

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

In the matter of:

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

Pittsburgh Hilton and
Towers Hotel
Pittsburgh, Pennsylvania

Wednesday, January 25, 1995

The above-entitled matter came on for hearing
pursuant to notice, at 8:37 a.m.

BOARD OF INQUIRY:

Jim Hall, NTSB Chairman

William G. Laynor, Deputy Director,
Office of Aviation Safety

Ronald L. Schleede, Chief,
Major Investigations Division
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

TECHNICAL PANEL:

Mr. Thomas Haueter
Mr. Gregory Phillips
Ms. Cynthia Keegan
Mr. Charles Leonard
Mr. Thomas Jacky
Mr. Roff Sasser

STAFF:

Michael Benson. Office of Public Affairs

Daniel Campbell, Director,
Office of General Counsel

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

PARTIES TO THE HEARING:

Federal Aviation Administration
Department of Transportation
Mr. 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
Building 3-800.3, Bay A2
Seattle, Washington 98108

Boeing Commercial Airplane Group
Mr. Jean McGrew
7342 East Marginal Way, South
Building 3-800.3, Bary A2
Seattle, Washington 98108

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

PARTIES TO THE HEARING: (continued)

USAir, Inc.
Captain Gene Sharp
115 Commerce Drive
RIDC Parkridge 2
Pittsburgh, Pennsylvania 15275

International Association of Machinists and
Mr. Jack Wurzel
Aerospace Workers
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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P R O C E E D I N G S

2 (Time Noted: 8:37 a.m.)

3 CHAIRMAN JIM HALL: We will convene day three
4 of this hearing. I would like to call as our first
5 witness this morning, Mr. Paul Cline. Mr. Cline is a
6 hydraulics/flight control engineer on the Boeing 737,
7 with the Boeing Commercial Airplane Group in Seattle,
8 Washington.

9 Mr. Cline, if you could please come forward.

10 (Witness testimony continues on the next
11 page.)

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2 PAUL CLINE, B-737 HYDRAULICS/FLIGHT CONTROL ENGINEER,
3 BOEING COMMERCIAL AIRPLANE GROUP, SEATTLE,
4 WASHINGTON.

5
6 Whereupon,

7 PAUL CLINE,
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 CHAIRMAN HALL: Mr. Schleede, please begin.

12 MR. SCHLEEDE: Mr. Cline, please give us your
13 full name and business address for the record?

14 THE WITNESS: My name is Paul Cline.
15 Business address is Boeing Commercial Airplane Group,
16 P.O. Box 3707, Seattle, Washington.

17 MR. SCHLEEDE: What position do you hold at
18 Boeing?

19 THE WITNESS: I'm a flight control design
20 engineer.

21 MR. SCHLEEDE: How long have you worked for
22 Boeing?

23 THE WITNESS: Four and a half years.

24 MR. SCHLEEDE: Would you give us a brief

description of your education and background that
2 brings you to your position?

3 THE WITNESS: I have a BS in chemical
4 engineering from Montana State University. As I said,
5 I've been with Boeing for four and a half years working
6 in the Power Servos and Actuators Design Group.

7 MR. SCHLEEDE: I couldn't hear the last part.

8 THE WITNESS: Excuse me?

9 MR. SCHLEEDE: Say the last part you were
10 working with?

11 THE WITNESS: I've been at Boeing in the
12 capacity of the Power Servos and Actuators Design
13 Group.

14 MR. SCHLEEDE: Are you a designated
15 engineering representative for the FAA?

16 THE WITNESS: No, I am not.

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

19 MR. PHILLIPS: Good morning, Mr. Cline.

20 THE WITNESS: Good morning.

21 MR. PHILLIPS: In your position at Boeing in
22 the flight control mechanical systems area, what do you
23 generally do in your day-to-day duties?

24 THE WITNESS: I have the details design

responsibility for the power servos and actuators for
2 the 737 and 757 narrow body.

3 MR. PHILLIPS: So the main rudder power
4 control unit package that we've discussed in previous
5 testimony is an area of responsibility that you have?

6 THE WITNESS: Yes, it is.

7 MR. PHILLIPS: How long have you been
8 responsible for that package?

9 THE WITNESS: Four and a half years now.

10 MR. PHILLIPS: From the beginning of your
11 time at Boeing then?

12 THE WITNESS: Yes.

13 MR. PHILLIPS: What other similar packages do
14 you have design responsibility for that's used on the
15 737 aircraft?

16 THE WITNESS: On an elevator PCU, that's the
17 power control unit. Flights boiler PCU, 57's flight
18 boilers. I've had involvement at one time or another
19 with just all the primary axes for the 737 and the 757.

20 MR. PHILLIPS: Are all those manufacturers or
21 all those actuators manufactured by Parker?

22 THE WITNESS: No, they are not.

23 MR. PHILLIPS: In your day-to-day duties, are
24 you involved with reviewing in-service activities,

deficiency reports from operators?

2 THE WITNESS: Yes, I am. I'm occasionally or
3 actually quite often are contacted by our customer
4 service's engineering to help them with any issues any
5 airlines might be having with any of the components we
6 have responsibility for.

7 MR. PHILLIPS: Then you are involved in also
8 design improvements to rudder actuation systems in the
9 areas of responsibility that you hold?

10 THE WITNESS: That's true, yes.

11 MR. PHILLIPS: What has been your involvement
12 with the NTSB investigations in the Colorado Springs
13 accident and the Pittsburgh USAir accident?

14 THE WITNESS: For the Colorado Springs
15 accident, I didn't get involved until the summer of '92
16 when the NTSB took special interest in the main control
17 valve for the 737 rudder PCU. For the Pittsburgh
18 accident, I wasn't involved in any of the on-scene
19 work. However, I supported the systems group in just
20 about all of their investigation into the flight
21 control power servos and actuator component.

22 MR. PHILLIPS: In support of the
23 investigation, you've been directly involved in testing
24 that's been performed by the group?

THE WITNESS: Yes, I have.

2 MR. PHILLIPS: Yesterday we've heard
3 testimony from Mr. Turner about the general flight
4 control systems in the airplane. Today or this
5 morning, we would like to get more specific with the
6 rudder actuation system and, in particular, the main
7 rudder power control unit.

8 I would like to ask you to give us, first of
9 all, a brief summary of the PCU package, what it is,
10 how it operates, some of its design features. Then
11 we'll go into a little more detail into the compounds
12 after that.

13 THE WITNESS: I guess I would like to start
14 with an exhibit then. Please put up exhibit 9-AH, page
15 1. Can I have 9-AH instead of 9T?

16 CHAIRMAN HALL: Nine A-H?

17 THE WITNESS: Yes. That's the correct one up
18 there now.

19 (Slide shown.)

20 THE WITNESS: This is an isometric view of
21 the rudder PCU linkage. The manifold and its
22 associated caps and plugs and filters have been
23 stripped away for simplicity. Also, the things that we
24 will be talking about later on in this testimony are

kind of labeled here just to give everybody an idea of
2 what we're talking about. But as discussed in earlier
3 testimony, this is a dual load path component.

4 If you look at all these linkages, they all
5 have two load bearing members. For example, if you
6 look at the input crank, you can see one crank stacked
7 on top of the other. The normal operation, they are
8 both operating in carrying the load.

9 If one fails for any reason, the second piece
10 of structure -- in this case, the crank -- is there to
11 carry the load. That follows all the way from the
12 input point on the PCU all the way into the dual
13 concentric servo valve.

14 MR. PHILLIPS: Could I just in there for one
15 second? The purpose of the dual load path is what?

16 THE WITNESS: Just for redundancy. For
17 failure mode protection.

18 MR. PHILLIPS: So that if one part of the
19 valve would fail and would not be able to carry the
20 load, the other part would take its place?

21 THE WITNESS: Of the PCU linkages, yes.
22 That's true.

23 MR. PHILLIPS: It is sized and rated to carry
24 the full load of the package?

THE WITNESS: Each single load path is
2 carried for a full load of the package, yes.

3 Continuing on, there's really two methods that this
4 package can receive inputs.

5 One of them is directly from the pilot
6 through the pedals and the cables to the aft quadrant.
7 It eventually ends up at what's called the pilot input
8 point on this exhibit. That would really kind of be
9 considered a manual command. That command would be
10 transferred through the H link and through the input
11 crank into the internal summing levers and finally to
12 the dual concentric servo valves.

13 At which point, the servo valve would then
14 command the main piston to move, the main system would
15 move and resolve that command into some position of the
16 surface.

17 The other method for this package to receive
18 an input is through the yaw damper actuator. Commands
19 for the yaw damper actuator are originated at the yaw
20 damper coupler as electrical commands that go to the
21 PCU directly to the electro-hydraulic servo valve on
22 the PCU, which is not shown here, which eventually
23 commands the yaw damper actuator to move.

24 That yaw damper actuator then moves the

internal summing levers, which again move the slides of
2 the dual concentric servo valve, which command the
3 piston to move, and again resolve a position of the
4 surface.

5 We have a video that we can show that kind of
6 helps illustrate the operation of this unit a little
7 better.

8 MR. PHILLIPS: Before we get into the video,
9 I just had a couple of questions. The pilot input
10 connection point and the yaw damper actuator are the
11 only two -- or are they the only two inputs to the
12 package to move the rudder?

13 THE WITNESS: Yes, they are.

14 MR. PHILLIPS: How much does the pilot input
15 linkage move on the normal input or what's its range of
16 travel?

17 THE WITNESS: The linkage itself moves about
18 plus or minus two inches from the position shown there,
19 which can result in plus or minus 26 degrees of the
20 rudder surface on the ground. In other words, when
21 there's no load on the rudder, the yaw damper or the
22 yaw damper actuator can only command, in this case,
23 three degrees of rudder.

24 MR. PHILLIPS: Approximately how much does

that yaw damper or mode piston actuator move?

2 THE WITNESS: The piston or the actuator
3 itself moves plus or minus .225 inches.

4 MR. PHILLIPS: So less than one quarter of an
5 inch, .225?

6 THE WITNESS: Yes.

7 MR. PHILLIPS: This motion is translated
8 through the summing levers into a motion in the dual
9 concentric servo valve. How much does the dual
10 concentric servo valve move to make a rudder command?

11 THE WITNESS: The movement of the dual
12 concentric servo valve is dependent upon the rate of
13 the command. But the maxed displacement of the servo
14 slides would be forty-five thousandth for the primary
15 slide, an additional forty-five thousandth of effective
16 stroke for the secondary slide, plus another eighteen
17 thousandth of non-effective stroke. That gives us a
18 total of just over a tenth of an inch total stroke of
19 the valve.

20 MR. PHILLIPS: So from the two inch input
21 that comes through the rudder cables, it would be
22 resolved into a tenth of an inch input to control the
23 valve. Is that correct?

24 THE WITNESS: The command of the pilot input

is really in the form of a position which gets
2 translated into a rate command by the time it gets to
3 the servo. But, yes, a full displacement of the pilot
4 input is about two inches, and a full displacement of
5 the servo valve is just over a tenth of an inch.

6 MR. PHILLIPS: We heard in earlier testimony
7 that the pilot's rudder pedals move approximately four
8 inches?

9 THE WITNESS: That's plus or minus four
10 inches, yes.

11 MR. PHILLIPS: Plus or minus four inches.
12 Would you go ahead and describe your video, if you're
13 ready to carry on there?

14 THE WITNESS: Before we show the video, I
15 guess I should describe what we're going to see. We
16 adapted this from a computer platform. It was somewhat
17 interactive on the computer. So it does come across a
18 little bit not quite exactly as it would on film, just
19 because you lose some of that inter-activeness.

20 So what we did is we showed the different
21 operation modes of the PCU. They will repeat a couple
22 of times just so you can get an idea of how it works.
23 The first thing that will be shown is what would happen
24 from a pilot input. It will cycle through that a

couple of times.

2 It will then show a yaw damper input. What's
3 labeled here as the yaw damper actuator, you will see
4 the outer portion of that dissolve away so that we can
5 see the inside of the piston and we can see it move. I
6 will be able to describe what limits its stroke at that
7 point.

8 From there, we will go to the function of the
9 walking beam. We'll actually see how that operates.
10 We will probably explain later what the purpose of that
11 walking beam is, but at least we'll see it now.

12 I would like to point out before we show the
13 video, though, that in transferring it from the
14 computer format to the video format, there was an error
15 that was created. I will try to point that out in the
16 first part of the video. So everybody can keep that in
17 mind.

18 MR. PHILLIPS: Along those lines, is the
19 model we're going to look at is it to scale? Are there
20 any distortions of size or scale?

21 THE WITNESS: No, there are no distortions.
22 Everything is to accurate engineering scale. It was
23 generated using our engineering CAD system, which we
24 call CATIA. However, when we put it in video format,

we did apply some perspective to it to make it look
2 more three dimensional. So that effect will be
3 somewhat evident. But it's accurate in its
4 representation of size.

5 MR. PHILLIPS: Is its orientation in the
6 video the same orientation as it is in the airplane?

7 THE WITNESS: Yes, it is. I think the video
8 will be pretty self-explanatory in getting this from
9 the airplane into the PCU in its location.

10 MR. PHILLIPS: Whenever you're ready.

11 THE WITNESS: If we can show that now.

12 MR. PHILLIPS: Can we get the lights dimmed,
13 please, and in the audience as well?

14 (Video shown.)

15 THE WITNESS: As I mentioned, this is the
16 portion of the video that kind of orients us to the
17 detail of the airplane and the rudder surface. That is
18 the surface moving there. What is shown is accurate in
19 its 26 degrees of deflection, either side of neutral.

20 The rest of the video will be shown from
21 roughly this position of the camera. This is the pilot
22 input that I was talking about. This is some of the
23 inter-activeness. I think I'm going to just let this
24 run by and we'll get to a clean cycle here where we

won't see this fading in and out.

2 The portion I wanted to point out that's
3 slightly inaccurate is in this area right here. That
4 should not be moving at this point in time. Right now
5 when it's moving, that point should be fixed.
6 Everything at this end is accurate, however.

7 As I mentioned earlier, this is the pilot
8 input. What's shown here is if you were to pick center
9 about there, from here to here is about two inches. If
10 you watch carefully, you can see that when the pilot
11 commands, you get a command created in the servo.

12 We're rooming up on that area now. This is
13 really a command in there. When everything nulls out,
14 at that point in time, you can see that the piston
15 stops. NOW, there was a command again and the piston
16 took off. It's just simply cycling at this point in
17 time.

18 Again, we're still on the pilot input. I
19 think the next one we'll see will be a north graphic
20 view of the pilot input, which looks more two
21 dimensional. Again, this area up here, these two
22 pieces should not be moving at this point. That should
23 be more of a fixed point there.

24 If you watch carefully, you can see when an

input is created right now, you can see a command
2 created up here, which then gets resolved by the
3 piston. Now we're at the point of resolve.

4 I think in the next sequence, we'll see a
5 zoom of this area. This is what you might hear
6 testimony later on that refers to external servo stops.
7 This is the summing lever here. You can see how it
8 contacts the external servo stops. That's some of the
9 control.

10 You can also see very well in this one the
11 relative motion between the primary slide and the
12 secondary slide. There is the relative motion there.
13 I think the next sequence we're going to go into will
14 be the yaw damper operation.

15 If you notice the output of the piston, it
16 will be much smaller. It's a three-degree limit. This
17 is the yaw damper piston here that's cycling between
18 the yaw damper en-cap and the ODT diaphragm. Those two
19 pieces control just exactly how far that piston can
20 stroke. As I mentioned earlier, it's about plus or
21 minus .225 inches.

22 This is a close up of the same thing. We're
23 not showing any control valve command in this just to
24 make it simpler to visualize.

1 This is the walking beam function that I
2 mentioned earlier. This vertical piece here really has
3 the ability to -- what we call to break to kind of
4 displace itself. It's really to protect the internal
5 components of the PCU. We will show a close up of
6 that. It will be a little more explanatory.

7 This is the walking beam here. There's a CAM
8 and spring arrangement in this area. As it breaks, the
9 CAM compresses the spring and provides us with our
10 walking beam break out force.

11 I think that's all we have.

12 MR. PHILLIPS: This engineering model
13 simulation was created by Boeing for use in the
14 investigation and also further studies we may be doing.
15 Could you give us an estimate of how much time was
16 required to created that video simulation and who was
17 involved in that?

18 THE WITNESS: It takes much more time than
19 you would expect. It starts by me sitting down at one
20 our computer rated design terminals, which again is
21 called "CATIA," and actually created each one of these
22 pieces. At that point, some kinematic laws are written
23 so the computer can understand how the pieces should
24 move, what controls the movement of the pieces.

We make what's called "key frames" for each
2 one of these positions. From there's, it's dumped over
3 to our media department, which takes these key frames
4 and generates many, many in between positions. The
5 film you were looking at was 30 frames a second.
6 That's what gives it a very smooth look.

7 For each frame, we have to render that, which
8 gives it the 3-D solid type look. Then we have to
9 convert that to video. In the past three weeks, I
10 think we've had several graphic computers running full
11 time, 24 hours a day to get that accomplish. That
12 doesn't include any of the time that was originally put
13 into generating the CATIA data set.

14 I actually started generating that data set
15 when I joined the company, which was back in 1990.

16 MR. PHILLIPS: Has this tool been used in
17 visualizing any other accident scenarios or has it been
18 applied to an accident investigation in your knowledge
19 in the past?

20 THE WITNESS: Not to my knowledge, but I'm
21 sure in one way or another, it's been applied.

22 MR. PHILLIPS: So its basic function within
23 the company normally is for design purposes?

24 THE WITNESS: The CATIA software, yes. Its

basic function is for design. However, the graphics
2 group is really out of our maintenance training group,
3 which we use for training the operators.

4 MR. PHILLIPS: So if this model was created
5 with engineering drawings and controlled by engineering
6 staff, if there was a defect or something that didn't
7 work right, it would become apparent in this model for
8 the first time or could it be used for that?

9 THE WITNESS: Well, this is the first time
10 that that model has been presented in the format as
11 visually pleasing as that. On CATIA itself, the
12 kinematics and the operation of the PCU in much more
13 dry, less pleasing engineering terms has been worked
14 out many times over.

15 MR. PHILLIPS: When the original drawings
16 were done for this unit, they were done on traditional
17 ink and paper or regular drawing systems?

18 THE WITNESS: Excuse me?

19 MR. PHILLIPS: There wasn't any computer
20 modeling done at the time the package was originally
21 designed in the '60s?

22 THE WITNESS: No, when this package was
23 originally designed, it was all done on paper, hand
24 calculations. It's the same thing we would do on the

computer, just much more labor intensive.

2 MR. PHILLIPS: Turning now into your
3 experiences in the investigations of the Colorado
4 Springs and the USAir 427 accidents. I would like to
5 start with the Colorado Springs accident. When did you
6 become first involved in the investigation of the
7 rudder system for that accident?

8 THE WITNESS: I became first involved with a
9 United pilot squawked an airplane during a flight
10 control's check. He squawked the rudder system. The
11 United mechanics removed the rudder PCU, the main
12 rudder PCU. During their testing of that unit, they
13 uncovered a condition where the PCU wouldn't
14 necessarily respond correctly to its input.

15 Myself and the Parker Hannifin Corporation
16 were notified. With United engineers, Boeing engineers
17 and Parker engineers, we all convened at the Parker CFO
18 facility in Irvine, California, to again perform the
19 same type of testing that the United mechanics had
20 done.

21 We were able to duplicate their effort and
22 realize we had uncovered some operational modes within
23 the dual servo that we weren't aware of before. I
24 think at that point in time, the NTSB was notified.

They became involved. Because of the accident
2 investigation on Colorado Springs, there was kind of
3 some open rudder issues.

4 When they became involved, they brought along
5 the dual concentric servo from the Colorado Springs
6 airplane. We went through the same sort of testing
7 scenarios with that as we had with the original United.

8 MR. PHILLIPS: Could you briefly describe the
9 event with the United airplane that led to your
10 involvement? You said that during some -- there was a
11 pilot squawk that initiated the removal or the testing
12 of the PCU and the removal. Do you recall exactly what
13 that fault was?

14 THE WITNESS: I don't recall the exact words,
15 but it was to the point that when the pilot performed
16 the control's check, what he called as the rudder
17 stalled or hung up. In other words, he couldn't move
18 his pedals. I think he said they stopped at about 25
19 percent of rudder travel.

20 When the United mechanics removed it from the
21 airplane and put it on their test bench, they were
22 testing it per the Boeing overhaul manual. When they
23 came to a test called the "force versus input linkage"
24 -- I'm sorry -- the "force versus input displacement

test," they put the PCU in the test fixture for that
2 test, started to perform the test and the PCU actually
3 went the wrong direction. And what the test intended
4 and it damaged part of their test fixture, that's when
5 they notified Boeing and we got involved.

6 MR. PHILLIPS: The pilot found this fault on
7 the airplane while he was taxiing out before he got into
8 the air?

9 THE WITNESS: Yes, he did. He found it as
10 part of his normal pre-flight control's check.

11 MR. PHILLIPS: This was the first time in
12 your knowledge that any such fault had ever been
13 reported to Boeing?

14 THE WITNESS: Any fault of this nature, yes.

15 MR. PHILLIPS: Of that nature. As a result
16 of the motion that wasn't expected in the test, what
17 did you do then?

18 THE WITNESS: That's when the PCU was taken
19 to Parker Hannifin and we duplicated the results of the
20 test at Parker Hannifin. We didn't destroy any test
21 fixture because we were kind of aware of what was going
22 to happen. But it took us several weeks to figure out
23 exactly what was happening and why it was happening,
24 but it turns out that the summing levers -- maybe we

could put the 9-AH exhibit back up, sheet one.

2 (Slide shown.)

3 THE WITNESS: It turns out that the summing
4 levers in this area -- on that particular airplane,
5 there was a secondary summing lever, which is this
6 lower one -- had an incorrect mismachined chamfer near
7 the external servo stop, which is this area here just
8 on the other underside. Instead of the lever stopping
9 against that face, it could tend to slip past it and
10 cause the secondary to stroke farther than it was
11 really intended to for normal operation.

12 When it did that, it took the secondary into
13 what we call an over-stroking region. The control
14 passages at that point begin to flow in a way that we
15 didn't intend and we can end up with some residual
16 pressures that under certain conditions can actually
17 reverse the rudder PCU.

18 MR. PHILLIPS: So then the result of a pilot
19 input to that particular package would be a motion of
20 the rudder opposite the intended direction?

21 THE WITNESS: On the particular unit that
22 United had found, on the airplane when the pilot moved
23 the rudder pedals, he wasn't stroking the secondary far
24 enough to cause a reversal, but he was causing some

1 very low residual pressures, some very, very hinge
2 moment of the rudder PCU and he was just physically
3 unable to move the rudder surface. That's why he felt
4 the pedals kind of what you would call the stall or
5 lock up.

6 MR. PHILLIPS: Would that have only occurred
7 in one direction of rudder movement?

8 THE WITNESS: On that particular PCU, yes.
9 It's feasible it could happen in both directions. Most
10 of the units we've looked at, if they do it at all,
11 only do it in one direction.

12 MR. PHILLIPS: You've used the word residual
13 pressure and hinge moment. Maybe it would be a good
14 place here to stop and define residual pressure in
15 layman's terms and also what a hinge moment is?

16 THE WITNESS: Let me start first with hinge
17 moment. I think in earlier testimony, the words that
18 were used were torque. It's really the force that the
19 PCU applies to the surface to cause the surface to
20 deflect. We refer to that as hinge moment.

21 Residual pressure is just simply -- it takes
22 a differential pressure across the piston to create a
23 force, to create the hinge moment. Residual pressure
24 is simply a major of the effective pressure that

remains to the piston. So really it's a measure of the
2 effect of the rudder hinge moment.

3 Usually when we say residual pressure, we're
4 usually talking something that's not what we want it to
5 be at that point in time. So it's something less than
6 what we hoped it to be.

7 MR. PHILLIPS: So if we said something like
8 "leftover," would that be the same as residual?

9 THE WITNESS: Yes, that's another way to say
10 that.

11 MR. PHILLIPS: As a result of the findings of
12 the testing and the motion of the rudder opposite of
13 the command, what was done to correct that problem?

14 THE WITNESS: The servo valve really contains
15 two sets of stops. The one set I've mentioned already
16 is the external servo stops. It also has stops
17 internal to the servo, which can't be seen here but
18 they would be inside the servo at this end.

19 Anytime you stroke past the external servo
20 stops, then you're relying on the internal stops to
21 control the stroke of the slides. Those internal stops
22 were simply set too far and under certain conditions,
23 they allowed the slides to stroke too far.

24 So the design change was really just to

1 modify the tolerances to more accurately control the
2 location of the internal stops, which in turn control
3 the stroke of the secondary slide. We kept the
4 residual pressures and everything where we wanted them
5 by doing that.

6 MR. PHILLIPS: so after 20 years -- 20 some
7 odd years of operation, this was something that was
8 first discovered?

9 THE WITNESS: Yes, that's true. It takes a
10 very specific set of circumstances to over stroke the
11 secondary. Under normal operation, everything would
12 work perfectly fine and you would never run across
13 this. It takes something such as a mismachined chamfer
14 or a jam within the servo to cause that.

15 Those two events are so rare that it took
16 that amount of time for us to really discover the
17 situation we had.

18 MR. PHILLIPS: So would it be safe to say in
19 the 20 years of operation of this fleet of airplanes,
20 with this package and no significant changes, it just
21 appeared one day because of the circumstances that came
22 together?

23 THE WITNESS: Yes, it became evident.

24 MR. PHILLIPS: At the time of this event, was

there any testing, in your opinion, that would have or
2 should have detected this position or this condition?

3 THE WITNESS: I'm not sure what you're asking
4 me. You're asking if there was any testing that was in
5 existence that should have?

6 MR. PHILLIPS: At the time of the event and
7 preceding the event, were there any tests at the
8 manufacturers level or in the operation of the airplane
9 that would have detected this event before it happened?

10 THE WITNESS: Yes, there were two tests that
11 really would detect this event. One is at the
12 manufacturing level, also at the overhaul level of the
13 PCU. That's the test I referred to earlier called the
14 force versus input travel or input displacement test.
15 That really strokes the valve to its fullest position.
16 Measures the force while it's doing that.

17 If at that point in time there's anything
18 wrong with the valve or the conditions exist to cause
19 over stroking, it would become evident. Also at the
20 airplane level, the pre-flight control's check, any
21 time the pilot moves the pedals to their full range
22 freedom of motion, he accomplishes the same thing.
23 That's really what happened with the United pilot
24 discovered this on the control's check.

2 There was a case where the secondary slide
wouldn't necessarily -- I always go beyond the external
3 stop. Sometimes it engaged normally and sometimes it
4 could slip past. It really took a situation where the
5 yaw damper actuator and the pilot input had to be at
6 the right place at the right time. That's what he
7 accomplished when he did his control check.

8 MR. PHILLIPS: So that day when the United
9 pilot did his control's check and discovered this, that
10 was the beginning of the first indication we had ever
11 had that this could exist?

12 THE WITNESS: Yes, that's true.

13 MR. PHILLIPS: There's been changes made in
14 the design to keep that from happening again?

15 THE WITNESS: Yes, there's been changes made
16 in the design and changes made in the testing as well.
17 We know, as I mentioned earlier, the PCU that came off
18 of the United airplane was somewhat intermittent. So
19 the pre-flight control's check on a daily basis, at
20 that point, was the best check for that.

21 We've now modified the overhaul and
22 acceptance test procedures for this rudder PCU. so now
23 we can purposely stroke the secondary to its internal
24 limits and monitor the output of the PCU while we're

doing that. That, without a doubt, will check for this
2 condition.

3 MR. PHILLIPS: When did you routinely begin
4 those tests?

5 THE WITNESS: They routinely began somewhere
6 early '93, I believe, January of '93.

7 MR. PHILLIPS: So all units that have been
8 manufactured have been returned for service to Parker,
9 then have gone through that test?

10 THE WITNESS: Since January of '93, yes.

11 MR. PHILLIPS: Since January of '93. Do you
12 recall whether the Colorado Springs actuator or package
13 had been tested for this condition?

14 THE WITNESS: Yes, it had been tested for
15 this condition. I might have failed to mention earlier
16 that this condition doesn't really exist on all dual
17 concentric servos. It's really a matter of tolerances.
18 When you take many parts and stack them together, your
19 final dimension is not necessarily going to be the same
20 every time you do that.

21 So some units we'll stack up and they can
22 never have a problem. Other units or tolerance stack
23 up might be such that under the right conditions we
24 could over stroke the secondary.

When we tested the unit from Colorado Springs, it happened to be one of the units that the stack up was correct. It could not at any point have been a unit that caused any sort of reversal or lock up of the PCU because of secondary over stroking.

MR. PHILLIPS: So in your opinion, based on the testing and your observations of the Colorado Springs accident, that unit was not capable of reversing?

THE WITNESS: That's true.

MR. PHILLIPS: The testing that began in '93 to uncover this condition, have there been any other reports of reversals or loss of control or binding in systems that you're aware of?

THE WITNESS: Since January of '93, since we've implemented the new design tolerances and the new test procedures, there hasn't been any that I'm aware of at all.

MR. PHILLIPS: I believe the FAA issued an airworthiness directive to require the changes you're talking about?

THE WITNESS: Yes, they did.

MR. PHILLIPS: Could you briefly describe -- we'll have later testimony concerning that, but in your

view, could you briefly describe what that accomplishes
2 and what kind of time frame that we'd expect to see the
3 737 fleet modified in?

4 THE WITNESS: The AD that the FAA wrote
5 requires that all 737 operators update the dual
6 concentric servo valve within the rudder PCU. To
7 update them, that unit is sent to the supplier who test
8 the unit to determine exactly what its operational
9 characteristics are.

10 From that test, they can then determine how
11 to modify the internal stops to make it operate
12 correctly all of the time, if they need to. It's given
13 a new part number at that point in time. Then it can
14 go back into service.

15 The FAA has given the operators five years
16 from I believe it's March of '93 to accomplish that.
17 That date may not be exactly correct. The five years
18 is correct. I'm not sure at what point in time the
19 five years started though.

20 MR. PHILLIPS: Do you have any indication
21 what that five year time period was based on and what
22 went into the decision to say five years rather than
23 three years or two years?

24 THE WITNESS: There's a lot of things that go

into that decision. Many I'm probably not aware of.
2 But it's based on the ability for the airlines to
3 accomplish, to fix, as well as maintaining the safety
4 of the fleet while they're accomplishing the fix. The
5 FAA would be better to answer that question.

6 MR. PHILLIPS: We'll ask them in later
7 testimony. Is there any guarantee that this condition
8 would be found on an airplane that hasn't been
9 modified? Is there any test that the pilots do, the
10 pre-flight control's check, would that be adequate to
11 find the fault that we've discussed here?

12 THE WITNESS: In most cases -- well, probably
13 all cases, the pre-flight control's check is adequate.
14 However, we also developed what we called an on-wing
15 check. A check that you can accomplish on the
16 airplane. The FAA has mandated that that check be
17 performed at 750 hour intervals until the PCU is
18 modified -- or I'm sorry, the servo is modified. That
19 check just tends to add to the confidence and verify
20 the results of the pre-flight control's checks that the
21 pilots are performing every day.

22 MR. PHILLIPS: Do you know whether the PCU
23 that was installed in USAir 427 had been modified with
24 this change?

THE WITNESS: No, it had not.

2 MR. PHILLIPS: It had not. Are you aware of
3 whether the checks had been performed by USAir to
4 verify that it was functioning correctly?

5 THE WITNESS: I think the checks had been
6 performed, yes, correctly.

7 MR. PHILLIPS: We'll have some USAir
8 testimony later on. We'll ask that question again. In
9 your observations of the USAir 427 accident, could you
10 briefly describe your participation with the systems
11 group investigation, the sequence of events that we
12 followed and give us a general discussion of that?

13 THE WITNESS: Yes, I can. I wasn't involved
14 in the on-scene work, but I was first contacted by
15 Steve Weik of Parker Hannifin to consult in the removal
16 of the rudder PCU, the main rudder PCU at the accident
17 scene. Steve was at the scene.

18 During my discussion with him, we decided
19 that we wanted to try to get the PCU into a laboratory
20 environment as undisturbed as possible from the
21 accident scene. To do that, we realized that if we
22 shimmed the input crank relative to the manifold, we
23 could really kind of freeze the position of the PCU and
24 its internal component for shipment. That was

accomplished on-scene.

2 During the removal, I actually had to cut
3 away some of the structure to make it easier to remove
4 the PCU without disturbing it. That PCU was removed
5 and shimmed and sent to a lab environment. The first
6 place it went to was the equipment quality analysis lab
7 at the Boeing facility.

8 In the EQA lab, the first thing we
9 accomplished was to video document everything we could
10 externally on the PCU. What the commission of it was,
11 were all lock wires intact, were all the caps and bolts
12 and nuts bottomed? That type of thing.

13 We also x-rayed the PCU at that point in time
14 to look inside to see if we could see large foreign
15 objects or if we could see anything in a position that
16 it shouldn't have been in or basically just to document
17 what we could see inside the PCU before we ever tested
18 it.

19 From there, the PCU was taken to the Parker
20 Hannifin facility. They really have much better test
21 facilities for testing the PCU. It would have been
22 possible to do it at Boeing, but it would just take
23 much set up and we didn't really have the time or the
24 place to do that.

While it was at the manufacturer's facility,
2 in order to prepare the PCU for testing, we had to
3 remove the existing piston external summing lever and H
4 link because they were damaged, they were bent during
5 the accident. During the removal or replacement of
6 those components, we took some fluid samples. I think
7 I have an exhibit we can look at to really determine
8 where the samples were taken from.

9 If you could put up Exhibit 19, please.

10 (Slide shown.)

11 THE WITNESS: There's really four places of
12 interest that are labeled on this exhibit. Starting
13 from the left side of that exhibit, you can't see all
14 of it, but it says A system pressure filter. We remove
15 the cap from that filter and took a fluid sample from
16 around that filter.

17 Although this is a schematic, it does show
18 kind of an accurate representation of the cap and the
19 filter. So you can just imagine unscrewing the cap
20 around the filter and then pouring the fluid out of
21 that cavity while we were holding the filter in place.
22 We did not want to disturb anything by removing the
23 filter. So we held it in place while we poured the
24 fluid out of there.

1 I would like to mention that the flow of the
2 hydraulic fluid through that filter is from outside to
3 inside. So that when you're pouring the fluid away
4 from the outside of the filter, you're really getting
5 the dirty side of the fluid. You're pouring out
6 everything that the filter had trapped there.

7 We did that at the A system pressure filter.
8 We did that at the B system pressure filter, which is
9 on the right-hand side of the exhibit. We did that at
10 the yaw damper filter, which is just above the B system
11 pressure filter.

12 One of the last places we did that was in an
13 area we call the link cavity, labeled kind of in the
14 upper center of the exhibit. That's a cavity that the
15 linkage as we saw in the video are inside that cavity.
16 So it's a fairly large cavity. It did have a
17 significant volume of fluid in it.

18 I would like to point out, too, that that is
19 -- as fluid flows through the component, that is the
20 last place it is before it leaves the component. So
21 that link cavity is really downstream of everything
22 else in the PCU, including the dual concentric servo
23 valve.

24 Moving on in the testing we accomplished at

Parker, after we obtained samples and put the new
2 components on it, we performed what we call the top
3 assembly acceptance test procedure. We did that per
4 the instructions in the Boeing overhaul manual.

5 The PCU passed all tests except for one.
6 That would be test number five, which measures some
7 input force levels. It turned out that the plot we
8 accomplished during that clipped one of the corners of
9 the limits. It's really a judgment call as to whether
10 it failed that test or not.

11 I think if you ran that test more than once,
12 you would probably pass sometimes and not pass other
13 times. It was borderline. But in any case, it
14 wouldn't really affect the operation of the PCU.

15 From that point, we then went to the
16 component level to check the dual concentric servo
17 valve. To do this, you have to remove the PCU from the
18 servo. When you remove the PCU -- I'm sorry. You have
19 to remove the servo valve from the PCU. When you
20 remove it, you have to partially disassemble the PCU
21 and the servo itself.

22 So while we did that disassembly, we were
23 examining parts, looking for any sort of foreign object
24 or debris or damage that might be in there on both the

PCU and the servo. We found no damage, no debris,
2 nothing that would really key us into any sort of
3 problem the PCU would have or the servo.

4 We then took the servo and put it on a
5 different test fixture and tested it for another set of
6 requirements, which we call "component level
7 requirements." They are also contained with the Boeing
8 overhaul manual. That servo again passed all
9 acceptance tests, except for two. One was the full
10 scale flow test on the B system. The other was a
11 primary slide friction test.

12 The primary slide friction test was .5 ounces
13 too high. It has an upper limit of 12 ounces. We
14 measured it at 12.5 ounces, which is really
15 insignificant.

16 MR. PHILLIPS: That's the amount of force it
17 takes to move the primary slide?

18 THE WITNESS: Yes, it is.

19 MR. PHILLIPS: Let me jump in here. You've
20 said "we" a lot and you're referring to a lot of
21 testing. Can you tell me who was directing the testing
22 and were the test plans and control of the testing came
23 from?

24 THE WITNESS: All the testing was directed by

1 the NTSB. The test plans and the direction of the
2 testing was coordinated and agreed upon within the
3 systems group. So at this point we've tested the PCU's
4 assembly and the servo as a component. I would like to
5 show Exhibit 9-A, page 52.

6 MR. PHILLIPS: I would like to note that I
7 believe you've got an over-qualified view graph turner
8 over there.

9 THE WITNESS: It would could slide it up.
10 I'm only really interested in the bottom portion of
11 that.

12 (Slide shown.)

13 THE WITNESS: These are the conclusions that
14 after this phase of testing, the systems group sat down
15 and we said, okay, what do we know at this point? This
16 was actually written in the field notes. I guess I
17 would kind of like to read it just because it's easy to
18 do.

19 Number one, "Testing and examination
20 conducted on the rudder PCU validated that the unit is
21 capable of performing its intended functions as
22 specified by the Boeing Commercial Airplane Group."
23 Number two, "Testing validated that the unit was
24 incapable of uncommanded rudder reversal." Number

three, "The yaw damper system components of the unit
2 functioned normally and the yaw deflection limit of
3 plus or minus three degrees was verified."

4 That test was kind of a test that it
5 generated some interest within the systems group. So
6 we kind of devised a special test to verify that the
7 yaw damper really did only go to three degrees and its
8 rate limit was the 50 degrees per second as the design
9 specified.

10 The subcomponent performance variations noted
11 during testing did not affect the overall PCU function.
12 That really says that the full-scale flow gain and the
13 primary slide friction really don't affect the PCU
14 operation to a detectable level.

15 BY MR. PHILLIPS:

16 MR. PHILLIPS: So these conclusions written
17 by the NTSB systems group summarize that the testing,
18 although there were some anomalies noted, it did
19 indicate that the belief of the group was that the unit
20 did what it was supposed to do?

21 THE WITNESS: Yes, that's true. We really
22 spent the next three months performing a lot of
23 different types of testings and examinations that
24 really only further validated those conclusions. I

think this was probably the best work we did. We just
2 didn't realize it at that point in time.

3 MR. PHILLIPS: You bring up the point that
4 additional testing occurred after the initial
5 observations. Could you go into those tests?

6 THE WITNESS: Yes, I can. I mentioned that
7 we had removed the fluid samples from the PCU. What I
8 didn't mention is that when we sent those fluid samples
9 to the Monsanto Corporation, we got the results back.
10 The particulate count, although you would expect it to
11 be high on the filter samples because we did collect
12 fluid from the dirty side of the filters, it was also
13 high in the link cavity.

14 When I say high, I mean Monsanto uses the
15 Boeing NAS 1638 Class 9 delivery requirement as kind of
16 their baseline for what they consider to be high or
17 not. We exceeded class 9. I think in the link cavity,
18 it was class 12. So that generated some interest about
19 what these particles with this particulate
20 contamination could really do to the operation of the
21 PCU.

22 Specifically it generated some questions
23 about how the control valves, the dual concentric
24 control valve, would react to certain types of

particulates. That really caused us to do two types of
2 testing and a lot of examination. Well, first of all,
3 let me mention the two types of testing. We can
4 discuss those later.

5 One of the tests we performed was called the
6 chip shear test where we actually put particulates in
7 the servo valve to shear those pieces to see, number
8 one, what kind of force it would take to shear them.
9 And, number two, what kind of evidence or damage does
10 it do to the servo valve itself.

11 MR. PHILLIPS: Let me jump in there. Are you
12 really trying to shear chips or are you trying to
13 detect the presence of the jam as a result of the chip
14 or both?

15 THE WITNESS: Both is a better answer.
16 That's an option.

17 MR. PHILLIPS: When were those tests
18 conducted?

19 THE WITNESS: The chip shear test itself was
20 conducted, I think the second week of January '95.
21 That, again, was done at the Boeing equipment quality
22 analysis lab under the direction of the NTSB with the
23 entire systems group involved.

24 MR. PHILLIPS: Are you going to describe the

results of that testing?

2 THE WITNESS: Yes, would you like me to do
3 that?

4 MR. PHILLIPS: If you would?

5 THE WITNESS: We selected several materials
6 to shear. I think approximately ten materials. Most
7 of those or all of those materials are represented
8 within the make up of the PCU itself. If I were to
9 read some of the examples of materials we subjected the
10 valve to, it would be EPR rubber, which is the rubber
11 O-rings. It's made out of teflon. That's what the
12 back ups and seals in the component are made out of.
13 We used some 302 stainless. Some music wire, which is
14 a very hard wire. Some 20 and 24 aluminum. Some 52-
15 100 aluminum ricobronze chrome. Some 43-40 stainless.

16 What we really found was that we could shear
17 everything we put in the valve except for one piece,
18 and that was a piece of 52-100. Fifty-two one hundred
19 is a very hard material. But what we found was that
20 the soft materials we could shear very easily, have
21 very low force levels. In one case, we were just over
22 a pound.

23 Materials like the music wire and the
24 stainless, we sheared those between anywhere from 20 to

37 pounds. But what we really found out was that at
2 about 20 pounds of force, if there's anything in the
3 valve that causes the valve or tries to stick the valve
4 with at least 20 pounds of force or more, it does
5 damage to the valve. It breaks the edge of the lands.
6 It kind of smears the edge of the valve a little bit.
7 It creates very visual evidence. Something that you
8 can see at 25 times magnification very easily.

9 MR. PHILLIPS: Could I jump in here? The
10 selection of materials that you used for the -- that we
11 used for the chip shear test, what was the basis for
12 using 52-100 teflon and those materials?

13 THE WITNESS: Part of the was the types of
14 particulates we have found in the fluid samples. Also
15 the types of materials that are used within the PCU and
16 the control valve. The 52-100 that you mentioned is
17 what the sleeves or the wafers, as we call them, of the
18 control valve are made out of. So we just use
19 materials that were represented in the PCU itself.

20 MR. PHILLIPS: The particle size of the chips
21 that were used in the shear test, did that represent
22 the size of any chip that was found in the fluid
23 samples?

24 THE WITNESS: No, that's a good point. What

1 was found in the fluid samples ranged between a five
2 and 100 micron. A hundred micron is almost four
3 thousandth of an inch. Some of the pieces we used were
4 fifteen thousandths by forty thousandths. We used
5 pieces that were many, many, many times greater than
6 any particulate we found in the fluid samples.

7 Number one, it's very difficult to take a
8 five micron particle and even control the placement of
9 it. Number two, the -- number two actually slipped my
10 mind.

11 MR. PHILLIPS: Well, one was good enough, I
12 guess. After the chip shear tests were done, was there
13 any additional tests done or review of the USAir 427
14 components in regards to that test?

15 THE WITNESS: Yes. Like I said earlier, we
16 realized that at 20 pounds, it created a lot of damage.
17 Most of the damage we created was on the very edge of
18 the lands or the slides. However, when we put the
19 piece of 52-100 there, that's the one piece that we did
20 not shear at the force levels we tested at.

21 We did not create any damage on the very edge
22 of the land or the slide, partially because of the
23 geometry of the chip. We actually didn't contact the
24 edge of the slide. It kind of hooked around and

1 contacted the face of the slide. But we did create
2 damage on the face of the slide. That was one area
3 that we hadn't really specifically looked at on the
4 accident valve.

5 So we went back and looked at that again just
6 to make sure that there wasn't a similar type of chip
7 within the accident valve that created damage on the
8 face rather than the edge. We did not find anything.

9 MR. PHILLIPS: Could you relate the findings
10 of the chip shear task in your observations in general
11 to what was observed on the USAir 427 components, both
12 in relationship to markings that would have been left
13 by a jam and the ability of the unit to shear chips?

14 THE WITNESS: Well, the ability of the unit
15 to shear chips was actually much better than I had
16 expected personally. In one case, we didn't even
17 realize we were shearing the chips. We thought we had
18 the test set up wrong until we realized we had chopped
19 up the chip and it was laying in there already. But
20 the evidence created in the chip shear test was, like I
21 said, a fairly large magnitude. Something you could
22 see very easily with 25 times magnification. None of
23 that type of evidence existed on the accident valve.

24 The accident valve was examined with a

scanning electro-microscope in the NTSB laboratories up
2 to several thousand time magnifications. We couldn't
3 find anything that was not related to manufacturing of
4 the valve.

5 MR. PHILLIPS: So it's your belief that if a
6 chip large enough to jam the valve would have been
7 present in the accident valve, it would have been
8 observed during the testing that was performed?

9 THE WITNESS: Yes, and it would have been
10 observed very easily and very readily.

11 MR. PHILLIPS: Then would it be safe to go
12 another step and say that you see no evidence that this
13 valve had been jammed?

14 THE WITNESS: Yes, that's very true.

15 MR. PHILLIPS: What, in your opinion, is the
16 concern about a jammed valve? What would be the
17 effects if it had jammed?

18 THE WITNESS: If both slides of the valve had
19 jammed, you really negate the effect of the PCU
20 feedback loop to null the valve, and the PCU would just
21 continue to go until it stopped, from running out of
22 stroke, which would really be a hard over rudder. And
23 because of the earlier testimony that the performance
24 group is back to back, where the yaw moment was seen on

the FDR data, that keyed the systems into looking very
2 closely at the rudder components and anything that
3 could cause it to go hard over like that.

4 A dual jam of the control valve is something
5 that could produce a hard over. However, a dual jam
6 that -- number one, a dual jam I don't think anybody
7 I've talked to has ever seen a dual jam dual of a dual
8 concentric valve. Number two, there wasn't any
9 evidence of any sort of jam whatsoever on the accident
10 valve.

11 MR. PHILLIPS: So to the best of your
12 knowledge, there is no evidence that a dual jam has
13 ever occurred in this control valve?

14 THE WITNESS: To the best of my knowledge,
15 Yes, that's true.

16 MR. PHILLIPS: You mentioned additional
17 testing beyond the chip shear test. Was there
18 additional contamination testing performed?

19 THE WITNESS: Yes, we did some additional
20 particulate contamination testing. What we did was we
21 took a brand new rudder PCU and we removed the new
22 servo valve from that PCU and we installed the servo
23 valves that we had obtained from in-service. We wanted
24 to kind of use a representative sample.

So we took a valve that had some service
2 hours on it and installed it under the new PCU, a new
3 rudder PCU. Then tested that rudder PCU in an
4 environment in which we had purposely introduced
5 contaminants into the hydraulic fluid. The
6 contaminants we introduced, they ranged between five
7 and 100 microns. I'm sorry, maybe five and only 80
8 microns. Very similar to the fluid samples
9 particulates that we had found in the accident rudder
10 PCU.

11 Let me back up a little bit. Before we
12 started introducing the contaminated fluid in the PCU,
13 we removed all the filters from the PCU. So we had no
14 filtration protection on the PCU itself. So then we
15 put that PCU in an environment with this particulate in
16 the fluid. And what we did is we started out with an
17 NES 1638 Class 12 particulate count level, which is the
18 level that we found in the link cavity of the lever
19 PCU.

