the
17 investigation has been very, very thorough. We still
18 are talking about possibly running some other tests.
19 We mentioned the standby actuator testing. Again, I
20 don't think it's directly applicable to the accidents

1 but I'm at a loss to come up with anything that would
2 make sense that hasn't already been done.

3 CHAIRMAN HALL: All right. Well, Mr.
4 Kullberg, we appreciate your testimony and you are --
5 may step down.

6 (Witness excused.)

7 CHAIRMAN HALL: Before we call the next
8 witness, I would just like to bring to the attention of
9 the audience and the news media, because the question
10 has been brought to my attention, that at the
11 Pittsburgh hearing on January 27th, at the close of
12 that hearing, I made the following statement. And I'm
13 going to read from the transcript:

14 The Board welcomes any information or
15 recommendations from the parties or the public which
16 may assist in its efforts to ensure the safe operation
17 of commercial aircraft. Any such recommendations
18 should be sent to the National Transportation Safety
19 Board, Washington, D. C. 20594, to Mr. Tom Haueter's
20 direction. That's Mr. Haueter right there.

1 And Mr. Haueter patiently responded to many,
2 many letters that we have gotten from the general
3 public and others in regard to information or
4 recommendations that they present.

5 And I want to say today the Board welcomes
6 any information from the public. And I again will read
7 into the record again, nine months later, that if
8 anyone has anything useful, of course we want to see
9 it. Tom Haueter is the investigator-in-charge. His
10 phone number is 382-6830. So if you don't want to call
11 him -- write him, you can call him.

12 This leads me to say that obviously I would
13 question the motives of anyone who would sit on the
14 cause of this accident and not submit it to the
15 scrutiny or to objective testing. Anyone who would
16 wait to the day of the hearing, of a hearing that has
17 been planned for two months, I would have to come to
18 the conclusion that the purpose of that individual is
19 to manipulate the processes of this hearing for private
20 motives.

1 Therefore, again, I say anyone who knows the
2 cause of this accident has a public duty to come
3 forward and you can reach Mr. Haueter at 382-6830, area
4 code 202.

5 I'd like to call now our next witness, Mr.
6 Paul Knerr, the Vice President, Engineering, at Canyon
7 Engineering, Society of Automotive Engineers. He's the
8 A6 Committee Member and he's come here from Valencia,
9 California.

10 (Witness testimony continues on the next
11 page.)

1 PAUL KNERR, VICE-PRESIDENT, ENGINEERING, CANYON
2 ENGINEERING, SOCIETY OF AUTOMOTIVE ENGINEERS,
3 A6 COMMITTEE MEMBER, VALENCIA, CALIFORNIA
4

5 Whereupon,

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

10 MR. SCHLEEDE: Mr. Knerr, could you give us
11 your full name and business address for our record,
12 please?

13 THE WITNESS: My name is Paul Knerr and I
14 work for Canyon Engineering in Valencia, California.

15 MR. SCHLEEDE: And what is your position at
16 Canyon Engineering?

17 THE WITNESS: I'm Vice President of
18 Engineering.

19 MR. SCHLEEDE: Could you give us a brief
20 description of your background and education that bring

1 you to your present position?

2 THE WITNESS: I've worked for Canyon for 10
3 years. And prior to that, I worked for the Lee Company
4 in Connecticut for 11 years. During this period of
5 time, I've designed products for aircraft and also
6 worked with the SAE Committee for 15 years in
7 contamination and filtration.

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

10 MR. PHILLIPS: Good evening, Mr. Knerr.

11 First of all, I'd like to talk a little bit
12 about your responsibilities as Vice President of
13 Engineering of Canyon Engineering. What does Canyon
14 Engineering do?

15 THE WITNESS: Canyon Engineering is a small
16 business that builds primarily valves, flow control
17 valves, relief valves, check valves, for hydraulic
18 systems. We built nozzles and that sort of thing for
19 fuel systems and we build some lube systems also.

20 We're a secondary or sub tier supplier to

1 Parker Hannifin and other companies like that.

2 MR. PHILLIPS: Do you build parts for Boeing?

3 THE WITNESS: We don't build the parts
4 directly for Boeing.

5 MR. PHILLIPS: Have you manufactured any part
6 of the 737 main power control unit?

7 THE WITNESS: Not to my knowledge.

8 MR. PHILLIPS: How about the standby rudder
9 actuator?

10 THE WITNESS: Not to my knowledge.

11 MR. PHILLIPS: Have you ever been involved in
12 any testing of either one of those two components?

13 THE WITNESS: No, I haven't.

14 MR. PHILLIPS: Anyone at your company that
15 you know of?

16 THE WITNESS: No.

17 MR. PHILLIPS: How big is your company?
18 Number of people.

19 THE WITNESS: We're 42 people.

20 MR. PHILLIPS: And do you do original design

1 work or do you do modifications of original design?

2 THE WITNESS: We do design OEM products to
3 specification to companies, again, like Parker. We
4 also build to their prints.

5 MR. PHILLIPS: And that's where they supply
6 you the drawings and you manufacture the parts?

7 THE WITNESS: That's correct. I'd like to
8 also say that we do the complete testing and assembly
9 of those parts to acceptance test procedures that are
10 supplied by those companies.

