NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

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In the matter of: :
:
THE INVESTIGATION OF USAIR, INC. :
FLIGHT 427, A BOEING 737-300, N513AU, :
ALIQUIPPA, PENNSYLVANIA, :
SEPTEMBER 8, 1994 :
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Pittsburgh Hilton and
Towers Hotel
Pittsburgh, Pennsvylania

Wednesday, January 25, 1995

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

BOARD OF INQUIRY:

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Office of Aviation Safety

Ronald L. Schleede, Chief,
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C O N T E N T S

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I N D E X

<u>Witness(es)</u> <u>Page:</u>

(continued)

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P R O C E E D I N G S

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

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

Mr. Cline, if you could please come forward.

(Witness testimony continues on the next page.)

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

Whereupon,

PAUL CLINE,

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:

CHAIRMAN HALL: Mr. Schleede, please begin.

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

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

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

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

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

THE WITNESS: Four and a half years.

MR. SCHLEEDE: Would you give us a brief

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

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

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

THE WITNESS: Excuse me?

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

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

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

THE WITNESS: No, I am not.

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

MR. PHILLIPS: Good morning, Mr. Cline.

THE WITNESS: Good morning.

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

THE WITNESS: I have the details design

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

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

THE WITNESS: Yes, it is.

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

THE WITNESS: Four and a half years now.

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

THE WITNESS: Yes.

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

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

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

THE WITNESS: No, they are not.

MR. PHILLIPS: In your day-to-day duties, are you involved with reviewing in-service activities, deficiency reports from operators?

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

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

THE WITNESS: That's true, yes.

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

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

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

THE WITNESS: Yes, I have.

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

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

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

CHAIRMAN HALL: Nine A-H?

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

(Slide shown.)

THE WITNESS: This is an isometric view of the rudder PCU linkage. The manifold and its associated caps and plugs and filters have been stripped away for simplicity. Also, the things that we will be talking about later on in this testimony are kind of labeled here just to give everybody an idea of what we're talking about. But as discussed in earlier testimony, this is a dual load path component.

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

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

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

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

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

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

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

THE WITNESS: Each single load path is carried for a full load of the package, yes. Continuing on, there's really two methods that this package can receive inputs.

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

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

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

That yaw damper actuator then moves the

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

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

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

THE WITNESS: Yes, they are.

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

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

MR. PHILLIPS: Approximately how much does that yaw damper or mode piston actuator move?

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

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

THE WITNESS: Yes.

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

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

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

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

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

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

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

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

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

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

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

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

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

THE WITNESS: No, there are no distortions. Everything is to accurate engineering scale. It was generated using our engineering CAD system, which we call CATIA. However, when we put it in video format, we did apply some perspective to it to make it look more three dimensional. So that effect will be somewhat evident. But it's accurate in its representation of size.

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

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

MR. PHILLIPS: Whenever you're ready.

THE WITNESS: If we can show that now.

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

(Video shown.)

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

The rest of the video will be shown from roughly this position of the camera. This is the pilot input that I was talking about. This is some of the inter-activeness. I think I'm going to just let this run by and we'll get to a clean cycle here where we won't see this fading in and out.

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

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

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

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

If you watch carefully, you can see when an input is created right now, you can see a command created up here, which then gets resolves by the piston. Now we're at the point of resolve.

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

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

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

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

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

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

I think that's all we have.

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

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

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

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

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

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

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

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

THE WITNESS: The CATIA software, yes. Its basic function is for design. However, the graphics group is really out of our maintenance training group, which we use for training the operators.

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

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

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

THE WITNESS: Excuse me?

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

THE WITNESS: No, when this package was originally designed, it was all done on paper, hand calculations. It's the same thing we would do on the computer, just much more labor intensive.

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

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

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

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

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

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

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

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

When the United mechanics removed it from the airplane and put it on their test bench, they were testing it per the Boeing overhaul manual. When they came to a test called the "force versus input linkage" -- I'm sorry -- the "force versus input displacement test," they put the PCU in the test fixture for that test, started to perform the test and the PCU actually went the wrong direction. And what the test intended and it damaged part of their test fixture, that's when they notified Boeing and we got involved.

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

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

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

THE WITNESS: Any fault of this nature, yes.

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

THE WITNESS: That's when the PCU was taken to Parker Hannifin and we duplicated the results of the test at Parker Hannifin. We didn't destroy any test fixture because we were kind of aware of what was going to happen. But it took us several weeks to figure out exactly what was happening and why it was happening, but it turns out that the summing levers -- maybe we could put the 9-AH exhibit back up, sheet one.

(Slide shown.)

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

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

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

THE WITNESS: On the particular unit that United had found, on the airplane when the pilot moved the rudder pedals, he wasn't stroking the secondary far enough to cause a reversal, but he was causing some very low residual pressures, some very, very hinge moment of the rudder PCU and he was just physically unable to move the rudder surface. That's why he felt the pedals kind of what you would call the stall or lock up.

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

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

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

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

Residual pressure is just simply -- it takes a differential pressure across the piston to create a force, to create the hinge moment. Residual pressure is simply a major of the effective pressure that remains to the piston. So really it's a measure of the effect of the rudder hinge moment.

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

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

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

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

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

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

So the design change was really just to

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

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

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

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

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

THE WITNESS: Yes, it became evident.

MR. PHILLIPS: At the time of this event, was there any testing, in your opinion, that would have or should have detected this position or this condition?

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

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

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

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

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

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

THE WITNESS: Yes, that's true.

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

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

We've now modified the overhaul and acceptance test procedures for this rudder PCU. So now we can purposely stroke the secondary to its internal limits and monitor the output of the PCU while we're doing that. That, without a doubt, will check for this condition.

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

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

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

THE WITNESS: Since January of '93, yes.

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

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

So some units we'll stack up and they can never have a problem. Other units or tolerance stack up might be such that under the right conditions we 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 and what kind of time frame that we'd expect to see the 737 fleet modified in?

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

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

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

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

THE WITNESS: There's a lot of things that go into that decision. Many I'm probably not aware of. But it's based on the ability for the airlines to accomplish, to fix, as well as maintaining the safety of the fleet while they're accomplishing the fix. The FAA would be better to answer that question.

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

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

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

THE WITNESS: No, it had not.

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

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

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

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

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

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

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

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

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

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

If you could put up Exhibit 19, please.

(Slide shown.)

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

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

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

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

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

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

Moving on in the testing we accomplished at

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

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

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

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

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

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

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

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

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

THE WITNESS: Yes, it is.

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

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

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

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

(Slide shown.)

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

Number one, "Testing and examination conducted on the rudder PCU validated that the unit is capable of performing its intended functions as specified by the Boeing Commercial Airplane Group." Number two, "Testing validated that the unit was incapable of uncommanded rudder reversal." Number three, "The yaw damper system components of the unit functioned normally and the yaw deflection limit of plus or minus three degrees was verified."

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

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

BY MR. PHILLIPS:

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

THE WITNESS: Yes, that's true. We really spent the next three months performing a lot of different types of testings and examinations that really only further validated those conclusions. I think this was probably the best work we did. We just didn't realize it at that point in time.

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

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

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

Specifically it generated some questions about how the control valves, the dual concentric control valve, would react to certain types of particulates. That really caused us to do two types of testing and a lot of examination. Well, first of all, let me mention the two types of testing. We can discuss those later.

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

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

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

MR. PHILLIPS: When were those tests conducted?

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

MR. PHILLIPS: Are you going to describe the results of that testing?

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

MR. PHILLIPS: If you would?

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

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

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

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

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

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

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

THE WITNESS: No, that's a good point. What was found in the fluid samples ranged between a five and 100 micron. A hundred micron is almost four thousandth of an inch. Some of the pieces we used were fifteen thousandths by forty thousandths. We used pieces that were many, many, many times greater than any particulate we found in the fluid samples.

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

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

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

We did not create any damage on the very edge of the land or the slide, partially because of the geometry of the chip. We actually didn't contact the edge of the slide. It kind of hooked around and contacted the face of the slide. But we did create damage on the face of the slide. That was one area that we hadn't really specifically looked at on the accident valve.

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

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

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

The accident valve was examined with a

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

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

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

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

THE WITNESS: Yes, that's very true.

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

THE WITNESS: If both slides of the valve had jammed, you really negate the effect of the PCU feedback loop to null the valve, and the PCU would just continue to go until it stopped, from running out of stroke, which would really be a hard over rudder. And because of the earlier testimony that the performance group is back to back, where the yaw moment was seen on the FDR data, that keyed the systems into looking very closely at the rudder components and anything that could cause it to go hard over like that.

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

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

THE WITNESS: To the best of my knowledge, yes, that's true.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(Slide shown.)

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

You can see that it's kind of translucent and clear and you can see into the bottom. When we took these photographs, what doesn't show up is in reality, you could see some very -- you can see things sparkling in there, and it doesn't show up on the photograph. If you know what you're looking for, there's one right there, and there's others in there, but there's just these very fine sparkles. That's the particulate contaminant that was in the link cavity accident valve or accident rudder PCU.

(Slide shown.)

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

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

If we could show the next picture.

(Slide shown.)

THE WITNESS: This is a picture of the primary slide removed from that test unit. These are what we call the balanced grooves. As you can see, they are all filled up with contaminant. What that really is is conglomeration of a bunch of contaminants. When you take very small particles like that under high pressure, you can actually kind of make them into a conglomeration that they kind of stick to themselves.

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

THE WITNESS: Yes, I can provide that.

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

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

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

CHAIRMAN HALL: Thank you.

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

(Slide shown.)

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

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

(Slide shown.)

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

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

I'm told that the series of -- this will appear as 9-AF-2. You may not have a copy of that yet, but it will be under that cover number. I believe what he's showing there is 9-S exhibit.

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

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

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

(Slide shown.)

THE WITNESS: What happens during our particulate test was as the fluid went by the edge -- we'll use this picture as an example -- it kind of wore out part of the edge. Then as it was deflected down to hit the root diameter of the slide, it created these huge divots. These are kind of like a pocket that's actually worn away inside the root diameter of the slide. That's from this fluid with particulate. It's almost like a slurry just impinging on that root diameter and simply wearing it away.

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

BY MR. PHILLIPS:

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

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

MR. PHILLIPS: Had any testing like this ever been performed by Boeing or Parker, to the best of your knowledge?