20 We cycled at that level until we felt
21 confident that that wasn't causing any sort of problem.
22 Then we introduced more contaminant until we got to 50
23 times the level that was found in the accident PCU link
24 cavity. Again, we continued to cycle at that level.

We had a lot of difficulties with the test in that we
2 kept destroying pumps. We actually had to put four
3 pumps in the test.

4 MR. PHILLIPS: But were these aircraft
5 hydraulic pumps or lab pumps?

6 THE WITNESS: They were aircraft pumps, I
7 believe. Some old pumps from the 707.

8 CHAIRMAN HALL: Excuse me, Mr. Cline, is that
9 test in the record of this hearing?

10 THE WITNESS: I think it's been introduced as
11 an exhibit, yes.

12 MR. PHILLIPS: We don't have copies of it.
13 The testing was just, I believe, last week -- last
14 Friday finished up. We have some video and some photos
15 from the test, but the test results are not in the
16 record at this moment.

17 CHAIRMAN HALL: How soon can we get the test
18 results, Mr. Phillips, and put them in the record? Can
19 we do it before this hearing adjourns at the end of
20 this week?

21 MR. PHILLIPS: Let me throw that over to Mr.
22 Cline.

23 THE WITNESS: Yes, we have several copies of
24 the videos available, and we can make hard copies of

the --

2 CHAIRMAN HALL: Everybody's worked real hard,
3 but we need to be sure that we're sitting here talking
4 about something that's part of the public record.
5 Please proceed.

6 THE WITNESS: Maybe I should just start now
7 by showing some of the photographs of the results of
8 that test. This probably isn't going to look --

9 CHAIRMAN HALL: Can you turn those lights
10 off, please? Thank you.

11 (Slide shown.)

12 THE WITNESS: This is actually a photograph
13 from the rudder PCU that was removed from the flight
14 427 aircraft. The reason I showed this is this is a
15 picture of a link cavity. If you look in the upper
16 left, you kind of see that. I think you'd call it kind
17 of a caramel color. That's actually the fluid, and
18 you're kind of looking -- it's like looking into a bowl
19 of fluid in this area right here.

20 You can see that it's kind of translucent and
21 clear and you can see into the bottom. When we took
22 these photographs, what doesn't show up is in reality,
23 you could see some very -- you can see things sparkling
24 in there, and it doesn't show up on the photograph. If

1 you know what you're looking for, there's one right
2 there, and there's others in there, but there's just
3 these very fine sparkles. That's the particulate
4 contaminant that was in the link cavity accident valve
5 or accident rudder PCU.

6 (Slide shown.)

7 THE WITNESS: The next slide shows -- this is
8 the same picture from the PCU that we performed the
9 testing on. This view is almost the same view you saw
10 before. But now because there's so much contaminant in
11 there, you can't see to the bottom. It's like looking
12 into a muddy bowl. You can't see the bottom of the
13 bowl anymore.

14 Like I said, this is a contaminant level
15 that's 50 times what was found in the accident rudder
16 PCU. You can see it kind of gummed up all over on
17 here. You can't really tell. It's just a slurry in
18 there. When they used the q-tip to kind of move it
19 around, it was like stirring up mud.

20 If we could show the next picture.

21 (Slide shown.)

22 THE WITNESS: This is a picture of the
23 primary slide removed from that test unit. These are
24 what we call the balanced grooves. As you can see,

they are all filled up with contaminant. What that
2 really is is conglomeration of a bunch of contaminants.
3 When you take very small particles like that under high
4 pressure, you can actually kind of make them into a
5 conglomeration that they kind of stick to themselves.

6 CHAIRMAN HALL: Mr. Cline, we had a question
7 up here as to what the composition of the contaminant
8 is?

9 THE WITNESS: Yes, I can provide that.

10 MR. PHILLIPS: I would also like to make the
11 point here for the record, too, that this is not the
12 accident airplane part. This is a test specimen.

13 THE WITNESS: We obtained the contaminants
14 from a place called Fluid Technologies, Inc., which is
15 in Stillwater, Oklahoma. Maybe I should just read what
16 we put in. We put in standard fine air cleaner test
17 dust that ranged from five to 80 microns. We used some
18 steel participles, some 43-40 that were ten micron or
19 less. Some aluminum nickel bronze of ten micron or
20 less. Some teflon particles and flakes that ranged
21 between 50 and 100 microns. That's it.

22 That is kind of representative of the same
23 type of particulates that we determined to be in the
24 accident PCU fluid sample.

CHAIRMAN HALL: Thank you.

2 THE WITNESS: If we can go to the next slide.

3 (Slide shown.)

4 THE WITNESS: This slide is really a pretty
5 dramatic slide of what happens when you put that much
6 particulate in hydraulic fluid and then accelerate it
7 through a control valve. Yesterday an exhibit was
8 shown that will help clarify what we're looking at.
9 Let me look up what exhibit that was.

10 If we could put up Exhibit 9-S, page 12.

11 (Slide shown.)

12 CHAIRMAN HALL: Greg, was this a systems
13 group test or is this part of Boeing's work?

14 MR. PHILLIPS: This was a follow on from the
15 systems group. It wasn't directed by the systems
16 group. It was an additional phase. The chip shear
17 test was done under the direction of the systems group
18 due to the scheduling of the hearing and work going on
19 with that. This was work that was conducted by Boeing,
20 not in the presence of the systems group, but with the
21 knowledge and approval of the group.

22 I'm told that the series of -- this will
23 appear as 9-AF-2. You may not have a copy of that yet,
24 but it will be under that cover number. I believe what

he's showing there is 9-S exhibit.

2 THE WITNESS: Yes, this is 9-S, page 12.
3 What this shows is a cross-section of a generic control
4 valve. But the reason I put this one up here is to
5 show -- this shows a really good -- I don't think it
6 was intentionally done to show it.

7 However, if you were to push fluid from this
8 area to this area, you would kind of get the fluid
9 traveling like that arrow and it accelerates quite
10 rapidly depending on the pressure differential across
11 this area. The fluids would actually hit the root
12 diameter of the slide and then deflect back up and go
13 to wherever the control passage takes it.

14 So the thing to keep in mind is this edge
15 here and this root diameter. Then if we could put the
16 picture back up.

17 (Slide shown.)

18 THE WITNESS: What happens during our
19 particulate test was as the fluid went by the edge --
20 we'll use this picture as an example -- it kind of wore
21 out part of the edge. Then as it was deflected down to
22 hit the root diameter of the slide, it created these
23 huge divots. These are kind of like a pocket that's
24 actually worn away inside the root diameter of the

slide. That's from this fluid with particulate. It's
2 almost like a slurry just impinging on that root
3 diameter and simply wearing it away.

4 Again, this is at a level that's much greater
5 than was found in the accident rudder PCU. But it's
6 important to note that the slides on the accident PCU
7 didn't show any sort of these characteristics at all.
8 This is exaggerated to quite a level, but we didn't see
9 even the beginnings of this on the accident valve.

10 BY MR. PHILLIPS:

11 MR. PHILLIPS: So then the purpose of this
12 test was to define a contaminated condition? What the
13 effects of the contamination would be on the valve?

14 THE WITNESS: Yes, and also to confirm the
15 operation of the dual servo in high particulate level
16 contamination. What I haven't mentioned yet is that we
17 always monitor input to the PCU and output of the PCU.
18 And at all times during this test, although the input
19 force tended to creep up simply because of all the
20 bearings and everything being clogged up with this
21 particulate, the PCU output always agreed with the
22 input, which tells us that the control valves always
23 operated as it tended.

24 MR. PHILLIPS: Had any testing like this ever

1 been performed by Boeing or Parker, to the best of your
2 knowledge?

3 THE WITNESS: Yes, testing like that has been
4 performed many, many years ago. Unfortunately, at
5 least in the Boeing, I wasn't able to find any specific
6 documentation. That's kind of why we -- and it wasn't
7 performed on this particular unit in the past. It was
8 performed on similar units. That's one of the reasons
9 I think everybody elected to perform this again was
10 because we didn't have this unit.

11 MR. PHILLIPS: As a result of this testing,
12 have you found any changes that you would make to the
13 design of the PCU?

14 THE WITNESS: No, we haven't.

15 MR. PHILLIPS: I would like to ask that in
16 reference to the chip shear testing also?

17 THE WITNESS: You're asking if there's any
18 changes being made to the PCU as a result of the chip
19 shear testing?

20 MR. PHILLIPS: That's correct.

21 THE WITNESS: No, that test really showed
22 that the PCU and the valve performed as intended.

23 MR. PHILLIPS: I would like to go back a
24 little bit now back to our discussion on jams and the

testing that was done on the USAir 427 PCU. Could you
2 briefly describe the testing done for residual pressure
3 differential?

4 CHAIRMAN HALL: Excuse me. Is that the end
5 of the slides for a while?

6 MR. PHILLIPS: Yes, it is.

7 CHAIRMAN HALL: Let's put the lights back up,
8 please.

9 (Pause.)

10 THE WITNESS: What was done by the systems
11 group with the dual concentric valve concerning
12 residual pressures was to simulate various jam
13 positions of the primary and secondary slides and
14 determine exactly what residual pressure that would
15 give us for this particular unit.

16 There were four conditions that were
17 simulated. Each of the two slides jammed in each of
18 the two extreme positions, for a total of four.

19 In exhibit 9 -- I'm sorry. Exhibit 9-AH,
20 page 2.

21 (Slide shown.)

22 THE WITNESS: These are the results of the
23 residual pressure test that we did on the accident
24 servo valve. Like I said, on the left column are the

four conditions we simulated. Let's just look at the
2 first one as an example.

3 If we were to produce a full rate command of
4 the rudder PCU for any reason at all and then jam the
5 secondary at that position, the summing loop of the PCU
6 would then try to use the secondary -- I'm sorry -- the
7 primary to negate the jammed position of the secondary.

8 If it was a perfect world, it would negate it
9 exactly. We would have what we would call zero
10 residual pressure. It's not a perfect world, and we
11 have manufacturing tolerances and everything is not
12 built exactly like the previous one. So in this case,
13 we end up with a twelve and a half percent residual
14 left rudder.

15 So if we started with a left rudder command,
16 we jammed the secondary. The primary can't quite
17 exactly take it to zero, and it leaves us with a twelve
18 and a half percent residual pressure.

19 What that means is that at any given air
20 speed, the rudder will be at twelve and a half percent
21 of its blow-down hinge moment if we met this condition.

22 BY MR. PHILLIPS:

23 MR. PHILLIPS: These were tests done on the
24 accident airplane's components?

1 THE WITNESS: Yes, these were tests done on
2 the accident airplane components.

3 MR. PHILLIPS: When were the tests done?

4 THE WITNESS: That again was either the first
5 or second weekend of January in 1995.

6 MR. PHILLIPS: What would be in this table or
7 in this slide, what would be the worst condition as far
8 as the airplane would be concerned in controllability?

9 THE WITNESS: The worst condition is the one
10 I just described, the twelve and a half percent. This
11 would be a case of the pilot commanded the left rudder
12 and he commanded it very rapidly and when he did that,
13 the secondary jammed. Now the primary is trying to
14 null it out.

15 If the pilot just takes his feet off the
16 pedals, at that point in time and lets everything go to
17 neutral, the rudder won't come all the way back to
18 neutral. It will remain at twelve and a half percent
19 of its deflection at that air speed. That is the worst
20 case. You can see that on the next one down we're only
21 going to get eight and a half percent.

22 The last two cases, the numbers look bigger,
23 but you really have to look at the sign of the numbers.
24 These are simulating the same scenario, except the

primary jam. In other words, we have a full rate
2 command. We jam the primary. And now the secondary is
3 trying to negate the primary. Not only can the
4 secondary negate the primary, but it can still provide
5 residual control over the rudder.

6 So if we look at the bottom condition, if we
7 have a right rudder command, a full right rudder
8 command, it would jam the primary and we would try to
9 negate it with the secondary. In the left rudder
10 direction, the secondary -- or in the left rudder
11 direction, the PCU would be able to provide 50 percent
12 hinge moment in the direction intended. In the right
13 rudder direction, it would be normal control.

14 So it's just a case of reduced control in one
15 direction and absolutely normal control in the other
16 direction for that situation.

17 MR. PHILLIPS: So this data says that in the
18 worst condition, the pilot with this valve would have
19 had approximately one eighth of residual left rudder
20 available to him, 12 percent?

21 THE WITNESS: Yes.

22 MR. PHILLIPS: Twelve and a half percent?

23 THE WITNESS: Yes, 12 percent of rudder.

24 MR. PHILLIPS: Would this vary from valve to

valve?

2 THE WITNESS: Yes, it varies from valve to
3 valve. That's why we tested this specific valve.

4 MR. PHILLIPS: Has this test ever been
5 conducted before?

6 THE WITNESS: Yes, it has.

7 MR. PHILLIPS: Is it a part of a routine test
8 for the valves as they're manufactured?

9 THE WITNESS: On some valves, it is. On this
10 particular valve, it's not part of the routine tests at
11 this point in time.

12 MR. PHILLIPS: Should it be?

13 THE WITNESS: I can't answer that without
14 knowing what the -- there's currently an analysis being
15 performed to figure out what the worst case could be,
16 giving the worst case tolerances. That's all
17 analytical because we can't build one at worst case,
18 just like you can't build one perfect.

19 Without knowing what the worst case is and
20 without knowing from an airplane standpoint what kind
21 of requirement it would be, I can't answer whether
22 that's something that should be a test or not.

23 MR. PHILLIPS: I guess the point that I'm
24 making is that if you have a test method available to

show you conditions that may cause you to be able to
2 null the rudder out or not, it seems to me that that
3 would be a valid test in production of the valve.

4 THE WITNESS: It may be a valid test, but a
5 test without requirements is not valid at all. Until
6 have the requirements, which come from the airplane's
7 performance, what would we test to? You're just doing
8 a test to do a test at that point.

9 CHAIRMAN HALL: What do you need to build a
10 test? Requirements?

11 THE WITNESS: Well, for any test you need a
12 set of requirements to either say that the unit passes
13 or it doesn't pass. Ultimately, those requirements
14 would come from the airplane performance.

15 CHAIRMAN HALL: How long has the plane been
16 performing?

17 THE WITNESS: Almost 30 years.

18 BY MR. PHILLIPS:

19 MR. PHILLIPS: Are you aware of any other
20 tests that have been conducted by Boeing, by Parker or
21 in the course of the NTSB investigation of either the
22 Colorado Springs or USAir 427 accidents that would
23 better describe to us the function and performance of
24 this rudder package?

THE WITNESS: I guess I'm a little bit
2 confused with what you're asking.

3 MR. PHILLIPS: It's along question. Have
4 there been other tests done by anyone to detect failure
5 conditions of this package that we haven't discussed?

6 THE WITNESS: Not that I'm aware of. We've
7 spent three months testing and thinking about this
8 package and I think we've covered everything known to
9 this date.

10 MR. PHILLIPS: Do you know of any plans to do
11 additional testing following this hearing concerning
12 this package?

13 THE WITNESS: I don't know of any current
14 plans for additional testing. The one thing that we
15 didn't test that we didn't think was necessary at one
16 point in time was the bypass valve, bleed orifice flow.
17 That's a very simple test. We normally do it and for
18 some reason, I think for efficiency and time, we
19 decided that that wasn't an important test at the time
20 we were testing the rudder PCU.

21 MR. PHILLIPS: In your position as the
22 engineer responsible for the operation and function of
23 this package, are you satisfied that everything has
24 been done that's possible to determine whether this

rudder PCU package effected the flight of USAir 427?

2 THE WITNESS: Yes, I'm satisfied. I have
3 come to the conclusion that this rudder PCU on this
4 aircraft did what the rudder control system told it to
5 do.

6 MR. PHILLIPS: I've got no further questions,
7 unless you would like to add something that I've
8 omitted.

9 THE WITNESS: I don't think I have anything
10 to add at this time.

11 MR. PHILLIPS: No further questions from me
12 at this time.

13 CHAIRMAN HALL: The command system, you're
14 saying, was what you thought caused the movement of the
15 rudder on the accident flight?

16 THE WITNESS: No, I didn't make any
17 conclusions as to what I thought caused the movement of
18 the rudder. I just simply said that the rudder PCU,
19 based on the testing we've done, did what the control
20 system told it to do. I have no idea what the control
21 system told it to do.

22 CHAIRMAN HALL: Do the parties have any
23 questions for this witness? I see one hand, two hands.
24 I see a third hand. We will then go back to Mr. Wurzel

with the Machinists for his questions of this witness.

2 MR. WURZEL: Good morning, Mr. Cline.

3 THE WITNESS: Good morning.

4 MR. WURZEL: Do you know how many hours from
5 overhaul or equipment manufacturer the United Airlines
6 July '92 unit had on it?

7 THE WITNESS: I'm not sure what unit you're
8 specifically talking about.

9 MR. WURZEL: When you mentioned the Colorado
10 Springs unit or the unit was tested other than the
11 Colorado Springs unit, I should say, the first one had
12 jammed how many hours did it have on it?

13 THE WITNESS: Well, there wasn't any valves
14 that jammed that we tested. I don't know how many
15 hours were on that.

16 MR. WURZEL: I believe it was the summing
17 levers had a manufacturing defect.

18 THE WITNESS: I don't know how many hours
19 were on that unit.

20 CHAIRMAN HALL: Your question is how many
21 hours of the rudder PCU you had on it or specifically--

22 MR. WURZEL: That's correct.

23 CHAIRMAN HALL: -- the Mack Moore unit on the
24 Colorado Springs flight?

MR. WURZEL: No, the unit in I believe it was
2 Chicago.

CHAIRMAN HALL: Oh, Chicago, okay.

4 THE WITNESS: I don't know how many hours
5 that unit had on it.

6 MR. WURZEL: Thank you. Was the flight 427
7 main power control unit damaged in any way from the
8 accident and would you describe it?

9 THE WITNESS: It was damaged. The main
10 piston was bent. When the main piston bent, it took
11 the external summing lever and the H link with it.

12 MR. WURZEL: Have either chip shear or
13 contamination tests been accomplished on the secondary
14 slides in any servos?

15 THE WITNESS: No, we didn't perform a chip
16 shear test on the secondary slide, because the systems
17 group concluded that there would be no difference in
18 shearing performing between the primary and secondary
19 or the secondary and the body. With the particulate
20 testing, because we tested an entire rudder PCU, yes,
21 the secondary was tested also.

22 MR. WURZEL: You stated that modification to
23 the power control unit or the AD would preclude any
24 problems with uncommanded rudder movement. Are you

aware if the Continental 1737 had a modified rudder
power control unit?

THE WITNESS: I don't know whether that was
modified or not.

MR. WURZEL: What is used as redundancy in
case of jamming of the internal or external linkages of
the power control unit?

THE WITNESS: I'm not quite sure I understand
the question.

MR. WURZEL: The summing levers, if they
jammed either internal or external, what would be the
back up system?

THE WITNESS: I'm not sure exactly what
you're specifically talking about jamming. But it is a
dual load path system from the torque tube all the way
into the dual concentric servo valve. That provides
redundancy there.

MR. WURZEL: Would the standby be available
to work in that mode?

THE WITNESS: You're asking if the accident
or if the standby rudder PCU from the accident was
available to operate?

MR. WURZEL: NO. In any unit would a standby
be able to work in that condition?

THE WITNESS: I don't understand the
2 question. I'm sorry.

3 MR. WURZEL: All we're asking if what's
4 available to return the rudder to neutral, if that
5 condition happens?

6 THE WITNESS: If what condition happens?

7 MR. WURZEL: If the summing lever is jammed
8 or failed? If they broke, it would probably go into a
9 neutral condition, but if they jammed --

10 THE WITNESS: Well, anything that jams or
11 breaks the feedback loop of the PCU causes an open loop
12 condition. Any time you have an open loop condition,
13 you no longer have position control of the rudder PCU.

14 MR. WURZEL: Thank you. That's all the
15 questions I have.

16 CHAIRMAN HALL: The Airlines Pilot
17 Association. Captain?

18 CAPTAIN LeGROW: Thank you, Mr. Chairman.
19 Good morning, Mr. Cline. I have just a few questions.
20 You testified earlier on a United Flight where a PCU
21 was removed. I believe it was in Chicago during a
22 flight control test. You said that it found that the
23 flow could be in the opposite direction. Is that true?

24 THE WITNESS: No, I didn't say that the flow

could be in the opposite direction. I said that that's
2 when we discovered the generic problem of the flow
3 could be in the opposite direction. On that particular
4 unit, the flow did not -- I'm sorry. On that
5 particular unit, yes, the flow could reverse.

6 CAPTAIN LeGROW: Thank you. Would the result
7 be the rudder movement in the opposite direction in
8 which the crew would expect in that case?

9 THE WITNESS: If you meant all the conditions
10 necessary to get the secondary and over stroke, yes.

11 CAPTAIN LeGROW: Thank you. Is it Boeing's
12 practice for the flight crew to check the controls for
13 anything other than freedom of movement?

14 THE WITNESS: No, it is not. Not that I'm
15 aware of anyway.

16 CAPTAIN LeGROW: So then the only guidance
17 that Boeing gives to flight crews is just to check the
18 controls for freedom of movement. Is that correct?

19 THE WITNESS: That's correct.

20 CAPTAIN LeGROW: If this check is not done at
21 a rapid rate, could there be a potential of over
22 stroke?

23 THE WITNESS: If it's not done at a rapid
24 rate, but the full freedom of movement is checked, it

accomplishes identical results.

2 CAPTAIN LeGROW: But Boeing doesn't give any
3 guidance to what rate to check the controls. Is that
4 correct?

5 THE WITNESS: That's correct. But what I was
6 saying was rate is independent of full freedom of
7 movement. If a pilot accomplishes a full freedom of
8 movement check, he is essentially commanding a full
9 rate to the rudder PCU simply by bottoming the pedals.
10 It's the same thing.

11 CAPTAIN LeGROW: So what you're saying is the
12 rate of rudder input doesn't matter? You're still
13 going to check both the primary and the secondary
14 slides?

15 THE WITNESS: As long as you go to full
16 freedom of movement you will, yes.

17 CAPTAIN LeGROW: What is the maximum -- we
18 talked about chip shear earlier on the 737 servo valve.
19 What is the maximum force available?

20 THE WITNESS: Are you talking in general or
21 on a specific unit?

22 CAPTAIN LeGROW: What is the specifications?
23 What is the maximum?

24 THE WITNESS: The maximum is -- I don't have

the test data sheet with me, but it's in the
neighborhood of 95 pounds.

CAPTAIN LeGROW: How would this compare with
other servo valves?

THE WITNESS: How would this compare with
what?

CAPTAIN LeGROW: With other servo valves?

THE WITNESS: The chip shearing function
really isn't a -- the chip shearing force isn't a
function of the servo valve. It's a function of the
component it's installed within.

CAPTAIN LeGROW: What was it in the accident
airplane? What was the maximum in the accident
airplane?

THE WITNESS: In the accident airplane, in
one direction it was I think 44 pounds. In the other
direction, 48 pounds.

CAPTAIN LeGROW: How would this compare with
other valves?

THE WITNESS: If you compare it with other
components, it's somewhat lower.

CAPTAIN LeGROW: How much lower would it be?

THE WITNESS: It all depends on what
component you compare it against.

CAPTAIN LeGROW: Would it be the lowest?

2 THE WITNESS: I don't know. I haven't done
3 the study of every component we have.

4 CAPTAIN LeGROW: You said that no one you
5 have ever talked to has ever seen a dual jam until the
6 United incident that you talked about earlier. Is that
7 correct?

8 THE WITNESS: I didn't talk about any dual
9 jam on a United incident earlier.

10 CAPTAIN LeGROW: I must have misunderstood
11 you. During the acceptance test that was done on the
12 427 accident servo valve, you said it failed test five.
13 Could you tell us why you bother to have test five if
14 it doesn't matter if it fails?

15 THE WITNESS: Well, it does matter if it
16 fails test five. I just said in the manner that it
17 failed test five, it was really -- on the airplane, it
18 would be completely undetectable. It just simply
19 picked up the secondary slightly early. That's in the
20 order of two-thousandths.

21 CAPTAIN LeGROW: I believe what you said is
22 that it wouldn't have any effect on the PCU's
23 operation.

24 THE WITNESS: That's true. It doesn't have

any effect on the PCU's operation.

2 CAPTAIN LeGROW: Could you explain exactly
3 what that test five is? I'm unclear why you have a
4 test. If it fails the test, it's still released to go
5 back on an airplane?

6 THE WITNESS: It can't go back on an airplane
7 if it fails a test. It has to be reworked until it
8 passes the test. I just simply stated that as this PCU
9 was when it came off the airplane, it didn't pass the
10 test. But in the manner that it failed the test, you
11 would have never been able to detect that failure on
12 the airplane. It would have caused nothing on the
13 airplane.

14 CAPTAIN LeGROW: Thank you. I have no
15 further questions.

16 CHAIRMAN HALL: Thank you. Mr. McGrew,
17 Boeing.

18 MR. MCGREW: Yes, Mr. Chairman. First of
19 all, we would like to apologize for not having been --
20 we would like to apologize for not having some of these
21 data to you before earlier in this.

22 As I think you're well aware, we have been
23 working a great number of hours preparing for the
24 hearing. A number of these people have been running

1 the tests simultaneously. So, frankly, it has been an
2 outstanding effort.

3 CHAIRMAN HALL: I appreciate that comment and
4 all the hard work. My only interest is being sure. If
5 we're discussing anything here, that it's part of our
6 record.

7 MR. MCGREW: We will give you before the end
8 of the week. a summary report of this last test, the
9 contamination test, as well as the data that we have of
10 course.

11 CHAIRMAN HALL: Thank you very much.

12 MR. MCGREW: We have a few questions for Mr.
13 Cline. Perhaps more than a few.

14 First of all, Mr. Cline, are you aware of any
15 incidents in the 737 fleet of a dual servo jam of one
16 of our servos?

17 THE WITNESS: I am not aware of any at all.

18 MR. MCGREW: Perhaps a more difficult
19 question. Can you tell us through the testing
20 procedure and the analysis procedure that you've been
21 through, of those events where the NTSB or members of
22 the parties were not involved in it, is there anything
23 that we did independent of them and please feel free to
24 answer everything you know? For examination, the

contamination test was not done with anybody from the
2 NTSB at the facility.

3 THE WITNESS: Yes, it was -- I'm not sure
4 what you're asking, but we're always as engineers
5 trying to figure out what happened. So on their own,
6 we might sit down at a CATIA terminal and do an
7 analysis on our own or go to the lab and look at
8 components on our own or we're always trying to -- I
9 mean, this bothers me as much as it bothers anybody
10 else.

11 I've spent many a nights awake trying to
12 figure out what happened. There's some things that
13 I've looked at without the NTSB present. Some things
14 I've analyzed on my own and really come to dead ends.
15 So it's something that I didn't make a point of
16 explaining my wasted efforts so to speak.

17 MR. MCGREW: But in the area of handling
18 components and disassembling them and moving them and
19 transporting them and that sort of thing, has there
20 been any of that?

21 THE WITNESS: No, we weren't -- we have not
22 done anything to the components without the NTSB and
23 most of all the time, the systems group was always
24 present.

MR. MCGREW: A little switch now. In the
2 chip shear test, which we carried out with some
3 trepidation, was that a representative test in terms of
4 what actually got in through the ports into the valve
5 itself? In other words, could those particles actually
6 flow through and achieve those positions?

7 THE WITNESS: Some of the particles we put in
8 were too large to physically get to the metering
9 orifice on their own. During the test, we had some
10 special machine parts where we EDM access to the
11 metering ports so that we could get the chips in there.
12 So we were putting much larger chips in than were
13 somewhat realistic, yes, in some cases.

14 MR. MCGREW: Are you confident now that
15 anything that conceivably could actually jam one of
16 these valves, would leave a mark on an indication that
17 would tell us that a jam, indeed, had occurred?

18 THE WITNESS: Yes, I'm confident it might.

19 MR. MCGREW: On the contamination test, which
20 was run independent of the NTSB but with their
21 knowledge, how many cycles did we run the servo through
22 in that test?

23 THE WITNESS: It was a total of 30 hours of
24 testing, which doesn't seem like a lot, but it was

wrought with problems because we had a hard time making
2 the other components in the tests, such as the pumps
3 stand up to the testing. We replaced many pumps. I
4 think we accomplish something just over 5,000 cycles,
5 if my numbers are right.

6 MR. MCGREW: What are the levels of
7 filtration used in the hydraulic system today in the
8 basic system?

9 THE WITNESS: In the hydraulic system, the
10 pressure filters at the pump are 15 micron absolute.
11 When we get to the PCU, they are at 25 micron absolute,
12 ten micron nominal. What that means is that the
13 absolute rating means that any particle of any single
14 dimension of 25 microns or greater will not pass
15 through the filter.

16 The nominal rating says that 90 percent of --
17 I can't remember if it's 90 or 98 percent of all
18 particles with a single dimension of ten microns or
19 greater will not pass through the filter.

20 MR. MCGREW: How about in the unit itself?

21 THE WITNESS: Those are filters -- the last
22 filters I spoke of were the filters in the rudder PCU.
23 There was a total of three filters; two pressures in
24 the filters and one yaw damper filter.

MR. MCGREW: You did not deal in any of your
2 presentation or discussion with the standby actuator.
3 Is there any comments that you would like to make with
4 respect to that unit?

5 THE WITNESS: Yeah. I didn't make any
6 comments about it, but we did test the standby actuator
7 from the accident aircraft. We tested it to the
8 supplier's component maintenance manual.

9 If I recall that unit passed all tests except
10 for one, which was a -- I believe it was an internal
11 fluid leakage test. One of those tests it did pass was
12 a force test on the input lever. We have a half a
13 pound limit for the input force on that lever. It met
14 that requirement. I can't seem to find -- here they
15 are.

16 We measured .2 pounds and .32 pounds
17 depending on which direction we moved the lever.

18 MR. MCGREW: A couple of last questions. The
19 United PCU with the mismachine summing levers, those
20 problems were not in any way found on either the USAir
21 or the Colorado Springs units. Is that correct?

22 THE WITNESS: That's correct. We used a
23 baroscope to verify that we were getting full
24 engagement of the external servo stops and verified

1 that the dimensions and the numbers were correct in
2 both cases. In the case of the Colorado Springs,
3 because that PCU was burned up pretty bad, we didn't
4 actually use a baroscope while the unit was together to
5 verify that. We used witness marks the unit created
6 when it wears. When it contacts, it creates the wear
7 marks. We could see that it had full engagement.

8 MR. MCGREW: Finally, a summary question. In
9 terms of jams on the USAir unit, there was absolutely
10 no evidence of any primary or secondary or residual
11 pressure difficulties?

12 THE WITNESS: That's correct. There was
13 absolutely no evidence of either slide being jammed.

14 MR. MCGREW: Finally, the yaw damper was, in
15 deed, limited to the plus or minus three degrees from
16 the unit itself?

17 THE WITNESS: Yes, that yaw damper was, in
18 deed, limited to plus or minus three degrees, verified
19 by test.

20 MR. MCGREW: Thank you, Mr. Cline.
21 Mr. Chairman, that concludes our questions.

22 CHAIRMAN HALL: Thank you very much. Let me
23 respond briefly, because I think it's an appropriate
24 place to do so. Mr. Cline, I appreciate very much your

two hours of testimony. That's the good news. The bad news is there's a lot more questions for you. I want to take a short break, but I do want to comment here as a follow up your comment of Mr. McGrew's comment, and just be sure that Mr. Phillips has the record straight on this.

There has been a lot of work independently by the parties, which we appreciate very much. Everyone's concerned about this accident and trying to determine the cause of this accident. In addition, I have read hundreds of of letters that have come in to the safety board from concerned citizens, pilots, engineers, passengers, all with their own thoughts about this accident.

However, we are in a fact-finding process here, and when we talk about a test, there is procedures for independent verification of tests. I want to put everything on the record, but we need to be clear those tests that the NTSB has independently verified through the party process and other information which is certainly maybe pertinent to this hearing, but needs to -- that just needs to be identified as we go through this. I think we have in the past and will continue to do so.

With that, we will take a break until 10:45
2 and continue with this witness.

3 (Whereupon, a recess was taken.)

4 CHAIRMAN HALL: On the record. Let's get
5 everyone back to their seats. We will get started here
6 momentarily. We will be back in session. I was
7 informed that Monsanto had their hand up and the
8 Chairman was oblivious to it. Is that correct? Did
9 you-all have some questions for this witness?

10 MR. JAKSE: Yes, Mr. Chairman. Thank you.

11 CHAIRMAN HALL: I apologize. Mr. Cline,
12 Monsanto has some questions for you. Mr. Jakse, go
13 right ahead, please.

14 MR. JAKSE: Mr. Cline, on the rudder PCU from
15 flight 427, were the filters in place?

16 THE WITNESS: Yes, they were.

17 MR. JAKSE: During your contamination testing
18 on the rudder PCU, would filters have removed particles
19 in this test?

20 THE WITNESS: If we would have left them in,
21 they would have, yes. We removed those filters for
22 this test, which I should point out is somewhat
23 unrealistic for an airplane in-service type case.

24 MR. JAKSE: One final question. Based upon

1 your contamination testing, did you conclude that the
2 hydraulic fluid did not cause any jamming of the power
3 control unit or the rudder on flight 427?

4 THE WITNESS: Yes, that's a conclusion. The
5 level of contamination that we found in the link cavity
6 of flight 427 was roughly class 12. We ran class 12 in
7 our test for approximately ten hours, and that was with
8 the filters removed, and that test performed perfectly
9 fine. From that we conclude that level of
10 contamination is not a problem.

11 MR. JAKSE: Thank you.

12 CHAIRMAN HALL: Any more questions from the
13 parties?

14 (No response.)

15 CHAIRMAN HALL: If not, Mr. Marx.

16 MR. MARX: I would just like to clarify the
17 position of the strokes on the primary and the
18 secondary and the internal residual stroke that occurs.
19 Was the primary to the secondary a stroke of
20 approximately forty-five thousandth?

21 THE WITNESS: Yes, it is.

22 MR. MARX: The picking up of the secondary
23 then would be another forty-five thousandth stroke if
24 we went at full rate?

THE WITNESS: Another forty-five thousandth
2 of effective stroke, yes.

3 MR. MARX: What is this residual, eighteen
4 thousandth that you're speaking of?

5 THE WITNESS: That's not a residual stroke.
6 That's just a non-effective stroke.

7 MR. MARX: What do you mean by that?

8 THE WITNESS: It's a stroke where we're not
9 opening any additional area of the metering orifice.
10 So we don't increase the rate of the PCU at all. It's
11 just simply a non-effective stroke.

12 MR. MARX: Well, can it move -- can that
13 secondary move another eighteen thousandth?

14 THE WITNESS: Yes, it can. The secondary
15 moves a total of sixty-three thousandth.

16 MR. MARX: Sixty-three thousandth. Would it
17 hit the internal stops when it does that?

18 THE WITNESS: At sixty-three thousandth, it
19 would be hitting the external stops.

20 MR. MARX: External stops.

21 THE WITNESS: And it would have to move
22 farther to hit the internal stops.

23 MR. MARX: How much farther would it have to
24 move on the accident servo to hit the internal stop?

THE WITNESS: I can't remember that number
2 off the top of my head, and I don't think I have
3 anything here to look that up.

4 MR. MARX: Can you give me a ballpark figure?

5 THE WITNESS: Ballpark it would be somewhere
6 between -- I think if I said between five and twenty
7 thousandth, I would cover it.

8 MR. MARX: Five to twenty thousandth, okay.
9 Now you were also testifying about the so-called United
10 fault on the servo. I think that's what was your
11 terminology for it. I think this was also have been
12 classified as a Mack Moore unit. Is that correct?

13 THE WITNESS: Yes. That's correct.

14 MR. MARX: On that particular unit, it was
15 reported through your analysis at Parker, that this
16 could have occurred as a result of an over stroke. Is
17 that correct?

18 THE WITNESS: Over stroke of the secondary
19 slide, yes.

20 MR. MARX: Secondary slide within the stroke
21 to what position to produce that reversal?

22 THE WITNESS: Well, it would have been
23 stroking some position beyond the external stop and I
24 don't remember what that number was. That was on the

order of a few thousandths on that particular one.

2 MR. MARX: What is the limiting factor then?
3 Is that the internal stop?

4 THE WITNESS: The ultimate leveling factor or
5 the secondary stroke is the internal stop, yes.

6 MR. MARX: To keep this thing from happening
7 again, what was the fix for or the modification to the
8 servo that is done to make sure that it doesn't over
9 stroke again?

10 THE WITNESS: We modified the tolerances of
11 the pieces to relocate that internal stop to a position
12 closer to the external stop.

13 MR. MARX: You don't happen to know what that
14 is, but you think it's between five and twenty
15 thousandths, roughly?

16 THE WITNESS: I don't know what that is
17 exactly, and between five and twenty thousands I quoted
18 you was for the accident valve.

19 MR. MARX: For the accident valve?

20 THE WITNESS: No, for new design -- for the
21 currently produced valves. It's not going to be the
22 same number. I don't know what that is off the top of
23 my head.

24 MR. MARX: On the United aircraft fault

servo, what was the over stroke? Do you happen to know
2 what that was?

3 THE WITNESS: I don't know.

4 MR. MARX: You also testified that this over
5 stroke that occurred on United fault servo, was a
6 result of mismachining of the chamfer or an internal
7 jam. Is that correct?

8 THE WITNESS: I testified that it was a
9 result of the mismachining of the external summing
10 lever, yes.

11 MR. MARX: Well, is it possible to get an
12 internal jam between a primary and a secondary that
13 would produce an over stroke?

14 THE WITNESS: Yes, that's possible.

15 MR. MARX: During your examination of that
16 particular unit, how did you determine that it was not
17 a jam between the primary and secondary?

18 THE WITNESS: Can you tell me which unit
19 we're talking about again?

20 MR. MARX: This is the United aircraft fault
21 Mack Moore unit.

22 THE WITNESS: And the question, I'm sorry?

23 MR. MARX: I understand that this over stroke
24 -- this is the stroke in which the secondary moves

relative to the housing and goes as far as -- I mean,
2 if you can over stroke its normal position, then it can
3 occur from prior testimony from a jam between the
4 primary and the secondary.

5 THE WITNESS: That is true, yes.

6 MR. MARX: Now you also indicated and I
7 believe you have a statement that this over stroke can
8 occur as a result of an internal jam or a mismachine
9 chamfer. I think that you ultimately determined it was
10 a chamfer. Is that correct?

11 THE WITNESS: On the particular unit you're
12 talking about that was the cause, yes.

13 MR. MARX: Well, how did you determine that?

14 THE WITNESS: We did that with -- we actually
15 set the unit up where we didn't have it -- I take that
16 back. We did have it hydraulically pressurized, just not
17 to a full 3,000 psi. We had the cover plate removed so
18 we could put a baroscope in and see the interaction
19 between the secondary summing lever, the secondary
20 slide and the servo external stops.

21 We witnessed. I think we actually recorded
22 the secondary, hitting the external stop, and then
23 writing up on the chamfer and then the PCU reversing.

24 MR. MARX: Could you absolutely rule out the

possibility that the primary jammed to the secondary
2 that could produce the over stroke?

3 THE WITNESS: We're still talking on the Mack
4 Moore unit?

5 MR. MARX: On the Mack Moore unit; that's
6 correct.

7 THE WITNESS: We looked at that unit --

8 MR. MARX: I understand that this was an
9 intermittent problem.

10 THE WITNESS: correct.

11 MR. MARX: A problem that didn't occur. And
12 from your testimony, you also indicated that during
13 original manufacturer, during the overhaul, this would
14 be tested for that type of an over travel. Is that
15 correct?

16 THE WITNESS: That's correct.

17 MR. MARX: It didn't occur apparently on the
18 -- it would have been found under original
19 manufacturer, would it not, if it occurred?

20 THE WITNESS: That's the nature of an
21 intermittent problem. You don't necessarily find it
22 every time. If I happen to test it on the time that it
23 doesn't happen, I'm not going to find it.

24 MR. MARX: Well, back to the situation where

1 if it didn't happen during original manufacturer or at
2 some overhaul time, how do you know that it was the
3 chamfer that produced this problem and not a jam
4 between the primary and the secondary?

5 THE WITNESS: All I can say in response to
6 that is we were able to duplicate the type of response
7 the pilot wrote up, that the United mechanics witnessed
8 on their test bench, and that we witnessed on the
9 Parker test bench, and we duplicated that by in some
10 cases helping the secondary summing lever miss its stop
11 and in some cases just doing it until it did it on its
12 own.

13 There was no reason for us to think that
14 there was other causes. But I can't say during the
15 examination before, we knew what the cause was. We
16 examined the primary and secondary slides.

17 Our level of education on the primary and
18 secondary slides today is much greater than it was back
19 then. So I can't say that we used the same scrutiny we
20 would have today, but there was no reason to think that
21 there was a jam on that particular unit.

22 MR. MARX: Let's assume that there would have
23 been a jam between the primary and secondary slide.
24 This would be on the Mack Moore unit. What would be

the shear forces, the shear load? What is actually
2 producing the shear load if you're trying to drive that
3 primary, retract it into the servo, try to push it into
4 the servo? What would be reacting against that?

5 THE WITNESS: Well, what actually produces
6 the shear load is the main piece of your piston. That
7 has an extremely high output force. But what
8 ultimately defines the shear load is the walking beam
9 break out force just prior to contacting the manifold's
10 box.

11 So the piston generates the force which is
12 very high in the walking beam limit that force, which
13 gives us our chip shearing force.

14 MR. MARX: I want to get into specifics where
15 we're talking about the primary moving into the servo.
16 As the primary moves into the servo and something jams
17 between the secondary now, which the secondary wants to
18 move with the primary, what is the shearing forces that
19 are reacting? Would that be a spring in the back
20 portion that wants to push the secondary out of the
21 servo?

22 THE WITNESS: No, it's the feedback loop that
23 wants to bring the secondary out of the servo.

24 MR. MARX: I'm only going in the moment of

time where we are pushing the primary in its process of
2 being pushed into the servo. Let's go back and ask.

3 There are some springs that are internal, is there not,
4 in the servo?

5 THE WITNESS: Yes, there's some secondary
6 detent springs, and there's a primary bias spring also.

7 MR. MARX: So there's a primary bias and a
8 secondary detent. What is the function of the
9 secondary spring?

10 THE WITNESS: The secondary detent spring is
11 because there is relative motion between the primary
12 and the secondary. There needs to be something to hold
13 the secondary in place. The primary has the primary
14 summing lever valve. We pulled it in its place. The
15 secondary, because of that relative motion, it needs
16 the caging springs to hold it in its neutral position.

17 MR. MARX: What would the spring force be for
18 that secondary?

19 THE WITNESS: Those caging springs are set I
20 think between ten and 12 pounds.

21 MR. MARX: Ten and 12 pounds. So if we were
22 pushing the primary into the servo and there happens to
23 be something stuck between the primary and the
24 secondary, the reaction would be from the spring roll,

would it not, of ten to 12 pounds that would try to
2 shear whatever it is that's stuck between the two? I'm
3 trying to get the secondary to an over travel position
4 only.

5 THE WITNESS: If I jammed the primary before
6 I start to move it, that jam only has to overcome the
7 secondary detent springs until the secondary contacts
8 the internal stops.

9 MR. MARX: That's correct.

10 THE WITNESS: Now I have to overcome the
11 walking beam break out. So depending on where you are
12 at the stroke --

13 MR. MARX: I'm talking about the very first
14 part of the stroke and where we're trying to get it
15 into an over traveled position?

16 THE WITNESS: That would be the secondary
17 detent spring force then.

18 MR. MARX: So on the United fault Mack Moore
19 unit, all we needed to do was to get it into an over
20 travel position and it would reverse. Is that correct?

21 THE WITNESS: That's correct. Yes.

22 MR. MARX: So if you had a particle of some
23 sort, it was between the primary and the secondary, and
24 it would only react with a shear force of ten to 12

pounds to get it into the over traveled position?

2 THE WITNESS: That's correct.

3 MR. MARX: Would that be a far less load than
4 what is normally on that unit for shear forcing, such
5 as -- you said it was between 40 and 50 pounds. I
6 think 48 pounds?

7 THE WITNESS: Yes. I would like to continue
8 with that, though, in the fact that as soon as the
9 primary causes the secondary to contact the internal
10 stops, the shear force goes way up.

11 MR. MARX: Goes way up?

12 THE WITNESS: Yes.

13 MR. MARX: I understand that. However, in
14 the case of the United fault, this would have reversed
15 the ram. Is that correct?

16 THE WITNESS: In the case of United, if the
17 reversal was caused by the jam of the primary to the
18 secondary, initially the primary would have started
19 driving the secondary into the over stroking region.
20 The PCU would have then started to reverse. The
21 summing loop would have caused it to drive the primary
22 only harder into the secondary until we met the maximum
23 chip shear force.

24 MR. MARX: Now we've had a lot of testimony

1 previously that had to do with rudder rigs. The rudder
2 rigs have varied, depending on who was testifying. I
3 think that the rudder rigs went all the way from 2.5
4 degrees per second up to approximately 7.5 degrees to 8
5 degrees per second.

6 Could you show us through some of your
7 exhibits that you had before at what position the
8 primary would have to be in to produce those rudder
9 rigs?

10 THE WITNESS: I don't know if I really had a
11 good exhibit to show a position of the primary slide,
12 but to produce a rate as low as 2 degrees a second,
13 you're talking about a very, very small displacement of
14 the primary.

15 MR. MARX: About how small?

16 THE WITNESS: Depending on -- again, I should
17 back up. Assuming these are no load rates, so there's
18 no load on the PCU. If we're talking -- the rate of
19 the PCU is dependent upon the load and the rate
20 command. It's not a singular function. So if we're
21 talking a no load rate of 2 degrees per second, it's a
22 very small displacement of the primary slide.

23 MR. MARX: Well, let's say that we had a
24 double jam between the primary and secondary, and the

secondary and the housing unit. At what position would
2 we have to have the primary to the secondary -- for
3 instance, just using that as a scenario -- to produce a
4 2.5 degrees to 7 degrees or 7.5 degree rudderick?

5 THE WITNESS: Is this a no load condition?

6 MR. MARX: No, because we're jamming them
7 whether it's load or no load. I would say it's under
8 load then.

9 THE WITNESS: I can't answer that without
10 knowing what the load is then. I mean, in other words,
11 if I command -- let's say I have no load to the PCU and
12 I set a command at the servo at 5 degrees a second.
13 It's going to go at 5 degrees per second.

14 If I put a huge load on that, then I can
15 stall it, I can stop it, but my command is the same.
16 If I vary that load, I can change the rate to anything
17 I want. You can't talk in singular terms and ask me
18 what a rate of a PCU is or the position of the slide
19 without giving definitive load of the PCU.

20 MR. MARX: I'm trying to understand what it
21 is that drives the actual ram or the actuator itself.
22 In going through this system, we have a pressure
23 differential on each side of the ram that can drive it.
24 Is that correct?

THE WITNESS: That's correct. Yes.

2 MR. MARX: What is the normal pressure that
3 you would have for each system? We have two systems
4 also; is that correct?

5 THE WITNESS: That's correct.

6 MR. MARX: In each system, what is the
7 pressure that can drive it?

8 THE WITNESS: We have a 3,000 psi supply
9 pressure and approximately a 50 psi return pressure.
10 So we have a maximum of about 2950 psi differential per
11 system.

12 MR. MARX: On the one system we consider the
13 A system, we have approximately a 3,000 pound, minus 50
14 pounds as I understand. What is the cross-section on
15 the area of the ram itself in square inches?

16 THE WITNESS: It's a 1.003 square inches.

17 MR. MARX: Roughly one square inch?

18 THE WITNESS: Roughly one square inch, yes.

19 MR. MARX: So if we had 3,000 pounds upon one
20 side of that piston and 50 pounds on the other, what
21 would be the total load approximately?

22 THE WITNESS: We have 2950 pounds.

23 MR. MARX: Twenty-nine hundred fifty pounds,
24 that's for a system?

THE WITNESS: That would be for a single
2 system, yes.