11 MR. PHILLIPS: Do you participate in the
12 development of acceptance test procedures in your
13 design work?

14 THE WITNESS: We generally write our own
15 acceptance test procedure that details our detailed
16 procedures to testing those parts. Those are based on
17 the company's ATP's but are further modified for our
18 own needs.

19 MR. PHILLIPS: I'd like to talk for just a
20 minute about the SAE. The Chairman asked us in a

1 meeting a few weeks ago what was the SAE and exactly
2 what's the organization all about.

3 Could you give us a few sentences about the
4 SAE and about your committee in general?

5 THE WITNESS: Okay. The SAE is the Society
6 of Automotive Engineers. The terminology is somewhat
7 misleading in that when it was originally conceived in
8 1909 the word automotive meant any kind of automotive
9 product, whether it be on land, sea or air.

10 Right now, they handle standards and
11 recommended procedures for both aircraft and ground
12 vehicles and seagoing vehicles, too.

13 My involvement there has been for about 15
14 years. The way that the SAE runs, it's a volunteer
15 organization made up of individuals who have an
16 interest or an area of expertise in the areas that
17 they're writing standards on. And I became involved
18 with the contamination and filtration panel and also
19 more recently with the components panel.

20 MR. PHILLIPS I've had some discussions

1 prior to the hearing with the SAE headquarters, I guess
2 you could call it. And I think this is the place to
3 make the point that Mr. Knerr isn't speaking or isn't
4 testifying on behalf of the SAE. He's testifying on
5 behalf of his experiences at Canyon Engineering and his
6 professional experience, so I'll make that clear,
7 although we recognize your affiliation and we want to
8 have a little bit more discussion about that.

9 You said you were at Lee for quite a while.
10 Can you tell me a little bit about what Lee does?

11 THE WITNESS: Lee builds similar components.
12 They're smaller, generally, micro hydraulics. They're
13 used in flight controls as well. My role there was
14 first as project engineer and then chief engineer in
15 charge of valves.

16 MR. PHILLIPS: So for your whole career
17 you've been involved with hydraulic valves and
18 components?

19 THE WITNESS: Before that I was with Hamilton
20 Standard and before that with NASA.

1 MR. PHILLIPS: And what did you do for NASA?

2 THE WITNESS: Basically, an engineering
3 trainee during the Apollo days.

4 MR. PHILLIPS: So would you consider yourself
5 an expert in hydraulic component design, hydraulic
6 systems?

7 THE WITNESS: Yes, I would.

8 MR. PHILLIPS: I'd agree.

9 CHAIRMAN HALL: And that's why we have him
10 here, right?

11 MR. PHILLIPS: Certainly is.

12 CHAIRMAN HALL: And we appreciate you being
13 present because you are an expert in hydraulics and we
14 appreciate you being here, sir.

15 MR. PHILLIPS: You mentioned that the SAE has
16 a committee that looks into filtration and
17 contamination. Can you tell me how that subdivision of
18 a committee or group of people were formed and why?

19 THE WITNESS: The SAE A6 Committee deals with
20 all aspects of aircraft hydraulics. There are

1 committees that are broken down into various areas,
2 flight controls being one, servo actuators being one. A
3 number of other committees. This just happens to be
4 one of the ways that they broke it down.

5 Considering the filtration and contamination
6 is an important part of the hydraulic area, they
7 developed a committee. A committee is about 15
8 individuals right now.

9 MR. PHILLIPS: Do you attempt to define
10 standards for filtration for hydraulic systems?

11 THE WITNESS: Yes, we do.

12 MR. PHILLIPS: And who uses those standards?

13 THE WITNESS: These standards are AIR's,
14 Aerospace Information Reports; ARP's, which are
15 recommended procedures; and AS's, which are standards
16 of components. The aerospace industry, both the
17 military and commercial people, use those standards.

18 MR. PHILLIPS: The Committee, the A6
19 Committee, do companies such as Parker or Boeing have
20 participants on those committees?

1 THE WITNESS: Yes, sir, they do.

2 MR. PHILLIPS: Does the FAA or other
3 government agencies have people on those committees?

4 THE WITNESS: Yes. Werner is on the
5 committee.

6 MR. PHILLIPS: Werner Koch is a member of the
7 A6 Committee?

8 THE WITNESS: Yes, he is.

9 MR. PHILLIPS: How are people selected for
10 the committees? Are they volunteers or --

11 THE WITNESS: It's strictly volunteer. To
12 become a member, one has to just show a particular
13 interest and work on standards documents.

14 MR. PHILLIPS: You mentioned ARP. That's an
15 Aerospace Recommended Practice?

16 THE WITNESS: Yes, it is.

17 MR. PHILLIPS: And also, one of the -- in the
18 previous hearing we discussed an NAS, which is a
19 National Aerospace Standard 1638 which applies to
20 contamination. Are you familiar with those documents?

1 THE WITNESS: Yes, I am.

2 MR. PHILLIPS: Okay. 1638 and ARP 219. Are
3 you familiar with that document?

4 THE WITNESS: Right.

5 MR. PHILLIPS: Could you briefly describe
6 what ARP 219 is?

7 THE WITNESS: ARP 219 is a document which
8 addresses the issue of testing for contamination
9 sensitivity of components. It's a rather old document.
10 It was recently -- or is going through the process of
11 cancellation for various reasons.