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

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

THE WITNESS: No, we haven't.

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

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

MR. PHILLIPS: That's correct.

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

MR. PHILLIPS: I would like to go back a little bit now back to our discussion on jams and the testing that was done on the USAir 427 PCU. Could you briefly describe the testing done for residual pressure differential?

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

MR. PHILLIPS: Yes, it is.

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

(Pause.)

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

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

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

(Slide shown.)

THE WITNESS: These are the results of the residual pressure test that we did on the accident servo valve. Like I said, on the left column are the four conditions we simulated. Let's just look at the first one as an example.

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

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

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

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

BY MR. PHILLIPS:

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

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

MR. PHILLIPS: When were the tests done?

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

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

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

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

The last two cases, the numbers look bigger, but you really have to look at the sign of the numbers. These are simulating the same scenario, except the primary jam. In other words, we have a full rate command. We jam the primary. And now the secondary is trying to negate the primary. Not only can the secondary negate the primary, but it can still provide residual control over the rudder.

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

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

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

THE WITNESS: Yes.

MR. PHILLIPS: Twelve and a half percent?

THE WITNESS: Yes, 12 percent of rudder.

MR. PHILLIPS: Would this vary from valve to valve?

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

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

THE WITNESS: Yes, it has.

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

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

MR. PHILLIPS: Should it be?

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

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

MR. PHILLIPS: I guess the point that I'm making is that if you have a test method available to show you conditions that may cause you to be able to null the rudder out or not, it seems to me that that would be a valid test in production of the valve.

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

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

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

CHAIRMAN HALL: How long has the plane been performing?

THE WITNESS: Almost 30 years.

BY MR. PHILLIPS:

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

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

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

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

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

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

MR. PHILLIPS: In your position as the engineer responsible for the operation and function of this package, are you satisfied that everything has been done that's possible to determine whether this rudder PCU package effected the flight of USAir 427?

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

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

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

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

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

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

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

MR. WURZEL: Good morning, Mr. Cline.

THE WITNESS: Good morning.

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

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

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

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

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

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

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

MR. WURZEL: That's correct.

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

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

CHAIRMAN HALL: Oh, Chicago, okay.

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

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

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

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

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

MR. WURZEL: You stated that modification to the power control unit or the AD would preclude any 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 question. I'm sorry.

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

THE WITNESS: If what condition happens?

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

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

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

CHAIRMAN HALL: The Airlines Pilot Association. Captain?

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

THE WITNESS: No, I didn't say that the flow could be in the opposite direction. I said that that's when we discovered the generic problem of the flow could be in the opposite direction. On that particular unit, the flow did not -- I'm sorry. On that particular unit, yes, the flow could reverse.

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

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

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

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

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

THE WITNESS: That's correct.

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

THE WITNESS: If it's not done at a rapid rate, but the full freedom of movement is checked, it accomplishes identical results.

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

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

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

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

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

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

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

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?

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

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

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

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

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

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

THE WITNESS: That's true. It doesn't have any effect on the PCU's operation.

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

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

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

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

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

As I think you're well aware, we have been working a great number of hours preparing for the hearing. A number of these people have been running the tests simultaneously. So, frankly, it has been an outstanding effort.

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

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

CHAIRMAN HALL: Thank you very much.

MR. McGREW: We have a few questions for Mr. Cline. Perhaps more than a few.

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

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

MR. McGREW: Perhaps a more difficult question. Can you tell us through the testing procedure and the analysis procedure that you've been through, of those events where the NTSB or members of the parties were not involved in it, is there anything that we did independent of them and please feel free to answer everything you know? For examination, the contamination test was not done with anybody from the NTSB at the facility.

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

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

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

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

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

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

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

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

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

THE WITNESS: It was a total of 30 hours of testing, which doesn't seem like a lot, but it was wrought with problems because we had a hard time making the other components in the tests, such as the pumps stand up to the testing. We replaced many pumps. I think we accomplish something just over 5,000 cycles, if my numbers are right.

MR. McGREW: What are the levels of filtration used in the hydraulic system today in the basic system?

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

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

MR. McGREW: How about in the unit itself?

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

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

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

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

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

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

THE WITNESS: That's correct. We used a baroscope to verify that we were getting full engagement of the external servo stops and verified that the dimensions and the numbers were correct in both cases. In the case of the Colorado Springs, because that PCU was burned up pretty bad, we didn't actually use a baroscope while the unit was together to verify that. We used witness marks the unit created when it wears. When it contacts, it creates the wear marks. We could see that it had full engagement.

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

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

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

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

MR. McGREW: Thank you, Mr. Cline. Mr. Chairman, that concludes our questions.

CHAIRMAN HALL: Thank you very much. Let me respond briefly, because I think it's an appropriate 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 and continue with this witness.

(Whereupon, a recess was taken.)

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

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

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

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

THE WITNESS: Yes, they were.

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

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

MR. JAKSE: One final question. Based upon your contamination testing, did you conclude that the hydraulic fluid did not cause any jamming of the power control unit or the rudder on flight 427?

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

MR. JAKSE: Thank you.

CHAIRMAN HALL: Any more questions from the parties?

(No response.)

CHAIRMAN HALL: If not, Mr. Marx.

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

THE WITNESS: Yes, it is.

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

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

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

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

MR. MARX: What do you mean by that?

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

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

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

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

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

MR. MARX: External stops.

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

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

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

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

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

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

THE WITNESS: Yes. That's correct.

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

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

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

THE WITNESS: Well, it would have been stroking some position beyond the external stop and I don't remember what that number was. That was on the order of a few thousandths on that particular one.

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

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

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

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

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

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

MR. MARX: For the accident valve?

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

MR. MARX: On the United aircraft fault

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

THE WITNESS: I don't know.

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

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

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

THE WITNESS: Yes, that's possible.

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

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

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

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

MR. MARX: I understand that this over stroke -- this is the stroke in which the secondary moves relative to the housing and goes as far as -- I mean, if you can over stroke its normal position, then it can occur from prior testimony from a jam between the primary and the secondary.

THE WITNESS: That is true, yes.

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

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

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

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

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

MR. MARX: Could you absolutely rule out the possibility that the primary jammed to the secondary that could produce the over stroke?

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

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

THE WITNESS: We looked at that unit --

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

THE WITNESS: Correct.

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

THE WITNESS: That's correct.

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

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

MR. MARX: Well, back to the situation where if it didn't happen during original manufacturer or at some overhaul time, how do you know that it was the chamfer that produced this problem and not a jam between the primary and the secondary?

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

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

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

MR. MARX: Let's assume that there would have been a jam between the primary and secondary slide. This would be on the Mack Moore unit. What would be the shear forces, the shear load? What is actually producing the shear load if you're trying to drive that primary, retract it into the servo, try to push it into the servo? What would be reacting against that?

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

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

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

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

MR. MARX: I'm only going in the moment of time where we are pushing the primary in its process of being pushed into the servo. Let's go back and ask. There are some springs that are internal, is there not, in the servo?

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

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

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

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

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

MR. MARX: Ten and 12 pounds. So if we were pushing the primary into the servo and there happens to be something stuck between the primary and the secondary, the reaction would be from the spring roll, would it not, of ten to 12 pounds that would try to shear whatever it is that's stuck between the two? I'm trying to get the secondary to an over travel position only.

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

MR. MARX: That's correct.

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

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

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

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

THE WITNESS: That's correct. Yes.

MR. MARX: So if you had a particle of some sort, it was between the primary and the secondary, and it would only react with a shear force of ten to 12 pounds to get it into the over traveled position?

THE WITNESS: That's correct.

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

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

MR. MARX: Goes way up?

THE WITNESS: Yes.

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

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

MR. MARX: Now we've had a lot of testimony previously that had to do with rudder rigs. The rudder rigs have varied, depending on who was testifying. I think that the rudder rigs went all the way from 2.5 degrees per second up to approximately 7.5 degrees to 8 degrees per second.

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

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

MR. MARX: About how small?

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

MR. MARX: Well, let's say that we had a double jam between the primary and secondary, and the secondary and the housing unit. At what position would we have to have the primary to the secondary -- for instance, just using that as a scenario -- to produce a 2.5 degrees to 7 degrees or 7.5 degree rudderick?

THE WITNESS: Is this a no load condition?

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

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

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

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

THE WITNESS: That's correct. Yes.

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

THE WITNESS: That's correct.

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

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

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

THE WITNESS: It's a 1.003 square inches.

MR. MARX: Roughly one square inch?

THE WITNESS: Roughly one square inch, yes.

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

THE WITNESS: We have 2950 pounds.

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

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

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

THE WITNESS: Under what load condition?

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

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

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

THE WITNESS: No. The design case for the rudder is an engine out case, as you mentioned. It's somewhere around 120 knots. We have to be able to move the rudder full deflection. That's minus the compliance of the system, which is, I think, about a half degree in, I think, less than three quarters of a second. That's the design case for the rudder and that's with both hydraulic systems powered.

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

THE WITNESS: Yes, it would.

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

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

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

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

MR. MARX: What pressure would we have to have, what minimum pressure or load, I should say, and pounds would we need to get to that blow-down rate at 190 knots for 17 degrees rudder?

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

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

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

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

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

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

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

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

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

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

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

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

MR. MARX: Yes.

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

MR. MARX: Yes.

THE WITNESS: That would be a left rudder direction.

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

THE WITNESS: To a higher amount, yes.

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

THE WITNESS: No, it would not.

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

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

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

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

MR. MARX: Yes.

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

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

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

MR. MARX: A couple of thousands?

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

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

THE WITNESS: That's true.

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

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

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

In other words, we're talking about we will need a rate of 2.5 to 8 degrees per second of that rudder movement, based on the testimony that you've heard already. Where do we have to have the primary to do this?

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

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

THE WITNESS: You have to increase it, yes.

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

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

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

MR. McGREW: Yes, sir.

CHAIRMAN HALL: Could we have the Boeing

Commercial Airplane Group microphone, please?

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

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

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

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

THE WITNESS: Which exhibit was it?

MR. MARX: Nine-R, Romeo.

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

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

CHAIRMAN HALL: All right. Then proceed.

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

THE WITNESS: Yes. What page are we on?

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

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

MR. MARX: Which direction would the rudder be moving in that if you happen to have the secondary into the internal stop?