3 MR. MARX: Is that enough to drive the rudder
4 all the way to its full stop?

5 THE WITNESS: Under what load condition?

6 MR. MARX: Under the load conditions -- well,
7 let's put it this way. Can it drive the rudder at 190
8 knots to a position of 16 or 17 degrees?

9 THE WITNESS: I don't know what the blow down
10 at 190 knots is. I think it's -- for simplicity sake,
11 let's say it is the 16 or 17 degrees you mentioned. If
12 we have one system at a 2950 psi differential pressure
13 or you get halfway there -- well, I shouldn't say
14 halfway there. It's not a linear curve. It's a non-
15 linear curve. So you're going to get something less
16 than halfway there.

17 MR. MARX: What would be the engine out
18 requirements in which you have to have enough rudder to
19 take care of the yaw that occurs from the engine out?
20 Isn't one system enough to produce the amount of the
21 yaw that's needed to maintain flight?

22 THE WITNESS: NO. The design case for the
23 rudder is an engine out case, as you mentioned. It's
24 somewhere around 120 knots. We have to be able to move

1 the rudder full deflection. That's minus the
2 compliance of the system, which is, I think, about a
3 half degree in, I think, less than three quarters of a
4 second. That's the design case for the rudder and
5 that's with both hydraulic systems powered.

6 MR. MARX: We talked about the A system. NOW
7 what about the B system, would it have a similar type
8 of a load arrangement if we had them both going on at
9 the same time?

10 THE WITNESS: Yes, it would.

11 MR. MARX: So if 3,000 pounds were around one
12 side of the B side, it would be reacting against a
13 surface area which is approximately one square inch and
14 you would have another 3,000 pounds of load on the
15 actuator. Is that correct?

16 THE WITNESS: Yes, the two systems are
17 additive. So you can get approximately 5900 pounds of
18 force out of the PCU.

19 MR. MARX: At what position then can we go to
20 at 190 knots? Can we get to the blow-down rate or 17
21 degrees?

22 THE WITNESS: With both systems at a 2950
23 differential pressure, we would go to blow down, yes.

24 MR. MARX: What pressure would we have to

1 have, what minimum pressure or load, I should say, and
2 pounds would we need to get to that blow-down rate at
3 190 knots for 17 degrees rudder?

4 THE WITNESS: We need the full PCU hinge
5 moment. That defines blow down.

6 MR. MARX: I mean, would we need both
7 systems?

8 THE WITNESS: Yes, that's what defines full
9 PCU hinge moment, full system pressure, full
10 differential.

11 MR. MARX: Can you quantify what it is for
12 one system alone, for 3,000 pounds? How far would the
13 rudder go?

14 THE WITNESS: The rudder would produce a 50
15 percent hinge moment. I don't know what the load
16 versus deflection curve is, but it would give you
17 somewhere around 50 percent rudder deflection. Fifty
18 percent of your blow down.

19 MR. MARX: So it would only move to say 8
20 degrees. Is that your testimony?

21 THE WITNESS: I won't put a number on it,
22 because it's a non-linear curve, and I don't have the
23 load versus deflection curve for that air speed.

24 MR. MARX: The rate of travel of the rudder -

- that is, the speed of the rudder or the acceleration
2 of the rudder that would be in the degrees per second.
3 The speed of that rudder moving is dependent on some
4 flow rate that occurs inside the servo?

5 THE WITNESS: Yes. The rate of the rudder is
6 dependent upon the load on the rudder, the command to
7 the control valve, and the available supply pressure.

8 MR. MARX: So if we just -- if we had this at
9 neutral or we were just taken off of neutral where we
10 are pushing the primary into the secondary, what
11 direction, by the way, would that produce rudder
12 movement?

13 THE WITNESS: If we're commanding the primary
14 into the secondary?

15 MR. MARX: Yes.

16 THE WITNESS: When you say in, you mean into
17 the servo body?

18 MR. MARX: Yes.

19 THE WITNESS: That would be a left rudder
20 direction.

21 MR. MARX: If we move that primary a one or
22 two thousandth say into the secondary, that would
23 increase the flow rate from essentially a very little
24 amount to a higher amount. Is that correct?

THE WITNESS: To a higher amount, yes.

2 MR. MARX: The pressure would be the same,
3 would it not?

4 THE WITNESS: No, it would not.

5 MR. MARX: The pressure changed, as you go
6 from this position to a two thousandth in?

7 THE WITNESS: Yes, the pressure gain is we
8 get full pressure gain at very small displacements of
9 the valve.

10 MR. MARX: At one thousandth, what we will
11 have for a pressure? That's downstream or in towards
12 your-- it's inside your actuator yourself.

13 THE WITNESS: You're asking what my
14 differential pressure would be at one thousandth
15 displacement of the rudder side?

16 MR. MARX: Yes.

17 THE WITNESS: I don't have the pressure gain
18 curve in front of me. But if you had a pressure gain
19 curve, you could just -- you know, it's simply a matter
20 of --

21 MR. MARX: About how far would it have to go
22 to get full pressure?

23 THE WITNESS: Not very far. You just have to
24 --

MR. MARX: A couple of thousands?

2 THE WITNESS: Well, underlap of the primary
3 side is between one and two thousandths. As soon as we
4 cover up the -- or as soon as we move the full width of
5 the underlap, we have full system pressure, full
6 differential pressure.

7 MR. MARX: So you could have a load that's
8 occurring on the actuator itself of a 2950 pounds for
9 system A, a 2950 pounds for system B. Is that correct?

10 THE WITNESS: That's true.

11 MR. MARX: But how do we change the rate of
12 how fast that actuator moves?

13 THE WITNESS: We change the rate of how fast
14 it moves by -- let's assume it's a constant load. We
15 change the rate by changing the area of the orifice
16 that's open. The bigger the area, the faster the rate.
17 The smaller the area, the slower the rate.

18 MR. MARX: Can you give me an estimate then
19 what the orifice opening would have to be or how far
20 the primary would have to move to the secondary to
21 produce a rudder rate under a load at 190 knots to get
22 us to a blow-down rate of 15 to 16 degrees?

23 In other words, we're talking about we will
24 need a rate of 2.5 to 8 degrees per second of that

rudder movement, based on the testimony that you've
2 heard already. Where do we have to have the primary to
3 do this?

4 THE WITNESS: I mentioned earlier that the
5 load versus deflection curve is not linear. Therefore,
6 you can't pick a fixed position of the primary to give
7 you a linear rate. The only way you can get a linear
8 rate throughout that curve, throughout that deflection
9 is to change the area of the orifice as you're
10 deflecting the surface.

11 MR. MARX: So it increases? You have to
12 increase it?

13 THE WITNESS: You have to increase it, yes.

14 MR. MARX: As you move the actuator out, you
15 have to then increase the orifice to get more fluid
16 flow. Is that what you're stating?

17 THE WITNESS: Yes. You have to increase the
18 orifice so you get more fluid flow to react the load,
19 so that you can maintain a constant rudder deflection
20 rate.

21 CHAIRMAN HALL: Do you seek recognitions, Mr.
22 McGrew?

23 MR. MCGREW: Yes, sir.

24 CHAIRMAN HALL: Could we have the Boeing

Commercial Airplane Group microphone, please?

2 MR. MCGREW: Yes. Mr. Chairman and Mr. Marx,
3 I would suggest that some of the questions you're
4 asking now would require sitting down with some data
5 and some figures of curves and make some calculations
6 to answer these questions, which we would be very happy
7 to do. I suggest perhaps that we might move onto a
8 more general line of questioning, rather than the
9 specific answers you're looking for, and let us provide
10 you specific answers to that in the very near future.

11 MR. MARX: That's fine. I'm trying to get a
12 feel for certain positioning here in my line of
13 questioning. I'll move on, because I can see that I'm
14 getting no where here.

15 You testified to a pressure test that was
16 performed recently in January that dealt with the
17 movement of the secondary slides to the -- or the
18 primary to the secondary, and the secondaries to
19 different positions and opposite positions. I think
20 that you were referring to Exhibit 9-AH, page 2, when
21 you were speaking of that.

22 Are you also familiar with the Exhibit 9-R,
23 which has the actual figures for that? Could you get
24 that out in front of you, please, page 3?

THE WITNESS: Which exhibit was it?

2 MR. MARX: Nine-R, Romeo.

3 CHAIRMAN HALL: Mr. Marx, would it be
4 possible to submit these questions to Mr. Cline, and
5 let's recall him Thursday or Friday or Saturday? No?
6 Once these calculations were made?

7 MR. MARX: Well, I think the calculations can
8 be given to us from Boeing at a separate time. I'm
9 trying to get a feel for what it is that this witness
10 can answer right now.

11 CHAIRMAN HALL: All right. Then proceed.

12 MR. MARX: Do you have Exhibit 9-R?

13 THE WITNESS: Yes. What page are we on?

14 MR. MARX: Page 3. About midway down the
15 page we have an item 3, test condition, in which it's
16 listed as a secondary retract internal stop. What is
17 meant by that?

18 THE WITNESS: That means that the secondary
19 slide was moved in a retract direction. When we say
20 retract, that's the same thing you're referring to when
21 you said into the servo, until that contacted the
22 internal servo stop, and then they then fixed the
23 secondary slide in that position to perform the test.

24 MR. MARX: Which direction would the rudder

be moving in that if you happen to have the secondary
2 into the internal stop?

3 THE WITNESS: That's left rudder.

4 MR. MARX: Left rudder. What was done with
5 the primary in that case, the test three case?

6 THE WITNESS: The primary was then taken in
7 the opposite direction of the primary or the secondary.
8 It was extended out of the servo body.

9 MR. MARX: The original intent of that test
10 was to show what?

11 THE WITNESS: That that's the case of jamming
12 the primary slide hard over one direction. In this
13 case, the extend direction. And then trying to
14 overcome that command with the secondary in the other
15 direction.

16 MR. MARX: Would it also be consistent or
17 identical to the fact that if we took a secondary and
18 pushed it all the way into the servo and jammed it in
19 that position and pulled the primary back to its
20 farthest extend position?

21 THE WITNESS: You're asking if those two
22 conditions are the same?

23 MR. MARX: Yes.

24 THE WITNESS: No, they are not.

MR. MARX: Why are not they the same?

2 THE WITNESS: Because in the first condition,
3 which is on page 3, the primary is simulated to be
4 jammed. And in the case you're talking about, the
5 secondary is simulated to be jammed. So it's a case of
6 which slide are you trying to overcome, the primary or
7 the secondary. It's very different results.

8 MR. MARX: Well, the first condition, as I
9 understand it, is you take the primary and you move it
10 into the secondary. Is that correct? You're going to
11 left rudder.

12 THE WITNESS: Which condition are we talking
13 about?

14 MR. MARX: The first one. The first
15 secondary retract linkage stop. Is that the external
16 stop?

17 THE WITNESS: Yes, that's the external stop.

18 MR. MARX: Where would the secondary be if
19 you took that to full stop? If you took the primary in
20 as far as it will go and pick up the secondary and take
21 that as far as it will go, it will not be to the
22 external stop, as I understand it. The secondary will
23 not be to the external stop.

24 THE WITNESS: In stalling the PCU, it would

1 be, yes. The summing lever would first -- the primary
2 summing lever would first come move the primary slide
3 until it picked up the secondary slide. Then it would
4 take both slides until the summing lever contacted the
5 external servo stop.

6 MR. MARX: Now what position would be the
7 secondary? What would that be?

8 THE WITNESS: It would be at the external
9 stop position.

10 MR. MARX: The external stop position?

11 THE WITNESS: Yes.

12 MR. MARX: Would that be fully into the
13 servo, the secondary itself?

14 THE WITNESS: Well, not fully. I mean, it's
15 at the external position. If you went further, you
16 would get to the internal position.

17 MR. MARX: I know that you haven't been able
18 to come up with any figures on this, but your
19 guesstimate was five to 20,000 short of the internal
20 stop on the accident?

21 THE WITNESS: Yes.

22 MR. MARX: This test that we're talking about
23 are of the actual accident servo that you're testing?

24 THE WITNESS: That's true.

MR. MARX: If by chance you happen to get the
2 secondary pushed all the way into its internal stops,
3 it will go as far as it can and stop and jam at that
4 position, and linkage feedback from the ram will then
5 try to pull the primary back. Is that correct?

6 THE WITNESS: That's correct.

7 MR. MARX: It will come back as far as what?
8 How far would it go, assuming that the secondary is
9 jammed at the internal stops?

10 THE WITNESS: The primary would come back
11 until it contacted the secondary slides, like in the
12 case of this valve.

13 MR. MARX: Would it be the same as test
14 condition three?

15 THE WITNESS: Yes, the primary would come
16 back sixty-eight thousandths.

17 MR. MARX: In test condition three, what
18 would be the pressure differential between the
19 cylinders and which way would the rudder move?

20 THE WITNESS: In condition three?

21 MR. MARX: Yes.

22 THE WITNESS: Well, your condition, because
23 your condition is not what condition three is.

24 MR. MARX: Well, what I'm --

THE WITNESS: The slides are in the same
2 position, but the one that's being simulated as jammed
3 is different in each case and that provides different
4 results. You said that the secondary slide should be
5 jammed at the internal stop and we tried to overcome it
6 with a primary.

7 MR. MARX: That's correct.

8 THE WITNESS: That would be a negative 58
9 percent residual. If we jammed the primary hard over
10 and take the secondary to the internal stop, we have a
11 positive 58 percent residual.

12 MR. MARX: Yes, but this positive and
13 negative, I'm just trying to look at the actual
14 pressure that are occurring at that particular time.
15 In other words, the third condition in which the
16 secondary is taken to its internal stop, the primary --
17 and that would be in the push in condition, which is
18 left rudder. The primary is coming back to its
19 external stops as if it was going towards right rudder.
20 Is that correct?

21 THE WITNESS: Yes, that's for the most part
22 correct.

23 MR. MARX: In that condition, which way would
24 the rudder move? If you look at the C-2 and the C-1

pressure, the C-2 itself is trying to drive the rudder
2 which way, left or right? If you had a higher pressure
3 on C-2 versus C-1 would it go left or right?

4 THE WITNESS: It would go left.

5 MR. MARX: If you had a higher pressure on C-
6 4 versus C-3, which direction would it go?

7 THE WITNESS: That's left rudder also.

8 MR. MARX: Also left rudder. In the case of
9 test condition three, we have -- for those that do not
10 have a -- well, let's just ask you. What was the
11 pressure measured in that condition for C-2?

12 THE WITNESS: It was 2700 psi.

13 MR. MARX: And for C-1?

14 THE WITNESS: Five hundred and fifty psi.

15 MR. MARX: So there is a difference in
16 pressure between C-2 and C-1 of a magnitude. My
17 calculation shows about 2150 per square inch. The C-1
18 and the C-2 are to what system? Is that to the A
19 system or the B system?

20 THE WITNESS: That's to the B system.

21 MR. MARX: The B system. So we had a 2150
22 pound pressure differential that was going towards left
23 rudder.

24 THE WITNESS: That's correct.

MR. MARX: That would react against a ram
2 square area of one square inch?

3 THE WITNESS: Yes.

4 MR. MARX: Will give you approximately how
5 many pounds of load onto the ram?

6 THE WITNESS: For that system, it would be
7 2100 pounds.

8 MR. MARX: Twenty-one hundred and fifty
9 pounds. The C-3 and the C-4 are for what system?

10 THE WITNESS: Those are for the A system.

11 MR. MARX: The difference that I calculate
12 was 2150 pounds per square inch versus 1250 pounds is
13 1300. Approximately 1300 pounds per square inch.
14 That is also reacting against approximately one square
15 inch. Is that correct?

16 THE WITNESS: Yes, that's correct.

17 MR. MARX: That would give you approximately
18 how much additional load?

19 THE WITNESS: An additional 1300 pounds.

20 MR. MARX: So the total load that would occur
21 between those two systems in that condition would be
22 the sum of those two. Is that correct?

23 THE WITNESS: Yes, that's correct.

24 MR. MARX: The sum of those two conditions, I

think, I believe my calculations show 3450 pounds.

2 That would be in the direction of left rudder.

3 THE WITNESS: For the condition you talked
4 about, that would be in the direction of left rudder.
5 For the condition that was simulated in test three, it
6 would be for right rudder.

7 MR. MARX: Well, I'm speaking of a condition
8 -- well, let's talk again about what you mean by a
9 double jam, a dual jam condition. Does that mean that
10 the dual jam condition could move the rudder here and
11 left and right and continuing to move it in that
12 position, those jams would have to occur
13 simultaneously? Is that correct?

14 THE WITNESS: You're talking about jamming
15 both the primary and the secondary sides?

16 MR. MARX: Right. Would they have to occur
17 simultaneously?

18 THE WITNESS: Not necessarily simultaneously,
19 just concurrently.

20 MR. MARX: Well, how would they occur
21 otherwise?

22 THE WITNESS: Well, they don't have to occur
23 at the same instant in time. One can occur at time X
24 and one can occur at time Y, and you're going to have

still the same problems.

2 MR. MARX: I understand. But in order to get
3 the runaway of the rudder one way or the other, you
4 have to have those jams in place at the same time?

5 THE WITNESS: Yes, that's true.

6 MR. MARX: The scenario that we're looking at
7 here on test number three on Exhibit 9-R on page 3
8 indicates a condition where you would have a
9 possibility, if all my figures are right in the way I
10 think about it, is that you can have a way of getting a
11 secondary into a slower travelled position against the
12 internal stop by a jam, possible jam or some other
13 mechanism that we haven't discussed yet between the
14 primary and the secondary. It would be reacting
15 against the spring force, is that correct, to get it to
16 that position?

17 THE WITNESS: If you had a jam between the
18 primary and the secondary?

19 MR. MARX: correct.

20 THE WITNESS: Yes.

21 MR. MARX: Then to jam the secondary, if we
22 could jam the secondary in that position now -- that
23 is, full travel -- and shear off the particle or
24 whatever it is that's jammed between the primary and

secondary and let that go free so the primary can go
2 onto the right rudder condition, that would be a single
3 jam, would it not?

4 THE WITNESS: Well, you would be left with a
5 single jam after three failures, three failure
6 conditions.

7 MR. MARX: Right.

8 THE WITNESS: The initial jam, the second jam
9 --

10 MR. MARX: But that --

11 THE WITNESS: -- and the initial shear.

12 MR. MARX: I understand. I would like to
13 explore a little bit about the link cavity. In the
14 link cavity, is there any possibility of a particle or
15 debris or some type of jamming mechanism that can occur
16 in the summing lever that can cause an over travel in
17 the secondary?

18 THE WITNESS: There's no jam of the summing
19 levers that I'm aware of that could over travel the
20 secondary.

21 MR. MARX: My understanding so far in
22 testimony is that there's a very small distance in
23 which we have to go to get to the external stop. That
24 would be in the direction of left rudder and where

we're going in pushing the secondary into the housing.
2 I'm trying to find other ways in which we can get that
3 secondary full into the housing other than the two that
4 you talked about which was mismachine chamfer or
5 internal jam.

6 I'm looking now for another method of
7 possibility of an external jam that would be at the
8 summing lever itself that could cause the secondary to
9 go into the housing to its internal stops.

10 THE WITNESS: I haven't been able to come up
11 with one, and for certain reasons, I have thought about
12 that and I have not come up with any on my own, nor has
13 anybody presented any to me and nor am I aware of any.

14 MR. MARX: You also testified about the
15 primary slide test that you did where the force of I
16 think it was 2.5 ounces was measured on the accident
17 servo.

18 THE WITNESS: That was 12.5 ounces.

19 MR. MARX: Or excuse me, 12.5 ounces. YOU
20 indicated also that this would pick up the secondary
21 earlier. Is that correct?

22 THE WITNESS: Picking up the secondary is not
23 a result of the 12.5 ounces. It's just another
24 condition we had on that PCU.

MR. MARX: Oh, it's just another condition?

2 THE WITNESS: Mm-hmm.

3 MR. MARX: That is not a result of the spring
4 itself. It has to do with some other condition. What
5 would that condition be?

6 THE WITNESS: I think it might have been
7 something as simple as tolerances. Like I said
8 earlier, you can't mention everything. You have
9 tolerances. If that unit was to one side of the
10 tolerances and I also said earlier that depending on
11 how many times you tested it, you're going to probably
12 get different results, slightly different results.
13 That picked up so slightly, just a slight bit early,
14 that it's very possible that the first time or first
15 few times that was tested it passed. And the time we
16 tested it, it didn't pass.

17 I feel very confident if we were to test it
18 again several more times, we would get a distribution
19 that shows us it's very close to the limit. Sometimes
20 it will pass and sometimes it won't. I think that's
21 just the case we had with this PCU.

22 MR. MARX: If you picked up the secondary
23 earlier, would that have a tendency to move the
24 secondary farther into the servo if we are going into

the left rudder condition or pushing the primary into
2 the --

3 THE WITNESS: Yes, it would. I don't recall
4 whether it was on an extend or retract side that we
5 picked up earlier.

6 MR. MARX: Was there any other condition such
7 as the particle contamination of the link cavity that
8 can cause a secondary to be picked up earlier as you
9 move the primary? I mean, as you move the primary, can
10 it be picked up earlier from some particle
11 contamination?

12 THE WITNESS: Yes, that's just like anything
13 that would cause stickiness or jam between the primary
14 and secondary. It would cause it to pick up earlier.

15 MR. MARX: It would cause it to pick up
16 earlier?

17 THE WITNESS: Yes.

18 MR. MARX: Well, what would that stickiness
19 be? Would that be something that would get caught in
20 between the mechanism that is going from the link arm
21 towards the primary? Is there any free play, for
22 instance, in that unit?

23 THE WITNESS: Yes, there's relative motion
24 between the primary and the secondary. If you stuck

something in between the secondary pick up and the
2 secondary pick up lever or the secondary lever and the
3 secondary side itself, it would pick up early also and
4 it would pick up early by the magnitude of whatever you
5 stuck in there.

6 MR. MARX: Well, if we picked up earlier, say
7 five thousandth earlier, could it move the secondary
8 five thousandth farther into the --

9 THE WITNESS: Yes.

10 MR. MARX: And five thousandth is about how
11 many microns? Each thousandth is about 25 microns?

12 THE WITNESS: Yes.

13 MR. MARX: So it's about 125. I know there's
14 a lot to think of when you're answering questions here.
15 A hundred and twenty-five microns roughly would be five
16 thousandth. In the link cavity -- the particles that
17 were found in the link cavity, what were the maximum
18 sizes that were found?

19 THE WITNESS: There were some in excess of
20 100 microns.

21 MR. MARX: There was some less than or above
22 100 microns?

23 THE WITNESS: Yes.

24 MR. MARX: What was the largest particle?

1 THE WITNESS: I don't think they actually
2 count the largest particle. They just have a category
3 that's 100 micron or greater.

4 MR. MARX: A 100 micron or greater? Do we
5 have any idea how many particles that were 100 micron
6 or greater?

7 THE WITNESS: Yes, we do if we can locate
8 that exhibit.

9 MR. PHILLIPS: Exhibit 9-0. I believe it's
10 9-0. We haven't got a page yet. And for reference
11 your pick up is on 9-A, page 63 in the extend direction
12 for the early pick up of the secondary, if you wanted
13 to go back to that. That's the input force versus
14 input travel.

15 THE WITNESS: What page did you say that was,
16 Greg?

17 MR. PHILLIPS: Page 63 of 9-A.

18 THE WITNESS: Mr. Marx, to answer your
19 question about how many particles were greater than 100
20 microns in the link cavity sample, the sample we sent
21 to Monsanto, they reported 362.

22 MR. MARX: Three hundred and sixty-two? I
23 have just a few more questions. Maybe we can resolve
24 some of the other stuff later. During the -- were you

present at the time in which the PCU, the main PCU was
2 disassembled at Parker?

3 THE WITNESS: Yes, I was.

4 MR. MARX: You testified that you looked for
5 debris and you also looked for damage on the servo and
6 the linkages?

7 THE WITNESS: Yes, we did.

8 MR. MARX: How did you do that?

9 THE WITNESS: With a stereo-microscope.

10 MR. MARX: About what magnification did you
11 do?

12 THE WITNESS: I think that was about 25
13 times.

14 MR. MARX: How did you look for debris? Were
15 you looking for debris in the residual fluid that came
16 out as a result of it?

17 THE WITNESS: Yes, when we removed the servo
18 from the PCU, we used a cleaned metal pan underneath
19 the component while we disassembled it. We captured
20 all the fluid and anything else that came out of there.
21 Then that again was a visual examination of the fluid
22 after we disassembled the component.

23 MR. MARX: Also on the shear test that you
24 testified to, you indicated that the particle of 52-

100, which I understand is a material that's used in
2 the actual servo itself was used. Is that correct?

3 THE WITNESS: Yes, that's correct.

4 MR. MARX: How many tests did you use on 52-
5 100?

6 THE WITNESS: We just performed one test.

7 MR. MARX: The one test. And based on that
8 one test, you were able to make a statement that it
9 would always produce mark. Is that correct?

10 THE WITNESS: That statement is not based on
11 that single test. That's based on all the tests.
12 Anything with an applied force or anything that
13 required a chip shear force no more than 20 pounds
14 created damage.

15 MR. MARX: Well, my understanding of what was
16 testified to is that there was -- of all the other
17 material that you had, that would be the softer
18 material, except for chrome, which would be a hard
19 material, produced a visible mark that you could see at
20 relatively low magnification. Is that correct?

21 THE WITNESS: That's not completely correct,
22 because we -- I would like to say that that testing was
23 performed fairly recently. The systems group report of
24 that testing is not completed. It's in what I would

1 call a draft form. I noticed the same thing you're
2 noticing, and we went back and looked at the
3 photographic documentation we have.

4 I think the chrome also left damage, but
5 that's something that will -- because this is still in
6 a draft, that is something we have got to iron out
7 within the systems group as to what the report really
8 contains.

9 MR. MARX: But with the 52-100, you only did
10 one test --

11 THE WITNESS: That's true.

12 MR. MARX: -- and you looked at what the
13 results of that was, and you were able to make a
14 uniform statement that it will produce damage in every
15 case? So it's based on one on the 52-100, one test?

16 THE WITNESS: We ran one test with 52-100.
17 But the conclusion that 20 pounds or greater is not
18 based on that test solely.

19 CHAIRMAN HALL: Well, when is this test going
20 to be complete?

21 THE WITNESS: When is what test going to be
22 complete? The testing is complete. The documentation
23 is just not in its final form.

24 MR. PHILLIPS: The testing is complete. Mr.

1 Cline said that the draft report, which is listed as
2 Exhibit 9-R, needs to be revisited with his comments
3 noted. So there is no additional testing planned.

4 MR. MARX: Well, that leads me to one of the
5 few final questions I had, and that has to do with
6 other shear chip testing that has been performed in the
7 past. What other testing has been performed in the
8 past? I mean, is it part of the certification of this
9 valve or is it a result of some other or could you come
10 up and tell me what the actual tests were?

11 THE WITNESS: There was no chip shearing test
12 performed as a part of the certification for this
13 particular valve. Some time in the history of the
14 Boeing Company, there has been some chip shear test
15 performed. I haven't been able to find anybody that
16 actually witnessed those tests or I haven't been able
17 to find any documentation on those tests. so for all
18 purposes, there really isn't any information on any
19 past tests.

20 MR. MARX: I wanted to get one clarifying
21 thing here. It had to do with the pedal going to the
22 bottom, the four inch travel with the pedal to the
23 bottom. I don't know if you meant to say this but does
24 that mean that the secondary goes all the way to its

internal stop or goes as far as it can go in the case
2 of left rudder and as far as it can go out as far as
3 right rudder is concerned?

4 THE WITNESS: I think you're talking about
5 the control's check?

6 MR. MARX: Yes.

7 THE WITNESS: Yes, if you perform the freedom
8 control's check to the full extent of the rudder, the
9 pedal travel, you will move the secondary slide to its
10 external stop.

11 MR. MARX: So it doesn't really matter how
12 fast you're moving that pedal. It's just how far
13 you're moving it?

14 THE WITNESS: That's correct.

15 MR. MARX: So if you get to the full extent,
16 you can actually push that secondary all the way to its
17 limits?

18 THE WITNESS: That's true.

19 MR. MARX: One final question. It has to do
20 with the fluid contamination test that you performed
21 recently. I understand that we do not have any
22 exhibits on this presently. When you use different
23 types of materials, 43-40 and aluminum, bronze, teflon,
24 were these all mixed together in one slurry?

THE WITNESS: Yes, they were.

2 MR. MARX: I have no further questions.

3 CHAIRMAN HALL: Mr. Clark?

4 MR. CLARK: In an earlier statement, I
5 believe it was in regard to the contamination testing.
6 You said the unit went through 5,000 cycles. Can you
7 tell me what a cycle is in this case?

8 THE WITNESS: A cycle in this case was
9 starting in a neutral position, extending to -- we went
10 fairly close to full PCU extension. I would say
11 between 80 and 90 percent back to 80 or 90 percent of
12 PCU retraction and back to neutral again.

13 MR. CLARK: Then back to neutral?

14 THE WITNESS: Yes.

15 MR. CLARK: So basically that would be the
16 equivalent of 5,000 motions of the input lever arm?

17 THE WITNESS: Yes.

18 MR. CLARK: Rather than 5,000 flight cycles?

19 THE WITNESS: That's correct.

20 MR. CLARK: In the grand scheme of things in
21 your position at Boeing, where do you pick it -- do you
22 pick up the surface difficulty reports or how do you
23 become aware of problems in the field or on the line?

24 THE WITNESS: I'm made aware of those

1 problems by the service engineering group. They send
2 anything they feel is significant directly to us. They
3 call us. Sometimes they even need our support for
4 their responses to airlines.

5 MR. CLARK: So you would at least in the
6 atmosphere in the last several years, do you believe
7 you pick up most of the yaw damper reports and any
8 other problems with rudder packages?

9 THE WITNESS: Yes, I've picked up so many of
10 those, it's hard to keep them straight.

11 MR. CLARK: The service difficulty group
12 isn't filtering too many of those that you don't see?

13 THE WITNESS: No, I don't think they're
14 filtering any at all.

15 MR. CLARK: You also talked about the Mack
16 Moore unit and the summing lever over travel issue. I
17 assume you examined this unit for witness marks in that
18 area?

19 THE WITNESS: Yes, we examined for witness
20 marks and we visually verified that while a command was
21 being input, it contacted the external servo stops
22 correctly.

23 MR. CLARK: They were contacting the
24 inflation square and in the middle?

THE WITNESS: That's correct.

2 MR. CLARK: When you talked about units of
3 new manufacturer and those that are returned, when
4 those units are returned for service, are they tested
5 prior to the overhaul for evidence of the Mack Moore
6 type tolerance build up or is that all done after
7 they've been overhauled or during overhaul?

8 THE WITNESS: There is some testing, some
9 receiving testing done. I'm not positive if that input
10 force test is included in that.

11 MR. CLARK: Most of those units do go to
12 Parker Hannifin?

13 THE WITNESS: Most of them do, yes. All of
14 the units being retrofitted go to Parker Hannifin.

15 MR. CLARK: But do you do testing at the
16 Boeing facility for units or do the units come through
17 the Boeing facility at all?

18 THE WITNESS: Some of the units come to the
19 Boeing facility, but they just get forwarded to Parker.

20 MR. CLARK: I'll save my questions for that.
21 In Exhibit -- and I'm not sure if it's necessary to
22 pull up the exhibit. Maybe for you. But in Exhibit 9-
23 A, page 52, the conclusion was that testing validated
24 that the unit was incapable of uncommanded rudder

reversal or movement. Is that statement based on your
2 evaluation of the tolerance build ups that I assume you
3 made measurements and conducted the flow test? Is that
4 primarily based on the tolerance build ups that you saw
5 in the unit?

6 THE WITNESS: That conclusion is based on an
7 actual test where we took the servo at the servo level
8 and drove the secondary to its internal stops and
9 applied an equivalent force of the walking beam and
10 monitored the cylinder pressures and they did not
11 reverse.

12 MR. CLARK: When you were doing -- when you
13 say the secondary was driven to the stops, I've heard
14 terms of over travel. Is that your characterization of
15 that?

16 THE WITNESS: Yes. We drove it to the
17 internal stops, which would include any over travel
18 that existed.

19 MR. CLARK: Were there any -- when you were
20 doing the over travel tests, were there any pressure
21 reversals in the unit that you noted?

22 THE WITNESS: No, there were not.

23 MR. CLARK: Earlier you also talked about
24 chip shear and at one point, I heard a number that the

maximum force would be 95 pounds. Is that 95 pounds
2 that can be applied directly to the end of the primary
3 servo valve?

4 THE WITNESS: Yes. It's on the order of 95
5 pounds. I would have to look at the acceptance test
6 data to give you an exact number.

7 MR. CLARK: I guess it was my understanding
8 that the break-out unit would limit that force to
9 forces in the 55 pound range or 50 pound range. This
10 95 pounds applied at the end of the primary servo is a
11 higher number than I've heard in the past.

12 THE WITNESS: The reason for that is we only
13 put a minimum limit on the walking beam break out.
14 That minimum limit at the walking beam level is 40
15 pounds. In the same regards that the PCU type assembly
16 level, we have an envelope of what those forces can be
17 within. So if you look at the upper portion of that
18 envelope, it's in the 95 pound range.

19 MR. CLARK: That clarifies it. Then during
20 your testing if you saw the equivalent of a 40 pound
21 load physically pushing on the primary valve, that
22 would still be an acceptable test?

23 THE WITNESS: I'm not quite sure what you're
24 asking.

1 MR. CLARK: Let's break the unit out. If I
2 had a servo and I dropped a piece of contaminate in,
3 how much could I physically push directly on the end of
4 that primary servo before I reached the low end of the
5 walking beam break out? What force would that be?

6 THE WITNESS: That varies with units. But on
7 this unit, it was 44 pounds.

8 MR. CLARK: Forty-four pounds. So in other
9 words, if I had a contaminant in there that could
10 withstand that 44 pound load, then I could continue
11 with the jam without shearing the part?

12 THE WITNESS: That's correct.

13 MR. CLARK: Because the walking beam would
14 break out and not allow the loading to go any higher at
15 that point?

16 THE WITNESS: That's correct.

17 MR. CLARK: In your testing, did you ever
18 push the secondary fully to the internal stops and then
19 try to determine if there were any jams or binding at
20 that point?

21 THE WITNESS: There were several tests where
22 the secondary slide was taken to the internal stops.
23 We didn't specifically see if it was jammed at that
24 point. But whenever the test was released, the

secondary always returned.

2 MR. CLARK: In some of the noted similarities
3 between Colorado Springs, for example, and Pittsburgh,
4 preceding each event, we were in an area of turbulence
5 in which it could be assumed that the yaw damper may be
6 active, but they are also in a vertical acceleration.
7 Are there any requirements or testing to shake test the
8 unit in the vertical direction to see if that can
9 introduce problems or examine the entire airplane for
10 vertical movement of the linkage, the control cables,
11 for example, to see if that may introduce concurrent
12 problems with the yaw damper activation?

13 THE WITNESS: Yes. At the component level,
14 we do vibration testing. The airplane is divided up
15 into zones and vibration levels for each of those zones
16 defined. I don't know if the system, such as the
17 cables and the tubes in the quadrants in that, are
18 subject to a vibration test or not, but the components
19 such as the PCU are.

20 MR. CLARK: When they do those kinds of
21 tests, are they subjected to the 1 g, plus or minus .3
22 or .5 g's consistent with the type of data we have
23 recorded from these two accidents?

24 THE WITNESS: I think it's much greater than

that.

2 MR. CLARK: That would be an all up test with
3 the unit running and operational?

4 THE WITNESS: I can't recall whether we
5 actually operate it during that vibration testing or
6 whether it's just -- I can't recall. I don't know
7 right now.

8 MR. CLARK: I believe yesterday Mr. Turner
9 made a comment and I forgot to follow up with him, so
10 I'm going to ask you and we may have to go back to Mr.
11 Turner. The question then was can the yaw damper cause
12 full movement of the secondary valve. I think the
13 answer was yes. My question is can the full movement
14 of the yaw damper cause full movement of the secondary
15 valve?

16 THE WITNESS: I think if you have enough load
17 on the PCU, such as a cruise condition where your loads
18 are the highest on the surface and you're going to get
19 the slowest rates out of the PCU, I think, yes, you can
20 drive the secondary to its stops.

21 MR. CLARK: Basically what you're referring
22 to is if the yaw damper is moving, the rudder is trying
23 to keep up. So it's difficult to get full travel out
24 of the secondary. But if I were to drop back -- and

1 let's just assume for a moment the rudder wasn't moving
2 and look at an extreme situation. If we held the
3 rudder in place so we had no feedback and then simply
4 moved the yaw damper to a hard over, is that motion to
5 the summing levers enough to move the secondary to the
6 external stops?

7 THE WITNESS: Yes, in a static case like
8 that, yes, geometrically it is plenty of stroke to move
9 the secondary over.

10 MR. CLARK: Then also from a direct pilot
11 input, if that exceeds the rate of the rudder feedback,
12 the typical stop we hit would be the external stop on
13 the servo valve?

14 THE WITNESS: That would be the first one you
15 hit. If the rate of the pilot exceeded the PCU even
16 further, then you would hit the stops on the external
17 or the manifold of the PCU itself.

18 MR. CLARK: You would go through the break
19 out and then hit the --

20 THE WITNESS: Yes.

21 MR. CLARK: -- continue on to hit the
22 manifold external boy stop?

23 THE WITNESS: Yes.

24 MR. CLARK: Would that hold true also for a

yaw damper input?

2 THE WITNESS: The yaw damper won't ever, even
3 in your case of holding the feedback, the yaw damper
4 won't ever cause the external manifold stops to
5 contact. They purposely design it that way so that we
6 could never kick the pedals with the yaw damper.

7 MR. CLARK: I would like to get some
8 clarification on Exhibit 9-AH, page 2. We've talked
9 about the Mack Moore unit or the United unit, and my
10 understanding is to get that anomalous condition to
11 exist, we have to push both primary and secondary valve
12 in the same direction into an over travel situation?

13 THE WITNESS: Yes. That's correct.

14 MR. CLARK: Then all of these cases here,
15 we're looking at opposite motions of the primary and
16 secondary. We would move the secondary one way and the
17 primary the other?

18 THE WITNESS: Yes.

19 MR. CLARK: Let's take number one first. YOU
20 used the term residual, and earlier you defined that as
21 a leftover pressure. Can we get a more practical
22 definition, that if I'm in this situation and I'm
23 experiencing this 12 percent residual, what's going on?
24 First let me ask you, what would the pedal positions be

in that situation?

2 THE WITNESS: Depending on what air speed you
3 were at, you're going to be at whatever deflection
4 gives you a 12 percent of full hinge moment and in the
5 condition when it's going to be in the left rudder
6 direction. The pedals would lag that position by six
7 and a quarter degrees because of the clearance between
8 the input crank and the manifold stops.

9 MR. CLARK: Basically in this situation, we
10 have a secondary jam that would command a left rudder
11 movement. In my assumption from what I see here, the
12 pedal is trying to command a right movement. That's
13 where the primary would have moved to the full right
14 that we can get from a pedal input.

15 THE WITNESS: Yeah, you wouldn't even
16 necessarily need a pedal input because of the feedback
17 loop. For example, if the pilot commanded -- if we're
18 at an air speed where we have 20 degrees of rudder
19 available before we hit blow down and the pilot
20 commanded 10 degrees of left rudder and the secondary
21 jammed while the pilot was doing this with the full
22 rate command, first of all the surface would go to
23 where the pedals commanded it to. You wouldn't notice
24 anything at that point. When he removed his pedal

command and he tried to let the pedals go back to zero,
2 the rudder surface would only go back to 12.5 percent,
3 so four degrees.

4 MR. CLARK: Twelve percent of the maximum
5 travel at 20?

6 THE WITNESS: Right.

7 MR. CLARK: If we're at the 20 -- if the
8 blow-down limit is 20 degrees?

9 THE WITNESS: Right.

10 MR. CLARK: So we would see about 2 degrees
11 of rudder when the pilot took his feet off the pedal?

12 THE WITNESS: Yes, that's correct.

13 MR. CLARK: Two degrees. Then what would
14 happen as he continued to try to correct that situation
15 and push in right pedal?

16 THE WITNESS: He wouldn't get any response
17 out of the rudder. It would stay right there.

18 MR. CLARK: He could either break the unit
19 free or work through the break out in the PCU?

20 THE WITNESS: Yes, he would be -- the most
21 that would be happening is he would be physically
22 pushing on the manifold stops with whatever force he
23 excerpted in trying to move the rudder surface with
24 that force which in comparison to the PCU hinge moment

isn't that great of a force.

2 MR. CLARK: In this situation, we have looked
3 at an undefined jam in which we can move the secondary
4 to the external stop because from an external input,
5 that's as far as we could move the secondary. Then we
6 move the primary in the opposite direction. Then it's
7 limited by -- it's essentially limited by the position
8 in the summing lever tolerance of the secondary?

9 THE WITNESS: Yes. It's limited by the dead
10 band between the secondary summing lever and the
11 secondary slide.

12 MR. CLARK: If I took that maximum
13 difference, that's the number where we get the 12
14 percent residual?

15 THE WITNESS: Yes, that is.

16 MR. CLARK: Now if I maintained that relative
17 position and I can't define to you a mechanism to make
18 the valve move, but if I were to maintain that maximum
19 differential position and then move the secondary on
20 into the internal stop, what would happen to these
21 numbers?

22 THE WITNESS: That number would go from 12.5
23 percent to 57 percent.

24 MR. CLARK: Oh, that's a situation that

you've defined down here?

2 THE WITNESS: No, it's not the situation
3 defined down there, but it's the same value, just an
4 opposite sign.

5 MR. CLARK: Then if I took that relative
6 position or moving to the internal stop, the situation
7 would be dramatically improving as far as pilot
8 control? I mean, we're moving from a can't control
9 situation to having a 50 percent control?

10 THE WITNESS: I missed the first part of
11 that.

12 MR. CLARK: In the condition number one on
13 the servo is positioned at the equivalent of the
14 external stop and then in condition number four, the
15 servo would be positioned further into the internal
16 stop. But that amount of movement actually improves
17 the situation as far as controllability of the rudder
18 package?

19 THE WITNESS: Yes.

20 MR. CLARK: Let me go back then and if I were
21 -- if the situation for that maximum misalignment is
22 the situation number one, the worst condition, for
23 example, if I started moving -- maintained that same
24 differential and started moving the secondary back to a

more neutral position, would that be a worse situation?

2 THE WITNESS: No, that would be a better
3 situation from a controllability.

4 MR. CLARK: So this situation you've defined
5 here as the worst and then any motion even further on
6 or less is going to be an improving situation?

7 THE WITNESS: Yes. That's why those test
8 points were chosen, because they are the boundary test
9 points.

10 CHAIRMAN HALL: Mr. Clark, could I interrupt
11 you just for a moment?

12 MR. CLARK: That was my last question.

13 CHAIRMAN HALL: Well, are you sure?

14 MR. CLARK: Yes, sir.

15 CHAIRMAN HALL: Well, I don't want to --
16 here's what I would suggest we do. We have a gentleman
17 here who is here at the request of the board, a Mr.
18 Runkel. Where is Mr. Runkel? Mr. Runkel, you have to
19 leave at 2:00. Is that correct? What's that, sir?

20 MR. RUNKEL: I have a 3:30 flight.

21 CHAIRMAN HALL: Mr. Runkel, Mr. Haueter tells
22 me that your testimony is important to this hearing.
23 So what I'm going to suggest is that we continue until
24 12:30. We take a break, a 30-minute lunch break, from

12:30 until 1:00. I apologize for the shortness of the
2 break.

3 Mr. Runkel will then come and present his
4 testimony at 1:00. That will give us an hour. I am
5 told that that is an adequate period of time for Mr.
6 Runkel's testimony. Then we would ask Mr. Cline to
7 return. Then we will proceed and we will proceed
8 tonight until 8:00.

9 We will continue. We have this room
10 Saturday. If it is necessary to continue this hearing,
11 Saturday we will do so. It is nothing this Chairman
12 needs to add to the importance of this hearing and the
13 work to the American public, and I appreciate
14 everybody's patience in this, but it must continue and
15 we will continue on the schedule I just outlined.

16 Mr. Schleeede, you can -- Mr. Clark said he
17 was through. Are you sure, John, I did not cut you
18 off? I didn't mean to cut you off. If you had
19 anything else you needed to follow up on?

20 MR. CLARK: No, that was my last question.

21 CHAIRMAN HALL: He's under oath, Mr.
22 Schleeede, that that's his last question, so you may
23 proceed.

24 MR. SCHLEEDE: My first comment is to clarify

1 on the record, we've made several references to the
2 United incident and the Mack Moore unit and so forth
3 and so on. I just wanted the record to reflect that
4 that's an event that occurred on July 16, 1992, United
5 Airlines, Boeing 737-300. I think the testimony will
6 be clear. Oh, it's contained in Exhibit 9-L, 9 Leemah.
7 Excerpts from the Colorado Springs' accident report,
8 page 22.

9 A couple of follow ups to Mr. Clarks'
10 questions on this service history. I wanted to give
11 you an example. If a pilot had reported an anomaly
12 taxiing in the airplane or in flight in which he felt
13 rudder kicks and movements of the rudder pedals and
14 that was written up for maintenance and troubleshooting
15 took place, would that type of an event, regardless of
16 the result of the maintenance troubleshooting, would
17 that come to your attention?

18 THE WITNESS: If the airline submitted a
19 telex explaining -- I'm not sure what causes an airline
20 to submit a telex to our service group. But if that
21 telex got to our service group, it would then get to
22 me, yes.

23 MR. SCHLEEDE: Do you receive reports of that
24 nature?

1 THE WITNESS: Yes, quite often. I mean, not
2 of the nature you're talking about, but I receive
3 reports of a pilot squawking something and maintenance
4 action was taken.

5 MR. SCHLEEDE: If a pilot did have this type
6 of report and it was determined it was in flight. It
7 was taken in flight rudder kick, and it's unclear
8 whether the pedals moved or not, but it was reported as
9 a hard over type of event and the main rudder PCU and
10 the standby rudder PCU were removed during maintenance
11 and returned to the factory. Would that type of an
12 event come to your attention?

13 THE WITNESS: Yes, it would. A lot of times
14 we would travel down to wherever the component was
15 being tested to witness that testing. We would also
16 try to clarify what the pilot meant by a hard over.
17 Whether he was really meaning a yaw damper hard over or
18 a full surface hard over. We would try to get as much
19 information as possible.

20 MR. SCHLEEDE: When you do those types of
21 investigations of interface, like you say travel to
22 Parker, does the FAA participate in those examinations?

23 THE WITNESS: Sometimes they do. There is
24 some specific guidelines as to whether the FAA has to

1 be notified. I don't work for those guidelines, so I'm
2 not sure.

3 MR. SCHLEEDE: One last area has to do with
4 your testimony about the chip shear tests that were
5 conducted in December. I know you're -- I don't want
6 to go over it all, but you mentioned that there were
7 marks found on the servo valve after your work. I
8 heard you say one time 20 pounds created a lot of
9 damage. If it was jammed, it always left a mark. Is
10 that generally what you said about that testing?

11 THE WITNESS: Yes, that's what I said.

12 MR. SCHLEEDE: I wanted to try to get an
13 explanation for another document that's in the
14 exhibits. It's Exhibit 9, alpha delta, A-D. Do you
15 have that exhibit?

16 THE WITNESS: Yes, I do.

17 MR. SCHLEEDE: Page 6, upper right-hand
18 corner of page 6. Right in the center of this page is
19 item number 6. To put it in proper context, this is a
20 telex in response to an inquiry brought regarding an
21 incident involving a 747.

22 CHAIRMAN HALL: What exhibit is this? I
23 apologize.

24 MR. SCHLEEDE: Nine alpha delta. This

correspondence is Boeing correspondence, customer
2 correspondence. It's in reference to an incident
3 involving a Boeing 747-400 at Hethrow that's in Exhibit
4 9-Q.