12 MR. PHILLIPS: Is that document used by
13 manufacturers as a guideline for their contamination
14 concerns for design?

15 THE WITNESS: One of the reasons it's being
16 cancelled is because very few companies have used it.
17 To just characterize it, it's a rather severe test of
18 components using AC fine test dust and the feeling
19 generally is that it's much more severe than anything
20 that could occur in an aircraft hydraulic system.

1 MR. PHILLIPS: How was an original standard
2 set that missed the point?

3 THE WITNESS: I think the intent was more to
4 compare one valve design or one pump design for another
5 and it does that. It's a comparative sort of a
6 document. However, it doesn't relate to how long an
7 in-service vehicle would last. And generally, it's
8 pretty hard on the component. You can wear out a valve
9 or a pump in a very short amount of time and not know
10 how that relates to in-service times.

11 However, it was good for comparing one valve
12 against another.

13 MR. PHILLIPS: Is there any kind of
14 requirement for a manufacturer to use ARP 219?

15 THE WITNESS: There have been some
16 specifications issued by companies that require 219.

17 MR. PHILLIPS: Do you know if ARP 219 testing
18 was required in any of the 737 flight control
19 components?

20 THE WITNESS: I don't know that. No.

1 MR. PHILLIPS: NAS 1638. Could you briefly
2 describe that document?

3 THE WITNESS: That's a document that
4 establishes the classifications of cleanliness for
5 hydraulic fluids, broken down into a number of
6 different classes. Each class doubles in particulate
7 count and that is further broken down into size of
8 particles, the first size being 5 to 15 micron and on
9 up to 100 micron.

10 There is also an SAE document which ~~exp~~
11 on that. It's AS 4059, which is a more recent document
12 that includes 2 micron particles and further expands on
13 the document.

14 MR. PHILLIPS: Which document would be used -
15 - would be currently used to categorize particulate
16 contamination of hydraulic fluid?

17 THE WITNESS: NAS 1638 has been used for
18 years and that's the one that I've seen in most areas.

19 MR. PHILLIPS: Okay. Are you familiar with
20 any hydraulic fluid sampling that was done in the

1 process of this investigation of flight 427?

2 THE WITNESS: Yes, I am. There was a report
3 that the NTSB put out which I reviewed and did my own
4 analysis of.

5 MR. PHILLIPS: I'd like to take a little bit
6 of time and talk about your analysis of that work that
7 we've done. In the NTSB report you referenced, do you
8 generally recall what the report was about?

9 THE WITNESS: The report was to look at the
10 in-service airplanes, 737's. There were 21 airplanes
11 involved and 104 samples. And the intent was to
12 randomly look at the three airlines that were involved
13 and the 21 airplanes that were involved and see what
14 kind of fluid contamination existed -- this is
15 particulate contamination -- existed in the typical
16 fleet.

17 MR. PHILLIPS: Could you tell us a little bit
18 about the findings -- your analysis of the findings in
19 that report?

20 THE WITNESS: To briefly summarize, about 22

1 percent of the airplanes that were surveyed exhibited
2 particulate contamination greater than a Class 8, Class
3 8 being the normal military level for hydraulic
4 contamination. That is established in a mill spec,
5 both for components and for systems.

6 And I think speaking for the rest of us in
7 the SAE, Class 8 is a pretty typical level that we
8 would expect a fairly dirty hydraulic system to go to
9 and would not exceed.

10 MR. PHILLIPS: So in your opinion, a Class 8
11 would be the upper limit of acceptable according to NAS
12 1638?

13 THE WITNESS: Not according to NAS 1638. It
14 doesn't establish any levels. It's simply a
15 classification of those levels. To my knowledge, there
16 is no general commercial limit. However, the different
17 airlines range from 7 to 9. I'm sorry. The different
18 airframe manufacturers range from 7 to 9.

19 MR. PHILLIPS: So the manufacturers impose a
20 requirement for NAS 1638 limits of 7 to 9?

1 THE WITNESS: All except Boeing. Boeing does
2 not have an in-service limit.

3 MR. PHILLIPS: And there is no requirement at
4 Boeing. Who would be responsible then for a Boeing
5 airplane for setting the standard for hydraulic
6 cleanliness?

7 THE WITNESS: Boeing uses the philosophy that
8 it establishes the filter change time intervals based
9 on A, B and C checks and then leaves it up to the user
10 to determine if they take samples and what level of
11 cleanliness the aircraft will achieve.

12 MR. PHILLIPS: As a follow-on, I believe you
13 prepared a chart here that gives a relative description
14 of these classifications. Could we take a look at
15 that? It's page 2 of the exhibit.

16 And Rick, I think it will look like a 1 on a
17 piece of paper.

18 CHAIRMAN HALL: Which exhibit?

19 MR. PHILLIPS: It's page 2. 9M-

20 CHAIRMAN HALL: M as in Mike or N as in

1 November.

2 MR. PHILLIPS: M as in Mike.

3 THE WITNESS: I don't know how well you can
4 see this but in trying to describe what these
5 contamination levels look like, if you can visualize a
6 one gallon drum on the left-hand size with the
7 particles suspended in that drum, and then in the next
8 picture in the middle, if all of the particles were to
9 settle to the bottom of that drum, about a five inch
10 diameter disk. And then you were to magnify it
11 greatly, you would look at these three classes.