THE WITNESS: That's left rudder.

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

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

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

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

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

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

MR. MARX: Yes.

THE WITNESS: No, they are not.

MR. MARX: Why are not they the same?

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

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

THE WITNESS: Which condition are we talking about?

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

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

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

THE WITNESS: In stalling the PCU, it would be, yes. The summing lever would first -- the primary summing lever would first come move the primary slide until it picked up the secondary slide. Then it would take both slides until the summing lever contacted the external servo stop.

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

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

MR. MARX: The external stop position?

THE WITNESS: Yes.

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

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

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

THE WITNESS: Yes.

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

THE WITNESS: That's true.

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

THE WITNESS: That's correct.

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

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

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

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

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

THE WITNESS: In condition three?

MR. MARX: Yes.

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

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

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

MR. MARX: That's correct.

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

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

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

MR. MARX: In that condition, which way would 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 which way, left or right? If you had a higher pressure on C-2 versus C-1 would it go left or right?

THE WITNESS: It would go left.

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

THE WITNESS: That's left rudder also.

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

THE WITNESS: It was 2700 psi.

MR. MARX: And for C-1?

THE WITNESS: Five hundred and fifty psi.

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

THE WITNESS: That's to the B system.

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

THE WITNESS: That's correct.

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

THE WITNESS: Yes.

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

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

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

THE WITNESS: Those are for the A system.

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

THE WITNESS: Yes, that's correct.

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

THE WITNESS: An additional 1300 pounds.

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

THE WITNESS: Yes, that's correct.

MR. MARX: The sum of those two conditions, I think, I believe my calculations show 3450 pounds. That would be in the direction of left rudder.

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

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

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

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

THE WITNESS: Not necessarily simultaneously, just concurrently.

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

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

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

THE WITNESS: Yes, that's true.

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

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

MR. MARX: Correct.

THE WITNESS: Yes.

MR. MARX: Then to jam the secondary, if we could jam the secondary in that position now -- that is, full travel -- and shear off the particle or whatever it is that's jammed between the primary and secondary and let that go free so the primary can go onto the right rudder condition, that would be a single jam, would it not?

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

MR. MARX: Right.

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

MR. MARX: But that --

THE WITNESS: -- and the initial shear.

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

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

MR. MARX: My understanding so far in testimony is that there's a very small distance in which we have to go to get to the external stop. That would be in the direction of left rudder and where we're going in pushing the secondary into the housing. I'm trying to find other ways in which we can get that secondary full into the housing other than the two that you talked about which was mismachine chamfer or internal jam.

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

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

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

THE WITNESS: That was 12.5 ounces.

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

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

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

THE WITNESS: Mm-hmm.

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

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

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

MR. MARX: If you picked up the secondary earlier, would that have a tendency to move the secondary farther into the servo if we are going into the left rudder condition or pushing the primary into the --

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

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

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

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

THE WITNESS: Yes.

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

THE WITNESS: Yes, there's relative motion between the primary and the secondary. If you stuck something in between the secondary pick up and the secondary pick up lever or the secondary lever and the secondary side itself, it would pick up early also and it would pick up early by the magnitude of whatever you stuck in there.

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

THE WITNESS: Yes.

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

THE WITNESS: Yes.

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

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

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

THE WITNESS: Yes.

MR. MARX: What was the largest particle?

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

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

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

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

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

MR. PHILLIPS: Page 63 of 9-A.

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

MR. MARX: Three hundred and sixty-two? I have just a few more questions. Maybe we can resolve some of the other stuff later. During the -- were you present at the time in which the PCU, the main PCU was disassembled at Parker?

THE WITNESS: Yes, I was.

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

THE WITNESS: Yes, we did.

MR. MARX: How did you do that?

THE WITNESS: With a stereo-microscope.

MR. MARX: About what magnification did you do?

THE WITNESS: I think that was about 25 times.

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

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

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

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

THE WITNESS: Yes, that's correct.

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

THE WITNESS: We just performed one test.

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

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

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

THE WITNESS: That's not completely correct, because we -- I would like to say that that testing was performed fairly recently. The systems group report of that testing is not completed. It's in what I would call a draft form. I noticed the same thing you're noticing, and we went back and looked at the photographic documentation we have.

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

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

THE WITNESS: That's true.

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

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

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

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

MR. PHILLIPS: The testing is complete. Mr.

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

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

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

MR. MARX: I wanted to get one clarifying thing here. It had to do with the pedal going to the bottom, the four inch travel with the pedal to the bottom. I don't know if you meant to say this but does that mean that the secondary goes all the way to its internal stop or goes as far as it can go in the case of left rudder and as far as it can go out as far as right rudder is concerned?

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

MR. MARX: Yes.

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

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

THE WITNESS: That's correct.

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

THE WITNESS: That's true.

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

THE WITNESS: Yes, they were.

MR. MARX: I have no further questions.

CHAIRMAN HALL: Mr. Clark?

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

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

MR. CLARK: Then back to neutral?

THE WITNESS: Yes.

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

THE WITNESS: Yes.

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

THE WITNESS: That's correct.

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

THE WITNESS: I'm made aware of those

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

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

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

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

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

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

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

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

THE WITNESS: That's correct.

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

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

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

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

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

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

MR. CLARK: I'll save my questions for that. In Exhibit -- and I'm not sure if it's necessary to pull up the exhibit. Maybe for you. But in Exhibit 9-A, page 52, the conclusion was that testing validated that the unit was incapable of uncommanded rudder reversal or movement. Is that statement based on your evaluation of the tolerance build ups that I assume you made measurements and conducted the flow test? Is that primarily based on the tolerance build ups that you saw in the unit?

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

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

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

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

THE WITNESS: No, there were not.

MR. CLARK: Earlier you also talked about chip shear and at one point, I heard a number that the maximum force would be 95 pounds. Is that 95 pounds that can be applied directly to the end of the primary servo valve?

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

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

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

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

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

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

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

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

THE WITNESS: That's correct.

MR. CLARK: Because the walking beam would break out and not allow the loading to go any higher at that point?

THE WITNESS: That's correct.

MR. CLARK: In your testing, did you ever push the secondary fully to the internal stops and then try to determine if there were any jams or binding at that point?

THE WITNESS: There were several tests where the secondary slide was taken to the internal stops. We didn't specifically see if it was jammed at that point. But whenever the test was released, the secondary always returned.

MR. CLARK: In some of the noted similarities between Colorado Springs, for example, and Pittsburgh, preceding each event, we were in an area of turbulence in which it could be assumed that the yaw damper may be active, but they are also in a vertical acceleration. Are there any requirements or testing to shake test the unit in the vertical direction to see if that can introduce problems or examine the entire airplane for vertical movement of the linkage, the control cables, for example, to see if that may introduce concurrent problems with the yaw damper activation?

THE WITNESS: Yes. At the component level, we do vibration testing. The airplane is divided up into zones and vibration levels for each of those zones defined. I don't know if the system, such as the cables and the tubes in the quadrants in that, are subject to a vibration test or not, but the components such as the PCU are.

MR. CLARK: When they do those kinds of tests, are they subjected to the 1 g, plus or minus .3 or .5 g's consistent with the type of data we have recorded from these two accidents?

THE WITNESS: I think it's much greater than that.

MR. CLARK: That would be an all up test with the unit running and operational?

THE WITNESS: I can't recall whether we actually operate it during that vibration testing or whether it's just -- I can't recall. I don't know right now.

MR. CLARK: I believe yesterday Mr. Turner made a comment and I forgot to follow up with him, so I'm going to ask you and we may have to go back to Mr. Turner. The question then was can the yaw damper cause full movement of the secondary valve. I think the answer was yes. My question is can the full movement of the yaw damper cause full movement of the secondary valve?

THE WITNESS: I think if you have enough load on the PCU, such as a cruise condition where your loads are the highest on the surface and you're going to get the slowest rates out of the PCU, I think, yes, you can drive the secondary to its stops.

MR. CLARK: Basically what you're referring to is if the yaw damper is moving, the rudder is trying to keep up. So it's difficult to get full travel out of the secondary. But if I were to drop back -- and let's just assume for a moment the rudder wasn't moving and look at an extreme situation. If we held the rudder in place so we had no feedback and then simply moved the yaw damper to a hard over, is that motion to the summing levers enough to move the secondary to the external stops?

THE WITNESS: Yes, in a static case like that, yes, geometrically it is plenty of stroke to move the secondary over.

MR. CLARK: Then also from a direct pilot input, if that exceeds the rate of the rudder feedback, the typical stop we hit would be the external stop on the servo valve?

THE WITNESS: That would be the first one you hit. If the rate of the pilot exceeded the PCU even further, then you would hit the stops on the external or the manifold of the PCU itself.

MR. CLARK: You would go through the break out and then hit the --

THE WITNESS: Yes.

MR. CLARK: -- continue on to hit the manifold external boy stop?

THE WITNESS: Yes.

MR. CLARK: Would that hold true also for a yaw damper input?

THE WITNESS: The yaw damper won't ever, even in your case of holding the feedback, the yaw damper won't ever cause the external manifold stops to contact. They purposely design it that way so that we could never kick the pedals with the yaw damper.

MR. CLARK: I would like to get some clarification on Exhibit 9-AH, page 2. We've talked about the Mack Moore unit or the United unit, and my understanding is to get that anomalous condition to exist, we have to push both primary and secondary valve in the same direction into an over travel situation?

THE WITNESS: Yes. That's correct.

MR. CLARK: Then all of these cases here, we're looking at opposite motions of the primary and secondary. We would move the secondary one way and the primary the other?

THE WITNESS: Yes.

MR. CLARK: Let's take number one first. You used the term residual, and earlier you defined that as a leftover pressure. Can we get a more practical definition, that if I'm in this situation and I'm experiencing this 12 percent residual, what's going on? First let me ask you, what would the pedal positions be in that situation?

THE WITNESS: Depending on what air speed you were at, you're going to be at whatever deflection gives you a 12 percent of full hinge moment and in the condition when it's going to be in the left rudder direction. The pedals would lag that position by six and a quarter degrees because of the clearance between the input crank and the manifold stops.

MR. CLARK: Basically in this situation, we have a secondary jam that would command a left rudder movement. In my assumption from what I see here, the pedal is trying to command a right movement. That's where the primary would have moved to the full right that we can get from a pedal input.