5 My question has to do with item 6 where the
6 question was posed by the investigating team and Boeing
7 documented the reason for lack of markings on the
8 primary and secondary slides. This assumes Boeing
9 maintains that a jam caused the incident. Now I'm
10 aware that that was one of the earlier theories of that
11 investigation and was dismissed later that a jam
12 occurred.

13 My question has to do with the reply to this
14 question. It says microscopic marks on the slide and
15 servo parts are typical of those seen on in-service
16 parts. Intentional valve jam chip shear tests
17 previously done at Boeing with nitroloe slides and 52-
18 100 sleeves with various contaminant materials, showed
19 no marks with chrome or hard materials, but showed a
20 smear with soft materials, such as lock wire.

21 This may be unfair to you, but have you seen
22 this before, this particular document?

23 THE WITNESS: Well, the first time I had seen
24 it was this week reviewing the exhibits.

MR. SCHLEEDE: You testified that during this
2 investigation, you've tried to research. You're aware
3 of earlier chip shear tests done at Boeing, but you
4 were unable to find the documents. Have you got any
5 explanation for this which differs significantly from
6 the tests that were done in December?

7 THE WITNESS: Well, the explanation I have
8 for this is that this is a response written by a
9 service engineer. We have communicated with one of the
10 project engineers on this, and he thinks that possibly
11 there was some miscommunication between the project and
12 the service engineer. What really is the case is not
13 really what got printed and sent out. That is
14 something that we would have to further investigate to
15 know what the answer is, though.

16 MR. SCHLEEDE: Do you know if any of the
17 Boeing witnesses that are coming up later can enlighten
18 us on that?

19 THE WITNESS: I don't think so. Most of the
20 witnesses here are out of the Renton Division. This
21 piece of paper comes out of the Everett Division.

22 MR. SCHLEEDE: That's all the questions I
23 have, Mr. Chairman.

24 CHAIRMAN HALL: Mr. Laynor.

MR. LAYNOR: Mr. Cline, I'll try to be brief
2 also. In the beginning of your testimony, you talked
3 about your participation in the examination of the PCU
4 off of flight 427. You commented that you prose things
5 in the position and then x-rayed the unit and did
6 internal examinations. Can you briefly describe, first
7 of all, what did you find? Did you establish what
8 position the piston rod was in fairly competently and
9 talk about the valves and internal components?

10 THE WITNESS: Yes, I can establish fairly
11 comfortably where the piston was at the time of impact.
12 There was some -- of course, the piston was bent and
13 there was a lot of damage created by doing that. So
14 there was some impact marks on the rod relative to the
15 manifold and the in-glands and the bearings that
16 support that piston.

17 By doing a CATIA layout of the damage and a
18 CATIA layout of the installation, I could shift the
19 position relative until I got it a good match between
20 the impact marks and the items that would have caused
21 that impact mark. That should about a 2 degree right
22 rudder position at the time of impact.

23 One thing I can say, however, though is that
24 from the photos I've seen and from talking with the

1 people that were at the accident scene, it doesn't seem
2 like enough care was taken to handle those components
3 carefully on the accident scene. I've seen videos and
4 pictures of people walking on those kinds of
5 components, walking on the surfaces.

6 I understand it's hard to get around there,
7 but if in the future if anything can be done to help
8 preserve as much as possible at the accident scene, it
9 helps. In this case, it didn't hurt anything, but it
10 could help immensely in the investigation afterwards.

11 MR. LAYNOR: Well, we tried. How about the
12 internal complements, bypass valves and springs, the
13 yaw damper pistons and such, were they all pretty much
14 intact and were you to expect them to be?

15 THE WITNESS: Yes, they were. We didn't x-
16 ray the bypass valves because they are buried around a
17 lot of mass. You can't get a good x-ray of those. We
18 did x-ray the yaw damper piston. It was detented, as
19 you would expect.

20 We x-rayed the servo valve. The secondary
21 slide was detented, as you would also expect. The
22 primary slide, although we can't tell exactly where it
23 is, it was somewhere very near neutral.

24 MR. LAYNOR: Was the feedback mechanism

intact?

2 THE WITNESS: The feedback mechanism was bent
3 because of the piston rod being bent.

4 MR. LAYNOR: The next area, on the chip shear
5 test that you discussed, you said that large particles
6 on the order of perhaps 15 times what you would have
7 seen in the contaminant in the accident airplane, in
8 the samples, do you believe that those tests were
9 necessarily representative of what you would have seen
10 on the valve slide had it been jammed by smaller
11 particles, 30 to 100 microns perhaps?

12 THE WITNESS: We haven't come up with a
13 mechanism yet that small particles can jam the slide.
14 My answer to that would be between the particulate
15 tests and the chip shear tests, we feel very confident
16 that we represented that.

17 MR. LAYNOR: In the particulate test and I
18 assume by that you're talking about the tests that were
19 conducted just very recently that you showed the slides
20 on?

21 THE WITNESS: Yes.

22 MR. LAYNOR: I think in response to Mr.
23 Clark, you described a cycle and I was wondering
24 whether a cycle was a PCU piston rod full travel or

whether it involved full travel of both the primary and
2 the secondary slides and the servo valve?

3 THE WITNESS: The answer is both. We stroke
4 the piston very close to full travel and we varied the
5 input rate. Primary and secondary slide position is
6 only a function of commanded rate. So we varied the
7 rate purposely so that we did get a difference in
8 commanded position of the slides.

9 MR. LAYNOR: Was that accomplished by loading
10 the piston rod of the PCU?

11 THE WITNESS: No, that was accomplished by
12 just changing the rate of the input device. It went
13 through -- it was on a ten cycle spectrum. It went
14 through nine low rate cycles and one high rate cycle.

15 MR. LAYNOR: You can beat the servo or was
16 there any feedback group associated with this?

17 THE WITNESS: Yes, there was.

18 MR. LAYNOR: You can beat the servo when it's
19 unloaded?

20 THE WITNESS: Sure. It can only go 66
21 degrees per second and no load. So if you apply
22 anything greater than that, you're going to exceed its
23 rate.

24 MR. LAYNOR: Was the slide friction measured

for the primary and secondary slides following that
2 test or any time during the test?

3 THE WITNESS: It was measured at the
4 conclusion of the test at the PCU top assembly level,
5 like you would do during the force versus input test.

6 MR. LAYNOR: What were the findings, just
7 ballpark?

8 THE WITNESS: They were greater. I don't
9 have the numbers. But the thing to keep in mind is at
10 the PCU level when you're moving and it's not powered
11 hydraulically and you're moving the input, you're moving
12 the slides as well, but you're moving a lot of bearings
13 in there. As you saw from the pictures, those bearings
14 were sledge up and that added to the force.

15 MR. LAYNOR: I thought the slide friction was
16 measured by putting a force directly on the primary and
17 secondary slide?

18 THE WITNESS: It is at the servo level.

19 MR. LAYNOR: We didn't do that?

20 THE WITNESS: Not to my knowledge. I wasn't
21 -- this test was finished up on actually the
22 disassembly of the component was finished up on Friday.
23 I was traveling here at that point in time.

24 MR. LAYNOR: Then my next question was, you

showed the damage to the slides caused by the
2 impingement of the particles. Were the slides examined
3 under magnification for any damage that might be
4 consistent with jamming during any portion of the
5 tests?

6 THE WITNESS: I don't know the answer to that
7 either, because I wasn't at the tear down. There's a
8 57 minute video, though, if you want to watch it.

9 MR. LAYNOR: Well, I'm sure the test report
10 that we haven't yet received, but will receive, will
11 include that kind of examination.

12 THE WITNESS: Yes, it will.

13 MR. LAYNOR: How many cycles were put on the
14 PCU?

15 THE WITNESS: Something over 5,000, shortly
16 over 5,000.

17 MR. LAYNOR: Do we have any idea what that
18 would be -- how that would be represented in terms of
19 flight hours perhaps, normal operation?

20 THE WITNESS: I don't have an exact number,
21 but it's not very many flight hours. The yaw damper is
22 active on the -- as long as the yaw damper is on, it's
23 putting in quite a few cycles per flight.

24 MR. LAYNOR: Perhaps this is a question for

Mr. White, but on disassembly of parts, have we ever
2 seen damage to the slides representative of the damage
3 that you saw on those tests?

4 THE WITNESS: Not on this component I
5 haven't.

6 MR. LAYNOR: I mean, disassembly of parts
7 that have been in service for a long time?

8 THE WITNESS: I haven't, no, and not on this
9 component. On other components, we've had this kind of
10 damage.

11 MR. LAYNOR: That's all the questions I have.
12 Thank you, sir.

13 CHAIRMAN HALL: Mr. Cline, I think what the
14 Chairman is going to do is continue with you here for
15 another ten or 15 minutes, and we'll still take our
16 half hour lunch break. The flight is at 3:30?

17 MR. RUNKEL: Yes.

18 CHAIRMAN HALL: How long does it take to get
19 to the airport?

20 MR. RUNKEL: Half hour.

21 CHAIRMAN HALL: So Mr. Cline has been here
22 since 8:30. In fact, the Chairman just has a few
23 questions that are not technical in nature, at least
24 depending on the definition of technical, I guess.

How long did you say, sir, you have been with
2 Boeing?

3 THE WITNESS: Four and a half years.

4 CHAIRMAN HALL: Four and a half years. HOW
5 long -- I had this question. How long has Boeing built
6 the 737?

7 THE WITNESS: Since 1966.

8 CHAIRMAN HALL: Sixty-six. This particular
9 aircraft was manufactured when, do we know?

10 THE WITNESS: I don't recall. I think it was
11 the late '80s.

12 MR. HAUETER: In 1987.

13 CHAIRMAN HALL: In 1987. Now if I understand
14 what's transpired up to this point, we basically have
15 two accidents that have some similarities. One row
16 right and one row left. We have a situation that we
17 don't have a flight data recorder that gives us a lot
18 of information or any information on rudder movement.
19 Right?

20 THE WITNESS: Right.

21 CHAIRMAN HALL: But what we do have is based
22 on all of our simulations and tests no one, the experts
23 at Boeing and elsewhere -- and I don't ever want to get
24 in a situation -- but characterize that that there is a

2 real possibility that there was a rudder movement in
3 regard to this accident flight. What I'm trying to
4 ascertain is how long has this particular rudder and
5 this hydraulic system been on that plane? Since the
6 very beginning or has it been -- is that the same
7 rudder that was there in 1967?

8 THE WITNESS: It's the same rudder system,
9 yes. The particular rudder PCU that was on the
10 airplane had been put on in '92.

11 CHAIRMAN HALL: Has there been any changes to
12 it, substantial changes since the initial design?

13 THE WITNESS: Not what you would call
14 substantial, no. In fact, a PCU, an early PCU, if
15 there are any still out there, you can install it.
16 They're interchangeable. You could put it on a brand
17 new airplane.

18 CHAIRMAN HALL: This particular PCU, do we
19 know when it was manufactured? As Parker Hannifan,
20 would you have that information?

21 THE WITNESS: It's in the record.

22 CHAIRMAN HALL: It had been in for service --
23 well, I'll get into this with Mr. White then. When the
24 particular PCU we're talking about when it was
manufactured and what its service history was --Now

1 this certification test, special certification, the FAA
2 and Mr. Dormer are involved in, have you been involved
3 in that as well?

4 THE WITNESS: Yes, I've been called to their
5 CER team reviews to answer questions.

6 CHAIRMAN HALL: I assume we'll find out when
7 the FAA is going to have a report later in that special
8 certification, as well. How much testing has been done
9 in the last years or has this particular incident just
10 precipitated all this testing of this particular unit?

11 THE WITNESS: There's been a lot of testing,
12 to my knowledge, that started on this component in the
13 summer of '92 when the Mack Moore situation came up. I
14 think there's been a steady stream of tests performed
15 since then.

16 CHAIRMAN HALL: Since that period of time.
17 And the modification that was put in that we now have,
18 either you have it modified within a five-year period
19 or you test every 750 hours, are you familiar with the
20 tests that are supposed to be conducted every 750
21 hours?

22 THE WITNESS: Yes, I'm familiar with it.

23 CHAIRMAN HALL: What do they do?

24 THE WITNESS: In simple terms, they provide

1 very fast and full rate inputs to the rudder while
2 they're monitoring the rudder's position and internal
3 leakage, using a clamp and using the pumps.

4 CHAIRMAN HALL: If there was a malfunction,
5 how would you know it jammed or stuck or what would
6 tell you that there was a problem with that unit?

7 THE WITNESS: If you're having a problem with
8 that particular PCU, it would manifest itself in
9 several ways. It could stall the pedals or you would
10 feel a bump on the pedals or you would feel erratic
11 motion of the pedals. Your internal leakage might also
12 go way up.

13 CHAIRMAN HALL: Since they started that
14 testing, have there been any problems with any of the
15 particular PCUs that you're aware of?

16 THE WITNESS: No, there's been a lot of PCUs
17 removed because of that testing, but that's part of the
18 nature of the testing we removed. To be a little bit
19 on the safety side, we removed units that really don't
20 have problems. And none of the units we removed have
21 had a confirmed servo valve problem.

22 CHAIRMAN HALL: Do they go to you or to
23 Parker Hannifin?

24 THE WITNESS: They would go to Parker

Hannifin.

2 CHAIRMAN HALL: Are they rebuilt and returned
3 to service, or what has been happening to those units,
4 do we know?

5 THE WITNESS: In most cases, the operator has
6 written up a report about it and they want to know the
7 what's, where's and why's. So we usually meet them at
8 the overhaul facility, Parker's overhaul facility, and
9 go through the testing with them and try to see if we
10 can find anything. If we don't find anything, which
11 most cases we haven't -- in all cases, we haven't --
12 the servo valve is retrofitted and put back in service.

13 CHAIRMAN HALL: Well, I will look forward to
14 the testimony from Parker Hannifin, Mr. White. I
15 appreciate Mr. White being willing to let the
16 representative from Dowty precede him in the order of
17 things. We will continue after a half hour lunch
18 break.

19 (Whereupon, a lunch break was taken.)

20 CHAIRMAN HALL: If we could get everybody
21 back in, we'll call the next witness. The hearing will
22 come back to order. Our next witness, as soon as the
23 Chairman finds his correct name and title, is Mr.
24 Manfred Runkel. He is the vice president of

Engineering with Dowty Aerospace in Los Angeles,
2 California. Welcome, Mr. Runkel. I appreciate you
3 being here and Mr. Schleede will begin.

4 THE WITNESS: Thank you for accommodating me.

5 (The witness testimony continues on the next
6 page.)

7
8
9 MANFRED RUNKEL, VICE PRESIDENT, ENGINEERING, DOWTY
10 AEROSPACE, LOS ANGELES, CALIFORNIA

11
12 Whereupon,

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

17 MR. SCHLEEDE: Mr. Runkel, would you give us
18 your business address, please, for the record?

19 THE WITNESS: It's 1700 Business Central
20 Drive in Los Angeles, California. The company is
21 called Dowty Aerospace, the Los Angeles Division.

22 MR. SCHLEEDE: What is your position at
23 Dowty?

24 THE WITNESS: Vice president of Engineering.

MR. SCHLEEDE: How long have you held that
2 position?

3 THE WITNESS: Relatively briefly. Since
4 October of last year.

5 MR. SCHLEEDE: How long have you worked for
6 Dowty?

7 THE WITNESS: That's it.

8 MR. SCHLEEDE: Could you give us a brief
9 description of your background or education that
10 qualifies you for your present position?

11 THE WITNESS: I was educated in Germany.
12 I've got an equivalent of a bachelor's in mechanical
13 engineering. I came to this country in '67. Been
14 working with aerospace hydraulics since then.
15 Initially at Boeing and then subsequent at several
16 other supplier manufacturers.

17 I'm familiar with design and have designed,
18 evaluated, tested components like we've discussed
19 earlier.

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

22 MR. PHILLIPS: Good afternoon, Mr. Runkel.
23 In your position with Dowty, could you briefly describe
24 some of your day-to-day responsibilities at Dowty?

THE WITNESS: Well, they consist of managing
2 the engineering department, all the aspects involving
3 original design concepts through the detail design
4 phases, analytical testing, et cetera, and including
5 evaluations of products, field problems that may come
6 up.

7 MR. PHILLIPS: What kind of components does
8 Dowty manufacturer?

9 THE WITNESS: We make servo actuators. We
10 make complete systems. We have one fly by wire system
11 flying on the turbo prop. We make -- systems and
12 components.

13 MR. PHILLIPS: So do you make an actuator?

14 THE WITNESS: Absolutely, yes.

15 MR. PHILLIPS: Actuator similar to the main
16 rudder PCU?

17 THE WITNESS: Yes.

18 MR. PHILLIPS: Are you familiar with dual
19 concentric valve design and principles of that design?

20 THE WITNESS: Yes.

21 MR. PHILLIPS: I understand you're involved
22 with the Society of Automotive Engineers?

23 THE WITNESS: Yes, that's correct. For
24 several years now, I've been chairing the servo valve

and actuation panel for the SAE A6 committee. The A6
2 committee is a part of the aerospace council of the
3 SAE. Our charter is essentially to review standards,
4 generate new standards, disseminate technical
5 information among all the people in the hydraulic
6 aerospace association.

7 MR. PHILLIPS: So that committee is made up
8 of other manufacturer representatives?

9 THE WITNESS: Yes, the representatives are
10 all the prime manufacturers, the system manufacturers,
11 the component manufacturers, subsystem manufacturers,
12 down to the fluids.

13 MR. PHILLIPS: What's the product of that
14 committee? Do you write reports, make presentations?

15 THE WITNESS: We meet twice yearly. We
16 generate minutes of the meeting. That consisted of
17 stand up writing and reviewing activities. That also
18 consists of making technical presentations amongst the
19 group. It's usually attended by about 200 to 300
20 people.

21 MR. PHILLIPS: As part of the activities that
22 are involved in that committee, do you deal or have you
23 dealt with hydraulic fluid contamination and could you
24 give us a brief description of your experiences with

contamination?

2 THE WITNESS: Like I mentioned before, I
3 chair the servo valve and actuation panel. -- where it
4 utilizes off the hydraulic fluid, with the
5 contamination effects that are inherently in the
6 fluids. We do have parallel contamination panel, but
7 they are primarily chartered with establishing the
8 filtration systems and the filtration requirements. I
9 would say as a user, we discuss and elaborate on
10 contamination effects on servo valves and actuators in
11 particular.

12 MR. PHILLIPS: In your experience, do
13 particulates and contamination affect the performance
14 of servo valves?

15 THE WITNESS: If they're held within limits,
16 they don't show any effects. I mean, there is no way
17 that you get particulates out of fluids. They are
18 there. They're constantly produced in the whole
19 equipment primarily, pumps and motors, satellite motors
20 that are in the system. There are also generated
21 either during the manufacturing process and not
22 completely being flushed out. That's also
23 contamination.

24 Every time the system gets opened up, chances

of contamination is there.

2 MR. PHILLIPS: When a manufacturer is
3 designing with concern towards particular
4 contamination, what are some of the options that they
5 have to control the effects of those particulates in
6 the valve?

7 THE WITNESS: Well, you've seen a couple of
8 incidents in the previous presentation. There is the
9 particularly placed small filters upstream of the power
10 package unit. Typically we'll have one upstream of the
11 servo valve or transfer valve of its load supply. YOU
12 will also have an upstream of the ports themselves.

13 So this is like a last chance filtration,
14 because typically you rely on the main filters in the
15 hydraulic system. They were also mentioned earlier.
16 There's a typical air filter on the pressure side,
17 which makes sure the fluid coming down the line is
18 clean. The 50 microns is a typical number for the
19 commercial airliners.

20 The pump is protected in two ways. There's a
21 case train filter that picks up the case and most of
22 the particles are generated there. It's filtered at a
23 25 micron level before it gets back to the return loop.
24 And then before the fluid hits the reservoir, there's

another 25 micron filter there.

2 MR. PHILLIPS: So then the system is fairly
3 dependent on its filter performance to clear out the
4 particulates?

5 THE WITNESS: It's depending on the filter
6 performs itself, but it's also very much dependent on
7 the maintenance. If you let dirt accumulate in the
8 filters longer than recommended or necessary or
9 desired, then you'll end up with a dirtier system.

10 MR. PHILLIPS: In your experience have you
11 seen anyone's particular type of contaminate, either
12 particulate or chemical adversely affect servo valves?

13 THE WITNESS: I've got to go back way, way
14 back, all the way to the introduction. For a couple of
15 years there was a phenomenon or erosion of several
16 valve edges and significant efforts were undertaken
17 there to get this under control. But that phenomenon
18 is no longer with us. So this is the only area that I
19 remember where we had metering edges being eroded by
20 the fluid, not necessarily related to contaminants.
21 This was probably more of a chemical issue than a fluid
22 or contaminant related issue.

23 MR. PHILLIPS: In your experience, are you
24 familiar with any servo valve, problems with

particulate contamination that results in jamming of
2 the valve?

3 THE WITNESS: No, I don't know of any case.
4 The servo valves utilized on the commercial airlines
5 are somewhat more contaminate tolerant than servo
6 valves utilized on different equipment, in the military
7 for one. In as much as the type of the jet pipe valve
8 has a significantly large opening. I believe it's
9 somewhere around 125 microns or thereabouts. So it
10 will pass even the most largest particulates. It
11 developed itself as also one more filter built into the
12 valve itself.

13 MR. PHILLIPS: In listening to the earlier
14 testimony in this hearing, have you heard any
15 discussion or description that you would determine to
16 be detrimental to the performance or operation of the
17 servo valve we're talking about?

18 THE WITNESS: I would imagine if you put
19 contaminates in 50 times the value that's been observed
20 in recent cases, yes, it would probably have
21 detrimentation, but I have not ever encountered a
22 situation like that, that was utilized for this test
23 case, the accelerated devise.

24 MR. PHILLIPS: Are you referring to the

discussion this morning with the Boeing contamination
2 test?

3 THE WITNESS: Right, exactly.

4 MR. PHILLIPS: Do you have any comments in
5 general about the discussions with the chip shear
6 testing that was discussed this morning?

7 THE WITNESS: No, not really. I think they
8 are very much verified a study that the Air Force
9 conducted about three or four years ago. I'm not quite
10 sure. Maybe a little longer where the similar effort
11 was being done to determine the optimum of a minimum
12 chip shear force that would be required for particulate
13 valves.

14 MR. PHILLIPS: What are some of the design
15 considerations given to a servo valve with regards to
16 chip shear capability?

17 THE WITNESS: I believe on the typical
18 hydraulic servo valve, it probably generates about 80
19 pounds. And 100 pounds, 50 pounds, those are typical
20 numbers.

21 MR. PHILLIPS: Is there any kind of
22 specification or design guideline that you're aware of
23 that defines or controls minimum limits of chip shear
24 capability?

THE WITNESS: Yes, there have been some of
2 our customers that have generated specification and
3 that comes again from the military side where a
4 different type of servo valve is now employed. Where
5 the electromagnetic acting directly on a spool
6 obviously does somewhat limit in the force capability.

7 So the way the chip shear force is specified
8 now is you have to demonstrate that a wire, music wire,
9 which has pretty much high strings for it, placed into
10 the bigger slot will be overcome by the device. They
11 are also saying you're allowed to have a restoring
12 spring force to overcome that.

13 So that is the only specification that I know
14 that is very specifically ties a chip shearing to a
15 typical valve. Normally, the customers put in
16 historical values and say okay significantly, maybe
17 around 100 pounds.

18 MR. PHILLIPS: Is there any -- in the design
19 or consideration of chip shear capability, are there
20 any specific tests that you're aware of that take in
21 consideration materials that the valve may be presented
22 with?

23 THE WITNESS: No, I'm not aware of specific
24 test requirements.

MR. PHILLIPS: Could you briefly describe
2 related to your experience, the effects of particular
3 contamination as it relates to increasing NAS-1638
4 grades or levels? And more specifically, as a general
5 guideline in your experience, is there a class that
6 provides a basis for most servo valve, a minimum grade
7 for servo valve design?

8 THE WITNESS: Typically, we deal with classes
9 6, 7, 8, somewhere in between there. Those are
10 typically the ones that are recommended, that are
11 specified by our customers. That's about little worse
12 than the fluid when it gets delivered. I think it can
13 get delivered in a class 5 to 6. Tests are being
14 maintained at about a class 8 level. So typically the
15 industry or the manufacturing site deals with a class
16 8. I think also Boeing delivers them to a class 8 or
17 better.

18 MR. PHILLIPS: We will have some testimony
19 later on then as regards to what those classes mean and
20 the numbers involved. In your experience, if you
21 exceed class 8, class 9, is that any indication that
22 you would have a failure or would expect a failure to
23 the component?

24 THE WITNESS: I think in my experience, I

would classify it as the dirtier your system, the
2 shorter your component life is. That is basically a
3 statement based on the fact that you either have
4 abrasion or you have accumulation of those particles
5 that are floating around.

6 Abrasion, you have seen this morning very
7 vividly of what happened if you do it under high
8 pressure. You have like a jet stream blowing sand by.
9 Any metal gets in that way. With this happening, you
10 lose your performance of the servo. Your pressure
11 gains go down. Your internal leakage increases. That
12 means, you're pumping more fluid around it. It's not
13 doing anything. You're putting more heat in the
14 system. Eventually you have to pull these units out.

15 MR. PHILLIPS: Would this indicate that you
16 would expect a performance problem with the system
17 before you would find a loss of control?

18 THE WITNESS: Oh, definitely. We would not
19 lose loss of control. You may lose the crispiness.
20 You may have more perceived dead bend.

21 MR. PHILLIPS: Would it be obvious to a
22 manufacturer on an overhaul or a shop visit that the
23 unit had been operated in contaminated hydraulic fluid

24 THE WITNESS: Yes, by close examination of

the metering edges, you could also know how long the
2 unit has been out in the field. You could say it will
3 probably come from a contaminated system. More likely
4 than not, you may be taking a sample anyway.

5 MR. PHILLIPS: Does that provide a fairly
6 quantitative value for the wear of the system?

7 THE WITNESS: I wouldn't go so far to put
8 numbers.

9 MR. PHILLIPS: Dowty Aerospace is the
10 manufacturer of the standby rudder actuator for the
11 737. Are you familiar with the design and the
12 examinations of the USAir unit?

13 THE WITNESS: In principle, but not in
14 detail.

15 MR. PHILLIPS: One of the issues that was
16 discussed in earlier testimony was the concept of
17 galling. Could you give us a brief description in your
18 terms and in your knowledge what galling is and what it
19 does to a component?

20 THE WITNESS: Every time I talk to somebody
21 about galling, I get seldom in agreement, I guess, what
22 exactly is galling. But what I would classify galling
23 is a metal transfer from one surface to another. It's
24 an irreversible process. It will go on. It builds up

gradually against being operated, and it happens
2 typically between sliding phases. It doesn't happen
3 between stationary phases or oiling phases. You have
4 different phenomenons.

5 The one positive aspect about this incident
6 is that we tested the unit afterwards and have met the
7 original equipment test limits and operating force
8 which are a direct measure of the resistance that
9 galling may provide the alternator level. I cannot
10 imagine the scenario where there should have been
11 higher galling and all of a sudden it's free. That to
12 me, in my experience, has never happened.

13 I've observed galling on spools and sleeves
14 or 440-C against 440-C. Once they're galled, you're
15 not going to get them apart except to use very high
16 forces. And then after you've done this, you'll never
17 be able to get the parts back together. So this is an
18 enigma to me.

19 MR. PHILLIPS: So as general design
20 guideline, you would want to put hard surfaces against
21 hard surfaces, and soft surfaces against soft surfaces

22 THE WITNESS: Yes, you want some difference
23 there.

24 MR. PHILLIPS: Going back to servo valve

design and possibly relate it to galling, we've heard
2 some testimony of clearances in the order of millions
3 of an inch and very small particle size as far as
4 contaminants go. What purpose is served by
5 manufacturing or designing parts with such close
6 tolerances?

7 THE WITNESS: Well, usually you have to meet
8 leakage requirements. If you make very light tolerance
9 bands, you won't be able to meet a leakage
10 requirements. We also will not get good control valve
11 performance, because you have more fluid blowing by the
12 metering edges than going through the metering edges.
13 So there is the natural limits. You try to keep it as
14 tight as possible.

15 CHAIRMAN HALL: Mr. Phillips, could we
16 explore just very briefly? You say to have gall and
17 you get hard and soft metal. Is that correct?

18 THE WITNESS: NO. In order to avoid galling,
19 you want to make a difference between the metals.

20 CHAIRMAN HALL: What's that again?

21 THE WITNESS: In order to avoid galling, you
22 want to have a different metal.

23 CHAIRMAN HALL: Now what do we have in these
24 valves? Are they hard and soft or are they hard and

hard metals?

2 THE WITNESS: I don't know if I have the
3 right metal callers. I believe one is 440C. The other
4 one is a 416 stainless steel which is significantly
5 softer than a 440.

6 CHAIRMAN HALL: So you have the hard and
7 soft?

8 THE WITNESS: Combination like that, yes.
9 Now don't hold me to this. That is one of the details
10 that I'm not sure of.

11 MR. PHILLIPS: That is something we can
12 provide additional information on in the report.

13 THE WITNESS: I'm sure it's been recorded.

14 CHAIRMAN HALL: We've had a lot of
15 conversation about galling, and we're talking about
16 this particular valve. We're talking about specific
17 metals. It would be helpful for me and maybe for
18 others to know whether those two different metals that
19 we're talking about whether they're the hard and the
20 soft or the hard and the hard. We've got some experts
21 here. I want to take advantage of it and find out.
22 Proceed.

23 MR. PHILLIPS: Thank you. I guess one
24 question, one final question, in regards to in-service

difficulties, such as galling or performance that
2 involves your components, what would be the process
3 that would be used to correct a design deficiency if
4 one was noted? How would a problem be reported to you
5 and how would you go about making a change?

6 THE WITNESS: There are two ways that I would
7 find out about this. One way would be through our
8 organization or direct feedback from the airline. More
9 often than not, it comes from the Boeing organization.
10 They are the ones that collect many more inputs for any
11 service problems. They are the ones that get notified
12 first. If there is a trend perceived at Boeing, they
13 will contact us.

14 Then we will work closely with Boeing to
15 investigate why is this happening, what's happening,
16 and to make sure we understand totally the environment
17 that it's working in, because before you go and look at
18 a redesign of a 30 year old product that's been flying
19 out there, you want to make sure you do an improvement
20 and not stepping back.

21 MR. PHILLIPS: Is there a regular product
22 improvement program that you have in place for this
23 standby rudder actuator?

24 THE WITNESS: That's difficult to answer.

Let's phrase it this way, we're working very closely
2 with Boeing to review the situation. If we should
3 determine that there is an improvement possible, I'm
4 sure we would support it.

5 CHAIRMAN HALL: Well, be more specific. What
6 have you done since the accident in Colorado Springs?

7 THE WITNESS: Since this was ruled not to be
8 a cause, at least to our understanding, other than
9 looking at the design the way it currently is and
10 trying to understand what's going on, we have not gone
11 forward to look at the different options. We have an
12 upcoming meeting with Boeing. The purpose of this is
13 to review this one more time. That will be happening
14 shortly.

15 MR. PHILLIPS: I guess to answer your
16 question, Mr. Chairman, I'm unaware of any design
17 changes since the Colorado Springs accident.

18 CHAIRMAN HALL: The question was not just
19 design changes. The question was has Dowty sat down
20 with Boeing since Colorado Springs?

21 THE WITNESS: Oh, definitely.

22 CHAIRMAN HALL: Whether they've got some
23 galling on the standby? Am I correct or incorrect?

24 THE WITNESS: We have supported all NTSB

activities at the fullest. We were present at any of
2 the tear downs of the actuator, any of the testing of
3 the actuator. I didn't know that that's what you were
4 asking for.

5 CHAIRMAN HALL: No, that's what I was asking.

6 THE WITNESS: Oh, definitely, yes.

7 CHAIRMAN HALL: What has taken place since
8 then?

9 THE WITNESS: We've been not quite as active
10 as our colleagues at Parker, but certainly we supported
11 fully whatever was asked of us to do in conjunction
12 with this investigation.

13 MR. PHILLIPS: Are you aware of any pending
14 changes regarding the standby actuator?

15 THE WITNESS: I'm not aware of any pending
16 changes. I'm aware that we want to look at it and see
17 if there is a change that would be beneficial.

18 MR. PHILLIPS: I have no further questions at
19 this time.

20 CHAIRMAN HALL: Do the parties have any
21 questions? I see one hand. I want to be sure.
22 Monsanto does not have any questions. All right. The
23 only hand I see then is the Boeing group, John Purvis.

24 MR. PURVIS: Thank you. Mr. Runkel,

regarding erosion, would you differentiate between the
2 electrochemical erosion that we had several years ago
3 and the erosion that you maybe saw on the earlier
4 exhibits on the Boeing accelerated particle tests?

5 THE WITNESS: Yes, most definitely. I would
6 make a differentiation. I seem to recall pictures on
7 the chemical erosion where not just the edges were
8 eroded, but you could see a partway of the middling
9 slots on the side of the spools and slides. So those
10 are different appearance.

11 MR. PURVIS: And a different mechanism?

12 THE WITNESS: Yes, I believe so, but don't
13 ask me the details on that.

14 MR. PURVIS: Could you also please elaborate
15 on the Air Force chip shear study? Specifically, did
16 the chip shear leave marks on the slide or the spool?

17 THE WITNESS: I cannot answer that
18 positively. I don't know.

19 MR. PURVIS: Thank you very much. I have no
20 further questions.

21 CHAIRMAN HALL: Thank you. Mr. Marx?

22 MR. MARX: Mr. Runkel, have you see the input
23 shaft and the bearing from the accident airplane?

24 THE WITNESS: No, I have not seen it.

MR. MARX: Have you had a chance to look at
2 the exhibit number 9-B?

3 THE WITNESS: Which page?

4 MR. MARX: Well, you can look at page 4, 5,
5 6.

6 THE WITNESS: Yes.

7 MR. MARX: You had a chance to look at that
8 before?

9 THE WITNESS: Yes.

10 MR. MARX: Could you give me your opinion as
11 to what would have caused this type of wear damage or
12 galling that's on the shaft?

13 THE WITNESS: Well, I cannot give you an
14 opinion, because I don't understand it.

15 MR. MARX: You also mentioned that there
16 wasn't any design changes. But are you aware of the
17 fact that the unlubricated portion of the shaft has
18 been reduced in diameter throughout a design change?

19 THE WITNESS: That happened a few years, is
20 that not true?

21 MR. MARX: Yes, it is. As a result of
22 Colorado Springs, I think the safety board would out
23 with a recommendation about the fact that this reduced
24 diameter should be maintained on -- do you know the

reason for the reduced diameter on that?

2 THE WITNESS: I don't know. Could you tell
3 me?

4 MR. MARX: All right. You don't know.

5 MR. MARX: I have no questions.

6 CHAIRMAN HALL: Mr. Clark?

7 MR. CLARK: I have no questions.

8 CHAIRMAN HALL: Mr. Schleede?

9 MR. SCHLEEDE: Just one area I'm not sure if
10 you were asked. Do you have any knowledge of any jams
11 or frozen control valves in the standby rudder
12 actuators for the 737 service history?

13 THE WITNESS: Yes.

14 MR. SCHLEEDE: Could you describe that?

15 THE WITNESS: Yes. In December, I was in
16 Seattle I think at the same time when an EQA was
17 conducted at the unit returned from British Airways, if
18 I remember correctly. It was mentioned yesterday, it
19 was totally rusted.

20 MR. SCHLEEDE: How about prior to that?

21 THE WITNESS: NO.

22 MR. SCHLEEDE: Any knowledge of one prior to
23 that time?

24 THE WITNESS: NO.

MR. SCHLEEDE: Would you in your position
2 know of those if there had been prior ones?

3 THE WITNESS: I would assume that I would
4 have been told.

5 MR. SCHLEEDE: The one area you did mention
6 here that you were aware that there was a need to look
7 at the design of this unit and that Boeing is looking
8 into this.

9 THE WITNESS: I don't want to say the need to
10 look at it. I want to say maybe a desire to look at
11 it.

12 MR. SCHLEEDE: Do you know if there's an
13 active program to do that or Mr. Turner testified
14 yesterday that that was one area Boeing was
15 considering.

16 THE WITNESS: Yes, we have a meeting pending
17 to discuss this. I would imagine it will come up
18 within weeks, very shortly.

19 MR. SCHLEEDE: So there's no proposals at
20 this point? It isn't at that stage?

21 THE WITNESS: There are a couple of schedules
22 that we generated and we stuck those in the mail last
23 week. It was to Paul Cline. He has not seen it.

24 MR. SCHLEEDE: Have you seen them?

THE WITNESS: Yes.

2 MR. SCHLEEDE: What are they in regards to?
3 Are they in regards to the clearances in the input arm
4 shaft?

5 THE WITNESS: NO. It is basically a
6 statement, yes, this input arm bearing could be
7 designed differently. But before we settle on a
8 version of it, we need to understand exactly what is
9 going on with it.

10 MR. SCHLEEDE: Thank you very much, Mr.
11 Runkel. I have no more questions.

12 CHAIRMAN HALL: Yes, sir, let me ask you a
13 couple of questions here. You-all manufactured the
14 standby actuator?

15 THE WITNESS: That's correct.

16 CHAIRMAN HALL: Does that standby actuator
17 have fluid in it?

18 THE WITNESS: I hope so.

19 CHAIRMAN HALL: Good. Does it have filters?

20 THE WITNESS: NO.

21 CHAIRMAN HALL: No filters. Have you had
22 with that standby actuator -- again, the question is on
23 the metal, what type of metals interface and move in
24 there?

THE WITNESS: Could you repeat the question?

2 CHAIRMAN HALL: The input arm and what's the
3 other one, Mr. Schleede?

4 THE WITNESS: Bearing.

5 CHAIRMAN HALL: And the control valve. Are
6 those hard and soft metals or are those hard and hard
7 metals?

8 THE WITNESS: Yes, that's what I mentioned
9 earlier.

10 CHAIRMAN HALL: Have you had experience with
11 galling as a problem? How common a problem is galling
12 and what would cause the galling in you-all's
13 experience, 30 years experience, with this standby
14 actuator?

15 THE WITNESS: I cannot speak for the 30 years
16 experience. I've been told that occasionally we see
17 that which was pointed out earlier by Mr. Marx. I
18 think some people call it metal transfers or smearing.
19 I cannot tell you how often we have seen it.

20 CHAIRMAN HALL: Is there a program if there
21 is a problem with your standby actuator to detect the
22 problems and make modifications or exactly is there a
23 procedure with your company to handle those sort of
24 matters? I'm not looking for anything complicated,

sir.

2 I'm just looking for a simple situation. You
3 manufacturer a part. You tell me that the part has a
4 potential for a particular situation to develop. Could
5 you tell me if that situation develops, how you become
6 aware of it and once you become aware of it, what you
7 do about it?

8 THE WITNESS: If it is deemed to be a serious
9 problem, obviously we'll do something about it. The
10 way we do something about it is conjunction with Boeing
11 --

12 CHAIRMAN HALL: Let me ask you, have you read
13 the Colorado Springs' accident report?

14 THE WITNESS: Which particular one?

15 CHAIRMAN HALL: Issued by the National
16 Transportation Safety Board --

17 THE WITNESS: I believe I read --

18 CHAIRMAN HALL: -- regarding the United
19 Airlines Flight 585?

20 THE WITNESS: Yes, I read sections of it.

21 CHAIRMAN HALL: Have you read the sections
22 that pertained to the servo valve and the standby
23 actuator?

24 THE WITNESS: You're talking about the servo

valve now or are you talking about the input joint?

2 CHAIRMAN HALL: The standby valve, I'm sorry.
3 You have read parts of the report?

4 THE WITNESS: Yes.

5 CHAIRMAN HALL: My question then was what
6 actions, if any, did Dowty take on the basis of that
7 report?

8 THE WITNESS: I believe, and I'm not 100
9 percent, that based upon that report was the change
10 implemented to reduce the outer land, but somebody has
11 to verify that.

12 CHAIRMAN HALL: NOW, what, again, is the
13 procedure then if something has to be brought to your
14 attention, then what is the next step? Get with Boeing
15 or do you-all--

16 THE WITNESS: Yes, definitely.

17 CHAIRMAN HALL: -- independently --

18 THE WITNESS: No, we cannot do anything
19 independently. Boeing has approval right to our
20 design.

21 CHAIRMAN HALL: Boeing has what?

22 THE WITNESS: Approval right.

23 CHAIRMAN HALL: Approval right?

24 THE WITNESS: correct. We cannot make

changes like this on our own and we don't make changes
2 like this on our own.

3 CHAIRMAN HALL: Do you go to Boeing if there
4 are problems that you think that might be with the
5 parts you manufactured?

6 THE WITNESS: It's usually the other way
7 around. Like I stated earlier, it's Boeing that has
8 much more visibility of what's happening out there in
9 the field.

10 CHAIRMAN HALL: So who services the part?

11 THE WITNESS: We do or authorized service
12 centers.

13 CHAIRMAN HALL: I guess my question is if
14 you're servicing the parts, they're being sent to you,
15 and a problem -- let's just assume a problem with
16 galling was identified, would you then go to Boeing or
17 would you wait for Boeing to come to you-all?

18 THE WITNESS: We would certainly discuss this
19 with Boeing if we find a serious problem.

20 CHAIRMAN HALL: Is there anything, sir, that
21 you think that would be helpful to this hearing that
22 you would like to add that would help the parties, help
23 the investigation, help the American public understand
24 what happened to this USAir flight?

THE WITNESS: I believe that I am too new to
2 our product, the Dowty product, to render any
3 suggestions other than what I've made so far. I'm not
4 that totally familiar with the rudder system itself,
5 the combined function of the standby rudder that's
6 going along for the ride essentially of most of its
7 life and doesn't do anything with the main PCU. And
8 how the standby actuator moves when the yaw damper gets
9 exercised, I don't know the effects that it has on an
10 unpowered rudder.

11 So I cannot add any more than that. My plan
12 is to discuss those things with the Boeing Company.

13 CHAIRMAN HALL: Very well. We have notice
14 that you must leave by 2:00 and we have you out of here
15 by 2:00. So thank you.

16 THE WITNESS: Thank you very much.

17 (Witness excused.)

18 CHAIRMAN HALL: The next witness is Mr. Steve
19 Weik. He is the senior engineer for Parker Hannifin
20 Corporation in Irvine, California.

21 (Witness testimony continues on the next
22 page.)
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STEVE WEIK, SENIOR ENGINEER, PARKER-HANNIFIN
CORPORATION, IRVINE, CALIFORNIA

Whereupon,

STEVE WEIK,

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

MR. SCHLEEDE: Mr. Weik, give us your full
name and business address for the record, please?

THE WITNESS: Steven Charles Weik, Parker
Berteau Corporation, 14300 Alton Parkway, Irvine,
California.

MR. SCHLEEDE: How long have you worked for

Parker?

2 THE WITNESS: Sixteen years.

3 MR. SCHLEEDE: Was is your present position?

4 THE WITNESS: Project engineer of 737 primary
5 flight controls, 747 primary flight controls.

6 MR. SCHLEEDE: Could you give us a brief
7 description of your education and background prior to
8 reaching this position?

9 THE WITNESS: I have a degree in mechanical
10 engineering. I graduated from U.C. Irvine in 1979.
11 Hired in with Parker right out of school.

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

14 MR. PHILLIPS: Good afternoon, Mr. Weik?

15 THE WITNESS: Good afternoon.

16 MR. PHILLIPS: Could you give us a brief
17 description of organizationally what Parker is and
18 where your organization fits within the company?

19 THE WITNESS: There's two sides to our
20 division in terms of control systems division. We have
21 an OEM side that deals with the airplane manufacturers
22 and then we have another side that's the overhaul
23 facility that deals with the airlines. I am currently
24 and have always been on the OEM side.

1 I am the technical lead on that side. My
2 position since 1986 has been a liaison for Boeing
3 Engineering on their product to their part in our shop
4 that we manufacturer. I am also liaison to the service
5 side in communicating with them and the technical side
6 of the products, since their priorities are towards
7 overhauling and servicing. I provide technical
8 assistance to their side.

9 My other responsibility is to provide the
10 assembly and test area of our area, any assistance
11 needed in making the product to get out the door.

12 MR. PHILLIPS: We've heard the name Berte
13 and Parker Berte and Parker Hannifin. Could you
14 clarify to us who all those people are?

15 THE WITNESS: Sure. A little history lesson
16 is that originally it was Berte. I believe that
17 started in the -- I should know better. But I believe
18 in the early '50s. And Berte Corporation was bought
19 out by Parker Hannifin in, I believe, 1978. At that
20 time, it became Parker Berte Corporation. It's caused
21 over the years some confusion for a lot of people. So
22 recently in the last few years, it's been referred to
23 Parker Control Systems Division.

24 MR. PHILLIPS: So when we address you, it

would be Parker Controls Systems Division?

2 THE WITNESS: True.

3 MR. PHILLIPS: That would be most
4 appropriate. Where are your offices now?

5 THE WITNESS: We have an office in Irvine.
6 We also have -- actually, two offices. We have the OEM
7 office in Irvine on Alton Parkway. We also have the
8 Service Division on Irvine that is on Von Carmen. And
9 more recently, we have a facility in Ogden, Utah.

10 MR. PHILLIPS: In your position as an OEM
11 supporter, are you involved in the -- are you notified
12 when problems occur with your unit's in-service?

13 THE WITNESS: I'll describe the way our
14 operation works is the overhaul side, the service side
15 has two ways of hearing about an incident or some sort
16 of anomaly or problem or just a maintenance issue.
17 One, directly from the airlines. They will call our
18 maintenance and head of maintenance -- or excuse me,
19 head of our overhaul technical side is Mr. Walz. He is
20 contacted directly by the airlines or the people
21 working underneath him of something.

22 The other way is through Boeing Service
23 Engineering. Either of those two methods are used to
24 provide us with accounts of maintenance issues or

whatever.

2 MR. PHILLIPS: Do you have any kind of formal
3 trend monitoring or program within Parker that tracks
4 returns and repairs?

5 THE WITNESS: Since 1986, I think we've been
6 formalized and up on the computer. We basically --
7 when you receive a unit in from the airlines on the
8 overhaul side, it's gone through a functional receiving
9 test. That information is -- from that you can
10 determine what the discrepancy is or what performance
11 parameter it isn't meeting. That gets logged into a
12 database that we have. It basically gives a serial
13 number.

14 If we can get hours from airlines, that's not
15 necessarily something that's easy to get. But we get
16 the unit. We do a functional test. We write up
17 anything that is discrepant on it, and we record that
18 into our database. Now that database is used for
19 several purposes. One, to generate trends.

20 We have a policy that if you see more than
21 three discrepancies of the same nature, for instance,
22 external leakage, any sort of leakage problems, binding
23 friction, we have probably about 25, 30 categories
24 described of anomalies or problems.

2 What we do is if we get three in 20, we send
3 a flag up and the engineer in charge at the overhaul
4 facility will go out and run a check. They have
5 engineers on site. We have a trend report that's
6 published every month that gets over to me as the
7 project engineer.

8 At that time, I see it. If there is an issue
9 from the airline side or in the service side, then my
10 job is to contact and have a discussion with the
11 systems group involved in the product we're dealing
12 with.

13 CHAIRMAN HALL: Excuse me, Greg. If I could
14 ask a question here. This form with the number of
15 miles on it from the airlines, how many miles the plane
16 has flown. Is that what we're talking about?

17 THE WITNESS: NO.

18 CHAIRMAN HALL: How many hours?

19 THE WITNESS: Mr. Hall, that's something --
20 it's the airline's discretion if they're going to give
21 us hours on what the unit.

22 CHAIRMAN HALL: But doesn't the form you have
23 have hours on it?

24 THE WITNESS: It has -- I believe --

 CHAIRMAN HALL: To fill in hours?