12 The little one on the top there is Class 6.
13 The little worm in the middle of the page is just for
14 reference. That's a 100 micron hair which is a typical
15 human hair. And the particles that are shown are only
16 the 50 micron particles.

17 There would be only four particles on that
18 patch for Class 6. There would be many more particles
19 for Class 12, as you can see. And Class 18, which
20 represents about the level that Boeing did their test

1 at, is shown at the bottom.

2 MR. PHILLIPS: By the Boeing test, you're
3 referencing the contamination test done late last year?

4 THE WITNESS: Yes.

5 MR. PHILLIPS: We were talking about
6 requirements for cleanliness standards. Are you aware
7 of any requirements by the FAA placed on the
8 manufacturers?

9 THE WITNESS: I'm not aware of any
10 requirements. No.

11 MR. PHILLIPS: What kind of level do most
12 manufacturers maintain in their testing equipment?

13 THE WITNESS: Our ATP's that we receive from
14 most of our customers require a Class 6 or less. We
15 maintain our test stands to approximately Class 4.
16 We've seen them go up to Class 6.

17 MR. PHILLIPS: Are you aware of any testing
18 that's done at higher contaminate levels are part of a
19 certification process or part of the approval process?

20 THE WITNESS: Nothing specific. I have heard

1 of tests being run on specific components where
2 contamination might have been an issue. Back at the Lee
3 Company we ran some tests of sensitivity of small
4 valves to contamination. This was generally following
5 somewhat of the Boeing procedure where we put massive
6 amounts of Arizona road dust into the components.

7 MR. PHILLIPS: And what is Arizona road dust?

8 THE WITNESS: AC fine test dust. That's a
9 calibrated test dust that's used to calibrate particle
10 counters. There are several other test dusts that are
11 also used, but that's fairly common.

12 MR. PHILLIPS: Is it common to place other
13 materials as contaminants in solution like pieces of
14 metal or Teflon?

15 THE WITNESS: Yes. I haven't personally done
16 this but I know of other companies that have mixed
17 contaminants. The Boeing test was a mixed contaminant
18 test where metal particles and Teflon particles and
19 sand particles were put in.

20 MR. PHILLIPS: Do you know what the basis

1 would be for calculating the mix or finding
2 percentages?

3 THE WITNESS: Not specifically. I understand
4 that Boeing used in-flight sampling to match their
5 contaminant load with.

6 MR. PHILLIPS: You've described several
7 classes of contaminants. And this is based on
8 particulate count and excluding any chemical
9 contamination. Could you briefly describe the sources
10 of high particulate count in fluid samples?

11 THE WITNESS: There are a number of sources
12 of generation of particulate. The pump probably being
13 the primary generator of small flakes of metal; built-
14 in contaminants from the assembly procedures or from
15 breaks in the line for servicing.

16 The contaminants that get by the wiper seals
17 on actuators are brought into the system. The
18 actuators themselves generate particulate, both the
19 seals and the metal surfaces. These are some of the
20 kinds of sources.

1 In addition, the filters themselves do pass
2 contaminants. Filters are not specifically blocking
3 out all contaminants of a particular size but they're
4 sort of playing catch-up with the generation, and then
5 they do shed some particles also.

6 MR. PHILLIPS: On the subject of filtration,
7 can you give us some general guidance in how hydraulic
8 systems are filtered?

9 THE WITNESS: In most cases of aircraft
10 systems, there's three primary filters. There's a
11 pressure filter which takes the pressure from the pump
12 and goes out to the system. That's what's feeding the
13 hydraulic actuators. There's a return filter which
14 collects the debris from the system and there's
15 generally a case drain filter which is a smaller filter
16 that takes the case drain flow from the pump and feeds
17 it back into the system.

18 MR. PHILLIPS: What about filters on
19 individual components on the inlet lines?

20 THE WITNESS: There are also what we

1 generally refer to as last chance filters or smaller
2 filters in front of the PDU, in front of other critical
3 components. These are generally coarser than the
4 nominal filtration rating of the system filter.

5 The pressure and return filters on the 737
6 are 15 microns nominal. And again, that doesn't mean
7 it traps all 15 micron particles. That's just the
8 generic way of stating a filtration rate.

9 The case drain I believe is 20 microns. And
10 as was mentioned before, the inlet PDU filter is 25
11 microns.

12 MR. PHILLIPS: What drives the filter sizing
13 in the component? How's the 25 micron filter selected?

14 THE WITNESS: I can't answer that. That's a
15 system design problem.

16 MR. PHILLIPS: Okay. That's fair.

17 As filters get saturated or they trap
18 particles, does that affect their ability to filter and
19 continue to do the job they're supposed to do?

20 THE WITNESS: Yes, it does. The more heavily

1 a filter is loaded, the more it will shed.

2 MR. PHILLIPS: Going back to the SAE
3 committee that you're a part of, you mentioned a little
4 there today but in previous discussions we've had that
5 as a result of some recent activity there is a new
6 committee forming or new group. Could you please give
7 us a description of that?