THE WITNESS: Yeah, you wouldn't even necessarily need a pedal input because of the feedback loop. For example, if the pilot commanded -- if we're at an air speed where we have 20 degrees of rudder available before we hit blow down and the pilot commanded 10 degrees of left rudder and the secondary jammed while the pilot was doing this with the full rate command, first of all the surface would go to where the pedals commanded it to. You wouldn't notice anything at that point. When he removed his pedal command and he tried to let the pedals go back to zero, the rudder surface would only go back to 12.5 percent, so four degrees.

MR. CLARK: Twelve percent of the maximum travel at 20?

THE WITNESS: Right.

MR. CLARK: If we're at the 20 -- if the blow-down limit is 20 degrees?

THE WITNESS: Right.

MR. CLARK: So we would see about 2 degrees of rudder when the pilot took his feet off the pedal?

THE WITNESS: Yes, that's correct.

MR. CLARK: Two degrees. Then what would happen as he continued to try to correct that situation and push in right pedal?

THE WITNESS: He wouldn't get any response out of the rudder. It would stay right there.

MR. CLARK: He could either break the unit free or work through the break out in the PCU?

THE WITNESS: Yes, he would be -- the most that would be happening is he would be physically pushing on the manifold stops with whatever force he excerpted in trying to move the rudder surface with that force which in comparison to the PCU hinge moment isn't that great of a force.

MR. CLARK: In this situation, we have looked at an undefined jam in which we can move the secondary to the external stop because from an external input, that's as far as we could move the secondary. Then we move the primary in the opposite direction. Then it's limited by -- it's essentially limited by the position in the summing lever tolerance of the secondary?

THE WITNESS: Yes. It's limited by the dead band between the secondary summing lever and the secondary slide.

MR. CLARK: If I took that maximum difference, that's the number where we get the 12 percent residual?

THE WITNESS: Yes, that is.

MR. CLARK: Now if I maintained that relative position and I can't define to you a mechanism to make the valve move, but if I were to maintain that maximum differential position and then move the secondary on into the internal stop, what would happen to these numbers?

THE WITNESS: That number would go from 12.5 percent to 57 percent.

MR. CLARK: Oh, that's a situation that

you've defined down here?

THE WITNESS: No, it's not the situation defined down there, but it's the same value, just an opposite sign.

MR. CLARK: Then if I took that relative position or moving to the internal stop, the situation would be dramatically improving as far as pilot control? I mean, we're moving from a can't control situation to having a 50 percent control?

THE WITNESS: I missed the first part of that.

MR. CLARK: In the condition number one on the servo is positioned at the equivalent of the external stop and then in condition number four, the servo would be positioned further into the internal stop. But that amount of movement actually improves the situation as far as controllability of the rudder package?

THE WITNESS: Yes.

MR. CLARK: Let me go back then and if I were -- if the situation for that maximum misalignment is the situation number one, the worst condition, for example, if I started moving -- maintained that same differential and started moving the secondary back to a more neutral position, would that be a worse situation?

THE WITNESS: No, that would be a better situation from a controllability.

MR. CLARK: So this situation you've defined here as the worst and then any motion even further on or less is going to be an improving situation?

THE WITNESS: Yes. That's why those test points were chosen, because they are the boundary test points.

CHAIRMAN HALL: Mr. Clark, could I interrupt you just for a moment?

MR. CLARK: That was my last question.

CHAIRMAN HALL: Well, are you sure?

MR. CLARK: Yes, sir.

CHAIRMAN HALL: Well, I don't want to -- here's what I would suggest we do. We have a gentleman here who is here at the request of the board, a Mr. Runkel. Where is Mr. Runkel? Mr. Runkel, you have to leave at 2:00. Is that correct? What's that, sir?

MR. RUNKEL: I have a 3:30 flight.

CHAIRMAN HALL: Mr. Runkel, Mr. Haueter tells me that your testimony is important to this hearing. So what I'm going to suggest is that we continue until 12:30. We take a break, a 30-minute lunch break, from

12:30 until 1:00. I apologize for the shortness of the break.

Mr. Runkel will then come and present his testimony at 1:00. That will give us an hour. I am told that that is an adequate period of time for Mr. Runkel's testimony. Then we would ask Mr. Cline to return. Then we will proceed and we will proceed tonight until 8:00.

We will continue. We have this room Saturday. If it is necessary to continue this hearing, Saturday we will do so. It is nothing this Chairman needs to add to the importance of this hearing and the work to the American public, and I appreciate everybody's patience in this, but it must continue and we will continue on the schedule I just outlined.

Mr. Schleede, you can -- Mr. Clark said he was through. Are you sure, John, I did not cut you off? I didn't mean to cut you off. If you had anything else you needed to follow up on?

MR. CLARK: No, that was my last question.

CHAIRMAN HALL: He's under oath, Mr. Schleede, that that's his last question, so you may proceed.

MR. SCHLEEDE: My first comment is to clarify on the record, we've made several references to the United incident and the Mack Moore unit and so forth and so on. I just wanted the record to reflect that that's an event that occurred on July 16, 1992, United Airlines, Boeing 737-300. I think the testimony will be clear. Oh, it's contained in Exhibit 9-L, 9 Leemah. Excerpts from the Colorado Springs' accident report, page 22.

A couple of follow ups to Mr. Clarks' questions on this service history. I wanted to give you an example. If a pilot had reported an anomaly taxiing in the airplane or in flight in which he felt rudder kicks and movements of the rudder pedals and that was written up for maintenance and troubleshooting took place, would that type of an event, regardless of the result of the maintenance troubleshooting, would that come to your attention?

THE WITNESS: If the airline submitted a telex explaining -- I'm not sure what causes an airline to submit a telex to our service group. But if that telex got to our service group, it would then get to me, yes.

MR. SCHLEEDE: Do you receive reports of that nature?

THE WITNESS: Yes, quite often. I mean, not of the nature you're talking about, but I receive reports of a pilot squawking something and maintenance action was taken.

MR. SCHLEEDE: If a pilot did have this type of report and it was determined it was in flight. It was taken in flight rudder kick, and it's unclear whether the pedals moved or not, but it was reported as a hard over type of event and the main rudder PCU and the standby rudder PCU were removed during maintenance and returned to the factory. Would that type of an event come to you attention?

THE WITNESS: Yes, it would. A lot of times we would travel down to wherever the component was being tested to witness that testing. We would also try to clarify what the pilot meant by a hard over. Whether he was really meaning a yaw damper hard over or a full surface hard over. We would try to get as much information as possible.

MR. SCHLEEDE: When you do those types of investigations of interface, like you say travel to Parker, does the FAA participate in those examinations?

THE WITNESS: Sometimes they do. There is some specific guidelines as to whether the FAA has to be notified. I don't work for those guidelines, so I'm not sure.

MR. SCHLEEDE: One last area has to do with your testimony about the chip shear tests that were conducted in December. I know you're -- I don't want to go over it all, but you mentioned that there were marks found on the servo valve after your work. I heard you say one time 20 pounds created a lot of damage. If it was jammed, it always left a mark. Is that generally what you said about that testing?

THE WITNESS: Yes, that's what I said.

MR. SCHLEEDE: I wanted to try to get an explanation for another document that's in the exhibits. It's Exhibit 9, alpha delta, A-D. Do you have that exhibit?

THE WITNESS: Yes, I do.

MR. SCHLEEDE: Page 6, upper right-hand corner of page 6. Right in the center of this page is item number 6. To put it in proper context, this is a telex in response to an inquiry brought regarding an incident involving a 747.

CHAIRMAN HALL: What exhibit is this? I apologize.

MR. SCHLEEDE: Nine alpha delta. This

correspondence is Boeing correspondence, customer correspondence. It's in reference to an incident involving a Boeing 747-400 at Hethrow that's in Exhibit 9-Q.

My question has to do with item 6 where the question was posed by the investigating team and Boeing documented the reason for lack of markings on the primary and secondary slides. This assumes Boeing maintains that a jam caused the incident. Now I'm aware that that was one of the earlier theories of that investigation and was dismissed later that a jam occurred.

My question has to do with the reply to this question. It says microscopic marks on the slide and servo parts are typical of those seen on in-service parts. Intentional valve jam chip shear tests previously done at Boeing with nitroloe slides and 52-100 sleeves with various contaminant materials, showed no marks with chrome or hard materials, but showed a smear with soft materials, such as lock wire.

This may be unfair to you, but have you seen this before, this particular document?

THE WITNESS: Well, the first time I had seen it was this week reviewing the exhibits.

MR. SCHLEEDE: You testified that during this investigation, you've tried to research. You're aware of earlier chip shear tests done at Boeing, but you were unable to find the documents. Have you got any explanation for this which differs significantly from the tests that were done in December?

THE WITNESS: Well, the explanation I have for this is that this is a response written by a service engineer. We have communicated with one of the project engineers on this, and he thinks that possibly there was some miscommunication between the project and the service engineer. What really is the case is not really what got printed and sent out. That is something that we would have to further investigate to know what the answer is, though.

MR. SCHLEEDE: Do you know if any of the Boeing witnesses that are coming up later can enlighten us on that?

THE WITNESS: I don't think so. Most of the witnesses here are out of the Renton Division. This piece of paper comes out of the Everett Division.

MR. SCHLEEDE: That's all the questions I have, Mr. Chairman.

CHAIRMAN HALL: Mr. Laynor.

MR. LAYNOR: Mr. Cline, I'll try to be brief also. In the beginning of your testimony, you talked about your participation in the examination of the PCU off of flight 427. You commented that you prose things in the position and then x-rayed the unit and did internal examinations. Can you briefly describe, first of all, what did you find? Did you establish what position the piston rod was in fairly competently and talk about the valves and internal components?

THE WITNESS: Yes, I can establish fairly comfortably where the piston was at the time of impact. There was some -- of course, the piston was bent and there was a lot of damage created by doing that. So there was some impact marks on the rod relative to the manifold and the in-glands and the bearings that support that piston.

By doing a CATIA layout of the damage and a CATIA layout of the installation, I could shift the position relative until I got it a good match between the impact marks and the items that would have caused that impact mark. That should about a 2 degree right rudder position at the time of impact.