1 THE WITNESS: I believe it has a place, but
2 that's something that's at the discretion of the
3 airlines.

4 CHAIRMAN HALL: Why is that at the discretion
5 of the airlines, just out of curiosity?

6 THE WITNESS: I can't answer that, sir.

7 CHAIRMAN HALL: It may not be anything major.
8 I just happen to -- you were very nice and let me come
9 tour your facility and I looked at the forms that were
10 on the actuators -- I mean, the units that were coming
11 in, and I remembered looking at the hours and noticing
12 the hours. But what is required and what's not
13 required?

14 THE WITNESS: It's obviously very helpful.
15 We do generate those. As I said, one of the issues is
16 for me, as a project engineer, on sustaining hardware.
17 However, we also use it to generate new design and we
18 use it in our reliability group and trying to use
19 numbers when you see FEMA --

20 CHAIRMAN HALL: Will these units last
21 forever? Is there a lifetime to them in terms of
22 years, miles, hours, anything, or can you just continue
23 to over and over again recycle them?

24 THE WITNESS: That's a good question. There

1 is a rule of thumb or general -- it's usually described
2 in the standards that we receive in the spec. A rule
3 of thumb that floats around in the industry and, again,
4 I'm only one person, but it's around 60,000 hours that
5 a unit is designed towards.

6 Now whether or not we go through a
7 qualification testing on all units and it goes rather
8 severe testing and we get no where near that, we
9 usually deal in cycles and usually deal in millions of
10 cycles when we qualify this unit. We consider that
11 enough to meet the life requirements. Designs are
12 always determined way above what the expected life is.

13 CHAIRMAN HALL: I appreciate that, but I
14 believe a lot of these aircraft are operating long past
15 their lifetime. Is that correct? The anticipated
16 lifetime when they were initially manufactured?

17 THE WITNESS: Mr. Hall, I think I would like
18 to refer that question to the airlines. I'm not an
19 expert on that.

20 CHAIRMAN HALL: Go ahead.

21 MR. PHILLIPS: Backing up to the trend data
22 that we were discussing, what would be, in your
23 opinion, one of the more common failures you would
24 expect to see a PCU coming in for these days?

THE WITNESS: Specifically?

2 MR. PHILLIPS: I would just say if the first
3 thing that popped into the top of your head of why you
4 would expect a PCU to becoming into repair, what would
5 it be?

6 CHAIRMAN HALL: Isn't that information put on
7 a computer and maintained? I mean, do we have that
8 information?

9 MR. PHILLIPS: We haven't requested that
10 information.

11 MR. PHILLIPS: What I would like to do is get
12 some feeling as to what you might guess would be the
13 most common cause for a rudder PCU to be returned for
14 repair of any sort?

15 THE WITNESS: I think our numbers show that
16 it's around or about 75 percent external seal leakage
17 on the main ram seals. You have a requirement of one
18 drop in 25 cycles, which is a standard of four drops in
19 100 cycles of leakage.

20 Seventy-five percent of the units on a PCU
21 rudder that come in, I understand, that Parker services
22 about 30 percent of the marketplace. The other 70
23 percent is the airlines themselves, other outside
24 third-party houses. Our data shows that it's about 75

percent of external, of the removal reason for coming
2 in to our shop is to replace the worn seals on the main
3 ram.

4 MR. PHILLIPS: So once the unit is removed
5 from service and comes into your unit -- or into
6 Parker, could you give us a brief summary of what would
7 happen as it would be processed in for -- say, for
8 instance, if the initial squawk was that it was leaking
9 externally?

10 THE WITNESS: We go right -- there's a couple
11 of ways of approaching it. If it's a severe squawk,
12 we'll usually go right to it and try to determine the
13 anomaly right off in hopes that earlier testing or
14 other testing wouldn't destroy the evidence.

15 However, the norm is is we get a unit back in
16 and we usually perform the standard functional
17 maintenance manual that Boeing referred to earlier
18 testing, which covers about 22 parameters. We run it
19 through that test. We basically record that data and
20 put it in file. Then based on what we find, we'll do
21 repair work. We'll usually notify the airlines and
22 then we'll do the repair work based on their approval

23 MR. PHILLIPS: You said earlier that about 70
24 percent of the units are being worked on by airlines

rather than Parker. Is that correct?

2 THE WITNESS: That's ballpark number, yes.

3 MR. PHILLIPS: Ballpark number. Do they
4 follow the same procedures that you do when you bring
5 it in for review?

6 THE WITNESS: I can't answer that.

7 MR. PHILLIPS: That's something that is
8 worked out with Boeing then, the procedures they use to
9 overhaul their rudder PCU?

10 THE WITNESS: This is true. The overhaul
11 manual is a standard for the rudder PCU.

12 CHAIRMAN HALL: Just one quick question, and
13 I hate to keep injecting, but I like to follow this
14 logically. Do they come in only when they need repair
15 or do they come in on some regular suggested interval?

16 THE WITNESS: Again, Chairman Hall, I believe
17 I would refer that to the airlines. The norm that we
18 see is either under warranty work or that they have
19 some squawk. Whether that follows some routine check,
20 the C-check or other.

21 CHAIRMAN HALL: What kind of warranty do you-
22 all give if I go and buy me one of these things?

23 THE WITNESS: I guess I'm going to have to
24 say that there is others at my table that are more

versed in that. I really don't know.

2 CHAIRMAN HALL: Would anyone like to respond?

3 MR. SIMMONS: We don't have that data here.

4 We can supply it later.

5 CHAIRMAN HALL: All right. They are going to

6 supply the information later. Please proceed, Mr.

7 Phillips.

8 MR. PHILLIPS: In regards to the main rudder

9 PCU design, the original design, could you give us a

10 summary of the genesis of that part, it's beginning,

11 how it was designed, by who time frame?

12 THE WITNESS: I believe there's been some

13 earlier testimony on some of the history on it, but

14 I'll give you my best shot of it. Basically in the

15 late '60s, mid '60s, I believe more closer to the mid

16 '60s, Boeing was in a phase of designing the 37. At

17 the time, they were in need of engineers. Parker, at

18 the time, Berteau actually, supplied engineers as shop

19 jobbers under the direction of Boeing Engineering.

20 The testimony given yesterday by Mr. Sheng

21 indicated that he had linkage design -- had designed

22 the linkage on the rudder PCU. We also know that this

23 design is on Boeing paper and is under the design

24 constraints of Boeing Engineer.

Basically, Parker or actually Berteia supplied
2 job shopping engineers under the direction of Boeing.
3 When it went into production in the late '60s, 1967,
4 Berteia carried out the qualification and then
5 production of it since that time. Basically that's
6 where we are.

7 MR. PHILLIPS: Does anyone else manufacture a
8 main rudder PCU for the Boeing 737, to the best of your
9 knowledge?

10 THE WITNESS: NO.

11 MR. PHILLIPS: Do they manufacture any
12 components for the PCU, sub-level components?

13 THE WITNESS: I can't answer that.

14 CHAIRMAN HALL: Do we have how many have been
15 manufactured in the record?

16 MR. PHILLIPS: I don't know if we have a
17 total. We could get that.

18 THE WITNESS: We can give you that number. I
19 think a rough number that we're working off of in
20 regards to the airworthiness directive is roughly
21 around 2800, but it's well above that when it comes to
22 looking at spares and others.

23 CHAIRMAN HALL: Do you currently manufacturer
24 new units?

THE WITNESS: You bet.

2 CHAIRMAN HALL: How many do you put out a
3 year?

4 THE WITNESS: Well, depending on how many
5 people are buying 737s, the shipment rate, at this
6 time, I think is around eight ship sets. A rough
7 ballpark number right now.

8 CHAIRMAN HALL: And what does one of them
9 cost or is that proprietary?

10 THE WITNESS: I would decline to answer that.

11 MR. PHILLIPS: I doubt that we could afford
12 one. In the eight units you speak of, are eight units
13 per month?

14 THE WITNESS: That's correct.

15 MR. PHILLIPS: That's dependent upon the
16 airplane manufacturer rate that would require a PCU.
17 Is that correct?

18 THE WITNESS: Basically, it could be down to
19 one or whatever quantity is demanded by their
20 manufacturer.

21 MR. PHILLIPS: In your experience, in your
22 position that you're in now, what significant changes
23 have you seen made to the PCU package, design changes?

24 THE WITNESS: There's currently 11 different

1 configurations of this rudder. The only significant
2 change is are when we change from a dual yaw concentric
3 or dual yaw system to a single yaw system, and when we
4 change from 4 degrees, 2 degrees to 3 degrees. Those
5 are all in different configurations and you could
6 determine which configuration you're working with.

7 Then later on -- and that was very early on
8 in the program, the '70 time frame, early '70s. Later
9 on, as I stated, external leakage is nothing new to us
10 and it's been something that's kind of inherent on this
11 particular package.

12 We've been working towards trying different
13 seals through the different seal manufacturers, have
14 worked with Parker and Boeing to try to address
15 premature or what we consider -- what we would like to
16 see as an extended wear on any of these seals.

17 So the last few configuration changes have
18 been based on seal changes and attempting to reduce the
19 amount of external leakage.

20 MR. PHILLIPS: How would external leakage
21 affect the performance of the package in relationship
22 to the airplane?

23 THE WITNESS: External leakage when you're
24 talking about one drop in 25 cycles or four drops in

100 cycles as we deliver it new and the service limits
2 go up a little bit, I think it doubles. If you'll ask
3 the airlines, I think the airlines will say it's more
4 of a nuisance.

5 The fluid used in these packages is BMS-311
6 and it's very acoustic to paint, human hands, skin,
7 whatever. It's not a very friendly fluid. In terms of
8 performance, again, I think I would like to -- Boeing
9 would be the better person to answer that.

10 MR. PHILLIPS: I guess I could ask, are you
11 aware of any reported control difficulties of loss of
12 control as a result of external leakage?

13 THE WITNESS: To my knowledge, the leakage
14 that we see is usually a nuisance. It's not considered
15 a performance problem.

16 MR. PHILLIPS: Any other regards in your
17 experiences in this position, have you seen any other
18 changes to the package, design changes?

19 THE WITNESS: It's been stated in earlier
20 testimonies that we are currently in the process of
21 carrying out an AD. That AD is against the servo
22 valve. That is probably the most significant change
23 that we've gone through in the last 20 years.

24 MR. PHILLIPS: Did you participate in the

early phases of that AD process that define the changes
2 that were required to the package?

3 THE WITNESS: Yes, I did.

4 MR. PHILLIPS: In regard to the accident
5 investigations of the Colorado Springs airplane, USAir
6 427 and the other United airplane we've referred to in
7 earlier testimony, were you involved in each of those?

8 THE WITNESS: Yes, I was.

9 MR. PHILLIPS: Could you briefly describe
10 your involvement in the Colorado Springs'
11 investigation?

12 THE WITNESS: I first got involved in April
13 of '91 at the Irvine facility, the overhaul Irvine
14 facility. The NTSB, United, and I believe the whole
15 systems group at that time, came to our facility or
16 came to the overhaul facility, and I was contacted to
17 support the technical end of it.

18 At that time, I believe it's PCU serial
19 number 833, was brought in in severely burned and what
20 appeared to be impact damaged state and was in several
21 pieces, many pieces. There was not anything intact
22 that you would see go out of an overhaul facility or a
23 new facility.

24 The servo valves were also detached and

carried in separately. In fact, the servo valve itself
2 was missing the end cap and the spring in the back of
3 the servo valve. So it had been pulled apart. That
4 was my first involvement with the flight 585 or PCU
5 833.

6 Later in 1992, in the summer, there was
7 earlier testimony, a unit came in. I believe that was
8 PCU 2228. More commonly referred to as the Mack Moore
9 unit. I think we've heard testimony on what was seen
10 and what the results of that was.

11 We did several other PCU testing during that
12 time. There seemed to be a -- well, basically we were
13 going through quite a bit of testing on different units
14 that they felt that I think we saw several United units
15 come back. Then we also had the 585 valve
16 reinvestigated or looked at, the servo valve.

17 I would like to comment, though, that the
18 servo valve initially in April was ceased and placed
19 due to fire damage. The fire had baked and frozen the
20 primary and secondary together. It had to be removed
21 forcefully and was later cleaned up in terms of what we
22 call in the industry, was done as a light wipe so that
23 the parts could slide in its normal fashion.

24 There's already documentation in the Colorado

1 Springs' docket as to the condition of the valve. We
2 were able to test it, but there was damage in this
3 valve. There are individual wafers. Those wafers were
4 separated, which caused some problems in its
5 performance. We believe the separation was due to
6 impact.

7 We went through a rather extensive
8 investigation with the Colorado Springs. However, for
9 the phenomenon that later resulted in the AD.

10 MR. PHILLIPS: Do you recall whether that
11 Colorado Springs' valve ever reversed on any of the
12 testing that was performed at Parker?

13 THE WITNESS: No, it did not.

14 MR. PHILLIPS: And by reversing, you mean
15 reverse flow or reverse porting of the fluid? Were we
16 able or were you able in all cases to test the valve in
17 its original as manufactured condition?

18 THE WITNESS: To the extent, we were able to
19 test the valve, understanding that there was damage to
20 the stacks and that it was not a perfect condition
21 valve that you would see out of a new. That we were
22 able to test it in that state.

23 MR. PHILLIPS: You stated that when you
24 received the valve or you saw it the first time that it

was in some state of disassembly, where was that done
2 and who had done that?

3 THE WITNESS: I was not involved at the site
4 or at the hanger in United. Mr. Walz of our
5 organization, who is our DER or FAA representative, he
6 was involved with a man from the quality organization.
7 He was there present at the time. I would have to
8 refer the questions to Mr. Walz on that part of the
9 investigation. That was in April, several weeks later,
10 that I was involved.

11 MR. PHILLIPS: Was it under the control of
12 the NTSB at the time?

13 THE WITNESS: That's correct.

14 MR. PHILLIPS: The Mack Moore testing, the
15 United airplane, was that under the control of the NTSB
16 at the time also?

17 THE WITNESS: There was some confusion on
18 that. United witnessed it, and they contacted Boeing
19 and Parker. Parker representatives met up at United.
20 To my recollection, they did not see the reversal up
21 there after it happened the one time or they did see a
22 stall. They brought it back down to Parker, at our
23 facility. At that time, United and Boeing and
24 ourselves were together.

1 It was a few days that lapsed that the NTSB
2 was brought in. At that time, there was some feeling
3 that the NTSB was being excluded and that was not the
4 case. It was just a matter of lack of understanding on
5 some of our parts that NTSB was still investigating the
6 Colorado Springs.

7 There had been a fair amount of time lapsed
8 between that event and the Colorado Springs.

9 MR. PHILLIPS: Could you describe your
10 participation in the investigation of the USAir flight
11 427 accident?

12 THE WITNESS: I guess, based on lessons
13 learned or some experience that we have gained in
14 getting educated on the 585 investigation, we were
15 contacted. Mr. Walz was contacted as being our FAA
16 representative, I believe, on September 13th, and was
17 asked if we would like to participate under the auspice
18 of NTSB to help in removal of the rudder or witness the
19 removal of the rudder.

20 So on September 14th, we appeared in
21 Pittsburgh and on September 15th, we aided in assisting
22 the systems group in trying to prevent any loss of
23 evidence on this valve. Because of 585, we were aware
24 that the things that were of concern were in the

1 thousandth of inch category or .001, and when you look
2 at an airplane, it's in the scales of feet. We felt it
3 was important that if this valve was going to be
4 scrutinized, that we maintain as much evidence as
5 possible.

6 So we came in through the hanger after it had
7 been removed from the site. That's where we proceeded
8 to get involved.

9 MR. PHILLIPS: Did you feel -- Mr. Cline
10 testified earlier this morning that the possibility
11 that some of the initial data may have been compromised
12 by handling. Do you share that feeling?

13 THE WITNESS: Yes, I do.

14 MR. PHILLIPS: So more specifically in
15 regards to the position of the actuator at the time of
16 removal from the accident site until the time that you
17 were involved, could the position of the valve have
18 been changed?

19 THE WITNESS: That's a possibility.

20 MR. PHILLIPS: Would that have affected any
21 of the investigations or examinations that we've done
22 to this point?

23 THE WITNESS: Yes.

24 MR. PHILLIPS: How so?

THE WITNESS: Well, when we secured the unit
2 and brought it back to Boeing and as already testified
3 by Mr. Cline, we were able to determine the position of
4 the main ram PCU at impact. On this particular case,
5 because the piston rod was bent, I believe that we can
6 give an honest calculated position of the rudder at
7 impact.

8 However, had that unit not been bent in that
9 position and in picking up the vertical fin and people
10 touching the actual rudder surface, there would be the
11 possibility of pushing the rudder, retract or extend,
12 and we would, therefore, lose possible positioning of
13 the rudder.

14 Since we don't have flight data recordings as
15 to where the rudder electronically is determined to, we
16 only have this somewhat archaic way. Therefore,
17 anything can be possible.

18 MR. PHILLIPS: I understand your point. HOW
19 confident are we or are you in the position that's been
20 determined as the position of the rudder at impact?

21 THE WITNESS: I think we took every
22 precaution possible once it was in the hanger to secure
23 it. I think from the witness marks on the piston and
24 realizing that it had to be cut out of there and there

1 was no movement of any type when we were cutting it
2 out. It was in there pretty good. Meaning, it was in
3 its normal position as it would have been installed and
4 was secured between the strut and the horn arm, that I
5 believe that it is a good representation of where it
6 was at impact.

7 MR. PHILLIPS: So the reported position of
8 approximately 2 degrees right rudder is, in your
9 opinion, an accurate position of the rudder at impact?

10 THE WITNESS: Yes.

11 MR. PHILLIPS: Based on the witness marks?

12 THE WITNESS: Yes.

13 MR. PHILLIPS: I guess, the point of your
14 testimony is that had we not had a bent rod, we stood
15 the chance in handling the wreckage of losing that
16 position in the absence of having a recorded position
17 by flight data recorder?

18 THE WITNESS: That's correct.

19 MR. PHILLIPS: So then can I go one step and
20 say that you would recommend additional flight
21 parameters or position parameters for flight data
22 recording?

23 THE WITNESS: As an engineer, I think you
24 heard earlier testimony that all of us in the technical

world would benefit. I think being in the sustaining
2 engineering area, not related to the airlines, but even
3 in our field where we get a lot of information based on
4 squawks, it's very difficult to analysis what that
5 means in PCU terms.

6 If we had flight data recordings that showed
7 specific positions of the rudder, we could probably go
8 to the anomaly quicker than what we are doing at this
9 time.

10 MR. PHILLIPS: Backing up a little bit to the
11 point where we picked up the rudder and began the
12 testing, could you take us through the chronology of
13 the testing that was accomplished at Parker and your
14 involvement at testing at Boeing?

15 THE WITNESS: I'll pick it up from where we
16 left Boeing and were down at Parker. We, again,
17 because of the experience that many of us who were
18 there had gone through with 585, we were very cautious
19 in allowing any of the parts to move, any links, the
20 ram, that sort of thing. We very slowly disassembled
21 the unit.

22 To get fluid samples was one of our first
23 things that we did. We also did a dialectic.
24 Essentially in a nutshell, we did the full acceptance

test procedure. When we eventually got down to
2 witnesses the actual state, we video it. We took many,
3 many pictures to verify the condition before we
4 disturbed anything.

5 Then we went through and checked forces,
6 input forces on the pilot input point. As Mr. Cline
7 earlier testified, that we went through and took lots
8 of fluid samples in different areas under the NTSB's
9 direction. We had to replace parts. The main ram was
10 damaged. The H-link and the pilot input link was
11 damaged.

12 We had to put in -- we had to disassemble the
13 unit enough to get the main ram out of there and put in
14 a new ram. It was under the members' consensus that we
15 didn't feel that that would damage any of the internal
16 summing linkage or any of that.

17 At that time, the crank arm was still
18 secured, as I believe, and my recollection is fading a
19 little bit. But I believe that the main ram was -- or
20 the external crank arm was still shimmed while we put
21 in these different components so we wouldn't disturb
22 that.

23 Then we went back and had a new piston in
24 there and a new H-link, a new pilot summing arm. We

believe that that information, there was no way around
2 testing, unless we replaced that.

3 So we went through that procedure and then
4 diligently went through and checked the summing lever
5 arms. We opened up the cap. Looked at the summing
6 lever arm to determine their position. When we took
7 some measurements that normally aren't taken and it was
8 somewhat difficult to do, but it was a first shot at it
9 to determine where the primary and secondary slides
10 were.

11 We proceeded on to do all the functional
12 testing on the top level. Then at that time, we had a
13 caucus and tried to determine what we should do next.
14 One of the things we did is similar to what we had
15 tried and what we had performed in the case of 228.
16 That was that in order to get it to dual reversal, you
17 take the pilot input arm and you cycle it at probably a
18 rate beyond what the pilot could do.

19 You cycle it back and forth, as fast and as
20 hard as you can in an attempt to make it reverse. We
21 did this until everybody had an opportunity to do it
22 amongst the members, until their hands got sore, and we
23 didn't see any sort of reversal.

24 At that time, I believe we came down to

disassembling it. The scrutiny would go towards the
2 servo valve. Am I getting too detailed?

3 MR. PHILLIPS: I'm going to jump in and give
4 you a rest here for a minute. Mr. Cline testified
5 earlier that as a result of the testing, although there
6 were anomalies found, there was a summary conclusion by
7 the group that the unit was capable of functioning for
8 the purpose it was designed. Were you part of those
9 discussions and did you agree to that?

10 THE WITNESS: Yes, I did. Yes, in both
11 cases.

12 MR. PHILLIPS: You believe that his testimony
13 this morning was accurate?

14 THE WITNESS: Yes.

15 MR. PHILLIPS: After the disassembly,
16 examinations and testing at Parker during that phase,
17 was there any additional testing performed that you
18 participated in?

19 THE WITNESS: I think it's been recorded that
20 we have met seven times in different locations under
21 the NTSB's direction. So we've done numerous,
22 different tests beyond the normal performance
23 parameters that we check on PCUs that go out.

24 MR. PHILLIPS: I guess more specifically, I

would like to address the two issues of the chip shear
2 testing that was done at Boeing and your participation
3 in that. Also, the residual pressure, differential
4 tests that were discussed this morning in some detail
5 that were performed at Parker.

6 I think first we'll go in the order of the
7 tests. The residual pressure test on the servo valve,
8 did you participate in those tests?

9 THE WITNESS: Yes, I did.

10 MR. PHILLIPS: Could you describe to us the
11 Parker facility that was used for that testing and the
12 test set up?

13 THE WITNESS: We, in this occasion, worked at
14 the OEM facility. On the other occasions where we
15 gathered, we were usually doing it at the CSO facility.
16 But OEM and CSO are mere images, are one in the same
17 for that part.

18 We have hydraulic test boards that extent
19 that have flow capacity up to 80 GPM. On the servo
20 valve is what we did the residual pressure at. It
21 wasn't at the PCU level. We extracted the PCU or the
22 PCU was separated. We tested the PCU separately in a
23 fixture that we use for production to test the 13
24 different parameters that this valve is made to.

In this case, we deviated from those 13 tests
2 and we performed a test where we simulated different
3 failure modes of the valve. Basically, I think those
4 are stated in 9-AH. I'm not sure which docket.

5 At that time, we pressurized it to 3,000 psi,
6 which is inlet pressure, and we performed the different
7 positions of the slide and we read the gages. These
8 are gages that are plugged. It doesn't have the line
9 losses that are normal for a PCU. So these pressures
10 would be not 100 percent, but close enough.

11 CHAIRMAN HALL: Mr. Phillips, my
12 understanding is there was a design review conducted by
13 the FAA and Parker after the Colorado Springs'
14 accident. Is that correct?

15 MR. PHILLIPS: I'm not aware of an FAA design
16 review. The board wrote a safety recommendation asking
17 the FAA and Boeing to review Parker manufacturer dual
18 concentric valves in light of the secondary over travel
19 jamming or reversing. If you're speaking to that, we
20 can address that issue.

21 CHAIRMAN HALL: Well, I'm referring to the
22 recommendation 92-121, which asks the FAA to conduct an
23 exam review of servo valves manufactured by Parker
24 Hannifin, which are similar in design to the Boeing 737

rudder power control unit servo valve.

2 MR. PHILLIPS: Okay.

3 CHAIRMAN HALL: That's it?

4 MR. PHILLIPS: That's it.

5 CHAIRMAN HALL: My question is are any of
6 these tests related? Do they do the same test over
7 again or not? Are we talking about a different part of
8 the rudder?

9 MR. PHILLIPS: We'll ask Mr. Weik to address
10 that question, if he can.

11 THE WITNESS: That request came from Boeing.
12 The FAA, I believe, requested it of Boeing, and Boeing
13 came to us. We reviewed all our servo valves, both
14 dual concentric and single system or all our single
15 valve slide sleeve arrangement. The condition we
16 checked for, we checked all, I believe, it was nine
17 valves for a specific case of the valve that we saw on
18 flight 585.

19 So, yes, we did, and we found, I believe --
20 and it's strictly off memory, that document is
21 available. There was only one unit and it was out of
22 production and it was on a military airplane, and it
23 was not a big production. I think it was a limited
24 production on a 707, but that's strictly by memory. We

can qualify that. But we check all line valves that
2 are currently in production and there was no reversal
3 anomalies.

4 MR. PHILLIPS: So the testing was done
5 specific to the reversal condition. Were there any
6 other failure conditions or modes considered during
7 that review?

8 THE WITNESS: No, there were not.

9 MR. PHILLIPS: Was the direction for that
10 review just the specific requirement of the
11 recommendation of the FAA's goals and objectives or, I
12 guess, what set the objectives for that review?

13 THE WITNESS: Well, it was primarily based on
14 what we knew and we had gone through with the 10-91
15 which is off of the 585 valve.

16 CHAIRMAN HALL: Well, again, it says here
17 that they were going to look at flight control
18 malfunctions or reversals. So they looked at reversals
19 or they looked at both or --

20 MR. PHILLIPS: I think they selected the or,
21 the reversal condition.

22 CHAIRMAN HALL: Only?

23 MR. PHILLIPS: That's the answer that I'm
24 hearing. Is that correct, Steve?

THE WITNESS: Again, we supplied analytic
2 data that showed those specific servo valves to Boeing
3 and that's as far as I can go with that.

4 MR. PHILLIPS: Mr. Chairman, I would suggest
5 that in later testimony with the FAA, we will have
6 people involved who were involved in that.

7 CHAIRMAN HALL: That's fine with me, as long
8 as Steve's going to be here in case we want to ask any
9 more questions about this, because in all seriousness,
10 the taxpayers paid for a lot of tests after Colorado
11 Springs. What I'm trying to do is find out what tests
12 were made then and what's been done now. I think
13 that's a reasonable question.

14 THE WITNESS: I agree.

15 CHAIRMAN HALL: Please proceed.

16 MR. PHILLIPS: In the testing that was done,
17 I believe the second week of January in regards to the
18 over travel conditions that Mr. Cline spoke of this
19 morning, were there any additional tests performed
20 during that meeting of the systems group?

21 THE WITNESS: As Mr. Cline has stated and I
22 think the members of your system team can testify,
23 we've done a rather extensive look at this overall PCU
24 and the servo valve understanding that it's of high

profile.

2 MR. PHILLIPS: More specifically, the over
3 pressure test or the high pressure test?

4 THE WITNESS: correct. We looked at a
5 condition that because of the nature of the servo valve
6 and the understanding that all valves have very close
7 clearances that they are designed to, there was one
8 scenario that would leave no witness marks that might
9 have caused the jam and that would have been what we
10 would refer to as clamping, deflection of the inter ID
11 to the OD.

12 Actually, OD clamping on the ID of the slide
13 -- primary slide bore on the secondary slide being
14 clamped by the valve body. That is something that in
15 the initial design and the initial testing of the
16 valve, we go through and we have to hand fit each of
17 these valves to the type of clearances that have been
18 discussed earlier.

19 In light of that, we thought that to show
20 that there was no clamping, we took pressures that was
21 determined to be the maximum amount of pressure that a
22 pump could put out without kicking a check valve.
23 Again, that I will have to refer more to Boeing to give
24 you information on it. But we took a pressure of 3850

1 or 3,850 psi in a normal 3,000 psi system to see if we
2 had any restriction of movement on the primary or
3 secondary slide different from that of the 3,000 psi
4 that normally would be in there.

5 I think you'll look in that docket or in
6 exhibit -- what is it, 9. I think basically you'll see
7 information in there showing you that whether it was
8 3,000 psi or 3,850 psi, the forces to move the primary
9 slide and the secondary slide were the same. That we
10 felt strong that clamping could not be an issue here
11 that would have caused that valve to jam.

12 MR. PHILLIPS: Are you aware of any other
13 events where clamping has happened, occurred?

14 THE WITNESS: No, I am not.

15 MR. PHILLIPS: So the question was raised or
16 the test was done more out of curiosity than a
17 requirement that's specified anywhere?

18 THE WITNESS: That's true.

19 MR. PHILLIPS: In earlier testimony, we
20 discussed the effects of contamination. In particular,
21 particulate contamination on PCUs. Could you comment
22 generally on your experiences with contamination and
23 its effects on the rudder power control unit?

24 THE WITNESS: I really don't believe I can

add much more to what's already been testified. We
2 rely on the filtration system. Parker in 1971 -- like
3 all companies, we have an internal specifications.

4 We have a specification that's called the
5 BMF, which is a Berteau manufacturer specification that
6 we created to maintain a class 5 -- worse case class 5,
7 best case 2 on our test boards. We have a
8 contamination lab that monitors that on a daily basis.
9 So our hydraulic boards are maintained at a worse case
10 is class 5.

11 MR. PHILLIPS: More specifically, are you
12 aware of any main rudder Parker manufacturer Boeing 737
13 main rudder power control unit, that's operated in an
14 other than intended direction as a result of a jam?

15 THE WITNESS: Could you repeat that, please?

16 MR. PHILLIPS: Boy, that will be tough. Are
17 you aware of a jam ever -- have you ever heard, have
18 you ever tested, have you ever read at Parker about a
19 jam main rudder PCU from a 737?

20 THE WITNESS: I personally have not witnessed
21 any. I know there is -- being in part of the 585 and
22 I'm familiar with the documentation in there of the
23 different cases. All those were before my time. The
24 one that was stated was the corrosion one that happened

in the '90 time frame, I believe.

2 The origin of where that came from never
3 reached us. So to answer your question, no, I have
4 never personally seen a jam.

5 MR. PHILLIPS: Are you aware of any testing
6 that's been conducted without the NTSB's presence in
7 regards to either the Colorado Springs' accident or the
8 USAir 427 accident?

9 THE WITNESS: No, I'm not.

10 MR. PHILLIPS: Have you been involved in any
11 failure modes and effects analysis of the main rudder
12 PCU in your time with the unit?

13 THE WITNESS: Only in recall in the
14 airworthiness directive. We performed a functional
15 qualification test on that valve to assure us that we
16 had remedied the anomaly.

17 MR. PHILLIPS: So then you're saying as a
18 result of the airworthiness directive, the valve was
19 looked at again for its performance capabilities?

20 THE WITNESS: Not in its entirety.

21 MR. PHILLIPS: Specifically, what was changed
22 for the AD?

23 THE WITNESS: I think earlier talked that we
24 restricted some of the travel between the linkage stops

and the internal stops. We went back once. We
2 incorporated the design change. We went back in. We
3 tested. I believe you have that data in your
4 possession.

5 MR. PHILLIPS: In the process of reviewing
6 those stops and modifying the design, did you uncover
7 or did you come up with any data that would say that
8 Parker had ever or a PCU had ever been reported to
9 Parker that had reversed?

10 THE WITNESS: Not to my knowledge.

11 MR. PHILLIPS: Do you know whether the
12 question was asked or not or was that specifically
13 examined?

14 THE WITNESS: Again, as to whether Parker --
15 any Parker employee had seen a reversed rudder?

16 MR. PHILLIPS: I was looking more
17 specifically for a data that had been provided to
18 Parker from an operator that said that they had
19 experienced a reversal of a main power control unit?

20 THE WITNESS: I guess, I'm at loss on how to
21 -- we've so many units. We have not experienced any
22 reversal other than the 2228 Mack Moore unit. It's the
23 only one that anybody at Parker is familiar with.

24 MR. PHILLIPS: Recently a PCU was sent to

1 Parker under the NTSB control that was removed from a
2 Sahara India -- I believe Sahara India Airlines
3 airplane. Do you have any knowledge of that unit, the
4 squawk that it came in on and the test findings, just
5 in general terms?

6 THE WITNESS: That valve, the PCU came in
7 under the direction of the NTSB with the FAA present.
8 We ran the full functional test on the PCU and then
9 disassembled down the servo valve. I guess, in answer
10 to your question before, that one showed a reversal in
11 the -- I guess it would be both directions extend and
12 retract on the main PCU.

13 MR. PHILLIPS: That was experienced at Parker
14 or was that reported to you from another source?

15 THE WITNESS: That was verified by running a
16 test on the servo valve that simulates the earlier
17 testimonies that talk about the three conditions that
18 you need in order to achieve a reversal.

19 We, as a result of the AD, have a test on the
20 rudder top PCU and at the servo valve level to assure
21 ourselves that we will never have a reversal in any
22 condition if any of those three conditions align
23 themselves to occur.

24 So we took the Sahara India valve and

1 subjected it to that failure mode. All three of those
2 conditions do exist. And at that time, we saw that in
3 both directions, retract or extend, the valve would
4 reverse if you had those three conditions.

5 MR. PHILLIPS: Was there a determination made
6 during that testing as to what the cause of those
7 reversals was?

8 THE WITNESS: As far from our experience and
9 seeing the valves that are coming back and from the
10 dimensional analysis, if you have a retract rudder,
11 there's rarely a problem with the reversal. That even
12 with adverse tolerances and the other two conditions
13 aligning, you usually would not see a reversal.
14 However, in the other condition, you would.

15 This particular Sahara unit showed a reversal
16 in the direction that we least expected to occur. The
17 low percentage of occurring. It surprised me as to how
18 that could be so. In disassembling it, what we found
19 was some improper parts in the spring guides.

20 MR. PHILLIPS: Has there been any
21 determination made as to how those improper parts were
22 installed into the unit?

23 THE WITNESS: That unit was from the Middle
24 East, and a trace on the overhaul of that valve shows

1 that there were seven different times that that unit
2 was in for some sort of maintenance. There were, I
3 believe, three or four different maintenance shops that
4 worked on that valve.

5 We, in our facility, are unaware of all that
6 took place. In fact, the serial number on that unit
7 does not match any of the current records that we are
8 holding, and we hold all records from day one on the
9 PCU. Every unit we shipped, we have a record package
10 of the original data that it went out on and all of its
11 components.

12 We were unable to find that one in our -- it
13 had a serial number, but that was not a Parker serial
14 number.

15 MR. PHILLIPS: So then that would give us two
16 PCUs that have reversed. Both the United Mack Moore
17 with the summing lever condition, and the Sahara India
18 Airlines with the discrepant parts. Is that correct?

19 THE WITNESS: That's true.

20 MR. PHILLIPS: Were there any discrepant
21 parts found in the United 585 component or the USAir
22 flight 427 component?

23 THE WITNESS: The 585, my memory is that
24 there was not any. But as I recall, again, as I

1 stated, the 585 was in pretty poor shape as compared to
2 the valve on the 427. In terms of the 427, there were
3 no -- we didn't perform any dimensional analysis on any
4 of the components, but we did determine by acceptance
5 test procedure and the extensive testing outside of
6 that, that there was no hardware anomalies or tolerance
7 problems.

8 MR. PHILLIPS: Is it your opinion that any
9 additional testing should be performed on USAir flight
10 427 PCU? Should dimensional checks be made of those
11 parts to verify their condition?

12 THE WITNESS: To my knowledge, the procedures
13 of the tests that we've so far performed are indicative
14 of the valve, and I don't believe that there would be
15 anything gained by running dimensional checks on any of
16 the components.

17 The final say of this PCU is its ability to
18 meet the performance requirements. Understand that
19 each subcomponent goes through anywhere from eight to
20 12 different individual tests. Then they are brought
21 together and integrated at the top level where there it
22 goes through 22 different individual tests, checking
23 its performance.

24 The parameters are rather stringent

parameters and difficult. If they weren't met there,
2 they show up very easily.

3 MR. PHILLIPS: So that on the performance
4 test, any one failure of the performance test would
5 fail a complete unit?

6 THE WITNESS: That is true. If any one of
7 those 22 or down at the sub-level requires the valve to
8 or the PCU to be removed from the hydraulic bench and
9 determine the problem and the part replaced, if there's
10 something to that effect and then retested. So until
11 the unit passes the acceptance test procedure, it is
12 not released.

13 CHAIRMAN HALL: Mr. Phillips, we are nearing
14 time for a break. Do you want to continue and finish?
15 Do you have a few more questions or would you prefer we
16 break and come back? It's your call.

17 MR. PHILLIPS: I actually have about probably
18 about ten minutes more questions for myself.

19 CHAIRMAN HALL: We'll continue then.

20 MR. PHILLIPS: The next area I wanted to get
21 into just briefly was the yaw damper system and your
22 experience with the yaw damper operation. We've heard
23 testimony from Mr. Cline this morning about the
24 condition of USAir 427's yaw damper system. But once

again, could you describe to us what you saw in testing
2 of this unit?

3 THE WITNESS: All rudder PCUs, the 22
4 different performance parameters we checked in that is
5 extensive testing of the yaw system that's part of that
6 PCU package. One of the test that we do is simulate a
7 hard over electro-hydraulic valve or an open solenoid.
8 Basically, that would cause the yaw piston to travel
9 over to its extreme position, which is, as testified
10 earlier, has mechanical stops.

11 Understand that our test fixture is very
12 similar to what it would look like in the aircraft. We
13 have a wheel on the test fixture that shows zero
14 degrees through the plus or minus 26 degrees. When we
15 turn on and basically do that failure, we watch where
16 the yaw takes the rudder PCU. And in that case, we all
17 witnessed that it went 3 degrees depending on what
18 direction the failure would have been.

19 So based on that, there would have been no
20 physical way other than to travel -- it could not
21 travel any further than 3 degrees.

22 MR. PHILLIPS: To the best of your knowledge,
23 have you ever seen a rudder PCU travel beyond its
24 limits, its design limits?

THE WITNESS: NO. Understand again, there
2 are units out there with 2 degrees and 4 degrees. So
3 there can be ones with 4 degrees still roaming out
4 there. But as far as meeting those parameters, I have
5 never seen one that goes outside of the design
6 parameters.

7 MR. PHILLIPS: You would be in a position to
8 be aware of one if it had?

9 THE WITNESS: Yes, I am definitely contacted
10 of any anomaly that does occur, that would be that
11 significant.

12 MR. PHILLIPS: You would also be the best
13 person at Parker to ask if there's ever been a jam PCU
14 servo valve which caused a runaway or hard over
15 condition?

16 THE WITNESS: Well, I would probably be a
17 runner up. I think the testimony of Mr. Sheng, who's
18 been with the company for 30 plus years, he's strictly
19 our technical lead and he's a very practical minded,
20 besides being very intelligent, and he's seen a lot,
21 and he's somebody we consult with and has consulted
22 throughout the years. I think he's given testimony
23 that to what his experience was.

24 So between Sheng's testimony and my

testimony, I think you can get Parker's input as to we
2 have not, to our knowledge, seen any jams on the
3 rudder, 737 rudder PCU.

4 MR. PHILLIPS: One more time for the record,
5 did you see any evidence of a jam of the USAir 427
6 package?

7 THE WITNESS: No, I did not.

8 MR. PHILLIPS: That's all the questions I
9 have, unless you would like to add something that I've
10 omitted?

11 THE WITNESS: NO.

12 MR. PHILLIPS: Thank you.

13 CHAIRMAN HALL: I want to correct an item
14 that I mentioned a few minutes ago. Mr. Laynor, who is
15 our senior and most respected aviation accident
16 investigator, informed the Chairman that these tests
17 that had been requested after Colorado Springs and had
18 been conducted by the FAA and by Parker Hannifin and
19 Boeing, the majority of costs of those tests were borne
20 by Boeing and Parker Hannifin and not by the American
21 taxpayers. I apologize to you gentlemen.

22 I merely want to be sure that on the record
23 we have two accidents which are linked in the public's
24 mind, and that we inform them and are sure and clear

everything that has been done in that interval period
2 of time, regardless of who it was paid for, in order to
3 look for the cause of the problem.

4 With that, we will take a 15 minute break.

5 (Whereupon, a short recess was taken.)

6 CHAIRMAN HALL: The hearing will come back in
7 session. I believe we are now proceeding with the
8 party questions for this witness. Would you please
9 indicate which parties have questions? I see the FAA
10 and the Airline Pilots Association, International
11 Association of Machinists and Boeing. We will proceed
12 fir with the International Association of Machinists,
13 Mr. Wurzel.

14 MR. WURZEL: Good afternoon, Mr. Weik.

15 THE WITNESS: Good afternoon.

16 MR. WURZEL: Were you aware that all possible
17 documentation, both photographic and measurement wise,
18 were taken in the field by the NTSB systems group of
19 the main rudder power control unit and its relationship
20 to the rudder before the vertical fin and rudder
21 removed from the accident scene to the hanger?

22 THE WITNESS: I was not present at the site.
23 So I'm not aware of that.

24 MR. WURZEL: How would you characterize the

1 difficulty in removing the main rudder power control
2 unit in the AI hanger under the much better conditions
3 than at the accident scene? I think you were present
4 there.

5 THE WITNESS: It was a rather difficult
6 endeavor. It required once we secured any -- as long
7 as the unit was intact the way it was, it had all the
8 torque tubes and rods connected to it. Once we started
9 disassembling, we'd lose position and we took
10 precautions to secure the position of it.

11 Once we did that and started connecting --
12 disconnecting the connecting rods, from there because
13 of the damage to the piston rod, we were forced to cut
14 the PCU out so as not to disturb it. It would have
15 required retracting the piston rod in order to get the
16 PCU out of there. Obviously, that would take away any
17 evidence that it was there.

18 So it was a very difficult task, and it
19 required a lot of input from a lot of people.

20 MR. WURZEL: Have you ever come across any
21 bogus parts in the overhaul, the servo or the main
22 rudder power control unit at your overhaul
23 headquarters?

24 THE WITNESS: I don't know what you mean by

"bogus" parts. But parts other than being manufactured
2 from Parker, there has been one or two instances that
3 we are aware of.

4 MR. WURZEL: Are you familiar with the term
5 "silting," and could you explain its effects in
6 relation to the servo?

7 THE WITNESS: Silting is a common term in the
8 hydraulic fields. I don't know if it's a real term or
9 something that we hydraulic engineers use. Basically,
10 it's phenomenon that the electro-hydraulic valve people
11 I think first saw. That is if a slide stays in one
12 position while fluid is -- for instance, if it's an
13 underlap valve porting by it or it just hasn't been
14 exercised in a while, the fluid builds up a little bit
15 of a surface tension.

16 All fluids have a surface tension.
17 Basically, it increases the force to break that surface
18 tension, but we are all familiar with water. Not too
19 many of us can walk on water. So the bottom line is
20 it's just that sort of thing. It's maybe an ounce of
21 increased force to break it out. It's nothing that's a
22 big issue unless it's something like an electro-
23 hydraulic valve and the way they prevent it from being
24 an issue in performance. They just put a little bit of

a cycle -- input around neutral to prevent friction in
2 terms of this valve.

3 I don't think it's an issue.

4 MR. WURZEL: That concludes my questions.

5 Thank you, Steve.

6 CHAIRMAN HALL: Airline Pilots Association.

7 CAPTAIN LeGROW: Thank you, Mr. Chairman.

8 Good afternoon, Mr. Weik. Could you tell me in your
9 involvement with the USAir 427 accident airplane, how
10 much time was on the main PCU?

11 THE WITNESS: In our investigation, I believe
12 that number came out, but I don't believe it's in the
13 public docket. I think I would prefer to have USAir
14 provide you with that number of the NTSB.

15 CAPTAIN LeGROW: Does 22,000 hours refresh
16 your memory?

17 THE WITNESS: Again, those were numbers that
18 I've heard. Unless they are in the public docket, I
19 don't know if I can say that's true or false.

20 CHAIRMAN HALL: Is it in the public docket,
21 Mr. Phillips?

22 MR. PHILLIPS: I believe that would appear in
23 the maintenance records report. We'll take a look and
24 see. My recollection is it is on the order of 22,000

hours for approximate discussion.

2 CHAIRMAN HALL: Since the issue has been
3 raised, would someone please go through the exhibits
4 and if it's in the docket, let's give the page number
5 and the correct exhibit.

6 MR. PHILLIPS: We'll do that.

7 CHAIRMAN HALL: Please proceed, Captain.

8 CAPTAIN LeGROW: Thank you, Mr. Chairman.
9 When the 737 PCU was originally put in service, did it
10 have a time life on it?

11 THE WITNESS: I'm not sure if I understand.
12 Let me just clarify that our acceptance test procedure
13 when it goes out, besides doing -- it takes about two
14 hours to run through the performance parameters. Then
15 it goes through an eight-hour duty cycle. Most units
16 that leave the factory to the OEM have that type of
17 time on it.

18 CAPTAIN LeGROW: I guess my question was did
19 it have a suggested time to overhaul when the unit
20 first went in service?

21 THE WITNESS: I'm not aware that there's
22 anything out there that states when to overhaul these
23 units. That's something I'm not familiar with.

24 CAPTAIN LeGROW: I'm asking when the unit

first went in service in 1967 or whatever date that
2 was?

3 THE WITNESS: There's definitely in-service
4 performance parameters. A lot of those performance
5 parameters in the world of hydraulics is determined on
6 how clean the fluid is. Fluid does cause wear which
7 causes larger clearances, which leads to increased
8 leakage. Most of our performance parameters revolve
9 around leakage requirements, but there is no time limit
10 that is specified. There's only requirements once it's
11 removed to assure that it's within its performance
12 parameters, to my knowledge.

13 CHAIRMAN HALL: Excuse me one moment,
14 Captain. Do we have the information now?

15 MR. PHILLIPS: Yes, Mr. Chairman, Exhibit 9-
16 A, I believe page 45, is the receiving paperwork that
17 we took to Parker on the initial test of 9-21-94. I
18 believe the accident unit at that time had 21,077.33
19 hours.

20 CHAIRMAN HALL: An answer to your question,
21 Captain. Thank you.

22 CAPTAIN LeGROW: Thank you, Mr. Chairman.
23 When the 737 PCU was originally certified, did the
24 specs call for type 3 fluid?

1 THE WITNESS: I believe that's correct. We
2 maintain to the specification of what we call the SCD,
3 source control dine. I believe at that time it was BMS
4 3-11 type 3 fluid.

5 CAPTAIN LeGROW: Today it uses type 4 fluid;
6 is that correct?

7 THE WITNESS: That's correct.

8 CAPTAIN LeGROW: Were there any additional
9 tests done between the time it went from type 3 to type
10 4 fluid?

11 THE WITNESS: I don't think I'm the qualified
12 person to answer that.

13 CAPTAIN LeGROW: You made reference in your
14 earlier testimony about the AD on the servo valve.
15 Could you explain exactly what that AD was?

16 THE WITNESS: In earlier testimony, there's
17 been discussion as to the travel of the primary and the
18 secondary slide. The AD affects the travel of the
19 secondary slide in the event that you have three
20 conditions that occur in line with one another.

21 The AD, in simple terms, just restricts the
22 amount of travel that the secondary can move in the
23 event that these three conditions align to prevent any
24 cross-porting fluid.