8 THE WITNESS: At the last meeting in San
9 Antonio in October of this year, the FAA approached the
10 SAE to respond to some of the recommendations from the
11 CDR in regards to contamination. Those issues are
12 being addressed by 16 volunteers within the overall
13 committee. The Committee, by the way, is about 300
14 engineers and maintenance people. And those volunteers
15 are from filter companies, from airlines, from valve
16 manufacturers, like myself, and other places.

17 We intend to meet in January to address the
18 issues that the FAA were asking us to address. Those
19 issues regard both particulate contamination and also
20 chemical contamination, such as water and chlorine.

1 And to address the issue of valve sensitivity testing
2 and tip shear limits, as well as limits to the overall
3 contamination class for an aircraft.

4 MR. PHILLIPS: Is one of the tasks of this
5 group to discuss the fact that Boeing doesn't have an
6 in-service requirement for particulate?

7 THE WITNESS: I think it's more to
8 standardize the requirement across the board. If it's
9 going to be a Class 8 like it is in the military, then
10 there should be a standard written that says that.

11 Boeing does have a limit to a shipped new
12 aircraft, which is Class 9. And several other
13 airframers do say Class 9 is a better number. And
14 that's what the effort would be, to establish a number
15 for everybody to use.

16 CHAIRMAN HALL: Mr. Phillips, at this point -
17 - how did that request come to you, verbally or in
18 writing?

19 THE WITNESS: It was in writing from the
20 Seattle office.

1 CHAIRMAN HALL: Could we make that a part of
2 the exhibits? Any problem?

3 MR. PHILLIPS: We'll look into it.

4 THE WITNESS: I have a copy of it here.

5 MR. PHILLIPS: So the attempt is to
6 standardize a NAS 1638 class among all manufacturers
7 that is generally agreed upon. Is that correct?

8 THE WITNESS: That's correct.

9 MR. PHILLIPS: In your experience working
10 with -- in valves over these years, could you describe
11 to us what you've seen along the lines of jamming? And
12 I want to start specifically with spool valves, sliding
13 spool valves.

14 Is it your belief that the indications of
15 jamming are normally readily apparent on those parts?

16 THE WITNESS: On aircraft parts where the
17 clearance is generally around one to six microns, I
18 have no experience whatsoever in particle jamming.

19 In larger clearance high pressure valves, we
20 have seen some cases of jamming. However, these are

1 generally not aircraft valves. They're industrial
2 valves in highly contaminated areas and the leakage
3 flow is completely through the clearance and the forces
4 are fairly low.

5 MR. PHILLIPS: Did this jam leave any visible
6 mark on the valve?

7 THE WITNESS: Yes, it did.

8 MR. PHILLIPS: Have you ever seen a dual
9 concentric valve, a two spool valve, where both spools
10 jammed?

11 THE WITNESS: No. I've never seen a dual
12 concentric valve.

13 MR. PHILLIPS: Have you ever heard of one?

14 THE WITNESS: I've heard of them, but no, we
15 have never -- I have never personally operated with any
16 of the dual concentric valves.

17 MR. PHILLIPS: Do you have any more details
18 specifically of the one that you've heard of?

19 THE WITNESS: I think relative to the silting
20 question, I think that's a big question in my mind as

1 to whether any kind of major hysteresis can occur. And
2 I think that's based primarily on the nature of the
3 contaminant.

4 If, for example, you use natural contaminants
5 generated from the aircraft which are usually very
6 small sliver metal particles, it is conceivable that
7 enough of those could get together and cause some
8 hysteresis in a valve. Whether that could cause a jam
9 that was greater than 42 pounds, I doubt. But again,
10 it's still a question in my mind.

11 MR. PHILLIPS: So would you follow Mr. Koch's
12 statement and you'd like to see some additional testing
13 done along those lines?

14 THE WITNESS: Yes, I would. I have to say
15 that the testing would be very difficult. It think it
16 would have to follow a procedure that's been set up in
17 various circles that talks about engineering
18 experiments, where we would take a number of parameters
19 of the valve and vary them and create a matrix of
20 experiments and then look at the nature of the

1 hysteresis or friction increase based on all of those
2 parameters.

3 The approach that Boeing took was certainly
4 the most direct way and that is to introduce some very
5 hard particles and a great number of them to see if the
6 actuator can withstand that kind of an environment.
7 However, we're working with something that is sort of a
8 very random nature and I think we'd have to do some
9 trending by these experiments to determine whether
10 there's a probability on a very rare occurrence.

11 MR. PHILLIPS: Do I understand your concern
12 is more for hysteresis rather than a total blockage or
13 jamming or inability to move the valve?

14 THE WITNESS: Yes. I think that if we were
15 to test this system and include all of the system; that
16 is, include the filters in the PDU and then allow the
17 natural contamination to build up within the pumping
18 system by simply going to coarser system filters, let
19 that build up to about a Class 12 and do some design
20 experiments. By design experiments, I mean change

1 surface features of the valves, surface finishes.
2 Perhaps taper on some of the spools and other
3 parameters like that. Very small parameters, indeed,
4 but change those in a systematic way and then look for
5 a build up in friction at about a Class 12 of natural
6 contaminants.