One thing I can say, however, though is that from the photos I've seen and from talking with the people that were at the accident scene, it doesn't seem like enough care was taken to handle those components carefully on the accident scene. I've seen videos and pictures of people walking on those kinds of components, walking on the surfaces.

I understand it's hard to get around there, but if in the future if anything can be done to help preserve as much as possible at the accident scene, it helps. In this case, it didn't hurt anything, but it could help immensely in the investigation afterwards.

MR. LAYNOR: Well, we tried. How about the internal complements, bypass valves and springs, the yaw damper pistons and such, were they all pretty much intact and were you to expect them to be?

THE WITNESS: Yes, they were. We didn't x-ray the bypass valves because they are buried around a lot of mass. You can't get a good x-ray of those. We did x-ray the yaw damper piston. It was detented, as you would expect.

We x-rayed the servo valve. The secondary slide was detented, as you would also expect. The primary slide, although we can't tell exactly where it is, it was somewhere very near neutral.

MR. LAYNOR: Was the feedback mechanism

intact?

THE WITNESS: The feedback mechanism was bent because of the piston rod being bent.

MR. LAYNOR: The next area, on the chip shear test that you discussed, you said that large particles on the order of perhaps 15 times what you would have seen in the contaminant in the accident airplane, in the samples, do you believe that those tests were necessarily representative of what you would have seen on the valve slide had it been jammed by smaller particles, 30 to 100 microns perhaps?

THE WITNESS: We haven't come up with a mechanism yet that small particles can jam the slide. My answer to that would be between the particulate tests and the chip shear tests, we feel very confident that we represented that.

MR. LAYNOR: In the particulate test and I assume by that you're talking about the tests that were conducted just very recently that you showed the slides on?

THE WITNESS: Yes.

MR. LAYNOR: I think in response to Mr. Clark, you described a cycle and I was wondering whether a cycle was a PCU piston rod full travel or whether it involved full travel of both the primary and the secondary slides and the servo valve?

THE WITNESS: The answer is both. We stroke the piston very close to full travel and we varied the input rate. Primary and secondary slide position is only a function of commanded rate. So we varied the rate purposely so that we did get a difference in commanded position of the slides.

MR. LAYNOR: Was that accomplished by loading the piston rod of the PCU?

THE WITNESS: No, that was accomplished by just changing the rate of the input device. It went through -- it was on a ten cycle spectrum. It went through nine low rate cycles and one high rate cycle.

MR. LAYNOR: You can beat the servo or was there any feedback group associated with this?

THE WITNESS: Yes, there was.

MR. LAYNOR: You can beat the servo when it's unloaded?

THE WITNESS: Sure. It can only go 66 degrees per second and no load. So if you apply anything greater than that, you're going to exceed its rate.

MR. LAYNOR: Was the slide friction measured for the primary and secondary slides following that test or any time during the test?

THE WITNESS: It was measured at the conclusion of the test at the PCU top assembly level, like you would do during the force versus input test.

MR. LAYNOR: What were the findings, just ballpark?

THE WITNESS: They were greater. I don't have the numbers. But the thing to keep in mind is at the PCU level when you're moving and it's not powered hydraulicly and you're moving the input, you're moving the slides as well, but you're moving a lot of bearings in there. As you saw from the pictures, those bearings were sledge up and that added to the force.

MR. LAYNOR: I thought the slide friction was measured by putting a force directly on the primary and secondary slide?

THE WITNESS: It is at the servo level.

MR. LAYNOR: We didn't do that?

THE WITNESS: Not to my knowledge. I wasn't -- this test was finished up on actually the disassembly of the component was finished up on Friday. I was traveling here at that point in time.

MR. LAYNOR: Then my next question was, you showed the damage to the slides caused by the impingement of the particles. Were the slides examined under magnification for any damage that might be consistent with jamming during any portion of the tests?

THE WITNESS: I don't know the answer to that either, because I wasn't at the tear down. There's a 57 minute video, though, if you want to watch it.

MR. LAYNOR: Well, I'm sure the test report that we haven't yet received, but will receive, will include that kind of examination.

THE WITNESS: Yes, it will.

MR. LAYNOR: How many cycles were put on the PCU?

THE WITNESS: Something over 5,000, shortly over 5,000.

MR. LAYNOR: Do we have any idea what that would be -- how that would be represented in terms of flight hours perhaps, normal operation?

THE WITNESS: I don't have an exact number, but it's not very many flight hours. The yaw damper is active on the -- as long as the yaw damper is on, it's putting in quite a few cycles per flight.

MR. LAYNOR: Perhaps this is a question for

Mr. White, but on disassembly of parts, have we ever seen damage to the slides representative of the damage that you saw on those tests?

THE WITNESS: Not on this component I haven't.

MR. LAYNOR: I mean, disassembly of parts that have been in service for a long time?

THE WITNESS: I haven't, no, and not on this component. On other components, we've had this kind of damage.

MR. LAYNOR: That's all the questions I have. Thank you, sir.

CHAIRMAN HALL: Mr. Cline, I think what the Chairman is going to do is continue with you here for another ten or 15 minutes, and we'll still take our half hour lunch break. The flight is at 3:30?

MR. RUNKEL: Yes.

CHAIRMAN HALL: How long does it take to get to the airport?

MR. RUNKEL: Half hour.

CHAIRMAN HALL: So Mr. Cline has been here since 8:30. In fact, the Chairman just has a few questions that are not technical in nature, at least depending on the definition of technical, I guess.

How long did you say, sir, you have been with Boeing?

THE WITNESS: Four and a half years.

CHAIRMAN HALL: Four and a half years. How long -- I had this question. How long has Boeing built the 737?

THE WITNESS: Since 1966.

CHAIRMAN HALL: Sixty-six. This particular aircraft was manufactured when, do we know?

THE WITNESS: I don't recall. I think it was the late '80s.

MR. HAUETER: In 1987.

CHAIRMAN HALL: In 1987. Now if I understand what's transpired up to this point, we basically have two accidents that have some similarities. One row right and one row left. We have a situation that we don't have a flight data recorder that gives us a lot of information or any information on rudder movement. Right?

THE WITNESS: Right.

CHAIRMAN HALL: But what we do have is based on all of our simulations and tests no one, the experts at Boeing and elsewhere -- and I don't ever want to get in a situation -- but characterize that that there is a real possibility that there was a rudder movement in regard to this accident flight. What I'm trying to ascertain is how long has this particular rudder and this hydraulic system been on that plane? Since the very beginning or has it been -- is that the same rudder that was there in 1967?

THE WITNESS: It's the same rudder system, yes. The particular rudder PCU that was on the airplane had been put on in '92.

CHAIRMAN HALL: Has there been any changes to it, substantial changes since the initial design?

THE WITNESS: Not what you would call substantial, no. In fact, a PCU, an early PCU, if there are any still out there, you can install it. They're interchangeable. You could put it on a brand new airplane.

CHAIRMAN HALL: This particular PCU, do we know when it was manufactured? As Parker Hannifan, would you have that information?

THE WITNESS: It's in the record.

CHAIRMAN HALL: It had been in for service -- well, I'll get into this with Mr. White then. When the particular PCU we're talking about when it was manufactured and what its service history was --Now this certification test, special certification, the FAA and Mr. Donner are involved in, have you been involved in that as well?

THE WITNESS: Yes, I've been called to their CER team reviews to answer questions.

CHAIRMAN HALL: I assume we'll find out when the FAA is going to have a report later in that special certification, as well. How much testing has been done in the last years or has this particular incident just precipitated all this testing of this particular unit?

THE WITNESS: There's been a lot of testing, to my knowledge, that started on this component in the summer of '92 when the Mack Moore situation came up. I think there's been a steady stream of tests performed since then.

CHAIRMAN HALL: Since that period of time. And the modification that was put in that we now have, either you have it modified within a five-year period or you test every 750 hours, are you familiar with the tests that are supposed to be conducted every 750 hours?

THE WITNESS: Yes, I'm familiar with it.

CHAIRMAN HALL: What do they do?

THE WITNESS: In simple terms, they provide very fast and full rate inputs to the rudder while they're monitoring the rudder's position and internal leakage, using a clamp and using the pumps.

CHAIRMAN HALL: If there was a malfunction, how would you know it jammed or stuck or what would tell you that there was a problem with that unit?

THE WITNESS: If you're having a problem with that particular PCU, it would manifest itself in several ways. It could stall the pedals or you would feel a bump on the pedals or you would feel erratic motion of the pedals. Your internal leakage might also go way up.

CHAIRMAN HALL: Since they started that testing, have there been any problems with any of the particular PCUs that you're aware of?

THE WITNESS: No, there's been a lot of PCUs removed because of that testing, but that's part of the nature of the testing we removed. To be a little bit on the safety side, we removed units that really don't have problems. And none of the units we removed have had a confirmed servo valve problem.

CHAIRMAN HALL: Do they go to you or to Parker Hannifin?

THE WITNESS: They would go to Parker

Hannifin.

CHAIRMAN HALL: Are they rebuilt and returned to service, or what has been happening to those units, do we know?

THE WITNESS: In most cases, the operator has written up a report about it and they want to know the what's, where's and why's. So we usually meet them at the overhaul facility, Parker's overhaul facility, and go through the testing with them and try to see if we can find anything. If we don't find anything, which most cases we haven't -- in all cases, we haven't -- the servo valve is retrofitted and put back in service.

CHAIRMAN HALL: Well, I will look forward to the testimony from Parker Hannifin, Mr. White. I appreciate Mr. White being willing to let the representative from Dowty precede him in the order of things. We will continue after a half hour lunch break.

(Whereupon, a lunch break was taken.)

CHAIRMAN HALL: If we could get everybody back in, we'll call the next witness. The hearing will come back to order. Our next witness, as soon as the Chairman finds his correct name and title, is Mr. Manfred Runkel. He is the vice president of

Engineering with Dowty Aerospace in Los Angeles, California. Welcome, Mr. Runkel. I appreciate you being here and Mr. Schleede will begin.

THE WITNESS: Thank you for accommodating me.

(The witness testimony continues on the next page.)

MANFRED RUNKEL, VICE PRESIDENT, ENGINEERING, DOWTY AEROSPACE, LOS ANGELES, CALIFORNIA

Whereupon,

MANFRED RUNKEL,

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. Runkel, would you give us your business address, please, for the record?