1 CAPTAIN LeGROW: So is my understanding
2 correct that it's an internal stop for the slide.
3 Would that be correct?

4 THE WITNESS: That's correct.

5 CAPTAIN LeGROW: On the original design of
6 the servo, did it have those stops on the original
7 design?

8 THE WITNESS: Yes, those stops are there and
9 have been there present from day one.

10 CAPTAIN LeGROW: What was the reason for the
11 AD if it had been there all along?

12 THE WITNESS: Basically, the valve was
13 intended to stop on its linkage stops. It was not
14 intended to stop on its internal stops. The internal
15 stops are your spring guides that in the event that you
16 have a mistolerance part, a jam and a full rate command
17 such that the external stops do not perform, then you
18 are reliant on the internal stops. And basically, we
19 have reduced the travel to hit the internal stops, but
20 they have always been present.

21 CAPTAIN LeGROW: So there's been no design
22 change in the servo valve since it went into service?

23 THE WITNESS: Other than the ability to now
24 limit the travel of the secondary slide, no, there has

not.

2 CAPTAIN LeGROW: That's been there since the
3 original design?

4 THE WITNESS: That's correct.

5 CAPTAIN LeGROW: Could you tell me when
6 Parker Hannifin or Parker modifies a PCU, how long it
7 takes?

8 THE WITNESS: Well, in this instance, again,
9 it's -- we're the manufacturer. So this case it's a
10 function of the design engineering on the Boeing side
11 and dependent on what the issues are, there's no
12 particular time. Things can happen quick or things can
13 happen -- it's really dependent upon what the actual
14 change is and what it has to do with performance.

15 CAPTAIN LeGROW: Are the users able to get
16 the units modified as rapidly as they request?

17 THE WITNESS: To my knowledge, the AD that is
18 taking place -- I'll give you some numbers. Roughly we
19 figure there's 2800 PCUs that fall under this AD that
20 are in operation today. To date, Parker has serviced
21 about 1250 PCUs with the retrofit. We're doing them at
22 about a rate of 50 per month. It's basically when the
23 airline gets it into us, we will turn it around.

24 CAPTAIN LeGROW: So am I to understand that

1 less than half the fleet has been modified to this
2 date?

3 THE WITNESS: To my knowledge, those are the
4 numbers that I just gave you, the most up-to-date
5 numbers. There's probably a plus or minus range of 20
6 in there.

7 CAPTAIN LeGROW: Does Parker have the
8 capacity to increase that time?

9 THE WITNESS: At this current time, 50 is a
10 taxing load on our organization, but we will comply
11 with whatever the industry or the FAA feels is
12 necessary.

13 CAPTAIN LeGROW: Parker produces other servo
14 valves. Is that correct?

15 THE WITNESS: That's correct.

16 CAPTAIN LeGROW: Has any other servo valve
17 that Parker produces ever been under the scrutiny that
18 this valve has been under?

19 THE WITNESS: I think all valves have. Just
20 probably is one of the more complex valves. The other
21 valves -- all of them go through scrutiny at design and
22 are tested through qualification. This particular
23 valve has received a lot more attention than what would
24 be normally.

Valves that we make today are very similar to
2 what we made 35 years ago until we've gotten into this
3 more electrical driven servo valves. But to answer
4 your question in short --

5 CAPTAIN LeGROW: But the point is Parker
6 Hannifin or Parker -- excuse me -- does produce other
7 dual concentric servo valves. Is that correct?

8 THE WITNESS: That's our line of work, yes.

9 CAPTAIN LeGROW: It just appears that this
10 valve has been under a lot more scrutiny than other
11 valves that Parker produces. I guess my question is
12 what makes this valve so unique?

13 THE WITNESS: I don't know if -- that's the
14 question that I have. It's not unique in terms. It's
15 a dual concentric. We make single slide valves, too.
16 That's probably the more predominant ones we make. But
17 the dual concentric is a very good design, and it
18 fulfills certain specific parameters that would not be
19 filled by a single valve.

20 I think the exposure to this valve has
21 basically been derived from the incident of 585 and now
22 the flight 429.

23 CAPTAIN LeGROW: Thank you. Could you tell
24 me -- we had some discussion earlier on chip shear.

1 Could you tell me what the chip shear is on the
2 accident airplane? What the chip shear was on the
3 accident airplane?

4 THE WITNESS: Basically, it can be determined
5 by looking at the functional test data that we ran.
6 Specifically on -- this is in Exhibit 9-A. If you'll
7 look in the functional data sheet at page 63, from that
8 graph, there's a ratio that you have to use in order to
9 term off that graph, but the Y axis is pounds.

10 If you take the pound rating and to be honest
11 with you, I don't know -- I don't recall the ratio off
12 the top of my head. I have it written down. It's
13 probably within the 40 -- it's better than 44 pounds.

14 CAPTAIN LeGROW: I think we heard some
15 testimony yesterday that it was around 44 pounds. My
16 question is how does this compare with other dual
17 concentric valves?

18 THE WITNESS: In terms of what other dual
19 concentric valves? I'm not sure?

20 CAPTAIN LeGROW: Would the chip shear be
21 higher or lower, about average?

22 THE WITNESS: Each valve is designed
23 differently. I think the dual concentric valve chip
24 shear is not as serious a consideration, because you do

1 have the other slide to compensate for any single jam,
2 that the other slide will give you half rate but full
3 authority.

4 CAPTAIN LeGROW: I understand that, but all
5 dual concentric valves will do that. Is that correct?

6 THE WITNESS: That's correct.

7 CAPTAIN LeGROW: My question is how does this
8 compare with valves in other controls that Parker
9 produces?

10 THE WITNESS: To my knowledge, there's ones
11 that are higher in the 50. Some as high as 100.

12 CAPTAIN LeGROW: Is there some as high as
13 200?

14 THE WITNESS: I guess, I would have to do
15 some research before I gave you that number for sure.

16 CAPTAIN LeGROW: Do you know if this is the
17 lowest?

18 THE WITNESS: Again, without going back and
19 looking at all of our valves with specific intentions
20 of looking at what chip shear requirements are for each
21 of those valves, I can't tell you where it is in the
22 scale of things.

23 CAPTAIN LeGROW: Thank you. Can you explain
24 to me how a PCU could be sent to Parker Hannifin or

Parker -- again, excuse me -- to be overhauled, be
2 requalified or qualified for service, then sent back to
3 Parker within a month, and found that because of pilot
4 squawks and found to have worn summing levers and fail
5 a dielectric test?

6 THE WITNESS: Well, if you want to take it in
7 a sense that I think we've all had personal experiences
8 where you take the car down for a specific failure and
9 drive out and two days later something else fails.
10 Understand that you do diagnostic testing and one of
11 the things that we do is we do as the airlines directs
12 us to do and fix only that. Everything we do obviously
13 has a price attached to it.

14 The airlines tells us specifically what they
15 want done. We obviously have the ATP requirements to
16 meet. But if they meet the requirements with arms that
17 are worn and a month later that wear turns in to mean
18 reducing or not being able to meet the performance
19 requirements, we have no control over that.

20 CAPTAIN LeGROW: So you're telling me that
21 it's possible for something to go through Parker's
22 facility, be qualified for service and have worn
23 summing levers?

24 THE WITNESS: I guess, the question is is

1 what do you define as worn? If you look at your units
2 and you look at them and you determine that these parts
3 meet all the performance requirements, do we go through
4 and do a dimensional check on every single part, I
5 guess that would be at the expense of the airlines if
6 we did that.

7 My answer to that is if we see anything
8 that's excessively worn, we would notify the airlines
9 and tell them that we believe this is not something
10 that should go back out.

11 CAPTAIN LeGROW: Is Parker the only facility
12 that overhauls this power control unit?

13 THE WITNESS: We basically have 30 percent of
14 the market share. The other 70 percent is out there
15 amongst the airlines and the third parties.

16 CAPTAIN LeGROW: Thank you. I have no
17 further questions, Mr. Chairman.

18 CHAIRMAN HALL: Boeing, Mr. Purvis.

19 MR. PURVIS: Thank you. I have some
20 questions for Mr. Weik.

21 I would like to go back to the Sahara unit,
22 please. Did the PCU that came from the Sahara airplane
23 as a top assembly actually reverse on the Parker test
24 bench?

THE WITNESS: No, sir, it did not. It met
2 all functional test requirements.

3 MR. PURVIS: So when you said the unit
4 reversed, you were referring to the control valve as a
5 component. Is that correct?

6 THE WITNESS: That's true. We were testing
7 the servo valve when we saw -- in fact, we tested the
8 servo valve for what we call the failure condition. At
9 that time, we saw that the servo valve if it failed,
10 would go in reverse, but the PCU did not reverse.

11 MR. PURVIS: The test that caused the servo
12 valve as a component to reverse, was that a normal mode
13 of operation or was it a failure mode being simulated?

14 THE WITNESS: That is correct also. It is a
15 failure mode that we simulated, as I said, to indicate
16 the worse condition that occurred.

17 MR. PURVIS: Could that valve then have
18 reversed in flight?

19 THE WITNESS: Only in the event that all of
20 those parameters necessary for a reversal came together
21 at the right time.

22 MR. PURVIS: I would like to go to your
23 involvement on the 427 PCU. Based on your close
24 connection with all the phases of the 427

investigation, did you find any evidence of a jam on
2 the primary or secondary flight?

3 THE WITNESS: I did not see anything that was
4 out of the normal of what we produce on the new valve.

5 MR. PURVIS: Was there any evidence that this
6 PCU could have reversed?

7 THE WITNESS: From every test that I
8 witnessed and outside of the normal functional testing,
9 the other test that we did to try to create failure
10 modes, no, there was no evidence.

11 MR. PURVIS: Was there any evidence from the
12 chip shear, the residual pressure or the fluid particle
13 test that would have affected the intended performance
14 of the 427 PCU?

15 THE WITNESS: NO.

16 MR. PURVIS: I missed an item on the Sahara
17 PCU that I wanted to ask you. Was there any evidence
18 that the dual spring guide had been so-called
19 "remachined" after delivery?

20 THE WITNESS: That was the case. In our
21 opinion, there was some remanufacturing of that part.
22 We believe, as I said before, that it had gone through,
23 I believe, four to five different maintenance houses
24 within its life span, which we can't even define what

it's life span was, because we can't identify the
2 serial number to one of our serial numbers.

3 MR. PURVIS: That's all the questions I have.
4 Thank you.

5 CHAIRMAN HALL: Do any of the parties have
6 additional questions? If not, I am going to turn it
7 over to Mr. Marx. At this point, I must excuse myself
8 briefly to make a phone call. I'm going to leave the
9 gable in Mr. Laynor's hands if for any reason the
10 questioning is concluded and we need to move forward
11 before I can return.

12 Mr. Marx.

13 MR. MARX: Mr. Weik, I realize that you've
14 been on the stand for quite a long time. It's quite
15 grueling up there. I've been there myself. I wanted
16 to clarify two things. Do you recall back in early
17 November when I came to Parker Hannifin?

18 THE WITNESS: Yes.

19 MR. MARX: At that particular time, was there
20 any dimensional checks that were made on the main
21 rudder PCU? That would be the servo valve itself.

22 THE WITNESS: The servo valve was in the
23 possession of the NTSB after every meeting that we were
24 together. There had been no dimensional inspection at

Parker until the time that you --

2 MR. MARX: Right. But, I mean, at that
3 particular time, we did do dimensional checks. It was
4 under my authority to do the dimensional checks, but I
5 wanted to just clarify that there had been some
6 dimensional checks that were made on the particular
7 servo valve. They are not part of the public record.

8 Do you recall any of those dimensions that
9 would indicate that this valve was not manufactured as
10 to the requirements of Parker Hannifin? In other
11 words, were there any possibility of any parts being in
12 there that were not Parker Hannifin's and to their
13 specifications?

14 THE WITNESS: No, there was not.

15 MR. MARX: NOW, you also spoke of there
16 wasn't any significant changes made to the PCU. That
17 would be maybe when we're talking about dimensional
18 changes. Could there have been some manufacturing
19 changes, such as the subcontracting out primary spools,
20 manufacturing primary spools?

21 THE WITNESS: All designs are controlled by
22 the Boeing Company and then from those designs, we
23 construct route sheets that basically define how the
24 parts will be manufactured that's under Parker's

control. Within the guidelines of the SCD that I've
2 spoken of, that we use the right materials, the right
3 speed feeds, and we also outside vend our parts
4 depending on load capacity and our company.

5 So, yes, it could have been done on a lays or
6 it could have been crushed ground. Basically, as long
7 as the product meets the end requirements in terms of
8 material, the hardness, the surface finish and the
9 dimensional parameters, where it's made is
10 inconsequential.

11 MR. MARX: I understand that. I just wanted
12 to clarify the design on the servo valve. I'm a little
13 bit confused. To your knowledge, is the design of the
14 servo valve a Boeing design or a Parker Hannifin
15 design?

16 THE WITNESS: The design is on Parker paper.
17 I understand that there's some sort of patent going on
18 with it, and to be honest with you, I can't say much
19 further.

20 MR. MARX: Are you familiar with the overhaul
21 procedures when a PCU comes into the shop for overhaul?

22 THE WITNESS: Yes, I am.

23 MR. MARX: Are there any written procedures
24 that you know of for disassembly of the primary from

the secondary and the secondary from the housing?

2 THE WITNESS: I'm not familiar with any.

3 MR. MARX: Or any procedures for reassembly?

4 THE WITNESS: In the overhaul manual, it does
5 describe -- the Boeing overhaul manual does describe
6 disassembly and assembly procedures. That manual is
7 used. So I stand corrected that we do not have our own
8 internal procedures on that. Actually, we do create
9 internal procedures off of the Boeing overhaul manual
10 that describe areas of caution.

11 For instance, the materials on the primary
12 and secondary slide are a very high aesthete and are
13 brittle, much like glass. If you drop them, they'll
14 chip. That sort of problems. So you definitely have
15 to do special handling on those things.

16 We have rubber mats on our benches to prevent
17 that. There are quite a few internal standards on how
18 to perform disassembly and assembly on all units.
19 There's a lot of generic practices. The specifics on
20 the servo valve are spelled out very clearly in the
21 overhaul manual.

22 Specifically, after the 585, there are some
23 very specific -- there's not a lot left that isn't
24 described on how to assemble that servo valve and test

it.

2 MR. MARX: Well, this would be on the
3 overhaul. My understanding is that this particular PCU
4 has been overhauled within a couple of years of the
5 accident. Is that correct, do you know?

6 THE WITNESS: No, that is not correct. The
7 PCU is overhauled for external leakage when a unit
8 comes in and it's squawked as external leakage. We
9 replace all the software. We replace all the filters.
10 There's a standard procedure. The servo valve was not
11 taken down to the sub-level and checked.

12 It was checked at the top level, which we
13 consider catches all the parameters and it met that
14 requirement. It was shipped out. There was no work
15 done to the servo valve.

16 MR. MARX: So it was never disassembled?

17 THE WITNESS: That there is not definition.
18 There are several ways of disassembling the ram. One
19 is to take out all the linkage and --

20 MR. MARX: I'm just speaking of the servo
21 valve.

22 THE WITNESS: The servo valve was not
23 disassembled. Understand, depending on how you take
24 the PCU apart, if you take the PCU apart, you have to

disassemble the servo valve in some cases and not all
2 cases. It depends on where you go to do your work.

3 If you do it on the internal linkage, you
4 have to remove the servo valve to do any work on the
5 summing levers. Down on the piston level, as we did in
6 this investigation on flight 427, we did not have to
7 disturb the internal summing levers or the main servo
8 valve.

9 So I don't have record as specifically there
10 was written on the receiving card or the overhaul card,
11 there was no work done to the servo valve. Only
12 software which we call all the seals and then the
13 filters were replaced at the time.

14 Then it was tested to the functional top
15 assembly ATP and passed all those and sent out back to
16 the customer.

17 MR. MARX: Just to make sure I understand
18 you. As far as the record showing and as far as your
19 understanding is, the servo valve since it was
20 originally manufactured, had not been taken apart and
21 put back together again?

22 THE WITNESS: I cannot say that.

23 MR. MARX: Up until the time of the accident?

24 THE WITNESS: There was no work done to the

servo, but in terms of whether it was taken apart or
2 not, I cannot definitively answer that.

3 MR. MARX: You were also talking about
4 different methodologies in which to produce a jam in a
5 servo valve. You were mentioning something about
6 clamping forces. The clamping forces would be those
7 produced between an outside diameter say of the primary
8 and the inside diameter of the secondary or the outside
9 diameter of the secondary to the inside diameter of the
10 housing.

11 Could this be because of dimensional
12 problems? That is that the overall dimensions are not
13 properly or uniformly along the lengths of the spool.
14 Is this what you were talking about?

15 THE WITNESS: The valves, the hand-fit
16 valves. Again, we have an internal requirement on all
17 of our servo valves for roundness and straightness call
18 out throughout the board that deals in the millionths
19 which is basically -- it's about ten millionths
20 roundness and straightness.

21 If you know that, that's five zeros to the
22 right of the decimal place and then a one or a five.
23 That's kind of roundness and straightness that we try
24 to maintain on these valves. You need special gages

and sorts. Then for performance sake, you have to keep
2 the clearances within the 150 millionths to 200
3 millionths, as already testified to.

4 Material properties, you have yield. All
5 material has yield to it. Basically we go through a
6 very extensive testing to what we call stabilize the
7 valve. We stabilize the valve so that this yield is
8 already pre-yielded, that you will not see any more
9 yield.

10 Then you fit the valve to make sure that you
11 will not have any further conditions where pressure
12 would cause this to clamp, i.e., we stabilize this at
13 6,000 pounds of pressure several different times to
14 make sure that we have no clamping. Then we come back
15 when we fit the valve and then we go through the normal
16 functional ATP of the servo valve.

17 We, therefore, check to see if we have any
18 binding or sticking of that valve, and then you open up
19 the clearances basically to meet your friction
20 requirements that were earlier discussed that are in
21 the ounces on the primary slide, roughly around 12
22 ounces. The secondary is a little higher because it
23 has the effects of the detents springs.

24 MR. MARX: Could particulate matter or some

debris also reduce the diametrical clearances in
2 certain areas of the valve that could increase to
3 clamping forces?

4 THE WITNESS: Understand the way the servo
5 valve is designed. It's much like in your garage
6 you've got dikes or wire snips, and that's the way the
7 servo valve is designed. You've got two pieces that
8 act like scissors or wire dikes.

9 Like anything, if you have scissors -- if you
10 have a pair of scissors that are a little worn and the
11 nut's basically backed off and you get a bigger gap in
12 there and you go to cut something, it will get jammed
13 up in between there.

14 Well, when you're talking about 150
15 millionths to 200 millionths, that doggone thing is
16 just about on top of the other blade. The materials we
17 use are 52-100, which holds a very high Rockwell
18 hardness in the 62 RC category and the nitroloid that
19 the primary slide is made of is a 58 RC. They act like
20 any very high strength dikes.

21 If there's anything that would fall in there,
22 as the chip shear test shows, it would be severed. The
23 particulate small in the micron level that you're
24 talking about, there is probably nothing that has that

kind of shear strength to withstand that kind of --

2 MR. MARX: Is it possible to get a very soft
3 material stuck that would not leave a mark against the
4 outside diameter of the spool in reference to the ID of
5 their main surfaces?

6 THE WITNESS: Are you asking me to speculate
7 that?

8 MR. MARX: Yes. I mean, is it possible to
9 get soft material in there?

10 THE WITNESS: I'm sure it's possible. I
11 don't believe that that would be the case based on the
12 clearances that we're dealing with here.

13 MR. MARX: Well, the clearances are being in
14 the neighborhood of 1.5 to 2 microns on each side, as
15 was testified by, I think, Mr. Turner was the one that
16 gave us that. It was in the neighborhood of 4 to 5
17 microns throughout the whole diameter, which is a very
18 small distance.

19 I just wanted to clarify about this clamping.
20 The clamping that we are speaking of is one in which we
21 have a reduced ID or an expanded OD or something that's
22 in between it that could do the same thing. This still
23 would be an active scenario for clamping or for
24 sticking of the valve, wouldn't it?

1 THE WITNESS: We tested for that as we spoke
2 earlier. Two weeks ago, we checked to see if clamping
3 was an issue. Clamping had no effect on this valve.

4 MR. MARX: During the last test that you're
5 talking about, you specifically did put materials
6 between the IDs and the ODs, or did you just do shear
7 tests?

8 THE WITNESS: No, we didn't do -- what I'm
9 speaking to is the fact that when I was speaking of
10 clamping, I am talking about the effects of higher
11 pressures coming into the servo valve.

12 MR. LAYNOR: Mr. Weik, I think Mr. Marx is
13 deferring to me to ask a question that he's been trying
14 to ask the previous witness.

15 Were you present during the test where the
16 pressure differentials were measured between the
17 pressure and return for the A and B systems to
18 determine residual pressures under different jamming
19 positions?

20 THE WITNESS: Yes, I was.

21 MR. LAYNOR: The tests were conducted with
22 the -- if you can refer to Exhibit 9-AH, page 2, I
23 guess it is. I think there's another exhibit that also
24 discusses these tests, but we'll use this one. NOW,

the tests were conducted with four different
2 conditions. Two of which involved the secondary spool
3 jammed to the housing in both directions with the left
4 rudder input and the right rudder input, and assuming
5 that the jam occurred with the secondary spool at the
6 full travel to the external stop and the primary spool
7 or slide free to move. Is that correct, are they the
8 first two conditions?

9 THE WITNESS: I believe I heard you
10 correctly.

11 MR. LAYNOR: The other two conditions assumed
12 that the -- or actually were conducted with the primary
13 slide jammed to the secondary with both a left and a
14 right rudder command, and the secondary free to move to
15 control the fluid flow through the servo valve. Is
16 that correct?

17 THE WITNESS: Yes.

18 MR. LAYNOR: I think what Mr. Marx was trying
19 to establish in questioning Mr. Cline earlier is that
20 if we were to assume that the secondary slide for some
21 reason, perhaps something like contamination in the
22 secondary slide pick up area, were to move prematurely
23 and move to the internal stop rather than the external
24 stop and then become jammed, what would the residual

pressure be or the residual percentage of rudder, and
2 what travel would the rudder be able to go with power
3 command?

4 THE WITNESS: Let me first off say, that when
5 you start getting into the system, that's not my area
6 of expertise. That's Boeing's. So my answering would
7 have to be based on just what the gages read and where
8 we put the positioning of the slides.

9 In terms of references to what the rudder
10 would do and that sort of thing, you've had testimony
11 and I'm sure you can get Boeing to come back up here
12 and explain it. I'd be glad to answer to you on where
13 what pressure of readings we got at certain specific
14 positions of the slide.

15 MR. LAYNOR: I think that that would be
16 sufficient for our purposes. What we're trying to
17 ascertain is if the secondary were to travel beyond the
18 external stop to the internal stop, what would these
19 first two conditions have produced as far as available
20 rudder travel and residual position with the best null
21 available?

22 THE WITNESS: Are we working with number one?

23 MR. LAYNOR: If we are working with number
24 one, and I'll perhaps go a little further into that in

the questioning. In our examination of these
2 conditions, it appeared to us, at least, that the
3 relative primary and secondary slide positions for
4 number one if the left rudder command and the maximum
5 opposite travel of the primary spool would be the same
6 condition, that you would have in condition number four
7 the same relative position for the primary and
8 secondary spool when the secondary spool was fully
9 driven to the internal stop.

10 THE WITNESS: Could we have a definition of
11 left rudder? I guess, left rudder is extend ram or
12 retract ram?

13 MR. LAYNOR: I think left rudder is retract.
14 I'm told it's extend.

15 THE WITNESS: The left rudder is extend
16 command?

17 MR. LAYNOR: Yes. Is that correct?

18 MR. MARX: The actual pressure measurement
19 for those tests are in Exhibit 9-R, page 3.

20 THE WITNESS: That's probably the better
21 language for me. Again, Mr. Laynor, understand that I
22 am somewhat familiar and I have learned a lot through
23 this investigation and what it does on the airplane,
24 but my knowledge is basically extend or retract on the

main PCU.

2 When it's integrated into the system, that
3 goes into the line of questioning for Boeing.

4 MR. LAYNOR: The number one scenario is
5 secondary retract linkage stop. I suppose instead of
6 linkage stop, we would say what would that be if it
7 were on the internal stop?

8 THE WITNESS: Are we in test condition one
9 now?

10 MR. LAYNOR: Test condition one.

11 THE WITNESS: If you have a secondary retract
12 against the linkage stop, that would create an extend
13 command on the PCU rudder. Basically, a 12 percent
14 residual pressure says that if the secondary was
15 against its linkage stops and held there, it would be
16 basically getting an extend PCU command and you tried
17 to go retract on the RAM, you would reduce the ability
18 load output to within 12 percent.

19 MR. LAYNOR: Basically, the ram would
20 neutralize within 12 percent of its output force.
21 That's the closest to the null position that you could
22 achieve by full movement of the primary slide. Is that
23 true?

24 THE WITNESS: That's true.

MR. LAYNOR: NOW, if in condition three --
2 and I know there's some problem with the signs in this
3 exhibit when you look at it in the terms we are now.
4 But condition three would be placing the secondary
5 retract to the internal stop rather than the linkage
6 stop. The residual pressure appears to be 58 percent
7 in the same direction as it does in test condition one.

8 THE WITNESS: In this case assimilating that
9 the primary --

10 MR. LAYNOR: Well, my question is could that
11 condition be comparable to a secondary spool, a
12 secondary slide jam at the internal stop?

13 THE WITNESS: The physical positions are the
14 same, but the condition of failure is different and the
15 ability to get output force is different. Basically,
16 you have a 12 percent reduction within -- I'm trying to
17 find the words, Mr. Laynor, to explain this.

18 MR. LAYNOR: Maybe we can let it go, but what
19 it appeared to us, at least, is that if you moved the
20 secondary slide to the internal stop, beyond the
21 external stop to the internal stop and jammed it, you
22 would have the conditions that you had in condition
23 three when you moved the primary slide full stroke in
24 the opposite direction.

In that case, a residual pressure would
2 result in a 58 percent of load down or maximum pressure
3 condition rather than 12 percent. The available travel
4 would be between 58 percent and 100 percent in one
5 direction, but it could not go in the other direction.

6 THE WITNESS: The difficulty that comes in
7 this data is the way it's presented is it's taken
8 through two different levels. There's a servo level
9 and then there's a PCU level, and then there's the
10 airplane and what it does in the airplane. I think
11 this is where we are running into some problems in
12 trying to interpret what it says.

13 It says the same thing. I think, in
14 testimony given earlier that, again, the residual in
15 the first two cases show that you can't reduce the
16 effects of the secondary being jammed against the
17 linkage stops.

18 In the case three and four, in the event that
19 the primary slides become jammed at full rate, you have
20 full authority with the secondary slides, no matter how
21 far they travel, that's against the internal stop. At
22 that rate, you'll have the authority of wherever the
23 secondary slide goes. In actuality, you would have
24 authority in both directions of the extend, retract or

load output.

2 MR. LAYNOR: I'm not going to pursue it any
3 farther. I'm going to turn it back to Mr. Marx, and
4 hopefully he won't either, but --

5 MR. MARX: I just merely looked at the
6 pressures and we went through this once before with Mr.
7 Cline, and it had to do with the C2, C1 pressures
8 versus the C4, C3 pressures. Looking at that, I
9 believe he testified, and I concur with his testimony,
10 that the rudder would be going left at that position.

11 THE WITNESS: Which case are we speaking to?

12 MR. MARX: This is number three, test
13 condition number three, Exhibit No. 9-R, Romeo, on page
14 3.

15 THE WITNESS: Okay.

16 CHAIRMAN HALL: Mr. Clark?

17 MR. CLARK: I have no questions.

18 CHAIRMAN HALL: You have no questions. Mr.
19 Schleede?

20 MR. SCHLEEDE: Just a couple here, hopefully
21 brief.

22 Mr. Marx asked you about the design of the
23 dual concentric servo valve, and I was confused about
24 your answer. Who was primarily responsible for the

design of the 737 servo valve? Was it Boeing or
2 Parker?

3 THE WITNESS: I think we can get that
4 information to you. I'm probably not the right one to
5 ask. That time frame was, obviously, a little before
6 my time.

7 MR. SCHLEEDE: Just, as you know, we have in
8 the exhibits some documents that pertain to an incident
9 involving a 747-400. I don't want to go into great
10 depth, because the exhibits speak for themselves. I
11 just want to know if you have reviewed -- I know you
12 have worked on this case, but have you reviewed the
13 report of the 747 incident involving a British Airways
14 airplane?

15 THE WITNESS: I have participated and am
16 still participating in an investigation with the Boeing
17 company, where the Boeing Company has been a lead in
18 this investigation, and we have provided services to
19 them. We have seen the report, and we are basically
20 just now in the process of going through the report and
21 evaluating what it is.

22 MR. SCHLEEDE: This is the report we're
23 speaking of it's Exhibit 9-Q, the Air Accident
24 Investigation Branch Report from the United Kingdom?

THE WITNESS: That's correct.

2 MR. SCHLEEDE: I was going to ask you if you
3 could comment on the findings, whether you agreed or
4 not. Do you have a position at this point?

5 THE WITNESS: I think we would like to defer
6 until we've looked at it further.

7 MR. SCHLEEDE: One little question about the
8 Sahara Airlines or the 737 incident. I know you
9 clarified the record about the servo valve under a test
10 condition reversed, not the full up PCU. But my
11 question was if the servo valve, control valve does
12 reverse -- and I realize it's a simulated situation
13 when it did reverse -- can you explain why since it is
14 a control valve that it wouldn't reverse the PCU in a
15 full up unit?

16 THE WITNESS: I guess the understanding is
17 that you have to understand in order to have a
18 reversal, you have to have three things occur
19 simultaneously. Those three things don't happen except
20 for out here in space, there's probably a probability
21 number for it. But it is a remote line up of
22 conditions in order to have that reversal.

23 So under normal operation that happens as we
24 have -- it's taken us this long to come to the

recognition that this condition existed, you can see
2 that the remote possibility is remote. So for the
3 Sahara one, it's basically one of those cases that you
4 have to go to that remote condition and test for that
5 remote condition before you can get the reversal.
6 That's what we do now with the AD is we go to lining up
7 three of those issues that need to occur simultaneously
8 and then check it to see.

9 In that failure mode, the Sahara would do it.
10 But the Sahara unit at the top level, at the top level
11 PCU, does not have those three elements in the failure
12 mode. So it cannot happen.

13 MR. SCHLEEDE: I understand now. Thank you.
14 One other question on the standby rudder actuator. I
15 know you were here during Mr. Turner's testimony
16 regarding a jam in the standby rudder actuator. I
17 wanted your comments. Do you agree with his testimony
18 about the compliance in the PCU that will allow normal
19 operation of the continued operation of the rudder with
20 a fully jammed standby?

21 THE WITNESS: Our responsibility stops right
22 around the pilot input point on the PCU. In terms of
23 anything back from that point is out of our
24 jurisdiction or out of our technical expertise. We're

just a PCU manufacturer.

2 MR. SCHLEEDE: Well, within the PCU itself,
3 are you aware of any occasions of jams that may have
4 been caused by external foreign objects other than what
5 we've talked about already within the servo valve or in
6 the summing levers? How about external interference
7 with the operation of the PCU?

8 THE WITNESS: Not to my personal knowledge,
9 no.

10 MR. SCHLEEDE: Thank you.

11 THE WITNESS: Could I clarify one thing, Mr.
12 Hall?

13 CHAIRMAN HALL: Surely.

14 THE WITNESS: At break, I think there was
15 some misunderstanding by some of the NTSB people in my
16 testimony about the Pittsburgh accident in the hanger.
17 I want to make it clear that it's only a possibility
18 that in the future that if this tragedy ever happens,
19 hopefully never, that participation from, i.e., the
20 Boeing systems group or something come in to assure
21 that there is no movement.

22 However, I want to state for the record, that
23 I do not believe that there was any movement to the
24 unit in the handling from the accident site to the

1 hanger. That the bent rod in itself secure that the
2 rudder was in the position that it was when it impacted
3 or just slightly off that, depending on the progression
4 of the impact on the vertical fins.

5 So for the record, please understand that the
6 rudder PCU information available to us at two degrees
7 right, I believe, that is the case.

8 CHAIRMAN HALL: Mr. Weik, I appreciate that
9 comment, but I want to be sure you understand and all
10 the parties understand that if there's anything that
11 the NTSB needs to be doing better, tell us. That's the
12 process here. Everybody has invested a lot of time and
13 effort into this investigation. Everybody is coming
14 here wanting to find the cause.

15 If there's something that wasn't done
16 properly and it was the NTSB that didn't do it
17 properly, then as the head of the NTSB, I want to know.
18 You have mentioned in a lot of your questions here that
19 you have to defer to your customers. Well, the board
20 has customers too we've got to report to. I want to be
21 sure that the report we give is a full one.

22 NOW, if you could help me and I'm not going
23 to get into technical questions about the slides or
24 anything, but I want to go back and ask you if you

could give me an overview and an understanding from the
2 Colorado Springs' accident. What has been done in
3 terms of looking at that rudder, whether it was the
4 FAA, the study that's going on right now, the study
5 that was -- and if it was just limited to reversals, it
6 was just limited to reverses.

7 But could you tell me what's happened between
8 Colorado Springs and now that Parker Hannifin has
9 participated in in regard to looking at that rudder? I
10 would like to lay that on the record. I think the
11 American people ought to know what's been done. I
12 think a lot's been done, but I would like to get it out
13 in the way people can understand it.

14 THE WITNESS: As it was testified earlier by
15 Mr. Cline, once there was an understanding of the
16 condition that resulted out of the extensive
17 investigation Mack Moore unit 2228, we felt that there
18 needed to be some improvement on this remote failure,
19 that it needed to be eliminated.

20 so we, therefore, redid the internal stops on
21 the primary around the secondary slide to restrict
22 valve, and that's basically the AD that has gone on.
23 We believe that that in itself, along with scrutiny of
24 the rudder in determining its performance just in terms

of the performance parameters, we felt that they were
2 still in line. That we have covered these sort of
3 things that were failure modes. As I said, this was a
4 remote one. We have eliminated this remote failure
5 mode.

6 Let me add to the fact that in precautions,
7 one of the things that we did learn is that there has
8 to be some very specific guidelines on how to put this
9 thing together and how to manufacture it.

10 Due to the nature of the product, it is very
11 performance oriented to the aircraft that it has to
12 have high standards in the quality world, and we have
13 put numerous additional steps within our route sheet on
14 how to manufacture and how to assemble this that has to
15 be bought off by a quality organization, which is
16 different from your manufacturing organization.

17 Therefore, you have another set of eyes that
18 are looking at this and determining that it's not
19 deviating from blueprint or performance requirements.
20 So, basically, I think the manufacture in itself has
21 tightened down its standards and left no room for
22 guesswork or just the hand me down attitude of giving
23 journeyman and then working them into technical
24 experts. We now have a documented procedure on how to

put this together and disassemble it and manufacture
2 it.

3 CHAIRMAN HALL: Thank you for that report.
4 NOW, if you just help me on one little item here so I
5 can again understand. The rudder on the 737 is moved
6 by what?

7 THE WITNESS: By this PCU.

8 CHAIRMAN HALL: By the PCU. And it has what
9 two or three major parts. Is that correct?

10 THE WITNESS: I'm sorry?

11 CHAIRMAN HALL: components. What are the
12 major components of the PCU?

13 THE WITNESS: There is bypass. There's a mod
14 piston. There is a main PCU -- or the main control
15 valve. There's an electro-hydraulic servo valve.
16 There's a solenoid. There's some inlet checks and some
17 filters. Each one of those are individually checked,
18 plus some connectors.

19 CHAIRMAN HALL: How many of those items have
20 been looked at as part of you-all's work? All of them?
21 Some of them?

22 THE WITNESS: Well, when they're integrated
23 at the top assembly, all of them are looked at in terms
24 of how they interact with one another. Then down at

the detailed level, we've look at the servo valve.

2 We've looked at the solenoid a little closer. We've
3 done some external tests on that.

4 CHAIRMAN HALL: Now this PCU is manufactured
5 to certain specifications, I assume?

6 THE WITNESS: That is true.

7 CHAIRMAN HALL: Are those specifications
8 approved by who? They come from Boeing and you-all do
9 the manufacturing?

10 THE WITNESS: That's correct.

11 CHAIRMAN HALL: Is there an FAA requirement
12 on that unit or is that a Boeing item?

13 THE WITNESS: Yeah, it's a Boeing item. Yes.

14 CHAIRMAN HALL: NOW, the particular unit that
15 was on the accident aircraft, had you-all done all the
16 service on that particular unit since manufacture?

17 THE WITNESS: That's correct.

18 CHAIRMAN HALL: How many times had it been in
19 for service?

20 THE WITNESS: One time after original
21 manufacturing.

22 CHAIRMAN HALL: Did you have, I assume, in
23 your computer what it came in for at the time it was
24 serviced previously?

THE WITNESS: That's correct.

2 CHAIRMAN HALL: What was that, please?

3 THE WITNESS: External leakage.

4 CHAIRMAN HALL: External leakage. Now the
5 filters on these units, how often are they supposed to
6 be changed?

7 THE WITNESS: Parker's policy is anything
8 that comes in is replaced, we replace that as a
9 standard item.

10 CHAIRMAN HALL: No, I'm talking about is it
11 changed in the field at all by the company?

12 THE WITNESS: When it comes under our roof,
13 Yes, we replace it. It's up to the airlines as to when
14 they remove it.

15 CHAIRMAN HALL: How often should the filters
16 be replaced?

17 THE WITNESS: I think there is some
18 requirements within a Boeing standard, but I don't know
19 if I can answer that.

20 CHAIRMAN HALL: I mean, I'm trying to get
21 this. I can understand, I have to change my oil every
22 3,000 miles. It used to be 10,000. Now they tell you
23 to do it every 3,000. Is there somewhere somebody
24 knows how to properly maintain this thing? I'm sure

there is. USAir coming on that. Okay.

2 Do you-all have a recommended interval that
3 filters are supposed to be changed?

4 THE WITNESS: I think we would follow in the
5 line of what Boeing recommended.

6 CHAIRMAN HALL: Well, I guess we'll have to
7 piece everything together as we go. We would like
8 to -- Mr. Weik, you are going to stay with us this
9 week, right?

10 THE WITNESS: Yes.

11 CHAIRMAN HALL: I appreciate, you've been up
12 here for a long time, and I appreciate your time up
13 here. We may want to recall you, but since you'll be
14 here with us, that wouldn't be a problem.

15 I would like to recall at this point in time
16 from Boeing -- you are excused.

17 THE WITNESS: Thank you, Mr. Chairman.

18 (Witness excused.)

19 CHAIRMAN HALL: I would like Mr. Cline to
20 please come up if he could just for five minutes. I
21 hate to have a situation where somebody says I don't
22 have the answer, somebody else does and they're sitting
23 in the room. So, Mr. Cline has graciously agreed to
24 come up here for five minutes.

Mr. Laynor is going to handle the questions.

2 You are already sworn, and, Mr. Laynor, I will give you
3 the microphone.

4 (Witness testimony continues on the next
5 page.)

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PAUL CLINE, B-737 HYDRAULICS/FLIGHT CONTROL ENGINEER,

4

BOEING COMMERCIAL AIRPLANE GROUP, SEATTLE,

5

WASHINGTON

6

7

Whereupon,

8

PAUL CLINE,

9

was recalled for examination by the NTSB and, having

10

been previously duly sworn, was examined and testified

11

further as follows:

12

MR. LAYNOR: Welcome again, Mr. Cline. Mr.

13

Cline, I think you understand the question I wanted to

14

recall you for. But if we can refer to Exhibit 9-AH,

15

page 2 or Exhibit 9-R where we have the pressure

16

differential measurements across the servo valve during

17

the test where we jam the spools in various positions.

18

You're familiar with that test, are you not?

19

THE WITNESS: Yes, I am.

20

MR. LAYNOR: The question is that if the

21

secondary slide over traveled for whatever reason to

22

the internal stops and jammed at the internal stop

23

instead of the external stop, what would the available

24

rudder travel **be** and what would the **point** at which the

rudder stalled or the residual position be?

2 THE WITNESS: The condition you're talking
3 about with the positions of the slides is the same as
4 those positions represented in condition three. In
5 condition three, we're simulating a primary jam, and
6 that's why you see the number as a positive 58 percent.

7 If you look at this assimilating a secondary
8 jam, so that the secondary jam is at the internal stop
9 and we're trying to overcome that with the primary, you
10 have to consider that a minus value, a negative 58
11 percent.

12 So, what that really means is that in this
13 case, once you've got the secondary to the internal
14 stops and you've jammed it there, that was a left
15 rudder command that got it there and now you try to
16 bring it back with the primary, you will only be able
17 to bring it back to 58 percent of the blow-down value.

18 I have to point out that in order to get the
19 secondary jammed at the internal stops, it really takes
20 three series of events or failures. First of all, you
21 have to have something that can overstroke the
22 secondary to get it to the internal stop. That would
23 be something like a primary or secondary jam.

24 Once you get the secondary to that internal

stop, then you have to jam the secondary and unjam the
2 primary. So that's three separate events to get there.
3 If you do that, you will be left with a 58 percent
4 residual pressure, which is 58 percent of the hinge
5 moment.

6 I would like to also point out that that 58
7 percent hinge moment on the case of the USAir flight
8 427 airplane, it would be consistent or inconsistent
9 with the full rudder blow-down deflection required to
10 produce the yaw moment that Mr. Kerrigan has previously
11 testified to.

12 MR. LAYNOR: Let's revisit just a little bit
13 the conditions it would take to get the secondary jam
14 to over travel. Is there any possibility that
15 contamination in the slot in which the roller picks up
16 the secondary slide could cause a premature pick up of
17 that slide without having a jam of the primary?

18 THE WITNESS: Yes, that would cause a
19 premature pick up and it would cause additional stroke
20 of the secondary equal to the magnitude or whatever
21 piece of material that was in that slot.

22 MR. LAYNOR: So if there were 100 micron
23 particle, it might over travel a certain distance of
24 twenty thousandths?

THE WITNESS: Yes, it would over travel. If
2 the particle was incompressible, it would over travel
3 100 microns.

4 MR. LAYNOR: Just for clarification, under
5 those conditions, if the pilot tried to introduce right
6 rudder that's jammed after a left rudder command, his
7 pedal would effectively be jammed by the feedback
8 mechanism through the pilot control linkage?

9 THE WITNESS: NOW, this is after we've
10 completed the three events to get to this?

11 MR. LAYNOR: Yes.

12 THE WITNESS: Yes, his pedals would come up
13 against the external manifold stops and he would -- to
14 him, they would feel like they were jammed in the one
15 direction.

16 MR. LAYNOR: So he would have left pedal to
17 control the rudder from this 58 degree or 58 percent,
18 I'm sorry, residual position to full travel to the
19 blow-down limit, but he could get nothing less than the
20 58 percent left rudder. He could get nothing to the
21 right?

22 THE WITNESS: That's correct.

23 MR. LAYNOR: Thank you, Mr. Cline.

24 CHAIRMAN HALL: Thank you very much for your

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FRANK JAKSE, SENIOR RESEARCH SPECIALIST, MONSANTO

8

COMPANY, ST. LOUIS, MISSOURI

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Whereupon,

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FRANK JAKSE,

12

was called as a witness by and on behalf of the NTSB,

13

and, after having been duly sworn, was examined and

14

testified on his oath as follows:

15

MR. SCHLEEDE: How long have you been with

16

the Monsanto Company?

17

THE WITNESS: I've been with Monsanto for 15

18

years.

19

MR. SCHLEEDE: Could you give us a brief

20

description of your education and background that

21

qualifies you for your present position?

22

THE WITNESS: Yes. I have a bachelor's of

23

science, master of science in chemistry. I've been in

24

research and development in the industry for 15 years.

1 In the last three years, I've been devoting my time to
2 Skydrol technology and technical support.

3 MR. SCHLEEDE: Thank you. I believe Mr.
4 Sasser is going to begin the questioning of Mr.
5 Phillips.

6 MR. PHILLIPS: Mr. Jakse, in your duties at
7 Monsanto, what are your responsibilities and what do
8 you do on a day-to-day basis for Monsanto?

9 THE WITNESS: I am senior research specialist
10 responsible for Skydrol marketing technical service. I
11 assist the sales people in explaining the technical
12 aspects and performance characteristics of our Skydrol
13 fire resistant aviation hydraulic fluid.

14 I am also technology team leader for Skydrol
15 for new product developments and also oversight of our
16 fluid analysis service.

17 MR. PHILLIPS: What is Skydrol?

18 THE WITNESS: Skydrol is a synthetic fire
19 resistant hydraulic fluid used exclusively in aviation
20 hydraulics. It consists of a phosphate ester base
21 stock which in part has the fire resistant
22 characteristics to it. They are blended up with a
23 precise mixture of performance additives that in part
24 certain performance characteristics to the fluid.

MR. PHILLIPS: Do other companies other than
2 Monsanto manufacturer hydraulic fluid?

3 THE WITNESS: Yes. Chevron is a competitive
4 of ours. They also supply a fire resistant phosphate
5 ester based hydraulic fluid to the commercial aviation
6 industry.

7 MR. PHILLIPS: To the best of your knowledge,
8 what type of hydraulic fluid was in the accident
9 airplane, the USAir flight 427?

10 THE WITNESS: The Boeing 737-300 was serviced
11 with fire resistant hydraulic fluid.

12 MR. PHILLIPS: Would that have been Skydrol,
13 your product?

14 THE WITNESS: Actually, it would be a
15 mixture. It is predominantly Skydrol, but as part of
16 the certification of the hydraulic fluids, they must be
17 mixable and miscible and compatible with other fluids,
18 other phosphate ester fluids in any and all
19 proportions. So there was a mixture of our product and
20 the Chevron product in flight 427.

21 MR. PHILLIPS: Could you characterize the
22 percentage concentrations of Skydrol versus Hyjet,
23 ballpark figures?

24 THE WITNESS: In ballpark figures, I think it

was, if I recall the numbers correctly, it was 84
2 percent Skydrol, 16 percent Hyjet.

3 MR. PHILLIPS: Have you participated in the
4 investigation of the USAir 427 accident?

5 THE WITNESS: Yes, I have.

6 MR. PHILLIPS: In what capacity?

7 THE WITNESS: The NTSB requested of Monsanto
8 support in the investigation and analysis of the
9 hydraulic fluid from the accident aircraft. We have
10 been a manufacturer of Skydrol for over 40 years to the
11 industry.

12 NOW, naturally we have a vast history of
13 experience with the fluid and understanding the
14 chemistry involved. We also operate an in-service
15 fluid analysis program for our customers. So we have
16 experience in analyzing hydraulic fluid.

17 MR. PHILLIPS: As part of the investigation,
18 you were called upon or Monsanto was called upon to
19 assist in the examination of the accident airplane's
20 hydraulic fluid. Is that correct?

21 THE WITNESS: That's correct.

22 MR. PHILLIPS: I believe you also were
23 involved in sampling or testing some other samples of
24 hydraulic fluid removed from other aircraft, 737

aircraft. Could you briefly describe the process and
2 the findings for that testing?

3 THE WITNESS: Are you talking specifically
4 about what analyses we have performed?

5 MR. PHILLIPS: Yes, first of all, I would
6 like to have a general overview of what samples were
7 taken and what the process was for analyzing the
8 samples?

9 THE WITNESS: At the direction of the NTSB,
10 samples were collected from the in-service operating
11 fleet of 737 aircraft. These fluids were collected
12 from the A and B reservoir and A returned and B
13 returned on each aircraft. Aircraft selected were from
14 Southwest Airlines, United Airlines and USAir. That
15 was one category of samples.

16 Another category of samples were collected
17 from rudder PCU units that were returned to Parker for
18 servicing or maintenance. I don't know the details of
19 why they were returned. Fluid was collected from these
20 rudder PCUs, from the B link cavity, A return yaw
21 damper, B large filter, I believe, were the four
22 locations. That was the second category of samples.

23 The third category of samples were fluid
24 samples collected at various locations from the

accident aircraft.