7 That's the way I'd run the test.

8 MR. PHILLIPS: That sounds to me like a test
9 that would -- the goal would be to design a standard
10 for the shape of the spools and that. Specifically, in
11 this accident investigation, if we were wanting to --
12 NTSB was wanting to determine that silting was an
13 issue, would you recommend a test, the same test?

14 THE WITNESS: That kind of rambled on. Could
15 you explain what you're asking?

16 MR. PHILLIPS: Yes. Everybody's laughing.
17 That's bad. I'll probably get my pilot's license taken
18 away.

19 Specifically, in the course of investigating
20 this accident as a step that we're looking into and

1 we've discussed today, would you recommend a silting
2 test where we introduce a Class 12 fluid with the
3 intent to see if we can change the valve or make it
4 fail? Or could we never have it happen? Would it have
5 to go for a long time?

6 THE WITNESS: Well, that's why I'm saying
7 we'd have to use this particular statistical approach
8 to determining whether there are trends towards
9 increasing friction by changing a number of parameters
10 at the same time. That sounds like it's against the
11 normal experimental method but that has been a proven
12 way to get at a solution a lot faster and doing a lot
13 less tests.

14 If, for example, we determined that a slight
15 amount of taper and a particular clearance produced the
16 worst hysteresis in a Class 12 natural environment,
17 then perhaps we can use that information to project
18 what may occur in a statistical improbable situation.

19 MR. PHILLIPS: In your experiences, can
20 normally tell? Can you look at a valve and tell that a

1 valve has been operating in contaminated fluid?

2 THE WITNESS: Can I look at a valve and
3 determine whether it can operate?

4 MR. PHILLIPS: Visual observation.

5 THE WITNESS: There are a number of
6 guidelines that engineers use to prevent contamination
7 being a problem or locking up a valve. One, for
8 example, is to have very sharp spool lands. Any
9 radiusing or rounding or tapering of those spool lands
10 will make the valve much more susceptible to jamming.

11 MR. PHILLIPS: Have you looked at this valve
12 that we're talking about, the main rudder power control
13 unit, the servo valve?

14 THE WITNESS: No, I haven't, but I've seen
15 valves that are similar to it. I'm sure that the edges
16 are very sharp, as originally manufactured. One of the
17 concerns that we might have with high particle counts
18 is that the erosion of the valves goes up very quickly
19 with high particle counts, which will round off the
20 edges of the spool and thereby create a situation where

1 jamming would be more probable.

2 MR. PHILLIPS: Are there any other processes
3 that can be done to the spools to raise the chip shear
4 capability or protect against jamming other than sharp
5 edges?

6 THE WITNESS: Certainly lack of taper. These
7 are generally ground and honed spools. But I can
8 conceive of ways in which taper could occur in the
9 manufacture of the parts and any kind of taper would
10 cause severe problems.

11 MR. PHILLIPS: Do you agree with the
12 testimony we've heard earlier today that an underlapped
13 valve generally is less susceptible to silting?

14 THE WITNESS: Yes, I do, but I think I'd
15 rather reserve judgment until I could see what the
16 actual configuration looked like. If those inlet ports
17 were completely annular, then I do agree. If, however,
18 there are multiple inlets or some kind of land that the
19 particles can jam in radially around the valve, then I
20 would question that.

1 MR. PHILLIPS: Is radial jamming a common
2 occurrence? Do you see that often?

3 THE WITNESS: No, but any time you have a
4 differential pressure across a clearance is where the
5 problem can occur.

6 MR. PHILLIPS: Have you read the FAA's CDR
7 report?

8 THE WITNESS: Yes, I have.

9 MR. PHILLIPS: Do you have any observations
10 or comments as to the areas that address the areas of
11 your expertise?

12 THE WITNESS: No. I thought it was a very
13 well written report and I appreciate the FAA coming to
14 the SAE and asking them to look into these things.

15 MR. PHILLIPS: So was there any correlation
16 or was there any connection with the SAE while the CDR
17 was in work or did it come after the report was
18 completed?

19 THE WITNESS: It came after the report was
20 written.

1 MR. PHILLIPS: I think that's about all I
2 have. Do you have anything else you'd like to add or
3 say?

4 THE WITNESS: No, not at this time.

5 CHAIRMAN HALL: Any other questions from the
6 Technical Panel?

7 (No response.)

8 The parties?

9 (No response.)

10 I see no hands from the parties. Very well.
11 Mr. Clark?

12 MR. CLARK: No questions.

13 CHAIRMAN HALL: I'm sorry?

14 MR. CLARK: No questions.

15 CHAIRMAN HALL: Mr. Purvis, with the Boeing
16 Commercial Airplane Group?

17 MR. PURVIS: You were talking about a test
18 just now and using -- I think you said Class 12 fluid.
19 How would you confirm that Class 12 is actually
20 present in the valve?

1 THE WITNESS: There are a number of methods
2 for determining particle contamination. At a Class 12,
3 I doubt if an automatic particle counter would be
4 valid, so I'd use ARP 598 which is a microscopic count
5 method; take patches, and verify that that was in fact
6 in the valve.