THE WITNESS: It's 1700 Business Central Drive in Los Angeles, California. The company is called Dowty Aerospace, the Los Angeles Division.

MR. SCHLEEDE: What is your position at Dowty?

THE WITNESS: Vice president of Engineering.

MR. SCHLEEDE: How long have you held that position?

THE WITNESS: Relatively briefly. Since October of last year.

MR. SCHLEEDE: How long have you worked for Dowty?

THE WITNESS: That's it.

MR. SCHLEEDE: Could you give us a brief description of your background or education that qualifies you for your present position?

THE WITNESS: I was educated in Germany. I've got an equivalent of a bachelor's in mechanical engineering. I came to this country in '67. Been working with aerospace hydraulics since then. Initially at Boeing and then subsequent at several other supplier manufacturers.

I'm familiar with design and have designed, evaluated, tested components like we've discussed earlier.

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

MR. PHILLIPS: Good afternoon, Mr. Runkel. In your position with Dowty, could you briefly describe some of your day-to-day responsibilities at Dowty?

THE WITNESS: Well, they consist of managing the engineering department, all the aspects involving original design concepts through the detail design phases, analytical testing, et cetera, and including evaluations of products, field problems that may come up.

MR. PHILLIPS: What kind of components does Dowty manufacturer?

THE WITNESS: We make servo actuators. We make complete systems. We have one fly by wire system flying on the turbo prop. We make -- systems and components.

MR. PHILLIPS: So do you make an actuator?

THE WITNESS: Absolutely, yes.

MR. PHILLIPS: Actuator similar to the main rudder PCU?

THE WITNESS: Yes.

MR. PHILLIPS: Are you familiar with dual concentric valve design and principles of that design?

THE WITNESS: Yes.

MR. PHILLIPS: I understand you're involved with the Society of Automotive Engineers?

THE WITNESS: Yes, that's correct. For several years now, I've been chairing the servo valve and actuation panel for the SAE A6 committee. The A6 committee is a part of the aerospace council of the SAE. Our charter is essentially to review standards, generate new standards, disseminate technical information among all the people in the hydraulic aerospace association.

MR. PHILLIPS: So that committee is made up of other manufacturer representatives?

THE WITNESS: Yes, the representatives are all the prime manufacturers, the system manufacturers, the component manufacturers, subsystem manufacturers, down to the fluids.

MR. PHILLIPS: What's the product of that committee? Do you write reports, make presentations?

THE WITNESS: We meet twice yearly. We generate minutes of the meeting. That consisted of stand up writing and reviewing activities. That also consists of making technical presentations amongst the group. It's usually attended by about 200 to 300 people.

MR. PHILLIPS: As part of the activities that are involved in that committee, do you deal or have you dealt with hydraulic fluid contamination and could you give us a brief description of your experiences with contamination?

THE WITNESS: Like I mentioned before, I chair the servo valve and actuation panel. -- where it utilizes off the hydraulic fluid, with the contamination effects that are inherently in the fluids. We do have parallel contamination panel, but they are primarily chartered with establishing the filtration systems and the filtration requirements. I would say as a user, we discuss and elaborate on contamination effects on servo valves and actuators in particular.

MR. PHILLIPS: In your experience, do particulates and contamination affect the performance of servo valves?

THE WITNESS: If they're held within limits, they don't show any effects. I mean, there is no way that you get particulates out of fluids. They are there. They're constantly produced in the whole equipment primarily, pumps and motors, satellite motors that are in the system. There are also generated either during the manufacturing process and not completely being flushed out. That's also contamination.

Every time the system gets opened up, chances of contamination is there.

MR. PHILLIPS: When a manufacturer is designing with concern towards particular contamination, what are some of the options that they have to control the effects of those particulates in the valve?

THE WITNESS: Well, you've seen a couple of incidents in the previous presentation. There is the particularly placed small filters upstream of the power package unit. Typically we'll have one upstream of the servo valve or transfer valve of its load supply. You will also have an upstream of the ports themselves.

So this is like a last chance filtration, because typically you rely on the main filters in the hydraulic system. They were also mentioned earlier. There's a typical air filter on the pressure side, which makes sure the fluid coming down the line is clean. The 50 microns is a typical number for the commercial airliners.

The pump is protected in two ways. There's a case train filter that picks up the case and most of the particles are generated there. It's filtered at a 25 micron level before it gets back to the return loop. And then before the fluid hits the reservoir, there's another 25 micron filter there.

MR. PHILLIPS: So then the system is fairly dependent on its filter performance to clear out the particulates?

THE WITNESS: It's depending on the filter performs itself, but it's also very much dependent on the maintenance. If you let dirt accumulate in the filters longer than recommended or necessary or desired, then you'll end up with a dirtier system.

MR. PHILLIPS: In your experience have you seen anyone's particular type of contaminate, either particulate or chemical adversely affect servo valves?

THE WITNESS: I've got to go back way, way back, all the way to the introduction. For a couple of years there was a phenomenon or erosion of several valve edges and significant efforts were undertaken there to get this under control. But that phenomenon is no longer with us. So this is the only area that I remember where we had metering edges being eroded by the fluid, not necessarily related to contaminants. This was probably more of a chemical issue than a fluid or contaminant related issue.

MR. PHILLIPS: In your experience, are you familiar with any servo valve, problems with particulate contamination that results in jamming of the valve?

THE WITNESS: No, I don't know of any case. The servo valves utilized on the commercial airlines are somewhat more contaminate tolerant than servo valves utilized on different equipment, in the military for one. In as much as the type of the jet pipe valve has a significantly large opening. I believe it's somewhere around 125 microns or thereabouts. So it will pass even the most largest particulates. It developed itself as also one more filter built into the valve itself.

MR. PHILLIPS: In listening to the earlier testimony in this hearing, have you heard any discussion or description that you would determine to be detrimental to the performance or operation of the servo valve we're talking about?

THE WITNESS: I would imagine if you put contaminates in 50 times the value that's been observed in recent cases, yes, it would probably have detrimentation, but I have not ever encountered a situation like that, that was utilized for this test case, the accelerated devise.

MR. PHILLIPS: Are you referring to the

discussion this morning with the Boeing contamination test?

THE WITNESS: Right, exactly.

MR. PHILLIPS: Do you have any comments in general about the discussions with the chip shear testing that was discussed this morning?

THE WITNESS: No, not really. I think they are very much verified a study that the Air Force conducted about three or four years ago. I'm not quite sure. Maybe a little longer where the similar effort was being done to determine the optimum of a minimum chip shear force that would be required for particulate valves.

MR. PHILLIPS: What are some of the design considerations given to a servo valve with regards to chip shear capability?

THE WITNESS: I believe on the typical hydraulic servo valve, it probably generates about 80 pounds. And 100 pounds, 50 pounds, those are typical numbers.

MR. PHILLIPS: Is there any kind of specification or design guideline that you're aware of that defines or controls minimum limits of chip shear capability?

THE WITNESS: Yes, there have been some of our customers that have generated specification and that comes again from the military side where a different type of servo valve is now employed. Where the electromagnetic acting directly on a spool obviously does somewhat limit in the force capability.

So the way the chip shear force is specified now is you have to demonstrate that a wire, music wire, which has pretty much high strings for it, placed into the bigger slot will be overcome by the device. They are also saying you're allowed to have a restoring spring force to overcome that.

So that is the only specification that I know that is very specifically ties a chip shearing to a typical valve. Normally, the customers put in historical values and say okay significantly, maybe around 100 pounds.

MR. PHILLIPS: Is there any -- in the design or consideration of chip shear capability, are there any specific tests that you're aware of that take in consideration materials that the valve may be presented with?

THE WITNESS: No, I'm not aware of specific test requirements.

MR. PHILLIPS: Could you briefly describe related to your experience, the effects of particular contamination as it relates to increasing NAS-1638 grades or levels? And more specifically, as a general guideline in your experience, is there a class that provides a basis for most servo valve, a minimum grade for servo valve design?

THE WITNESS: Typically, we deal with classes 6, 7, 8, somewhere in between there. Those are typically the ones that are recommended, that are specified by our customers. That's about little worse than the fluid when it gets delivered. I think it can get delivered in a class 5 to 6. Tests are being maintained at about a class 8 level. So typically the industry or the manufacturing site deals with a class 8. I think also Boeing delivers them to a class 8 or better.

MR. PHILLIPS: We will have some testimony later on then as regards to what those classes mean and the numbers involved. In your experience, if you exceed class 8, class 9, is that any indication that you would have a failure or would expect a failure to the component?

THE WITNESS: I think in my experience, I would classify it as the dirtier your system, the shorter your component life is. That is basically a statement based on the fact that you either have abrasion or you have accumulation of those particles that are floating around.

Abrasion, you have seen this morning very vividly of what happened if you do it under high pressure. You have like a jet stream blowing sand by. Any metal gets in that way. With this happening, you lose your performance of the servo. Your pressure gains go down. Your internal leakage increases. That means, you're pumping more fluid around it. It's not doing anything. You're putting more heat in the system. Eventually you have to pull these units out.

MR. PHILLIPS: Would this indicate that you would expect a performance problem with the system before you would find a loss of control?

THE WITNESS: Oh, definitely. We would not lose loss of control. You may lose the crispiness. You may have more perceived dead bend.

MR. PHILLIPS: Would it be obvious to a manufacturer on an overhaul or a shop visit that the unit had been operated in contaminated hydraulic fluid?

THE WITNESS: Yes, by close examination of the metering edges, you could also know how long the unit has been out in the field. You could say it will probably come from a contaminated system. More likely than not, you may be taking a sample anyway.

MR. PHILLIPS: Does that provide a fairly quantitative value for the wear of the system?

THE WITNESS: I wouldn't go so far to put numbers.

MR. PHILLIPS: Dowty Aerospace is the manufacturer of the standby rudder actuator for the 737. Are you familiar with the design and the examinations of the USAir unit?

THE WITNESS: In principle, but not in detail.

MR. PHILLIPS: One of the issues that was discussed in earlier testimony was the concept of galling. Could you give us a brief description in your terms and in your knowledge what galling is and what it does to a component?

THE WITNESS: Every time I talk to somebody about galling, I get seldom in agreement, I guess, what exactly is galling. But what I would classify galling is a metal transfer from one surface to another. It's an irreversible process. It will go on. It builds up gradually against being operated, and it happens typically between sliding phases. It doesn't happen between stationary phases or oiling phases. You have different phenomenons.