2 MR. PHILLIPS: These samples were tested
3 where?

4 THE WITNESS: These samples were first tested
5 in our laboratory in St. Louis as part of a -- it was
6 what would be categorized as a wet chemical analysis.
7 These fluids, if we had sufficient volume, and in many
8 cases we did not have sufficient volume, we subjected
9 the fluids to our standard analysis program, which
10 consists of just a physical appearance and observation
11 of color and clarity of the fluid, water content,
12 acidity, chlorine content, specific gravity, and then
13 gas chromatography.

14 Of these tests, all of them, except for acid
15 number, were addressing the potential contamination of
16 the hydraulic fluid. water, chlorinated solvents are
17 all -- I don't want to say routine, but are found quite
18 often in used hydraulic fluid.

19 Specific gravity also addresses the issue of
20 contamination. The phosphate ester hydraulic fluids
21 have a distinctive specific gravity. The introduction
22 of other fluids that may be used around in service of
23 the aircraft, if they were introduced inadvertently
24 into the hydraulic fluid, specific gravity would pick

that up.

2 Gas chromatography is even more sensitive to
3 detecting the presence of soluble impurities in the
4 fluid, contaminants in the fluid.

5 MR. PHILLIPS: Could you summarize your
6 findings concerning the USAir flight 427 samples?

7 THE WITNESS: The samples that we analyzed as
8 part of the in-service fluid program, they all met the
9 in-service limits as specified in the Boeing 737
10 service manual. If they were characterized or they did
11 have a high particle count, the service manual does not
12 specify an in-service limit for particle count.

13 We revert back to an NAS 16-38 class 9
14 specification as far as an in-service limit. That is
15 defined in a Boeing document discussing hydraulic fluid
16 contaminants for hydraulic fluid in new delivered
17 aircraft.

18 MR. PHILLIPS: Could you describe the class
19 of fluid that you found in the USAir airplane PCU?

20 THE WITNESS: We found rather high
21 concentrations of particle counts in the rudder PCU
22 fluid samples taken from the accident aircraft.
23 Specifically, the B link cavity had what I would
24 characterize as a very high count level in terms of

particulates.

2 MR. PHILLIPS: Was there any attempt to do
3 further analysis of the fluids beyond the systems that
4 were available at Monsanto?

5 THE WITNESS: In the case of the hydraulic
6 fluid, per se, no, we didn't pursue the analysis of
7 particulates in terms of what their composition was.

8 MR. PHILLIPS: In the other fleet samples
9 that were taken, I suppose were taken as a baseline to
10 compare against the USAir 427 sample?

11 THE WITNESS: That's correct. That was the
12 intent. It was to determine what the baseline fluid
13 characteristics were at these various points on the
14 aircraft.

15 MR. PHILLIPS: Could you generally
16 characterize the differences between the accident
17 airplane's fluid sample and those of the other samples
18 taken?

19 THE WITNESS: In terms of what I would call
20 the wet chemistry, we didn't see any difference between
21 the 427 fluid and in the baseline fluid. Essentially,
22 all fluid samples that we analyzed met the in-service
23 limits as specified in the 737 service manual.

24 In terms of **particle** counts, we did see some

high levels of particle counts in the in-service fleet.
2 There's really not a direct comparison you can make
3 between samples that were pulled from the rudder PCU of
4 the accident and aircraft and the in-service samples,
5 because they were collected at different locations.

6 MR. PHILLIPS: Could you give us an idea of
7 the sensitivity of the sample method, the variability
8 and results depending on the cleanliness and the
9 methods used in sampling the fluid?

10 THE WITNESS: Yes, our experience has been
11 that particle counts are very sensitive to the sampling
12 technique and handling of the sample. Specifically, we
13 supply clean sample bottles for our customers who wish
14 to sample their fleet. These bottles are certified to
15 be clean to a class 1 or zero level. So we are certain
16 that on the collection of the fluid into the bottle,
17 the bottle will not introduce particulates.

18 The 737 service manual gives a technique for
19 collecting a proper sample. They indicate that some
20 fluids should be drained prior to catching a midstream
21 sample, because of the possibility of settling in the
22 reservoir and getting a nonrepresentative sampling as
23 far as particle counts is concerned.

24 I would also add that in terms of the

collection of samples from the rudder PCU, we heard
2 testimony this morning regarding samples collected by
3 pouring fluid out of the filter bowl. Once again,
4 that's not a -- that's a non-standard method, if you
5 will, of collecting fluid sample for particle counts.

6 The location of where you take the sample on
7 the aircraft, how you collect the sample, and what type
8 of bottle, all play a role in what your ultimate counts
9 will be on that sample.

10 MR. PHILLIPS: We heard earlier testimony
11 relative to the size of the micron and how small some
12 of these particles are that we're speaking of. Could
13 you briefly describe the equipment used to identify and
14 even count particulates in hydraulic fluid?

15 THE WITNESS: We do have a slide show of some
16 of the analyses, analytical techniques we use. Perhaps
17 I could go through that, if you don't mind?

18 MR. PHILLIPS: It would be fine with me.

19 THE WITNESS: Could I have the first slide,
20 please?

21 (Slide shown.)

22 THE WITNESS: This laboratory here is our in-
23 service fluid laboratory. It is dedicated exclusively
24 to the analysis of fluid samples submitted by our

customers. There are a number of techniques. I'll go
2 through some of them individually.

3 Essentially, when we receive a sample, we log
4 it in, establish a log number, and then the sample goes
5 through a number of stations to determine the different
6 quality measures that were taken on the fluid.

7 Can I have the next slide, please?

8 (Slide shown.)

9 THE WITNESS: In 1994, we did over 7500 fluid
10 samples for our customers in the industry. Needless to
11 say, we have to adopt some automated techniques. This
12 is an auto-type reader to measure acidity in the fluid.

13 Next slide, please?

14 (Slide shown.)

15 CHAIRMAN HALL: Mr. Jakse, I believe those
16 slides are submitted as exhibits, are they not?

17 THE WITNESS: That's correct.

18 CHAIRMAN HALL: If you would not mind, Mr.
19 Phillips, I guess, for the record, they are not from
20 Exhibit No. 9-Z.

21 MR. PHILLIPS: That's correct, 9-Z.

22 CHAIRMAN HALL: Please proceed.

23 THE WITNESS: Shown here is our gas
24 chromatograph. We use gas chromatography, like I said

earlier, to detect the presence of other fluids that
2 may be present. We also can determine the
3 concentration of our product versus the competitions.
4 A very accurate, very sensitive method for detecting
5 contaminants, volatile contaminants.

6 Next slide, please?

7 (Slide shown.)

8 THE WITNESS: This addresses Mr. Phillips'
9 question. This is a highyac automated particle
10 counter. This allows us to do particle counts on a
11 sample. It's a laser light scattering method. We can
12 do an analysis of particle counts in the fluid in a
13 matter of a few minutes.

14 The alternative is a manual particle counting
15 method, whereby a laboratory person would filter the
16 fluid, collect the micron-sized particles on a filter,
17 put that filter under a microscope, and then visually
18 manually count the particles in a specified grid area.
19 That method takes on average an hour and a half to two
20 hours per sample versus a couple of minutes for this
21 technique.

22 There are differences between the two
23 methods; manual versus automated. The laser light
24 scattering method has been determined to be more

1 sensitive to smaller particles. That is in the range
2 of five to 15 microns. The manual particle count
3 method appears to be more sensitive regarding larger
4 particles and fibers, as well.

5 Can I have the next slide, please?

6 (Slide shown.)

7 THE WITNESS: We have now switched venues.
8 I've gone through the wet chemistry analysis of the
9 fluid. The NTSB requested that we do a chemical
10 composition of the particles in the fluid to determine,
11 if we could, the origin of these particles. I must say
12 right at this point that we have never, to my
13 knowledge, undertaken such a study. We do have the
14 equipment and the personnel and the expertise to work
15 with micron-sized specimens, but we have never worked
16 with micron-sized particles from aircraft hydraulic
17 systems.

18 What we're looking at here is a 48 transform
19 infrared spectrometer with a microscope. In this
20 method, essentially we collected the particles on a
21 filter. Then our scientists picked out by hand
22 selected particles from that filter pad, placed them on
23 a salt flat and then placed them under the infrared
24 **microscope.**

2 She then positioned the sample into the
infrared beam and took an infrared spectrum. The
3 infrared spectrum is, in many instances, a fingerprint
4 for the material you're looking at.

5 It's not fool proof, however. In that, if
6 you do not have a library of spectra to compare against
7 or pure compounds to compare against, you will still
8 get an infrared spectrum, but in many cases, you may
9 not be able to conclusively identify what the material
10 is.

11 May we have the next slide, please?

12 (Slide shown.)

13 THE WITNESS: The second phase of identifying
14 the composition of the particle was electron
15 microscopy. It's a scanning electron microscope
16 technique. We took the same filter pads that were used
17 in the infrared investigation, took a pie wedge out of
18 that filter pad, mounted it on a specimen platform, and
19 then took three views of that sample in the electron
20 microscope.

21 This particular technique allows us to
22 identify elemental contaminant -- I'm sorry --
23 elemental composition of the particles. It's
24 particularly good for identifying metals. Those were

the techniques we used to characterize the composition
2 of the particles in the samples.

3 MR. PHILLIPS: So you used literally
4 everything that was available to your company within
5 your knowledge as a research specialist with Monsanto
6 to categorize the fluid and also identify the particles
7 where possible?

8 THE WITNESS: That's correct.

9 MR. PHILLIPS: Based on those tests, do you
10 have any general statements to make about the quality
11 of the fluid, the condition of the fluid?

12 THE WITNESS: Yes. Like I said earlier, the
13 quality of the fluid that was available to us from
14 flight 427 was what I would characterize as good
15 service condition. I would not, if that sample had
16 been received as a normal in-service fluid sample,
17 there would be no action necessary by the operator in
18 terms of correcting any deficiencies in the fluid.

19 The moisture content was moderate, but it was
20 not beyond the in-service limit. We might point that
21 out to the customer, but like I said, the condition of
22 the fluid from an in-service quality aspect was good.

23 The particle counts were high. We provided
24 the information as far as infrared spectra and what we

call element maps that come out of the electron
2 microscope to the NTSB.

3 In the cases with the infrared spectroscopy,
4 we were only successful in identifying only a couple of
5 compounds. Most notably, teflon, which has a very
6 characteristic infrared spectrum.

7 In the case of the element maps, we saw
8 metal. We also saw fluorine, which would be consistent
9 with the teflon. We were not involved in further
10 characterization as far as identifying where the
11 particles came from.

12 MR. PHILLIPS: Are you aware of any other
13 test methods available that would have been able to do
14 additional analysis to the fluids?

15 THE WITNESS: No, not really. I think in
16 terms of what know as far as what provides good long-
17 term service of hydraulic fluid, we captured that in
18 our wet chemical method.

19 MR. PHILLIPS: One final area of questioning.
20 You stated in earlier testimony that Monsanto maintains
21 a database for customers or relates with customers
22 relating to fluid samples. Could you briefly describe
23 the use of this database and why would an operator want
24 to use your services?

THE WITNESS: We have been providing a
2 service to our customers, the in-service fluid
3 analysis, since 1987. In that time period, we've
4 analyzed over 30,000 samples from various aircraft
5 models, various operators.

6 What we include in that database is
7 essentially the information that's provided to us by
8 the operator. We request aircraft model, the carrier,
9 the tail number, flight hours, and the date the sample
10 is taken and any other comments that the operator may
11 want to include in that particular fluid sample.

12 All the data that we generate as far as
13 analyzing the fluid, that being water, specific
14 gravity, acid number, chlorine, and gas chromatography,
15 as well as our particle count are entered into that
16 data base. That allows us to do trend analysis on
17 fleet models, individual aircraft, particular carrier's
18 fleet, compare that to the industry fleet performance,
19 as well as provide us some information regarding our
20 product's performance versus the competition.

21 MR. PHILLIPS: Has USAir used those services
22 in sampling their hydraulic fluid?

23 THE WITNESS: Yes, they have.

24 MR. PHILLIPS: I have no further questions,

unless you would like to add a comment.

2 CHAIRMAN HALL: Do the parties have questions
3 for this witness? I see three. I see Boeing,
4 Machinists and Monsanto. We'll begin with Mr. Purvis
5 from the Boeing Corporation.

6 MR. PURVIS: Thank you. Can you tell me if
7 it's true that the only sample from 427 that was
8 subjected to particle counting was from the link
9 cavity. That the others were too small or diluted with
10 test stan fluid to be sampled or -- I'm sorry -- to be
11 subjected to particle counting?

12 THE WITNESS: That's a good point. That
13 requires clarification. It appears that any samples
14 that were designated as A system appeared to be
15 containing some test stan fluid. We have two samples.
16 We have the B link cavity and the standby rudder
17 sample, as well.

18 Both samples, as I recall, had high particle
19 count, but the B link cavity was the highest level.

20 MR. PURVIS: Wasn't the 427 link cavity
21 articulate level similar to the level obtained in the
22 link cavities of the other six in-service PCUs that
23 came to you?

24 THE WITNESS: That's correct. Virtually

every one, if not every one of the B link samples from
2 the rudder PCUs that were provided to us by Parker, did
3 have high particle counts, as well.

4 MR. PURVIS: Thank you very much. No more
5 questions.

6 CHAIRMAN HALL: Thank you. Mr. Wurzel with
7 the IAM.

8 MR. WURZEL: Mr. Jakse, good afternoon.

9 THE WITNESS: Good afternoon.

10 MR. WURZEL: You stated the sampling of fluid
11 from flight 427's PCU was done in a non-standard way.
12 Did this explain the higher level of contaminants in
13 the samples taken?

14 THE WITNESS: I, myself, did not witness the
15 sampling that you referred to. The explanation that
16 was provided this morning gave an indication of perhaps
17 some concern. Keep in mind also that we're not
18 accustomed or we have not had the occasion to analyze
19 samples from accident aircraft.

20 I'm speculating at this point, but I don't
21 think you can rule that out, given the sensitivity of
22 particle counts to the sampling procedure.

23 MR. WURZEL: That's all I have. Thank you
24 very much.

CHAIRMAN HALL: Of course, Mr. Jakse is the
2 designated representative for Monsanto. Since he is a
3 witness, who is going to be questioning, please?

4 MR. SIEGEL: I am, Mr. Chairman, Jim Siegel.

5 CHAIRMAN HALL: Mr. Siegel, please proceed.

6 MR. SIEGEL: Thank you. Mr. Jakse, we have a
7 couple of questions for you. Specifically, how high
8 were the particle counts in the accident aircraft
9 flight number 427 in terms of NAS 16-38 and can you put
10 those classes in perspective for us?

11 MR. SIEGEL: Sure. NAS 16-38 defines fluid
12 cleanliness levels in five categories. That's
13 determined by size ranges. The five size ranges are
14 five to 15 microns, 15 to 25 microns, 25 to 50 microns,
15 50 to 100 microns, and then greater than 100 microns.

16 In our high particle count method and also in
17 the manual particle count method, the particles are
18 counted in those classifications. so for every sample,
19 you get five numbers.

20 You compare those numbers to a scale as
21 defined by NAS 16-38. That will define the -- then
22 there's a numerical class designation, dependent upon
23 what's the maximum levels. The class designation
24 defines the **maximm particles** within that class.

1 For every class increase, you're essentially
2 doubling the counts of particles. So, for example, if
3 you have a class 5 fluid, a class 5 fluid versus a
4 class 6 fluid, a class 5 fluid would be twice as clean,
5 if you will, as a class 6. A class 7 would be four
6 times as dirty as a class 5.

7 Every class increase doubles the
8 concentration of particles.

9 MR. SIEGEL: What was the highest
10 classification that was seen on the accident aircraft?

11 THE WITNESS: The highest classification that
12 is designated by NAS 16-38 is class 12. I don't recall
13 the numbers exactly, but in the five to 15 microns
14 range, it's a little over a million particles in the
15 five to 15 micron range.

16 The fluid from the B link cavity from flight
17 427 was a class 12.

18 MR. SIEGEL: What's the purity of Skydrol as
19 sold to our customers?

20 THE WITNESS: The purity of Skydrol or the
21 specification is really defined by Boeing material
22 specification, BMS 3-11. That specification defines
23 the cleanliness levels for new fluid. Their
24 specification is class 7 per NES 16-38. Our production

and quality control on our Skydrol fluid typically
2 delivers class 6 or better.

3 In layman's terms, then we are at a minimum
4 twice as clean as required by the BMS 3-11.

5 MR. SIEGEL: In your examination of the
6 fluids on flight number 427, can you confirm as part of
7 the particle identification process, whether you found
8 any corrosion products, rust, et cetera?

9 THE WITNESS: In the samples we looked at, we
10 saw no evidence for corrosion products. The condition
11 of the fluid would be consistent with that in terms of
12 low acidity and low water contamination.

13 MR. SIEGEL: I have no further questions.

14 CHAIRMAN HALL: Are there any other questions
15 from the parties?

16 (No response.)

17 CHAIRMAN HALL: If not, Mr. Marx?

18 MR. MARX: In your terminology of 100 plus or
19 greater than 100 micron particles, could these be
20 anything say 300, 500 microns in size when you classify
21 those as greater than 100?

22 THE WITNESS: Yes, they could. I think in
23 those cases, the manual particle count would identify
24 those as a fiber. The highyac, since it's a laser

light scattering method, takes the mean diameter of a
2 tumbling particle.

3 So the highyac, if anything, would tend to
4 downsize the particles. But our channels can't
5 distinguish between 100 and 300 microns or whatever.
6 We just classify it as greater than 100 microns.

7 MR. MARX: Well, did you look at any of these
8 particles to see what they were and how big they were
9 in the B link cavity of the accident airplane?

10 THE WITNESS: In the process of identifying
11 the composition of the particles, there were several
12 particles that we focused our infrared beam on. I'm
13 speaking generally now, but I think the larger
14 particles tended to be teflon, teflon flakes, teflon
15 film.

16 MR. MARX: How big were those, do you have
17 any idea?

18 THE WITNESS: The biggest that I recall
19 seeing was in the 150 micron range.

20 MR. MARX: Thank you.

21 CHAIRMAN HALL: Mr. Schleede?

22 MR. SCHLEEDE: No questions.

23 CHAIRMAN HALL: Mr. Laynor?

24 MR. LAYNOR: No questions.

CHAIRMAN HALL: Just one question, I guess,
2 Mr. Jakse. Is there anything that -- this is the first
3 time that you-all have participated in an accident
4 investigation. Is that correct?

5 THE WITNESS: Yes, sir, it is.

6 CHAIRMAN HALL: Have you learned anything in
7 this investigation that would lead to any changes in
8 your-all's procedures or standards?

9 THE WITNESS: No, sir, I believe the NTSB has
10 worked very diligently. In our team, I have been very
11 impressed.

12 CHAIRMAN HALL: Do you have anything else to
13 add that you feel would be pertinent, please feel free
14 to do so?

15 THE WITNESS: Well, I know there's been an
16 issue associated with standards established in terms of
17 in-service limits. Our literature recommends annual
18 sampling or per the airplane manufacturer's
19 recommendations. It's been our experience that, in
20 general, that's an appropriate time frame as far as
21 annual sampling of hydraulic fluid.

22 However, I would caution that there are
23 instances out there where annual sampling may not be
24 appropriate.

CHAIRMAN HALL: Does that mean that you need
2 to do it more frequently?

3 THE WITNESS: Actually, either way. There is
4 some aircraft -- some systems out there that would --
5 as newer aircraft come on board, they are running
6 hotter and putting greater stresses on the hydraulic
7 fluid. The sampling may be warranted in those cases.
8 In other cases, there are situations where the
9 hydraulic fluid operates just fine.

10 So what I am cautioning is the establishment
11 of a standard must take into consideration improved
12 system performance and reliability across the spectrum.

13 CHAIRMAN HALL: Do you-all participate in
14 setting these in-service limits?

15 THE WITNESS: The in-service limits that we
16 quote in our brochure, now, I don't know if we were
17 involved in it. Those were established before I came
18 on board. I don't know.

19 CHAIRMAN HALL: All right. Well, Mr. Jakse,
20 thank you very much for your testimony. You're
21 excused.

22 (Witness excused.)

23 CHAIRMAN HALL: Our next witness is Michael
24 Cohen. He is the senior vice president for Engineering

and Maintenance with USAir, Inc. here in Pittsburgh,
2 Pennsylvania. Mr. Cohen, if you would please come up.

3 (The witness testimony continues on the next
4 page.)

5
6
7
8 MICHAEL COHEN, VICE PRESIDENT, LINE MAINTENANCE,
9 USAIR, INC., PITTSBURGH, PENNSYLVANIA

10
11 Whereupon,

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

16 CHAIRMAN HALL: Welcome, Mr. Cohen. Mr.
17 Schleede will begin the testimony.

18 MR. SCHLEEDE: Mr. Cohen, please give us your
19 full name and business address for the record?

20 THE WITNESS: My name is Michael Cohen. I'm
21 with USAir at Pittsburgh International Airport.

22 MR. SCHLEEDE: And your position?

23 THE WITNESS: My position is vice president
24 of line maintenance.

MR. SCHLEEDE: Give us a brief description of
2 your background and education that qualifies you for
3 this position?

4 THE WITNESS: Certainly. My education is a
5 bachelor of science degree in aeronautical engineering
6 with a major in structural analysis and a minor in
7 aerodynamics and mathematics. I hold a commercial
8 pilot's certificate with an instrument rating. I hold
9 a flight instructor's certificate and an airplane and
10 power plant mechanic's license.

11 MR. SCHLEEDE: How long have you been
12 employed for USAir?

13 THE WITNESS: It would probably be easier for
14 me to explain my background and my employment with
15 USAir. I have over 20 years experience in the
16 aerospace industry. The majority of it being with the
17 airlines and other time with manufacturers. I started
18 out as a stress engineer for North American Aircraft,
19 and continued as a stress engineer for the Northrup
20 Corporation. I joined Pacific Southwest Airlines in
21 1977.

22 At Pacific Southwest Airlines, I held a
23 number of positions there. I started out there as a
24 mechanical engineer for the company, and progressed

through the organization having responsibility at
2 various times for the manager of the engineering
3 organization, the director of engineering and the
4 quality organization.

5 Towards the end of the PSA era, I was the
6 director of maintenance. At which time, I was
7 responsible for all the maintenance that took place on
8 the USAir fleet; the overall maintenance, the line
9 maintenance, the shops, and all the productive
10 personnel that worked the aircraft.

11 In my tenure with PSA, I had responsibility
12 at one time for every department within the maintenance
13 department. In 1988, we merged with USAir and my
14 initial position after the merger was that of regional
15 director of line maintenance.

16 I remained based in San Diego, California,
17 where I had responsibility for six line stations and
18 the San Diego base. At that time, the San Diego base
19 was completing heavy overhaul maintenance work on MD-80
20 and British Aerospace 146 aircraft. We had the shops
21 that were based there, and then the various line
22 operations throughout California.

23 Subsequent to that, I became the vice
24 president of operations for Pacific Southwest Air

Motive, which was a subsidiary of USAir. It was an
2 engine overhaul facility where we did USAir engines and
3 third-party work.

4 After my job there, I continued on to
5 Pittsburgh where I became assistant vice president of
6 engineering and quality. In that job, I had
7 responsibility for the engineering department, the
8 quality control and quality assurance and audit
9 department.

10 Then most recently in June, I became vice
11 president of line maintenance where I have
12 responsibility for 36 line maintenance stations and an
13 excess of 3500 mechanics.

14 We handle all the day-to-day operation of the
15 aircraft that are operational. We take care of the C-
16 check, the B-check, the A-check, the transit check, all
17 of the overnight work load that takes place on the
18 fleets.

19 MR. SCHLEEDE: Thank you very much. Mr.
20 Sasser will continue.

21 MR. SASSER: Good afternoon, Mr. Cohen. Mr.
22 Cohen, can you please describe the process used by
23 USAir to develop and maintain their aircraft
24 maintenance program?

THE WITNESS: Yes, sir. USAir develops their
2 maintenance program through a fairly complex operation.
3 The cornerstone of our maintenance program is the MRB
4 document, which is the maintenance review board
5 document that is established when the aircraft is
6 certified, and the maintenance planning document, which
7 is the recommended items that should be accomplished
8 throughout the maintenance program when the airplane is
9 placed with the operator.

10 The maintenance review board document handles
11 the mandatory items and is established for a new
12 operator of the aircraft. It does not take into
13 consideration the experience that an operator may have
14 in operating that fleet or a similar fleet of aircraft.

15 Once those documents are received in addition
16 to the task cards that come with the document, we
17 establish a task force at our company. That task force
18 is made up of personnel from various departments; the
19 engineering department, the quality department, the
20 planning department, the production department and our
21 program management people.

22 The reason this is so important to us is
23 USAir with the size that it is and the diversity of the
24 fleet and the experience it's had with the various

products, brings to the maintenance program a lot of
2 its experience over the years.

3 So we take the documents, together with this
4 task group, and we evaluate all of the items in the MRB
5 documents and in the maintenance planning document, and
6 we determine whether that item is right for the
7 maintenance that's going to take place at USAir.

8 By doing that, we review it with our
9 technical people and we start to establish a matrix.
10 That matrix is shown to take the MRB item, the
11 maintenance planning item, and the USAir item. This
12 gives us a history of the development of the program so
13 that when we are through and we audit this program, we
14 can insure ourselves through a matrix that we have not
15 missed any items.

16 Now in the case of the 737, which we're
17 speaking of with this hearing, USAir had had experience
18 with the 737 prior to the 300 coming on board the
19 property. We had operated the 737-200 for quite a
20 time, and we were also the kick-off customer for the
21 300 aircraft.

22 So our personnel from our engineering
23 department and production department were involved in
24 the development of the MRB document. As I'm sure

1 **you're aware,** the MRB document is developed through a
2 consortium of FAA personnel, the manufacturing
3 personnel, various airlines that have operated similar
4 products, and everybody gets together to determine what
5 the proper maintenance to be done is and what the
6 frequency of that maintenance should be done at.

7 Again, I want to be sure to stress the fact
8 that when the MRB document comes out, it is developed
9 from the Boeing stand point for the lowest common
10 denominator. When I say that, it refers to a
11 maintenance organization that could be very small,
12 possibly do all of their maintenance through a third-
13 party operation, and not have the sophistication of
14 some of the larger airlines. So we have to take that
15 into consideration in the development of the program.

16 The next item that we do with this task force
17 is after the cards have been written and the matrix has
18 been established, we now validate the work through all
19 the groups independently. Instead of meeting as a task
20 force, we route the program through the various groups
21 so that they can bring all of their personnel together
22 to validate any concerns that they may have and bring
23 back to the panel or just to be insured that everything
24 has been covered.

Then the final step after it has been bought
2 off by all the internal USAir personnel would be to
3 send it to the FAA for their review and approval. This
4 is our local office where it would go to. We send them
5 the entire package; the work cards, the matrix, and
6 obviously the MRB document and all the planning
7 documents.

8 I should also note that the FAA throughout
9 the development of the program, takes part in some of
10 our development. While they don't necessarily
11 designate or dictate what should be done, there's
12 questions that arise and rather than wait till it gets
13 to the end and send it back and forth for revisions, as
14 a question comes up in USAir's mind, we will solicit
15 comments from the FAA to get their thoughts and beliefs
16 on how they would like to see it handled.

17 That's how we establish the program. NOW,
18 the program is a very dynamic program. It's in
19 constant revision. The revisions take place for many
20 reasons. Primarily they take place for two reasons.
21 One is revisions to the MRB document as a new aircraft
22 is developed. It's only the initial starting point
23 when these documents are released. But as various
24 airlines gain experience with the aircraft and its

1 systems and components, we then take that back to the
2 MRB, reconvene this MRB and make revisions to the
3 program.

4 In some cases, they only may be once or
5 twice. In some cases, they may be in excess of ten
6 times. It really depends on the sophistication of the
7 systems and the aircraft.

8 The other method that has the program in
9 constant change is the reliability program that is
10 operated within the airline. Our airline operates a
11 reliability program where we collect data constantly on
12 the tasks that we do, on the component reliability, and
13 on the effects of delays and everything that could
14 possibly affect the airplane.

15 In some cases, we will learn that an item we
16 are doing it too frequently and it does not need to be
17 accomplished that frequently. So we will modify our
18 program to do an extension. In other cases, we will
19 find that the task we're doing or the frequency we are
20 doing it at may be too long term and we will shorten
21 that frequency. But it's all driven by the reliability
22 of the aircraft and how the aircraft performs in our
23 operation.

24 It's very difficult to take the information

1 that the industry has with this aircraft and apply it
2 to a particular airline. Because, as I'm sure you're
3 aware, the environment with which you operate it in,
4 the level of maintenance you do, how often the aircraft
5 visits a maintenance station, all these things have an
6 effect on the maintenance program and we revise it as
7 these things change.

8 I should also add that any revision to the
9 maintenance program, whether it be through the MRB
10 process or through our internal process, is done by a
11 strict set of guidelines, which is referred to as the
12 MS-3 document.

13 This is a maintenance steering group document
14 that was developed years ago and has been revised over
15 the years to bring into account the various maintenance
16 actions, the maintenance processes and all the
17 validation of the work that you do.

18 It's done through a group of decision trees.
19 Where you can take an experienced reliability person
20 and let him work through decision diagrams, getting yes
21 or no answers and making determinations of where that
22 program should be.

23 MR. SASSER: All these changes that you've
24 referred to that come as a course of the program being

dynamic in nature, all of those changes, are they all
2 coordinated with the manufacturer and the local FAA
3 office?

4 THE WITNESS: The majority of the changes are
5 coordinated with the manufacturer. There's a lot of
6 things in the maintenance program that are USAir
7 internal that really do not have a requirement in the
8 maintenance program or the aircraft.

9 It's just things that we have learned by
10 doing our business, things that we prefer to do where
11 we won't get caught with a minor delay by doing a
12 grease shop a little bit earlier or having different
13 limits on various components. But anything that
14 requires an extension of a component that is under the
15 control of the MRB, they are all coordinated through
16 the manufacturer of that component and the OEM of the
17 airplane. In this case, being Boeing.

18 MR. SASSER: And the FAA, in addition to
19 that? The FAA is also in on that?

20 THE WITNESS: The FAA is also brought on
21 board. We advise them of all the items that we are
22 doing. There are certain items that don't require FAA
23 approval. The majority of them, especially when you
24 come to extensions or changes in your processees, they

all require FAA approval and the document is sent to
2 them for their review and approval before we implement.

3 MR. SASSER: This kind of brings us into our
4 next area. Can you tell us how USAir communicates with
5 the various manufacturers and uses them in the
6 resolution of problems that arise during the operation
7 of the fleet?

8 THE WITNESS: Yes. USAir, like most large
9 aircraft or airlines, have many of the manufacturer's
10 representatives on the property. We have a very
11 expensive engineering department that is our direct
12 communication link with our manufacturers and vendors,
13 but we do have reps on the property.

14 As an example with the Boeing Company, we
15 have their reps on our property in the Pittsburgh
16 Airport, in the Charlotte facility and in the Winston
17 facility. These are three of our major bases where we
18 do both overhaul work and line work. The Pittsburgh
19 office gets most of the inquiries because that is where
20 the majority of our engineers are located.

21 We use them as a clearinghouse, if you will,
22 for the information to go to the manufacturer and from
23 the manufacturer. We are in constant contact with
24 these people. They attend most of our daily meetings.

2 We have a daily operational meeting where we
3 go over the operation from the day before and any items
4 that need to have corrective action. They sit in on
5 that meeting. They sit in our reliability meetings.
6 Quite honestly, their offices are located right next to
7 our engineering department. We treat them as they're
8 one of our staff.

9 We very rarely even think of them as Boeing
10 personnel. I can give you a better analogy here. If
11 you were taking your car in to be worked on and you
12 happen to be driving a Ford and you had the Ford rep
13 living in the extra bedroom of your house. That's
14 really what it's like with these representatives.

15 We have representatives from Boeing. We have
16 representatives from CFMI, who is the engine
17 manufacturer and other manufacturers who are not
18 associated with this hearing, such as the Douglas
19 Corporation, the Foker Corporation, and even some of
20 our component people.

21 The reps spend an enormous amount of time on
22 the floor. They solicit comments and questions from
23 our maintenance personnel and our maintenance personnel
24 do the same from them. Also, any of the inquiries that
go into the Boeing Company are returned not only to the

1 rep, but they are returned by an E-mail. We have an E-
2 mail system within USAir throughout our 36 maintenance
3 stations.

4 We have a mailing list on that E-mail where
5 all of the responses and questions come through E-mail.
6 so most of our personnel -- certainly in the management
7 ranks and the foreman ranks -- are aware of the
8 conversations that are going on back and forth.

9 MR. SASSER: In testimony earlier today, a
10 question was raised about the compliance of the Boeing
11 737, known as flight 427, compliance with an FAA AD 94-
12 01-07. I refer you to Exhibit 9-F, page 32 through 46.
13 Can you tell us if the rudder PCU used on USAir flight
14 427 had been tested for proper operation in accordance
15 with this AD?

16 THE WITNESS: Yes, actually, USAir has a
17 little bit of a unique history with this AD, and I
18 would like to take a moment to explain that to you.
19 After the Colorado Springs' accident, there was a lot
20 of speculation as to the cause and determination of
21 that accident, and there was a lot of questions being
22 asked, as you are aware, in regards to the PCU.

23 Prior to that AD coming out, USAir, through
24 its engineering department and in coordination with

Boeing and some of the other operators of the aircraft,
2 developed an engineering order. Where we went out in
3 late '92 and early '93, we completed all the airplanes
4 within a 60 day period. Essentially, we had performed
5 the check that subsequently became the AD.

6 We did not write the AD, but we had knowledge
7 of what was going into the development of that AD. So
8 we had gone out and complied with that on all of our
9 300 fleet. When the AD came out, there were some
10 changes, but it was only for the 200 fleet.

11 After the AD came out, which came out March
12 3, 1994, the functional test that was required to be
13 done initially was complied with on the accident
14 aircraft on 3-21-94. It was done a second time on 6-
15 14-94, and it was done a third time on 8-8-94.

16 NOW, the interval between those times is 750
17 hours. In case you're asking yourself it seems like a
18 short time in between that, we frequently do a lot of
19 our checks early as a result of our scheduling process.
20 With 450 fleets, you can't always put your hands on the
21 airplane that you want. So we take the opportunity
22 when we have that aircraft in maintenance to do the
23 required maintenance that's coming up.

24 Also, earlier in some of the testimony, there

was a question of when that PCU was installed on that
2 aircraft. That PCU was installed on the accident
3 aircraft on January 21, 1993.

4 MR. SASSER: In your testimony, you talk
5 about your engineering department in compliance with
6 the AD and their interface with the manufacturer. Can
7 you describe your engineering organization and how that
8 interfaced between the manufacturers and the FAA work?

9 THE WITNESS: Yes, I can. I have a little
10 bit of a unique advantage coming from a production
11 department. If you hadn't picked up on it, prior to
12 June, I was responsible for the engineering department
13 and the quality department at USAir. We are quite
14 proud of our engineering department.

15 We have a group of over 70 degree engineers
16 that work with us. We have a group of 12 engineers
17 that are DPRs authorized by the FAA. We have them in
18 various disciplines. We have them in the structures
19 group. We have them in the interiors group. We have
20 them in the systems group. We also have engineering
21 personnel in the power plant organization and in the
22 avionics group.

23 We also have within our engineering
24 department a DAS authority. I believe there are only

handful of airlines in the U.S. that have DAS
2 authority. This authority gives us the authorization
3 through the FAA to be able to authorize supplemental
4 type certificate changes on behalf of the FAA. We have
5 a staff of personnel that have been trained and
6 certified to carry on that action.

7 Again, they are our primary communication
8 with our vendors and with our reps. We use them as a
9 clearinghouse, because for any of you that have worked
10 on the floor, the language we use on the floor isn't
11 the same language we use as an engineer, isn't the same
12 language we use as a manufacturer. And we try to get a
13 clear message across by putting in the proper
14 terminology as we transfer the message.

15 MR. SASSER: From your perspective, can you
16 tell us what the relationship between your office and
17 the Flight Standards District Office of the Federal
18 Aviation Administration here that has your certificate
19 for maintenance? What is that relationship like?

20 THE WITNESS: Well, as you might expect with
21 an airline the size of USAir, there is a lot of
22 activity between the local office and USAir. I would
23 simply classify it as a very businesslike, arm's
24 length, very communicative relationship.

Our local FAA spends an enormous amount of
2 time at our facility doing spot checks, doing ram
3 checks. They participate in a lot of our meetings, our
4 reliability meeting that takes place within USAir.
5 Frequently, they are asked to come in and discuss
6 concerns that they might have with our maintenance
7 management staff, so that there's no surprises out
8 there.

9 We try to keep open communication going all
10 the time. We also have a numerous amount of scheduled
11 meetings that take place on a regular basis. For one,
12 we attend a monthly meeting with all of the inspection
13 personnel and management personnel and the maintenance
14 department, along with the various groups within USAir
15 maintenance. We get together monthly and discuss
16 issues from both sides.

17 We typically hear from the inspectors things
18 that they're seeing that certainly are not a dangerous
19 situation, a safety issue or a regulatory situation,
20 but just things that they think we should take another
21 look at and possibly reconsider the way we do business.
22 We are also given the opportunity from the airline side
23 to raise issues that we have regarding the FAA and the
24 dealings that go back and forth.

1 We also have a quarterly meeting that is not
2 just the maintenance area, but it is the maintenance
3 area and the operation's area as well. It's the PTRS
4 system and we have a quarterly meeting to review the
5 trends that are being established.

6 If you're not familiar, the PTRS system is a
7 tracking system that the FAA uses with not only the
8 local personnel, but it's used with all the geographic
9 personnel throughout the USAir system. They analyze
10 that data on a regular basis and develop trends. We
11 meet together with our operation's groups to go over
12 these trends, whether they be negative or positive, to
13 develop corrective action, if needed, or just to bring
14 them to the surface so everybody knows what we're
15 dealing with on a regular basis.

16 There's also a tremendous amount of one on
17 one with the FAA. Frequently, I will probably not go a
18 day without having a phone conversation with somebody
19 in the FAA office, whether it be initiated by me or
20 initiated by the FAA. I see it as a very open
21 relationship and a very businesslike, arm's length
22 relationship.

23 Not to give them a compliment, because I hate
24 to do that, but they have a staff that has a lot of ex-

airline personnel. And you bring into that people who
2 that have had hand-on experience. They can bring a lot
3 to the table for the airline.

4 MR. SASSER: The FAA does inspections on your
5 organization, and I understand that you an internal
6 audit program that you operate at USAir, as well. Can
7 you explain your internal audit system and how that's
8 utilized in the operation of the maintenance program?

9 THE WITNESS: Yes, I can. Again, this is a
10 department that I really look to for guidance
11 internally. They have a tremendous amount of
12 responsibility. They have the responsibility and it's
13 based on the premise that USAir is primarily
14 responsible for continuously monitoring the operation
15 to be safe, to be within the regulatory requirements,
16 and to meet all of the federal air regulations.

17 This organization bypasses all lines of
18 authority at USAir and it reports within the
19 maintenance department directly to our most senior
20 officer, which is the senior vice president of
21 engineering and maintenance operations.

22 This program was initiated in 1989. As
23 you're aware, the advisory circular for internal
24 evaluation programs came out in 1992. USAir

participated in a lot of industry meetings and
2 participated in the development of this advisory
3 circular. We felt so strong about it, we started to
4 develop our program as the development of the advisory
5 circular was going on.

6 So our program really kicked off in 1989.
7 Some of the things that are people to look at, just to
8 give you some examples, they are responsible for the
9 continuing analysis and surveillance program throughout
10 the entire maintenance organization; the line
11 maintenance, the shops, the engineering. They do
12 audits for every one of our facilities and do spot
13 checks on personnel to see how a department is
14 developing and working.

15 They have the responsibility for oversight of
16 the continuous airworthiness maintenance program. As I
17 indicated earlier with the development of the program,
18 a lot of the groups take place in it. They are really
19 the final say before it goes out the door to give us
20 assurance that it's satisfies all the requirements of
21 the regulations.

22 They monitor our required inspection program.
23 They are responsible for the AD compliance program.
24 They are responsible for oversight of the maintenance

training program, the deferred maintenance program.

2 They insure that all the items fall within the
3 requirements that it takes to allow an item to be
4 deferred. They keep oversight of our weight and
5 balance program, our major repair and alteration
6 program, our fueling program.

7 They have a special group that just has
8 oversight of all our fueling vendors. We do all our
9 fueling with third-party vendors, and they have
10 oversight responsibility for all of them. Then they,
11 of course, look over our stores and material control
12 program.

13 In addition to that, we have some internal
14 programs that we have established that we find to be
15 extremely helpful within the USAir facility. One of
16 them is a hot-line program. We determined that it's
17 very difficult to receive input from the mechanics that
18 are working on the line, the people that are out there
19 on the third shift, the people that are really getting
20 the job done.

21 Frequently, if they are approached by
22 management personnel, as you might expect, they might
23 be hesitant in raising an issue. They may not be
24 available when the management personnel are available.

1 It's a very difficult task to get their concerns, their
2 inputs. These are the people that do the work every
3 day. They have tremendous input to the maintenance
4 program and to issues within USAir.

5 So we established a hot line for a couple of
6 reasons. One, so that it could be manned 24 hours a
7 day and receive input 24 hours a day, seven days a
8 week. And also so that if a maintenance personnel had
9 a concern that he thought might jeopardize his standing
10 in the company, he could do it without reporting who he
11 is or where he works, just being able to raise the
12 issue.

13 Every one of these items that comes into the
14 hot line is responded to. I must tell you, there's
15 some great items that come in and there's also some
16 garbage that comes in. But we make it a point to
17 address each and every item. If the people want to
18 have a response back as to our actions or our findings,
19 we will do that. If they do not have a desire to do
20 that, we do have a file on every item that comes in the
21 door.

22 We also have established in coordination with
23 the FAA an MRM program. I'm sure you are all aware of
24 the cockpit resource management program, the CRM

1 program. We are working towards a maintenance resource
2 management program. There has been some assistance
3 from the FAA.

4 We have been one of the subject airlines
5 where personnel that they have had on grants to do some
6 studies for them have participated in meetings within
7 USAir and worked with our personnel trying to determine
8 causes for poor communication, concerns for how we
9 develop work cards. So that there's not anything in
10 there that's going to lead people astray. And working
11 together in a team concept just like the cockpit is
12 working.

13 Now this program is in the development stages
14 right now. The FAA has been a participant in it. We
15 expect it to develop very quickly from this point on,
16 and hope it to be the kick-off program for the airline
17 industries.

18 That really summarizes what takes place in
19 our quality control, our audit program. We have an
20 inspection program, which I can talk to later as we get
21 into some of the other items.

22 MR. SASSER: Can you describe for us the
23 requirements for hydraulic fluid testing utilized at
24 USAir?

THE WITNESS: Yes. First of all, let me say
2 that hydraulic fluid testing, if you will, I would
3 prefer to break it into two categories; one is aircraft
4 and one is ground support equipment, GSE equipment.
5 The reason I do that is obviously the GSE equipment is
6 what we install the hydraulic fluid into the aircraft
7 with.

8 On the aircraft side of it, we follow all the
9 standards that are established through the manufacturer
10 of the aircraft and establish within the maintenance
11 planning and MRB documents.

12 The quality of fluid is primarily audited
13 through the change of filters throughout the system.
14 The 737-300, I believe, has 17 hydraulic filters on the
15 aircraft. We have a regular schedule of filter changes
16 in our maintenance program for all of these filters.

17 Should we find any contamination or particles
18 in the filters or anything that would lead us to
19 believe that there is suspect for the fluid, we would
20 take a sample of that fluid and send it out to our
21 engineering department for evaluation.

22 If we would have a failure in the system, if
23 we would fail a component, primarily if we would a
24 hydraulic pump, an engine driven hydraulic pump, we

will flush that system, change the filters, with the
2 change of the pump, and insure that we have clean fluid
3 going back into the aircraft.

4 The bottom line of our aircraft program is we
5 follow all the prescribed actions required by the
6 manufacturer. From our GSE side, we have a
7 considerable amount of various maintenance programs for
8 that equipment.

9 To give you some examples, our GSE equipment
10 comes in various sizes. One, we refer to as a Bowser,
11 which is a service cart. It's typically a cart that
12 contains anywhere from five to 15 gallons of fluid and
13 it's typically activated with a hand pump used to
14 service the hydraulic system on an aircraft.

15 When we do maintenance on the system and
16 break it and we lose some fluid or if there would be a
17 leak or any reason to service the system, we use these
18 carts to service those systems.

19 Now there's two levels of maintenance with
20 those carts. One is a monthly check where it is looked
21 at to be sure that it is intact and it's not dirty and
22 everything is working and the hose is intact. We also
23 remove the filter screen, evaluate it, and replace it
24 if necessary.

Then on an annual basis, we take those
2 service carts, we flush them out and replenish them
3 with all brand new fluid, replace the filter on there
4 with a brand new one, and, again, validate the hoses
5 and all the components of that system.

6 Our next group of units and they really come
7 in two sizes, but I'll describe them as one. They are
8 an external power cart used to either power an aircraft
9 when it's in the hanger so that we do not need to use
10 the engine driven pumps or the electric pumps on the
11 airplane.

12 It is actually an external hydraulic system
13 that has a reservoir, a pump and valves where
14 maintenance personnel can operate the entire hydraulic
15 system at 3,000 psi as if it was operating on engine
16 pumps or electric pumps.

17 We also have a smaller version of that that
18 we use in our shops, where we do various component work
19 so that we can power those components with 3,000 psi
20 and use them during the test process within the shops.

21 Now those components are both on a similar
22 program. On a monthly basis, they have a visual
23 inspection for general condition and we look at all the
24 hoses and the connections and insure the cleanliness

and insure that everything is intact on that unit.

2 Then on an annual basis, we actually have a
3 work card similar to that with which we work on an
4 aircraft with, that lays out all the required items.
5 Everything from looking at all the valves on the
6 interior to the paint condition, to the valve
7 condition, to the glass condition.

8 We inspect all the controls. We inspect the
9 reservoir for any leaks. We drain and flush the
10 reservoir. We evaluate all the hardware on there.
11 There's a tremendous amount of placards on there that
12 give directions on how to operate the equipment on the
13 safety procedures, on hook-up procedures, and we assure
14 that those are intact and certainly readable.

15 Then we replace all filter elements. Most of
16 these larger units have large filters, small filters,
17 almost as sophisticated as an aircraft. They don't
18 have 17, but most of them have two to five filters
19 installed on them.

20 They have kaystrain filters. They have
21 pressure filters, return filters. All of those are
22 replaced on an annual basis and then the reservoirs are
23 refilled.

24 MR. SASSER: Mr. Cohen, during the course of

the investigation, an issue was raised about the life
2 limit of the aircraft engine from the 737 program and
3 USAir's derating of engines. Can you briefly describe
4 the system used by USAir for this program?

5 THE WITNESS: I'm not sure that I can briefly
6 do it, but I'll try my best. First of all, a lot of
7 things were alluded to in the various articles that
8 came out, which I'm sure you are all aware of. The
9 bottom line of the project is I must tell you is that
10 during the aircraft certification in 1984 when this
11 aircraft was certified and as part of the type data
12 certification of the aircraft, there was a requirement
13 to be able to operate the aircraft with two power level
14 engines.

15 Let me go back and tell you that this
16 aircraft is certified to operate with an engine that we
17 refer to as a B-2 engine, which is certified to operate
18 at 22,100 pounds of thrust. The same aircraft is also
19 certified to operate with B-1 power, which is 20,100
20 pounds of thrust.

21 The obvious reason for the difference in the
22 thrust levels is the mission that the aircraft is going
23 to fly and the payload that you wish to carry with this
24 aircraft. As the aircraft was being certified, there

1 were carriers, such as USAir, that we're going to have
2 a mixed fleet of airplanes.

3 While USAir has a large fleet of 737-300s, we
4 really break it into two fleets. One which we call the
5 long-range aircraft, which we fly missions coast to
6 coast or those which we refer to as our short-haul
7 airplanes, which typically fly a mission of two and
8 half hours or less.