7 MR. PURVIS: And why did you choose Class 12?

8 THE WITNESS: Each class doubles in
9 particulate so this is 16 times more than the level
10 that we would expect to be normal in an aircraft
11 hydraulic system. It is also the level that was
12 approached and in one case exceeded on the 21 airplane
13 sampling that we saw.

14 So I think it would be typical of a fairly
15 dirty airplane. We could of course go to Class 18 or
16 even higher but I think what we're looking for is with
17 a typical operating system is is everything functioning
18 okay.

19 MR. PURVIS: On the samples that you
20 reviewed, those 21 samples, is there any chance that

1 say contamination from say poor sampling techniques
2 maybe contaminated the sample?

3 THE WITNESS: Very definitely. That was the
4 immediate reaction of the SAE panel was that those
5 samples that were well above the norm were due to
6 sampling error. And I agree that that is a very real
7 possibility.

8 I had another viewgraph that showed that this
9 was out of the normal distribution. The two datapoints
10 were way up there around Class 13 were out of the
11 normal distribution, which would tend to make you
12 believe that it was not a normal sampling. However,
13 the normal distribution does allow the level to go up
14 quite high.

15 MR. PURVIS: What was the normal distribution
16 on those airplanes?

17 THE WITNESS: The average of the 21 samples
18 was about a Class 7. The extension of the Bell curve
19 or the normal distribution went up to about a Class 11.

20 MR. PURVIS: I guess the question still begs

1 the question why use Class 12, given the considerations
2 of the various possibilities of contamination and the
3 distribution?

4 THE WITNESS: Well, you want to get a high
5 enough level to try to simulate some kind of fault or
6 at least some kind of trend. So I think you have to be
7 up to a level that at least will perhaps show
8 something. However, I don't want to be up at the kind
9 of levels that would mask the results. And I think
10 going beyond 12 would be impractical.

11 It seems clear to me that if the results of
12 the sampling of the 21 airplanes is due totally -- or
13 at the extremes is due totally to sampling error, then
14 perhaps we can go lower. But I'm not convinced that
15 it's due totally to sampling error.

16 I'm looking right now at some more sample
17 data that was furnished by another fluid company and
18 there's considerably more data there. And the Bell
19 curve is just as wide, if not wider.

20 MR. PURVIS: In the data that was in the

1 report, did you observe that some of those actually had
2 two samples taken from the same place with widely
3 different results?

4 THE WITNESS: Yes. And I pointed that out to
5 a -- I presented this data to the SAE committee back in
6 April of this year and one of the sources of error
7 other than sampling -- I'm sorry -- including sampling,
8 showed two datapoints that were five classes apart
9 taken by the same operator at the same point. And
10 therefore, it was very evident to me that at least that
11 one sample was in error. However, I don't know which
12 one was in error.

13 It's more likely for the dirtier sample to be
14 in error, but I don't know conclusively which one was
15 in error.

16 MR. PURVIS: The tests you described were
17 quite extensive, I'm sure. They sounded that to me.
18 We've got something like 150 million hours on the
19 Boeing fleet. Does that give you -- and without any
20 particular problems that we know of. Does that give

1 you a feeling of sufficient effects of silting or the
2 lack of effects of silting?

3 THE WITNESS: I fly Boeing 737's all the time
4 and I have no problem whatsoever with the safety of the
5 airplanes. What we're looking for here though is
6 something less than one in a billion chance and
7 something more than one in a million chance, an
8 occurrence. That's something that's very difficult to
9 find, but I think this design of experiments may help
10 us at least to go in that direction.

11 MR. PURVIS: No other questions, sir.

12 CHAIRMAN HALL: Any other ~~up~~ questions from the
13 parties?

14 (No response.)

15 If not, we'll go to Mr. Clark?

16 MR. CLARK: I have no questions.

17 CHAIRMAN HALL: Mr. Marx?

18 MR. MARX: No questions.

19 CHAIRMAN HALL: Mr. Schleede?

20 MR. SCHLEEDE: No questions.

1 CHAIRMAN HALL: Mr. Laynor?

2 MR. LAYNOR: No questions.

3 CHAIRMAN HALL: Mr. Knerr, what motivates you
4 to serve on this committee? It's volunteer; right?

5 THE WITNESS: Yes, sir. The same thing that
6 I guess motivates all 300 of us, and that is to
7 establish standards for the industry, both for safety
8 reasons and for establishing just general procedures.

9 CHAIRMAN HALL: Well, I applaud you for that
10 and I think the American public probably knows very
11 little about the excellent work the Society of
12 Automotive Engineers does. And I've been trying to get
13 up to speed on it myself. I was extremely impressed.

14 You mentioned, however, there were no
15 standards of cleanliness in this area. Is that
16 correct?

17 THE WITNESS: That's correct. At least for
18 commercial vehicles.

19 CHAIRMAN HALL: And is this an area that
20 there should be standards since your committee sets

1 standards or is it an area that you didn't feel
2 standards were important or --

3 THE WITNESS: Well, let me categorize that a
4 little bit.

5 CHAIRMAN HALL: I understand you recommend
6 standards. Mr. Schleede has corrected me.

7 THE WITNESS: There are standards within
8 individual documents. For example, AS 490 is a servo
9 valve standard. And in it, it formerly had indicated
10 that the level be Class 6. We have recently changed
11 that to Class 8 because we feel those servo valves can
12 withstand at least that level.