The one positive aspect about this incident is that we tested the unit afterwards and have met the original equipment test limits and operating force which are a direct measure of the resistance that galling may provide the alternator level. I cannot imagine the scenario where there should have been higher galling and all of a sudden it's free. That to me, in my experience, has never happened.

I've observed galling on spools and sleeves or 440-C against 440-C. Once they're galled, you're not going to get them apart except to use very high forces. And then after you've done this, you'll never be able to get the parts back together. So this is an enigma to me.

MR. PHILLIPS: So as general design guideline, you would want to put hard surfaces against hard surfaces, and soft surfaces against soft surfaces?

THE WITNESS: Yes, you want some difference there.

MR. PHILLIPS: Going back to servo valve

design and possibly relate it to galling, we've heard some testimony of clearances in the order of millions of an inch and very small particle size as far as contaminants go. What purpose is served by manufacturing or designing parts with such close tolerances?

THE WITNESS: Well, usually you have to meet leakage requirements. If you make very light tolerance bands, you won't be able to meet a leakage requirements. We also will not get good control valve performance, because you have more fluid blowing by the metering edges than going through the metering edges. So there is the natural limits. You try to keep it as tight as possible.

CHAIRMAN HALL: Mr. Phillips, could we explore just very briefly? You say to have gall and you get hard and soft metal. Is that correct?

THE WITNESS: No. In order to avoid galling, you want to make a difference between the metals.

CHAIRMAN HALL: What's that again?

THE WITNESS: In order to avoid galling, you want to have a different metal.

CHAIRMAN HALL: Now what do we have in these valves? Are they hard and soft or are they hard and hard metals?

THE WITNESS: I don't know if I have the right metal callers. I believe one is 440C. The other one is a 416 stainless steel which is significantly softer than a 440.

CHAIRMAN HALL: So you have the hard and soft?

THE WITNESS: Combination like that, yes. Now don't hold me to this. That is one of the details that I'm not sure of.

MR. PHILLIPS: That is something we can provide additional information on in the report.

THE WITNESS: I'm sure it's been recorded.

CHAIRMAN HALL: We've had a lot of conversation about galling, and we're talking about this particular valve. We're talking about specific metals. It would be helpful for me and maybe for others to know whether those two different metals that we're talking about whether they're the hard and the soft or the hard and the hard. We've got some experts here. I want to take advantage of it and find out. Proceed.

MR. PHILLIPS: Thank you. I guess one question, one final question, in regards to in-service difficulties, such as galling or performance that involves your components, what would be the process that would be used to correct a design deficiency if one was noted? How would a problem be reported to you and how would you go about making a change?

THE WITNESS: There are two ways that I would find out about this. One way would be through our organization or direct feedback from the airline. More often than not, it comes from the Boeing organization. They are the ones that collect many more inputs for any service problems. They are the ones that get notified first. If there is a trend perceived at Boeing, they will contact us.

Then we will work closely with Boeing to investigate why is this happening, what's happening, and to make sure we understand totally the environment that it's working in, because before you go and look at a redesign of a 30 year old product that's been flying out there, you want to make sure you do an improvement and not stepping back.

MR. PHILLIPS: Is there a regular product improvement program that you have in place for this standby rudder actuator?

THE WITNESS: That's difficult to answer.

Let's phrase it this way, we're working very closely with Boeing to review the situation. If we should determine that there is an improvement possible, I'm sure we would support it.

CHAIRMAN HALL: Well, be more specific. What have you done since the accident in Colorado Springs?

THE WITNESS: Since this was ruled not to be a cause, at least to our understanding, other than looking at the design the way it currently is and trying to understand what's going on, we have not gone forward to look at the different options. We have an upcoming meeting with Boeing. The purpose of this is to review this one more time. That will be happening shortly.

MR. PHILLIPS: I guess to answer your question, Mr. Chairman, I'm unaware of any design changes since the Colorado Springs accident.

CHAIRMAN HALL: The question was not just design changes. The question was has Dowty sat down with Boeing since Colorado Springs?

THE WITNESS: Oh, definitely.

CHAIRMAN HALL: Whether they've got some galling on the standby? Am I correct or incorrect?

THE WITNESS: We have supported all NTSB

activities at the fullest. We were present at any of the tear downs of the actuator, any of the testing of the actuator. I didn't know that that's what you were asking for.

CHAIRMAN HALL: No, that's what I was asking.

THE WITNESS: Oh, definitely, yes.

CHAIRMAN HALL: What has taken place since then?

THE WITNESS: We've been not quite as active as our colleagues at Parker, but certainly we supported fully whatever was asked of us to do in conjunction with this investigation.

MR. PHILLIPS: Are you aware of any pending changes regarding the standby actuator?

THE WITNESS: I'm not aware of any pending changes. I'm aware that we want to look at it and see if there is a change that would be beneficial.

MR. PHILLIPS: I have no further questions at this time.

CHAIRMAN HALL: Do the parties have any questions? I see one hand. I want to be sure. Monsanto does not have any questions. All right. The only hand I see then is the Boeing group, John Purvis.

MR. PURVIS: Thank you. Mr. Runkel,

regarding erosion, would you differentiate between the electrochemical erosion that we had several years ago and the erosion that you maybe saw on the earlier exhibits on the Boeing accelerated particle tests?

THE WITNESS: Yes, most definitely. I would make a differentiation. I seem to recall pictures on the chemical erosion where not just the edges were eroded, but you could see a partway of the middling slots on the side of the spools and slides. So those are different appearance.

MR. PURVIS: And a different mechanism?

THE WITNESS: Yes, I believe so, but don't ask me the details on that.

MR. PURVIS: Could you also please elaborate on the Air Force chip shear study? Specifically, did the chip shear leave marks on the slide or the spool?

THE WITNESS: I cannot answer that positively. I don't know.

MR. PURVIS: Thank you very much. I have no further questions.

CHAIRMAN HALL: Thank you. Mr. Marx?

MR. MARX: Mr. Runkel, have you see the input shaft and the bearing from the accident airplane?

THE WITNESS: No, I have not seen it.

MR. MARX: Have you had a chance to look at the exhibit number 9-B?

THE WITNESS: Which page?

MR. MARX: Well, you can look at page 4, 5, 6.

THE WITNESS: Yes.

MR. MARX: You had a chance to look at that before?

THE WITNESS: Yes.

MR. MARX: Could you give me your opinion as to what would have caused this type of wear damage or galling that's on the shaft?

THE WITNESS: Well, I cannot give you an opinion, because I don't understand it.

MR. MARX: You also mentioned that there wasn't any design changes. But are you aware of the fact that the unlubricated portion of the shaft has been reduced in diameter throughout a design change?

THE WITNESS: That happened a few years, is that not true?

MR. MARX: Yes, it is. As a result of Colorado Springs, I think the safety board would out with a recommendation about the fact that this reduced diameter should be maintained on -- do you know the reason for the reduced diameter on that?

THE WITNESS: I don't know. Could you tell me?

MR. MARX: All right. You don't know.

MR. MARX: I have no questions.

CHAIRMAN HALL: Mr. Clark?

MR. CLARK: I have no questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Just one area I'm not sure if you were asked. Do you have any knowledge of any jams or frozen control valves in the standby rudder actuators for the 737 service history?

THE WITNESS: Yes.

MR. SCHLEEDE: Could you describe that?

THE WITNESS: Yes. In December, I was in Seattle I think at the same time when an EQA was conducted at the unit returned from British Airways, if I remember correctly. It was mentioned yesterday, it was totally rusted.

MR. SCHLEEDE: How about prior to that?

THE WITNESS: No.

MR. SCHLEEDE: Any knowledge of one prior to that time?

THE WITNESS: No.

MR. SCHLEEDE: Would you in your position know of those if there had been prior ones?

THE WITNESS: I would assume that I would have been told.

MR. SCHLEEDE: The one area you did mention here that you were aware that there was a need to look at the design of this unit and that Boeing is looking into this.

THE WITNESS: I don't want to say the need to look at it. I want to say maybe a desire to look at it.

MR. SCHLEEDE: Do you know if there's an active program to do that or Mr. Turner testified yesterday that that was one area Boeing was considering.

THE WITNESS: Yes, we have a meeting pending to discuss this. I would imagine it will come up within weeks, very shortly.

MR. SCHLEEDE: So there's no proposals at this point? It isn't at that stage?

THE WITNESS: There are a couple of schedules that we generated and we stuck those in the mail last week. It was to Paul Cline. He has not seen it.

MR. SCHLEEDE: Have you seen them?

THE WITNESS: Yes.

MR. SCHLEEDE: What are they in regards to? Are they in regards to the clearances in the input arm shaft?

THE WITNESS: No. It is basically a statement, yes, this input arm bearing could be designed differently. But before we settle on a version of it, we need to understand exactly what is going on with it.

MR. SCHLEEDE: Thank you very much, Mr. Runkel. I have no more questions.

CHAIRMAN HALL: Yes, sir, let me ask you a couple of questions here. You-all manufactured the standby actuator?

THE WITNESS: That's correct.

CHAIRMAN HALL: Does that standby actuator have fluid in it?

THE WITNESS: I hope so.

CHAIRMAN HALL: Good. Does it have filters?

THE WITNESS: No.

CHAIRMAN HALL: No filters. Have you had with that standby actuator -- again, the question is on the metal, what type of metals interface and move in there?

THE WITNESS: Could you repeat the question?

CHAIRMAN HALL: The input arm and what's the other one, Mr. Schleede?

THE WITNESS: Bearing.

CHAIRMAN HALL: And the control valve. Are those hard and soft metals or are those hard and hard metals?

THE WITNESS: Yes, that's what I mentioned earlier.

CHAIRMAN HALL: Have you had experience with galling as a problem? How common a problem is galling and what would cause the galling in you-all's experience, 30 years experience, with this standby actuator?

THE WITNESS: I cannot speak for the 30 years experience. I've been told that occasionally we see that which was pointed out earlier by Mr. Marx. I think some people call it metal transfers or smearing. I cannot tell you how often we have seen it.

CHAIRMAN HALL: Is there a program if there is a problem with your standby actuator to detect the problems and make modifications or exactly is there a procedure with your company to handle those sort of matters? I'm not looking for anything complicated, sir.