9 The aircraft has the same air frame. The
10 primary difference between the two aircraft is the fact
11 that one operates with B-2 power and one operates with
12 B-1, and the long-range airplanes has an auxiliary fuel
13 tank mounted in the cargo hold to carry the extra fuel
14 to carry the load.

15 During the certification, as I said earlier,
16 it was important that the airlines had an opportunity
17 to operate with an inter-mix of engines. Not unique to
18 the Boeing aircraft, but very consistent with any
19 aircraft that has multiple engine models certified for
20 use.

21 The reason for that is that if you find
22 yourself one day where you only have a spare engine
23 available that is not of the higher thrust level, you
24 can install the engine with the lower thrust level and

then also derate the other engine so that they are both
2 operating at the same power level. But it gives you an
3 opportunity to use the aircraft instead of have it
4 sitting on the ground for lack of spares.

5 This enables us -- we certainly can't fly the
6 mission that we would if we had the two higher rated
7 engines, but we can use the aircraft in other
8 circumstances. So during the certification, Boeing
9 certified the aircraft to operate with either two B-2
10 engines, two B-1 engines or an inter-mix of both.

11 Now, what USAir has determined to do because
12 we have a limited number of long-range airplanes, we
13 are taking the majority of our airplanes were
14 delivered with B-2 power. So we really have an excess
15 of B-2 engines, if you will.

16 We use those B-2 engines on short-haul
17 airplanes. If we were to operate those engines
18 consistently at B-2 power at the 22,000 pound thrust
19 level, obviously the wear and tear on the engine would
20 take place in a faster manner than it would if you
21 operated at a lesser level.

22 Two great analogies for that is -- one, is a
23 box fan. You've got a box fan that has a motor on it.
24 That motor is capable of running that fan at a low

speed, a medium speed or a high speed. If I operated
2 all the time at a low speed, it doesn't take a rocket
3 scientist to figure out it's going to last us a longer
4 period of time.

5 So we elect to use those B-2 engines in a
6 derated form on the B-1 aircraft, and, thus, we extend
7 our maintenance requirements for a longer period of
8 time because we operate them at a lower power setting.
9 But the issue of time limits on the engine, I must tell
10 you we're talking about maintenance requirements now
11 and not time limits.

12 When that engine is certified, there are time
13 limits established for various components of that
14 engine. Most of them are rotating parts. Regardless
15 of whether that engine is operated in B-2 power,
16 whether it's operated at B-1 power, or, in fact, if you
17 operated it on a smaller aircraft, the 500 at 18,000,
18 when it receives those time limits and those are in
19 cycles -- a cycle being a take off and a landing --
20 those engines need to come off regardless of what stage
21 they are in the maintenance program.

22 The time limit is a drop dead time when the
23 engine must be removed. There are various components
24 to drive it. As soon as one component reaches that

time limit, the engine must be removed from service.

2 So the bottom line of our program at USAir was we
3 extended the life on the wing, but we did not extend
4 the life of the engine.

5 The airline nor our local FAA, not even
6 Boeing, has the authority to extend that life. That
7 life has to come through very expensive testing and
8 analysis through the engine certification branch of the
9 FAA and the manufacturer of the engine.

10 MR. SASSER: Mr. Cohen, that's all the
11 questions I have. Do you have anything to add that we
12 failed to talk about here this evening?

13 THE WITNESS: No, sir.

14 MR. SASSER: Mr. Chairman.

15 CHAIRMAN HALL: Thank you, Mr. Sasser. Do
16 the parties have questions for this witness?

17 (No response.)

18 CHAIRMAN HALL: I see no hands. Mr. Marx?

19 MR. MARX: No questions.

20 CHAIRMAN HALL: Mr. Clark?

21 MR. CLARK: No questions.

22 CHAIRMAN HALL: Mr. Schleede?

23 MR. SCHLEEDE: Just a couple areas.

24 Mr. Cohen, when you were describing the

1 hydraulic fluid testing program, I want to make sure it
2 was clear that that program you described was that in
3 effect at the time in September of 1994? You were
4 describing your sampling program and your fluid testing
5 program?

6 THE WITNESS: Yes, it was. To give you a
7 little bit more on it, since the accident aircraft, we
8 have taken a sample of our fleet just to go through the
9 fleet on an ad hoc basis to see the condition of the
10 fleet. But the requirement of the program is, in fact,
11 the same as it was from the day we start operating the
12 aircraft, which is totally in compliance with the
13 Boeing program.

14 MR. SCHLEEDE: I was going to ask you, other
15 than the sampling, are there any other changes in your
16 hydraulic fluid programs since the accident?

17 THE WITNESS: No, sir.

18 MR. SCHLEEDE: I wanted to ask you just
19 briefly about service difficulty reporting or defect
20 reporting. What type of items are normally required to
21 be reported to the FAA by an airline maintenance type
22 items, just general?

23 THE WITNESS: The typical items that get
24 reported are major structural defects found during an

1 inspection program or in service. Failures or service
2 difficulties with major components of the aircraft in
3 appliances, engines, avionics. Things that would cause
4 an interruption in the operation of the aircraft during
5 its intended flight, whether it would be a return to
6 field for a failure of an item or things like this.

7 MR. SCHLEEDE: So any item that causes an
8 interruption of the flight would have to be reported to
9 the FAA?

10 THE WITNESS: That's correct.

11 MR. SCHLEEDE: How about during scheduled
12 maintenance? You mentioned these major components. Is
13 there a clear definition of major components
14 malfunctions that would be reported?

15 THE WITNESS: Well, if you look at the FARs,
16 it's a laundry list that you can wear down both
17 sleeves. It goes on and on and on. Typically, it
18 handles all the components that could affect the safety
19 of flight or any structure that could affect the safety
20 of flight.

21 MR. SCHLEEDE: Do you as an airline make
22 reports directly to the Boeing Company or let's say the
23 manufacturer of the air frame?

24 THE WITNESS: We, as an airline, make reports

1 directly to the manufacturer through the reps at our
2 facility. As I explained earlier, the reps sit in on
3 our daily meetings, our operational meetings. In some
4 cases, I hate to admit it, but they're aware of the
5 problem before I am. But all the difficulties that we
6 have are reported through the manufacturers.

7 Actually, also USAir being the kick off
8 customer with the 737-300, a lot of development work
9 for the maintenance program, for improvements in the
10 aircraft and the engine really were done in
11 coordination with USAir. There was a lot of close work
12 done with the two groups.

13 I would also like to comment on the service
14 difficulty reports. USAir when I responsible for
15 quality, I would be less than honest if I didn't tell
16 you one of my concerns was the amount of items that we
17 did report. While there are a set of regulations out
18 there that say, you as an airline report this, this and
19 this, there's a whole matrix of what goes on in the
20 industry, and I'm sure you are aware of that.

21 When we took a sample of the industry, and we
22 have not changed our procedures since that time, but we
23 have taken a survey of the industry, USAir does more
24 reporting than any other airline out there. I believe

1 it's USAir and Northwest that are the two highest in
2 reporting items. That raises a difficult balance,
3 because we report a lot of things that are not
4 necessarily required, but we feel that the industry
5 should be aware of it.

6 We, as an airline, review the responses from
7 service difficulty reports just so we know what's going
8 out on the industry. We don't want to have our head
9 buried in the sand and say USAir is the only carrier
10 out there. So because we're interested in what's going
11 on out there, we feel that other people are interested
12 with what goes on with our fleet, because we have a
13 large fleet. So we do an extensive amount of
14 reporting.

15 MR. SCHLEEDE: Do you have on-line capability
16 to the FAA's SDR system, computer on-line?

17 THE WITNESS: No, we send it over to the
18 local office. Actually, I'm going to tell you I'm not
19 100 percent sure on that. I know it was in a
20 changeover. We have a form that we fill out through
21 our maintenance control and tech center. When I was
22 responsible for it, they were being hand carried over
23 and sent through the mail.

24 I can't tell you for sure honestly if we have

transformed into the electronic.

2 MR. SCHLEEDE: Well, I was actually referring
3 to searching this database itself?

4 THE WITNESS: No, we will go on over to the
5 FAA if we have an inquiry and go through them to get
6 the response.

7 MR. SCHLEEDE: I think you characterized it,
8 but could I ask you could you characterize the
9 usefulness of the SDR program?

10 THE WITNESS: We find them very useful. We
11 throw out a lot of data because if we find a carrier
12 that's operating in a very different environment or
13 operating the airline on different flight segments, we
14 will tend to toss that information out. We will look
15 for similar airlines with similar equipment and then
16 make a determination from that.

17 Yes, we find it valuable. A lot of times we
18 have to take the description that's given and we will
19 make a follow on phone call to the carrier, because we
20 know who it is, and get further data on it to see if
21 it's something that would impact us.

22 MR. SCHLEEDE: One last item, sir, and to the
23 left of that pile they gave you Exhibit 11-A-1. I know
24 this wasn't listed as one of your exhibits. It's A-1.

I think it's the one page one. It's the other one.
2 Look in the upper right-hand corner. It's addendum 1,
3 I guess.

4 THE WITNESS: Yes.

5 MR. SCHLEEDE: Have you seen this before?
6 It's an addendum to the Maintenance Records Group
7 Chairman's report for this particular accident. It's
8 an expansion of some history on the main rudder PCU
9 that was removed and replaced in January of '93 on the
10 accident airplane. Are you familiar with that?

11 THE WITNESS: No, I am not.

12 MR. SCHLEEDE: Well, the one thing I was
13 interested in is in the third paragraph along the lines
14 of our -- just to help me understand service reporting.
15 The third paragraph talks about the bolt that attaches
16 the PCU main rod to the rudder was worn and replaced
17 and shipped back. Is that something that you would
18 expect some type of a report to either Boeing or to the
19 FAA or even to your own -- into some kind of a database
20 or an SDR?

21 THE WITNESS: Well, when we do the change on
22 the component, as you're aware in the Boeing
23 maintenance manual, there are limits that the bolt can
24 be worn to. The requirements of our paperwork require

the inspector to go in and take the proper dimensions
2 and record it.

3 If the bolt is worn beyond limits, typically
4 unless it was almost to a catastrophic point, if it was
5 just at the limits or beyond the limits, we would not
6 report it. If it was really an extreme case where the
7 bolt was worn significantly through, we would certainly
8 report that. But on a normal day-to-day basis if we
9 exceeded it by a couple of thousandths, no, we would
10 not report that.

11 MR. SCHLEEDE: The third paragraph on the
12 bottom, our investigators looked at your reliability
13 department's computer printout for the work card, the
14 job cards specified here and determined if they were
15 reoccurring defects. We note here that PCU leaks were
16 found to be common, which we've already had other
17 testimony on. That's understandable.

18 It said no other case of bolt deformation or
19 damage was found. This would be in your system. Would
20 this other particular finding up here in paragraph 3,
21 would that have been put into your computer? Is that
22 something that would be put in so that if we wanted to
23 find it later, we could retrieve it?

24 THE WITNESS: I guess I'm not sure. Can you

restate your question again?

2 MR. SCHLEEDE: Well, I guess, in the third
3 from the bottom paragraph, we say we found no cases of
4 bolt deformation in your system, in your computer
5 printout. But would we find it? Would the one that's
6 cited up there in paragraph 3 be entered in there? If
7 we didn't find anything, they're not entered. I'd
8 understand why we didn't find them.

9 THE WITNESS: Yes, it would. In our
10 inspection program, every time an inspection finding or
11 discrepancy is found during the evaluation of the
12 aircraft, an OM-26 which is an internal form -- it's a
13 non-routine discrepancy form -- is filled out by the
14 inspection personnel.

15 Then the corrective action is added to that
16 card and it goes into our permanent records.
17 Typically, these are found during our Q-check which is
18 our overhaul maintenance. Those packages stay intact
19 and could be found in that system.

20 MR. SCHLEEDE: Thank you very much.

21 CHAIRMAN HALL: Mr. Laynor?

22 MR. LAYNOR: No questions.

23 CHAIRMAN HALL: Mr. Cohen, this particular
24 aircraft, when was it delivered and was it USAir at the

time that accepted this particular aircraft, the
2 accident aircraft?

3 THE WITNESS: To be perfectly honest with
4 you, I don't have the exact date. I believe it's part
5 of the record. I believe the airplane was delivered in
6 1988, if I'm not mistaken.

7 CHAIRMAN HALL: Was it delivered to USAir or
8 to who?

9 THE WITNESS: I can't tell you that for sure,
10 but I can tell you it was either delivered to USAir or
11 to Piedmont. Piedmont became another airline that
12 merged into the USAir system and we combined the
13 fleets.

14 CHAIRMAN HALL: The PCU was installed on the
15 accident aircraft you say January 21, 1993? That's
16 what you mentioned.

17 THE WITNESS: Yes, just let me find it. Yes,
18 it was installed January 21, 1993.

19 CHAIRMAN HALL: And was that a new PCU?

20 THE WITNESS: No, it was a PCU that had just
21 come back from Parker, who does our repair work. It
22 was removed from another aircraft in our fleet on
23 September 9, 1992 for an external leak.

24 CHAIRMAN HALL: The flight records on that

aircraft that were initiated, I guess, is there a
2 planning document for that aircraft, specific aircraft?

3 THE WITNESS: Do you mean for the maintenance
4 program?

5 CHAIRMAN HALL: Yes.

6 THE WITNESS: The planning document is for
7 the series of airplanes. They don't issue a planning
8 document for a particular tail number aircraft.

9 CHAIRMAN HALL: So you have the planning
10 document for all your 737-300s?

11 THE WITNESS: Absolutely.

12 CHAIRMAN HALL: This aircraft was covered
13 under that document, but we're not sure whether it was
14 a Piedmont or USAir. I'm just trying to wonder how
15 that was merged into the system when all these airlines
16 came together?

17 THE WITNESS: The fleets as far as the
18 maintenance program are identical. There is no
19 difference in the maintenance requirements for either
20 aircraft. When the merger took place, the Piedmont
21 aircraft were merged into the USAir maintenance
22 program. The USAir maintenance program was a more
23 intensive maintenance program, and we elected to
24 transition these aircraft in.

There was a transition check that was
2 developed and approved by our local FAA to transition
3 the aircraft that were presently on the Piedmont
4 program into the USAir program. So the bottom line of
5 that was there was certainly no maintenance missed. We
6 probably did more maintenance than we ever needed to do
7 to transition it in.

8 CHAIRMAN HALL: Now when do you-all decide to
9 repair a PCU yourselves and when do you decide to send
10 it back to Parker-Hannifin to repair?

11 THE WITNESS: We do not repair any PCUs in
12 house. That's one component that goes out all of the
13 time.

14 CHAIRMAN HALL: Routinely, how long do you-
15 all keep one in service or do you have any service
16 interval for them or it's just when they need to be
17 serviced?

18 THE WITNESS: There is no service interval
19 for the PCU. It's on condition. That's the
20 maintenance process for it, which would tell you that
21 it would only come off when there's a reason for it to
22 come off.

23 CHAIRMAN HALL: You said an engine had a life
24 to it, that you then stopped using that engine. Does

the PCU have a life to it?

2 THE WITNESS: No, it does not. Let me
3 explain that if you don't mind. A component that is on
4 condition goes for a period of time. As it
5 deteriorates over a time scale, it starts to develop a
6 discrepancy, whether that discrepancy be an external
7 leak, which the majority of them are, or some sort of a
8 mechanical item. As soon as it is squawked or found to
9 be leaking by our maintenance personnel, we take an
10 action.

11 We send it back to Parker to be reworked and,
12 in fact, what happens is it is restored and recertified
13 back to its original condition. So if I were to draw a
14 scale of it for you, you could take the reliability of
15 it or the deterioration of it and draw a straight line
16 down. I'm sorry, not a straight line down. A diagonal
17 line down and then it goes in for restoration.

18 You take it up to its original level of
19 reliability and operation. Then it deteriorates again
20 and it's like a saw tooth chart. It's constantly
21 restored as the requirement it. But there is no
22 requirement for a life limit on it.

23 CHAIRMAN HALL: What has been your experience
24 with this PCU? Do you keep a computer printout? Has

1 it been a dependable unit? Is it something that you
2 have more problems with than you would have with maybe
3 another hydraulic operation in the plane or what's your
4 experience with these PCUs? How many 737s do you-all
5 operate, by the way?

6 THE WITNESS: We have 235.

7 CHAIRMAN HALL: So you-all are pretty big in
8 that. So, okay, what is your experience then? I
9 guess, you would have a pretty good idea of what
10 experience you had with that PCU?

11 THE WITNESS: I would not classify it any
12 worse than any other hydraulic actuator on the
13 aircraft. It's very similar. The major reason that we
14 take the actuator off the aircraft is for external
15 leaks. It's a sensitive unit up there and it does have
16 a tendency to develop some leaks, but from a mechanical
17 standpoint, I wouldn't consider it any different than
18 any other actuator on the aircraft.

19 CHAIRMAN HALL: I assume, sir, that you are
20 aware of the accident involving that we've referred to
21 numerous times in Colorado Springs?

22 THE WITNESS: correct.

23 CHAIRMAN HALL: Have you read the accident
24 report the NTSB issued on that?

THE WITNESS: No, I have not.

2 CHAIRMAN HALL: Do you know what actions
3 USAir might have taken in regards to their 737 fleet or
4 was there any concerns that came out to you from either
5 the FAA or your Boeing person that stays there with
6 you-all in regard to anything you should be doing in
7 regard to that rudder?

8 THE WITNESS: Well, we are taking those
9 actions. The concerns that were raised at USAir and
10 they were raised internally through our engineering
11 department, the concerns were from the issues that came
12 out of the Colorado Springs accident. I'm telling you
13 I did not personally read the report, but it was gone
14 over in detail with our engineering folks.

15 The engineering folks, in coordination with
16 our flight department, issued what turned out to be the
17 AD prior to the AD ever coming out. It was complied
18 with on the USAir fleet.

19 In addition, USAir has accelerated the
20 replacement program and we anticipate having 235
21 aircraft retrofitted with the reworked PCUs by the end
22 of 1995. The restricting factor right now is how fast
23 we can turn them at the vendor. But we are constantly
24 -- we not waiting for a leak or any other discrepancy

to take place. When we get a PCU in our hands, we
2 replace it on an aircraft.

3 CHAIRMAN HALL: Let me, sir, applaud that
4 aggressive action. Are you aware that the National
5 Transportation Safety Board was unable to find a
6 probable cause in the Colorado Springs' accident?

7 THE WITNESS: Yes, sir, I am.

8 CHAIRMAN HALL: Are you aware of the items, I
9 guess, you have on your planes, called flight data
10 recorders?

11 THE WITNESS: Yes.

12 CHAIRMAN HALL: Do you-all have any plans as
13 a result of these two accidents to upgrade your flight
14 data recorders on your 737 fleet to provide the
15 National Transportation Safety Board, if regrettably if
16 we ever had another accident, there would be some
17 information on rudder movement and other flight control
18 information that might be beneficial to determining the
19 cause of an accident and preventing future accidents?

20 THE WITNESS: Well, let me answer that in a
21 couple of ways if I can. First of all, we are still
22 taking delivery of new aircraft. And those new
23 aircraft are coming with upgraded flight recorders.

24 CHAIRMAN HALL: How many parameters do they

have, do you know, sir?

2 THE WITNESS: If I'm not mistaken, there are
3 18. I would have to get you that answer to be
4 absolutely sure. That's not a positive. That's my
5 guess. But USAir is presently in a program of getting
6 the 11 parameter flight recorders on, which is the
7 present requirement. Do we have plans to retrofit
8 those up to the higher ones? Nothing has been
9 determined yet that we are for sure going there.

10 It is under consideration by the management
11 of USAir and the engineering department. We are still
12 in the development process. Obviously with every
13 project you do, there are things that you have to look
14 at. And that is, whose recorder are you going to use,
15 what modifications need to be done to get there, and
16 what's the reasonable time frame.

17 All that is under consideration right now,
18 but no decision has been made.

19 CHAIRMAN HALL: What type of recommendation
20 would you make to your company in that regard?

21 THE WITNESS: I'm not sure that's a fair
22 question.

23 (General laughter.)

24 CHAIRMAN HALL: Well, I believe, I have been

impressed with how fast you have risen in the business
2 and your presentation. Since you're the senior vice
3 president for engineering and maintenance, if I were
4 the president of USAir, I would pay attention to what
5 you recommended to me.

6 THE WITNESS: I will pass that message on.

7 (General laughter.)

8 CHAIRMAN HALL: Well, let me say without
9 putting you further on the spot, that I hope that you
10 will at least recommend to your chairman that they give
11 serious consideration to looking at upgrading the
12 flight data recorders on the existing 737 fleet that is
13 operating throughout this country in a very fine
14 fashion.

15 THE WITNESS: It is being considered at a
16 very high level. Not to make just of it, but obviously
17 USAir is very concerned with this accident, not only
18 the Colorado Springs' accident. A lot of things could
19 be resolved by knowing what caused this and if that's
20 what would help us get there, we're certainly going to
21 be part of that.

22 So it is getting a high level consideration.

23 CHAIRMAN HALL: The accident aircraft, could
24 you tell me and just walk me quickly through in your

position what you did to look at the maintenance
2 history and follow that aircraft through all its checks
3 and everything and trying to -- I assume you-all
4 independently have tried to determine yourselves what
5 happened. Right?

6 THE WITNESS: correct. We have engineering
7 personnel on all the teams that are involved in the
8 maintenance and technical side of it. We have dumped
9 the records. We have been trying to go out and make
10 sure that even the AD test is the right thing to do.
11 We have an entire engineering staff going over this
12 program daily.

13 We are just as concerned as anybody out there
14 to a resolution, so that we can get on with our life
15 and take the corrective action, if there's any needed,
16 and certainly put this one to sleep.

17 CHAIRMAN HALL: Well, I know that your
18 company has received a lot of publicity as regard of
19 this. Anything that you want to say or walk me through
20 in terms of what you-all have done to put on the
21 record, I would be glad to do so, because I think that
22 you know this board is very interested.

23 A lot of people are interested in the things
24 that you-all have done. I know that we're going to

1 hear later from your -- I believe we've got the
2 director of training from USAir. We've got your new
3 vice president for corporate safety and regulatory
4 compliance we're going to also hear from.

5 But since we have the senior vice president
6 for engineering and maintenance, anything that you want
7 to put on the record or if the record may already been
8 adequately documented in terms of your investigation, I
9 would offer you this opportunity to do so.

10 THE WITNESS: Well, first of all, let me
11 correct the record in case there's a confusion. I am
12 not the senior vice president of engineering and
13 maintenance. I am the vice president of line
14 maintenance. I report to the senior vice president of
15 engineering and maintenance.

16 However, if you would like to recommend to my
17 chairman my promotion, I would be more than gracious.

18 (General laughter.)

19 THE WITNESS: To be quite honest with you, to
20 add any additional --

21 CHAIRMAN HALL: Well, I apologize. That was
22 an error in our --

23 THE WITNESS: Oh, I enjoyed it.

24 CHAIRMAN HALL: I can understand why.

THE WITNESS: I don't have any additional
2 comments or requests. Quite honestly, we're on a
3 meeting on a weekly basis with the investigation, and
4 we get everything we need to say in on those meetings.
5 I would only like to compliment the board on their
6 activity on this. I know that they share the same
7 frustrations that we do in coming up with a resolve and
8 hope that we get there soon.

9 CHAIRMAN HALL: Well, that is why the
10 Chairman's frustrations go at least to being sure that
11 we upgrade flight data recorders. That's a decision
12 obviously of this full board -- of the full board of
13 the National Transportation and Safety Board, but it is
14 certainly something we're looking at. I'm pleased to
15 hear that you're looking at it.

16 Hopefully, that will get the same type of
17 aggressive action that you mentioned in the other
18 category.

19 Does anyone else have any other questions for
20 this witness?

21 (No response.)

22 CHAIRMAN HALL: Parties?

23 (No response.)

24 CHAIRMAN HALL: Sir, we appreciate very much

your presence and your testimony. You are excused.

2 THE WITNESS: Thank you.

3 CHAIRMAN HALL: The next witness of Mr. David
4 Cann or Conn. Is it Cann?

5 THE WITNESS: Cann.

6 CHAIRMAN HALL: Thank you, David. David,
7 please listen to what title I give you. If I'm not
8 correct, let me know, so I won't repeat it two or three
9 times. The principal maintenance inspector for USAir,
10 for the Federal Aviation Administration here in
11 Pittsburgh.

12 (The witness testimony continues on the next
13 page.)

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DAVID CANN, PRINCIPAL MAINTENANCE INSPECTOR, USAIR,
FEDERAL AVIATION ADMINISTRATION, PITTSBURGH,
PENNSYLVANIA

Whereupon,

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

MR. SCHLEEDE: Mr. Cam, give us your full
name and business address for the record?

THE WITNESS: David Cann, FAA Flight
Standard's District Office 19, One Thorn Run Center,
1187 Thorn Run Extension, Coraopolis, Pennsylvania.

MR. SCHLEEDE: What is your position with the
2 FAA?

3 THE WITNESS: Currently, I am the principal
4 maintenance inspector assigned to USAir.

5 MR. SCHLEEDE: Could you give us a brief
6 description of your education and background that
7 brings you to that position?

8 THE WITNESS: I started out as an aircraft
9 mechanic in the Air Force on transport category
10 aircraft. After that, I subsequently went to work for
11 an airline as a mechanic in flight engineer. Following
12 that, I worked for a 135 mechanic on leer jets and
13 Mitsubishi MU-2 aircraft. Following that, I became a
14 civilian employee of the Department of Defense as a
15 flight engineer on transport category aircraft.

16 In 1986, I came on with the FAA. The first
17 position with the FAA was that of a geographic
18 inspector responsible for 121 air carrier aircraft and
19 operators over a geographic area, including Pittsburgh,
20 Erie, Elmora, Ithica, Syracuse, Buffalo, Rochester and
21 Toronto.

22 I then assumed a position of assistant
23 principal maintenance inspector, USAir. Later I became
24 a partial program manager or fleet manager with

responsibility for the Boeing 767 aircraft and the BA-
2 146 aircraft. Then in February of 1990, I became the
3 principal maintenance inspector of USAir.

4 MR. SCHLEEDE: Thank you. What FAA rating
5 certificates do you hold?

6 THE WITNESS: I currently hold a mechanic
7 certificate with air frame and haul plant ratings, and
8 a flight engineer certificate with turbo propeller
9 rating.

10 MR. SCHLEEDE: Thank you. Mr. Sasser.

11 MR. SASSER: Good evening, Mr. Cann. Mr.
12 Cann, could you explain to us your role or rather the
13 role of the FAA in the development of USAir's
14 maintenance program and its continuing operation as
15 well?

16 THE WITNESS: As previous testimony stated,
17 when a new aircraft originally comes into a fleet of a
18 particular operator, with that, you have the
19 maintenance review board or the MRB document. That
20 document specifies the minimum requirements for a
21 maintenance program for a scheduled or routine
22 maintenance.

23 Additionally, the maintenance planning
24 document or MPD which is produced by the manufacturer

is also utilized. Specifically to the 737-300 Boeing
2 task cards are also associated which correspond to that
3 maintenance planning document.

4 Along with that, you have the maintenance
5 manuals that come with the appropriate aircraft. All
6 of these things are reviewed by the operator. After
7 review, the operator develops their own maintenance
8 program. It's obvious that there is more to it than
9 the MPD or MRB specifies, because there's non-routine
10 maintenance to be considered.

11 So each operator is somewhat different,
12 because of the operating environment, maybe the
13 configuration of the aircraft, modification status to
14 the aircraft, et cetera. All those things have to be
15 considered in the development of the maintenance
16 program, which is the responsibility of the operator at
17 that point.

18 MR. SASSER: You operate here in Pittsburgh.
19 And the terminology for your organization here that
20 handles USAir's maintenance is the certificate
21 management unit or CMU. Can you explain to us, give us
22 some explanation of the organizational structure of the
23 maintenance part of the CMU, please?

24 THE WITNESS: I'm the supervisor of the

maintenance portion of the certificate management unit.

2 I currently have ten inspectors. One being my
3 assistant or the assistant principal maintenance
4 inspector. I'll explain what acronyms we use. One is
5 a PPM or a partial program manager, which is common to
6 a fleet manager and an assistant partial program
7 manager.

8 I have a partial program manager and an
9 assistant partial program manager assigned to the DC-9
10 MD-80 fleet. I have a partial program manager and
11 assistant partial program manager assigned to the
12 Boeing 737-200 fleet.

13 I have a partial program manager and
14 assistant partial program manager assigned to the
15 Boeing 737-300/400 combined fleet. I have a partial
16 program manager and assistant partial program manager
17 assigned to the Boeing 757 and Boeing 767 fleet.

18 A partial program manager assigned to the
19 Fokker F-100 fleet. And a partial program manager
20 assigned to the Fokker F-28 and the Boeing 727 aircraft
21 fleet.

22 MR. SASSER: In the course of your operation,
23 you are required to do certain surveillance operations
24 on the air carrier. In planning the activity of the

people in the CMU and your personnel, can you explain
2 to us how you go about setting up a work plan for these
3 people for the type of inspections and number of
4 inspections that they'll accomplish during the year?

5 THE WITNESS: What we have to consider first
6 is what we call environmental or environment for USAir.
7 That consists of what work USAir currently does. What
8 kind of heavy checks. Those being D-checks or USAir
9 refers to them as Q. C-checks, B-checks, A-checks,
10 transit checks, et cetera, which are all different
11 intervals.

12 What kind of shop work they do, what kind of
13 overhaul, be it seats, components, engines, et cetera.
14 We also look at addition to components, facilities,
15 line stations, heavy maintenance, hangers, et cetera.
16 After considering all of these environmental
17 characteristics, we plug that into the database.

18 We also look at any trends that we've seen
19 over the previous year. We look at any emphasis areas
20 which could be new FAA policy, newly implemented
21 regulations. Deicing would be a perfect example. With
22 that, we focus our attention or our staffing in those
23 areas.

24 Additionally, we have the routine

surveillance that doesn't fit any of the categories
2 above. We work on this program. We put it into the
3 database, and then it's assigned to the office. This
4 program also encompasses those -- what we refer to as
5 R-items or required items which are put out nationally
6 at the direction of Washington and our region in New
7 York.

8 Those are items that they track specifically.
9 Those are duly noted on our work program. The work
10 programs are then sorted and selected and given to the
11 respective partial program manager or assistant partial
12 program manager by fleet.

13 MR. SASSER: Are these programs
14 accomplishable and have they been accomplished in the
15 last couple of years? In other words, are a large
16 percentage of the program being accomplished that were
17 planned for that year?

18 THE WITNESS: Our goal is always 100 percent
19 accomplishment. Sometimes we're at 98 percent, 99
20 percent, 97 percent. But we will always strive for 100
21 percent.

22 MR. SASSER: When we talk about surveillance,
23 what are we talking about? When we say you're going to
24 do a surveillance operation on an air carrier or an

operator, what does that mean?

2 THE WITNESS: Surveillance is made up of a
3 lot of different inspections. We have one type of
4 inspection called a ramp inspection. That's an
5 inspection of an aircraft that we refer to as being in-
6 service, an aircraft that's on the gate. Perhaps just
7 came in with passengers and is waiting to board to go
8 out.

9 In that situation, we would go to that
10 aircraft and using what we call a job aid or a
11 checklist, accomplish that inspection to denote or
12 detect any mechanical irregularities. If any are
13 found, we communicate it to the flight crew or to the
14 management personnel or a mechanic.

15 We also do in route inspections, which are
16 flight inspections to observe the operation of the
17 aircraft systems for system irregularities during
18 flight.

19 Another particular inspection is what we call
20 a spot inspection. That's a real hands-on inspection.
21 That's an inspection where a mechanic is doing a job
22 and we'll really go up to the mechanic to watch and
23 observe he or she doing a job. Make sure that they
24 have the knowledge. They have the required

publications, work task card or work instructions to
2 properly accomplish a task, and actually watch them,
3 observe them do it.

4 Other inspections are structural inspections.
5 The aging aircraft is a big consideration. We do a lot
6 of hands on there in that we observe the inspection,
7 the NDT inspections associated with aging aircraft.

8 Airworthiness directive compliance. AD
9 compliances is another very important work task. We
10 have obviously reliability evaluations. We have
11 records reviews, et cetera.

12 MR. SASSER: Could you give us some estimate
13 of how many of these surveillance inspections were
14 accomplished during the fiscal year in 1994?

15 THE WITNESS: I don't have the data for
16 fiscal year '94. I can tell you calendar year '94.

17 MR. SASSER: Calendar year '94.

18 THE WITNESS: The total, I believe,
19 inspections on USAir exceeded 3600. That's FAA wide.
20 Of that number, our office or my staff accomplished
21 approximately 41 percent or slightly under 41 percent
22 of those total inspections.

23 MR. SASSER: In accomplishing these
24 inspections, the reports are filled out and data is

collected and then you said was put into the system.

2 Can you tell us what's done with that data once it's
3 collected?

4 THE WITNESS: Upon completion of the
5 inspection, the inspector will return to the office and
6 enter into the computer or have entered into the
7 computer system what's called PTRS, a program tracking
8 and reporting system. It's the FAA database for data
9 collection of inspections.

10 We enter comments. We enter a description of
11 the inspection and number of aircraft location,
12 pertinent statistics like that, and any comments
13 associated with a comment code. Be it informational, a
14 potential problem or unacceptable. That data is then
15 input. We download this data weekly.

16 One reason we look weekly is for any
17 significant trends that need a quicker reaction than
18 any long-term trend. We also download this data
19 monthly and do a snapshot trend of this data.

20 Then quarterly, additionally we download all
21 the data. We do a trend analysis of that data. We
22 have a meeting with USAir, and share that data with
23 them for their corrective actions. I'll tell you that
24 this analysis is done by either me personally or by my

assistants.

2 MR. SASSER: Do you know of any surveillance
3 operations that are performed by other parties other
4 than your CMU or geographic units around the country
5 outside of your organization and any other surveillance
6 operation?

7 THE WITNESS: Outside of our office, there's
8 a program called the National Aviation Safety
9 Inspection Program or NASIP program within the FAA.
10 This program is generally made up of inspectors from
11 outside of the certificate holding region, which in
12 this case is the Eastern Region. A team will be
13 generated in the airworthiness and in the operations
14 area.

15 They will come in for a period of time to do
16 an inspection and sort of give a different set of eyes,
17 so to speak, to the inspection of the assigned
18 operator. In this case, USAir got a NASIP -- received
19 a NASIP inspection in 1993, I believe it was.

20 In addition to the NASIP program, the
21 Department of Defense has a responsibility for periodic
22 audits. That's conducted by the United States Air
23 Force out of Scott Air Force Base, Illinois. They came
24 in I believe in 1994 and did an audit on USAir, as

well.

2 MR. SASSER: The results of these NASIP
3 inspections and DOD audits are, I assume, given to you
4 and that is also put into your data for the now system
5 and implementation of corrective measures for USAir?

6 THE WITNESS: The NASIP information is
7 entered into the PTRS system. It's also a matter of
8 record. The Department of Defense gives us a written
9 report that we respond to, any findings that they so
10 note.

11 MR. SASSER: What method is used to insure
12 that the in-service problems are adequately addressed
13 by USAir?

14 THE WITNESS: In-service problems or what we
15 would refer to as trends or concerns, as I mentioned,
16 we trend weekly, monthly and quarterly. As previously
17 stated, quarterly we have a meeting with USAir to share
18 that information.

19 Additionally, monthly we have a meeting with
20 the USAir quality assurance and engineering departments
21 who come to our office and we go over any short-term
22 snapshot trends or any concerns that may not be a
23 trend, but they are concerns.

24 Additionally, our continuance surveillance

would verify any problems that we so noted and were
2 tracking. Also quarterly, we put out what we refer to
3 as a geographic newsletter. That's a newsletter that's
4 sent out through the FAA mail system to all the other
5 Flight Standard's District Offices throughout the
6 world. We request their assistance.

7 We give them specific emphasis items. We
8 give them codes to use. So that if they use those
9 codes and do the surveillance, it will help us better
10 in our trending. All of this together helps us to
11 follow up on any in-service problems or in-service
12 concerns that we have raised with USAir.

13 MR. SASSER: Mr. Cam, from your perspective,
14 what is the relationship between USAir and the FAA, and
15 what is USAir's attitude toward compliance with the
16 Federal Aviation Regulations?

17 THE WITNESS: My impression or my opinion of
18 their attitude regarding compliance is that they are
19 pro-active. As Mr. Cohen had been previously
20 testified, they initiated an internal evaluation
21 program three years prior to the advisory circular
22 being issued.

23 They used voluntary or self-disclosure
24 program that's covered by an advisory circular to

report discrepancies and violations that they do. They
2 are pretty up front with that. So I think my
3 impression of their attitude regarding compliance is
4 good based on that.

5 As well, we know historically that they have
6 brought in independent audit firms to assist in the
7 audit of their own company. To me, that's an indicator
8 of a pro-active approach to compliance.

9 MR. SASSER: Mr. Cam, are you aware of any
10 requirements to routinely collect and test hydraulic
11 fluid samples from the Boeing 737 fleet?

12 THE WITNESS: Specifically for the Boeing
13 737-300, I believe that the maintenance manual refers
14 to taking hydraulic samples when the operator's
15 experience determines that they are necessary to be
16 taken. Beyond that, I know of no requirement as such.

17 MR. SASSER: There's no hourly or yearly
18 requirement. I believe we heard testimony earlier from
19 Mr. Cohen that they did that on a regular basis. At
20 least annually, but there is no requirement that you're
21 aware of from Boeing.

22 THE WITNESS: NO.

23 MR. SASSER: I have no further questions, Mr.
24 Cann. Do you have anything that you would like to add

that we failed to talk about?

2 THE WITNESS: No, sir.

3 MR. SASSER: Mr. Chairman.

4 CHAIRMAN HALL: Thank you, Mr. Sasser. Do
5 any of the parties have questions of this witness?

6 (No response.)

7 CHAIRMAN HALL: Mr. Marx?

8 MR. MARX: No questions.

9 CHAIRMAN HALL: Mr. Clark?

10 MR. CLARK: 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 has some
16 questions, so. To just get a feel, you have ten people
17 that work for you, are employed with you, sir?

18 THE WITNESS: Yes, sir.

19 CHAIRMAN HALL: You all perform, what, about
20 1400 inspections a year? I was trying to take 40
21 percent of 3600. So roughly 1400, 1500?

22 THE WITNESS: Roughly, yes, sir.

23 CHAIRMAN HALL: Could you tell me routinely
24 in regard to the hydraulic systems on planes, what type

of inspection you would routinely run, if any, that
2 would impact the checking the proper maintenance of the
3 hydraulic systems?

4 THE WITNESS: Routinely, we would -- for
5 instance, we know that USAir issued a CD or what's
6 referred to as a campaign directive to sample hydraulic
7 fluid. We would take the initiative to go look to see
8 that they're sampling and sampling the fluid properly
9 in accordance with the maintenance manual requirement.

10
11 Another issue we know is the PCU, the power
12 control unit. The opportunity arises to observe a
13 power control unit replacement. We will obviously put
14 particular emphasis on that.

15 Other than that, we would observe routine
16 maintenance, including the use of the hydraulic round
17 test hands or hydraulic mules. Other than that
18 directly relative to the 737-300 hydraulic system
19 maintenance, it would be just a continuous oversight.
20 It would be hard to schedule. If somebody's working on
21 that system, obviously we observe the maintenance on
22 it.

23 CHAIRMAN HALL: Well, my understanding is
24 that FAA in its letter I referred to yesterday stated

1 that there were problems with the systems, the power
2 control system, et cetera, and I need to look to get
3 that correspondence in front of me. That could be
4 detected by manual checks that are taking place before
5 each flight.

6 Are you familiar with what I am talking about
7 or should I try and get that letter out?

8 THE WITNESS: I'm not familiar with the
9 letter. I don't know if you're referring to a check
10 that's done by the flight crew or not.

11 CHAIRMAN HALL: Yes, the ground check.

12 THE WITNESS: That's not done by maintenance
13 personnel. I believe that's done by the flight crew on
14 the originating flight, I believe, if I'm following you
15 correctly.

16 CHAIRMAN HALL: So if the flight check found
17 a galling condition that was then reported to the
18 maintenance crew, would that be a document that you-all
19 would review as part of your inspection?

20 THE WITNESS: That would be documented in the
21 log book. If it was a pilot discrepancy, the pilot
22 would obviously initiate an entry in the log book. We
23 routinely review log books. It's a big part of our
24 program. That's one of the ways that we detect trends.

CHAIRMAN HALL: Since the Colorado Springs'
2 accident, has there been any direction to you in terms
3 of your inspection of the rudder systems on the 737s?

4 THE WITNESS: If you're asking whether there
5 was any particular emphasis placed on us by higher
6 headquarters, I don't believe so. I know that we have
7 personally placed -- made it an emphasis item as a
8 result of 427.

9 CHAIRMAN HALL: But nothing prior to the 427?

10 THE WITNESS: No, sir, not to my knowledge.

11 CHAIRMAN HALL: Fourteen hundred inspections
12 is a lot of inspections for ten people, I would think.
13 How long does it take you to do an inspection and how
14 do you decide on a great big plane like that with lots
15 of things to inspect, how do you decide what you look
16 at?

17 THE WITNESS: As I said, if we are doing a
18 ramp inspection, we have a check list or a job aid that
19 we use. It may or may not be possible to accomplish
20 everything on the job aid because there could be
21 passenger boarding, et cetera.

22 Spot checks are quite easy, because the
23 aircraft is out of service. We have a significantly
24 more amount of time to spend. We can review the

1 maintenance material that the mechanics are using and
2 observe the work task being accomplished. Deicing
3 surveillance is somewhat different in that we can
4 actually get out and watch the deicing. We can get out
5 into the elements and observe those.

6 So each inspection that we do has different
7 hourly requirements. I use word requirements in that
8 it's really not a requirement. We know what we have as
9 far as a work rate for planning purposes, but we really
10 don't track the total work activity as such in man
11 hours.

12 CHAIRMAN HALL: You say that generally your
13 experience in relationship with USAir has been good.
14 How long have you been in this position, sir?

15 THE WITNESS: I've been the principal
16 maintenance inspector in USAir since February of 1990.
17 So, I'm coming up on five years.

18 CHAIRMAN HALL: An item such as the auxiliary
19 fuel tank that was referred to in the earlier testimony
20 that was installed on some of the 737s, I gather, that
21 go on the longer trips, and I understand that was a
22 modification that was made by the airline rather than
23 Boeing. What oversight do you have or what role does
24 the FAA play in that at all, if anything?

THE WITNESS: Sir, I think you're referring
2 to the PATS tank installation. That was an STC that
3 was issued to PATS which is the company manufacturers
4 the installation and that was done by Tramco in
5 Seattle. I don't think -- to the best of my knowledge,
6 USAir did not do any of those installations themselves.
7 It was done generally prior to delivery of the aircraft
8 in Seattle.

9 CHAIRMAN HALL: But did you-all have any role
10 in that, the FAA?

11 THE WITNESS: No, sir, we have after the
12 fact, because we knew that there were -- it was a trend
13 item that we looked at, and we knew it was a new
14 installation. So, we created an emphasis item to pay
15 attention to that once it was initially installed.

16 CHAIRMAN HALL: You-all were notified by
17 USAir of it before or after it was installed?

18 THE WITNESS: We were notified before the
19 aircraft came on board, because there were AFM or
20 flight manual revisions that were necessary, as well.
21 I mean, that also included pilot handbook changes, a
22 well as maintenance procedures. So, we were aware of
23 that.

24 CHAIRMAN HALL: Is there anything else that

you feel that you could add in your testimony that
2 would assist us in our investigation of this accident?

3 THE WITNESS: No, sir. The only thing I
4 might add was that in the previous testimony, to the
5 best of my knowledge, the accident aircraft, M-513-AU,
6 was a Boeing 737-3B7, which indicates that it was
7 delivered to USAir, if that would help clarify the
8 previous testimony.

9 CHAIRMAN HALL: Good. Good. Mr. Corm, I
10 don't believe -- Cann, I'm sorry. Right?

11 THE WITNESS: Yes, sir.

12 CHAIRMAN HALL: It's getting late. I don't
13 believe I have any other questions. Are you going to
14 be with the table for the rest of the week?

15 THE WITNESS: I will be here for the rest of
16 the week, sir.

17 CHAIRMAN HALL: Well, good. So if we get
18 into anything else, that would be helpful to us. But
19 thank you very much for your -- well, I did have one
20 other questions. Do you have an adequate number of
21 people to do the job that the FAA asks you to do?

22 THE WITNESS: Yes, sir. Obviously, I look at
23 quality rather than quantity. We look at doing quality
24 inspections. That's paramount. If I had more people,

1 I could do a higher quantity. If I had less people, I
2 could probably do a smaller quantity. But I'm worried
3 about the quality as opposed to the quantity.

4 CHAIRMAN HALL: And the experience of the
5 people that are employed there with FAA that you have
6 responsibility for, what type of previous federal
7 service -- what type of service do they have generally?

8 THE WITNESS: As far as airline service
9 experience?

10 CHAIRMAN HALL: Yes.

11 THE WITNESS: They are quite experienced.
12 One member is a member of PAN American Airlines for 20
13 some years. Others have been in the industry with
14 other airlines, Eastern Airlines, in fact, repair
15 stations, smaller airlines. So I believe I don't have
16 a person that's got less than 20 years experience in
17 the aviation industry.

18 CHAIRMAN HALL: Very good. Well, I wanted to
19 put that on the record because a lot's written about
20 everyone's roles here. Obviously, there's an important
21 role that the Federal Aviation Administration plays.
22 They have a number of dedicated employees, and you
23 certainly have represented them well today. Thank you,
24 sir. You're excused.

THE WITNESS: Thank you.

2 CAPTAIN SHARP: Excuse me?

3 CHAIRMAN HALL: I'm sorry, Captain. You had
4 a question? I'm sorry. Would you mind remaining,
5 please, Mr. Cann?

6 THE WITNESS: Yes, sir.

7 CHAIRMAN HALL: The microphone for USAir,
8 please?

9 CAPTAIN SHARP: Mr. Cam, could I just maybe
10 ask you one question about the PATS tank. There seem
11 to be a little bit of a point that maybe we need to
12 clarify on that.

13 Was it not your understanding that that PATS
14 tank was installed at the factory as an option from
15 other than Boeing, but installed while the airplane was
16 still a new airplane and owned basically Boeing
17 property before it was delivered to USAir?

18 THE WITNESS: It was my understanding, I
19 don't think, Captain Sharp, that that was ever raised.
20 The point that was raised to me that the aircraft was
21 new. It went from Boeing to Tramco to have the PATS
22 tank installed. I don't think we ever had question of
23 ownership or anything. That was never an issue that we
24 raised.

1 CAPTAIN SHARP: But the installation was done
2 by PATS, the company that had an STC, which had been
3 approved by the FAA for installation of the tank?

4 THE WITNESS: Yes, sir.

5 CAPTAIN SHARP: Thank you.

6 CHAIRMAN HALL: Does that conclude? Thank
7 you very much. You are excused this time.

8 (Witness excused.)

9 CHAIRMAN HALL: We are sitting here trying to
10 debate whether we should go one more time or whether we
11 should just adjourn and proceed in the morning. Are we
12 far enough along, Mr. Haueter, on this witness list
13 that we can wait and proceed in the morning?

14 MR. HAUETER: The next witness will probably
15 take an hour, an hour and a half, sir.

16 CHAIRMAN HALL: Well, I appreciate very much
17 the parties' willingness to stay this late and assist
18 us in working through this testimony. This is a long
19 hearing, but I want to be sure that everyone has
20 adequate time to ask whatever questions and put on the
21 record whatever needs to document our investigation at
22 this point.

23 We will, therefore, now recess until 8:30 in
24 the morning.

(Whereupon, at 7:26 p.m., the hearing was
2 adjourned. To be reconvened on Thursday, January 26,
3 1995, at 8:30 a.m.)

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