13 The problem as it appears to me as a
14 component manufacturer is that if I'm designing a valve
15 to a spec that says Class 6 and yet it's being used in
16 a Class 10, then we should at least know what the
17 component does. So we need to do some testing to
18 establish that.

19 Either we have to set the limits for the
20 system or we have to change the testing to be more in

1 line with what the aircraft we're flying.

2 CHAIRMAN HALL: Is there anyone from the
3 Boeing Commercial Airplane Group on one of these
4 committees, on the committee you serve on?

5 THE WITNESS: I believe, yes, Boeing is
6 represented.

7 CHAIRMAN HALL: I would think so.

8 But again, just so I'm clear and I don't
9 leave any confusion, you are like the NTSB. You can
10 only recommend.

11 THE WITNESS: That's correct.

12 CHAIRMAN HALL: But your standards are fairly
13 well accepted in the industry?

14 THE WITNESS: Yes, they are. If Boeing, for
15 example, wants to use an ARP or AIR in the
16 specification to a contractor, then those become part
17 of the contract.

18 CHAIRMAN HALL: Well, I appreciate your being
19 here.

20 Mr. Phillips, when we -- after Pittsburgh, I

1 started saying we'd find the best hydraulics experts in
2 the country and I believe he has done that.

3 Now is there anybody else that isn't on your
4 committee that ought to be involved in this voluntary
5 effort that the FAA has requested you to do?

6 THE WITNESS: We would much like to see more
7 airlines involved. They used to be back 20 years ago
8 and we would like to see more airline involvement.

9 CHAIRMAN HALL: Well, possibly, could we send
10 a letter to the airlines? I'll ask Mr. McSweeney, and
11 see if they wouldn't get involved with this process.
12 And January is the earliest you can begin this process?

13 THE WITNESS: We've begun the process. Manny
14 Runkle from Dowdy Aerospace is leading the team, and he
15 has prepared some paperwork for us all to review. It's
16 just that January is our first combined meeting.

17 CHAIRMAN HALL: Well, we are trying to pursue
18 any possibility, just as far as we can go. And
19 anything we can do to support your committee's work --
20 and I'm sure you'll receive a positive response from

1 the airlines -- we want to do. And I really appreciate
2 your leadership on this voluntary standards group and
3 your attendance here today.

4 Thank you very, very much.

5 THE WITNESS: Can I offer one more thing that
6 I forgot to mention?

7 CHAIRMAN HALL: Yes, sir, please. Anything
8 that you think.

9 THE WITNESS: I had initiated a program to
10 instrument a 737 at the pressure filter outlet with an
11 automatic particle counter. We tried to do that for
12 about a year and Boeing did cooperate in doing that.
13 That was the airplane that we were going to use for the
14 vortex test. We were going to piggyback this little
15 test on it.

16 But due to circumstances beyond everybody's
17 control, we were unable to do that. I think the reason
18 that it's important to find out the level of
19 contamination that's coming out of the main pressure
20 filter in real flight time because the filters tend to

1 change their behavior due to vibration and shock loads
2 and changing flow and that sort of things, for a
3 component manufacturer to know that that level varies
4 widely is very important in our analysis of a valve
5 design. We have an ongoing effort to do this perhaps
6 with the FAA 727 and just wanted to mention that we're
7 trying to do that.

8 CHAIRMAN HALL: Thank you. And you've kind
9 of triggered my mind. Do you think this FAA letter
10 requesting you to look at some of these
11 recommendations, how long do you think it would take
12 you to provide a response?

13 THE WITNESS: We're trying to get together a
14 response within six months from October, whatever that
15 makes it. Sometime in April, I guess. Just how
16 definitive that response will be, I don't know. That's
17 what we need to work on for the next couple of months.

18 CHAIRMAN HALL: Well, again, thank you very
19 much. I appreciate your being here and providing these
20 views.

1 (Witness excused.)

2 CHAIRMAN HALL: I assume we should quit for
3 the day or should we continue?

4 Mr. Haueter?

5 MR. HAUETER: I think I need to go back and
6 start answering phone calls in my office, so --

7 (Laughter.)

8 CHAIRMAN HALL: Okay. Well, you'll have to
9 find out of Dr. Loeb authorized voice mail for the
10 office yet.

11 We will continue this Board of Inquiry in the
12 morning, beginning with Mr. Walter Walz, who is a
13 Customer Service Representative for Parker Hannifin,
14 followed by Mr. Tom McSweeney who is the Director of the
15 Aircraft Certification Service for the FAA, and then
16 continue as far as we can go.

17 We're scheduled, Mr. Haueter, to begin at
18 9:00 a.m., again?

19 I appreciate everyone has an interest in this
20 who's spending their time to be here. Again,

1 appreciate the witnesses that came forward to present
2 testimony today.

3 And with that, we will stand in recess until
4 9:00 o'clock tomorrow morning.

5 (Whereupon, the proceedings were adjourned at
6 7:35 p.m., to be reconvened on Thursday, November 16,
7 1995 at 9:00 a.m. in he same place.)

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