I'm just looking for a simple situation. You manufacturer a part. You tell me that the part has a potential for a particular situation to develop. Could you tell me if that situation develops, how you become aware of it and once you become aware of it, what you do about it?

THE WITNESS: If it is deemed to be a serious problem, obviously we'll do something about it. The way we do something about it is conjunction with Boeing --

CHAIRMAN HALL: Let me ask you, have you read the Colorado Springs' accident report?

THE WITNESS: Which particular one?

CHAIRMAN HALL: Issued by the National Transportation Safety Board --

THE WITNESS: I believe I read --

CHAIRMAN HALL: -- regarding the United Airlines Flight 585?

THE WITNESS: Yes, I read sections of it.

CHAIRMAN HALL: Have you read the sections that pertained to the servo valve and the standby actuator?

THE WITNESS: You're talking about the servo valve now or are you talking about the input joint?

CHAIRMAN HALL: The standby valve, I'm sorry. You have read parts of the report?

THE WITNESS: Yes.

CHAIRMAN HALL: My question then was what actions, if any, did Dowty take on the basis of that report?

THE WITNESS: I believe, and I'm not 100 percent, that based upon that report was the change implemented to reduce the outer land, but somebody has to verify that.

CHAIRMAN HALL: Now, what, again, is the procedure then if something has to be brought to your attention, then what is the next step? Get with Boeing or do you-all--

THE WITNESS: Yes, definitely.

CHAIRMAN HALL: -- independently --

THE WITNESS: No, we cannot do anything independently. Boeing has approval right to our design.

CHAIRMAN HALL: Boeing has what?

THE WITNESS: Approval right.

CHAIRMAN HALL: Approval right?

THE WITNESS: Correct. We cannot make

changes like this on our own and we don't make changes like this on our own.

CHAIRMAN HALL: Do you go to Boeing if there are problems that you think that might be with the parts you manufactured?

THE WITNESS: It's usually the other way around. Like I stated earlier, it's Boeing that has much more visibility of what's happening out there in the field.

CHAIRMAN HALL: So who services the part?

THE WITNESS: We do or authorized service centers.

CHAIRMAN HALL: I guess my question is if you're servicing the parts, they're being sent to you, and a problem -- let's just assume a problem with galling was identified, would you then go to Boeing or would you wait for Boeing to come to you-all?

THE WITNESS: We would certainly discuss this with Boeing if we find a serious problem.

CHAIRMAN HALL: Is there anything, sir, that you think that would be helpful to this hearing that you would like to add that would help the parties, help the investigation, help the American public understand what happened to this USAir flight?

THE WITNESS: I believe that I am too new to our product, the Dowty product, to render any suggestions other than what I've made so far. I'm not that totally familiar with the rudder system itself, the combined function of the standby rudder that's going along for the ride essentially of most of its life and doesn't do anything with the main PCU. And how the standby actuator moves when the yaw damper gets exercised, I don't know the effects that it has on an unpowered rudder.

So I cannot add any more than that. My plan is to discuss those things with the Boeing Company.

CHAIRMAN HALL: Very well. We have notice that you must leave by 2:00 and we have you out of here by 2:00. So thank you.

THE WITNESS: Thank you very much.

(Witness excused.)

CHAIRMAN HALL: The next witness is Mr. Steve Weik. He is the senior engineer for Parker Hannifin Corporation in Irvine, California.

(Witness testimony continues on the next page.)

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 Bertea Corporation, 14300 Alton Parkway, Irvine, California.

MR. SCHLEEDE: How long have you worked for

Parker?

THE WITNESS: Sixteen years.

MR. SCHLEEDE: Was is your present position?

THE WITNESS: Project engineer of 737 primary flight controls, 747 primary flight controls.

MR. SCHLEEDE: Could you give us a brief description of your education and background prior to reaching this position?

THE WITNESS: I have a degree in mechanical engineering. I graduated from U.C. Irvine in 1979. Hired in with Parker right out of school.

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

MR. PHILLIPS: Good afternoon, Mr. Weik?

THE WITNESS: Good afternoon.

MR. PHILLIPS: Could you give us a brief description of organizationally what Parker is and where your organization fits within the company?

THE WITNESS: There's two sides to our division in terms of control systems division. We have an OEM side that deals with the airplane manufacturers and then we have another side that's the overhaul facility that deals with the airlines. I am currently and have always been on the OEM side.

I am the technical lead on that side. My position since 1986 has been a liaison for Boeing Engineering on their product to their part in our shop that we manufacturer. I am also liaison to the service side in communicating with them and the technical side of the products, since their priorities are towards overhauling and servicing. I provide technical assistance to their side.

My other responsibility is to provide the assembly and test area of our area, any assistance needed in making the product to get out the door.

MR. PHILLIPS: We've heard the name Bertea and Parker Bertea and Parker Hannifin. Could you clarify to us who all those people are?

THE WITNESS: Sure. A little history lesson is that originally it was Bertea. I believe that started in the -- I should know better. But I believe in the early '50s. And Bertea Corporation was bought out by Parker Hannifin in, I believe, 1978. At that time, it became Parker Bertea Corporation. It's caused over the years some confusion for a lot of people. So recently in the last few years, it's been referred to Parker Control Systems Division.

MR. PHILLIPS: So when we address you, it would be Parker Controls Systems Division?

THE WITNESS: True.

MR. PHILLIPS: That would be most appropriate. Where are your offices now?

THE WITNESS: We have an office in Irvine. We also have -- actually, two offices. We have the OEM office in Irvine on Alton Parkway. We also have the Service Division on Irvine that is on Von Carmen. And more recently, we have a facility in Ogden, Utah.

MR. PHILLIPS: In your position as an OEM supporter, are you involved in the -- are you notified when problems occur with your unit's in-service?

THE WITNESS: I'll describe the way our operation works is the overhaul side, the service side has two ways of hearing about an incident or some sort of anomaly or problem or just a maintenance issue. One, directly from the airlines. They will call our maintenance and head of maintenance -- or excuse me, head of our overhaul technical side is Mr. Walz. He is contacted directly by the airlines or the people working underneath him of something.

The other way is through Boeing Service Engineering. Either of those two methods are used to provide us with accounts of maintenance issues or whatever.

MR. PHILLIPS: Do you have any kind of formal trend monitoring or program within Parker that tracks returns and repairs?

THE WITNESS: Since 1986, I think we've been formalized and up on the computer. We basically -- when you receive a unit in from the airlines on the overhaul side, it's gone through a functional receiving test. That information is -- from that you can determine what the discrepancy is or what performance parameter it isn't meeting. That gets logged into a database that we have. It basically gives a serial number.

If we can get hours from airlines, that's not necessarily something that's easy to get. But we get the unit. We do a functional test. We write up anything that is discrepant on it, and we record that into our database. Now that database is used for several purposes. One, to generate trends.

We have a policy that if you see more than three discrepancies of the same nature, for instance, external leakage, any sort of leakage problems, binding friction, we have probably about 25, 30 categories described of anomalies or problems.

What we do is if we get three in 20, we send a flag up and the engineer in charge at the overhaul facility will go out and run a check. They have engineers on site. We have a trend report that's published every month that gets over to me as the project engineer.

At that time, I see it. If there is an issue from the airline side or in the service side, then my job is to contact and have a discussion with the systems group involved in the product we're dealing with.

CHAIRMAN HALL: Excuse me, Greg. If I could ask a question here. This form with the number of miles on it from the airlines, how many miles the plane has flown. Is that what we're talking about?

THE WITNESS: No.

CHAIRMAN HALL: How many hours?

THE WITNESS: Mr. Hall, that's something -- it's the airline's discretion if they're going to give us hours on what the unit.

CHAIRMAN HALL: But doesn't the form you have have hours on it?

THE WITNESS: It has -- I believe --

CHAIRMAN HALL: To fill in hours?

THE WITNESS: I believe it has a place, but that's something that's at the discretion of the airlines.

CHAIRMAN HALL: Why is that at the discretion of the airlines, just out of curiosity?

THE WITNESS: I can't answer that, sir.

CHAIRMAN HALL: It may not be anything major. I just happen to -- you were very nice and let me come tour your facility and I looked at the forms that were on the actuators -- I mean, the units that were coming in, and I remembered looking at the hours and noticing the hours. But what is required and what's not required?

THE WITNESS: It's obviously very helpful. We do generate those. As I said, one of the issues is for me, as a project engineer, on sustaining hardware. However, we also use it to generate new design and we use it in our reliability group and trying to use numbers when you see FEMA --

CHAIRMAN HALL: Will these units last forever? Is there a lifetime to them in terms of years, miles, hours, anything, or can you just continue to over and over again recycle them?

THE WITNESS: That's a good question. There is a rule of thumb or general -- it's usually described in the standards that we receive in the spec. A rule of thumb that floats around in the industry and, again, I'm only one person, but it's around 60,000 hours that a unit is designed towards.

Now whether or not we go through a qualification testing on all units and it goes rather severe testing and we get no where near that, we usually deal in cycles and usually deal in millions of cycles when we qualify this unit. We consider that enough to meet the life requirements. Designs are always determined way above what the expected life is.

CHAIRMAN HALL: I appreciate that, but I believe a lot of these aircraft are operating long past their lifetime. Is that correct? The anticipated lifetime when they were initially manufactured?

THE WITNESS: Mr. Hall, I think I would like to refer that question to the airlines. I'm not an expert on that.

CHAIRMAN HALL: Go ahead.

MR. PHILLIPS: Backing up to the trend data that we were discussing, what would be, in your opinion, one of the more common failures you would expect to see a PCU coming in for these days?

THE WITNESS: Specifically?

MR. PHILLIPS: I would just say if the first thing that popped into the top of your head of why you would expect a PCU to becoming into repair, what would it be?

CHAIRMAN HALL: Isn't that information put on a computer and maintained? I mean, do we have that information?

MR. PHILLIPS: We haven't requested that information.

MR. PHILLIPS: What I would like to do is get some feeling as to what you might guess would be the most common cause for a rudder PCU to be returned for repair of any sort?

THE WITNESS: I think our numbers show that it's around or about 75 percent external seal leakage on the main ram seals. You have a requirement of one drop in 25 cycles, which is a standard of four drops in 100 cycles of leakage.

Seventy-five percent of the units on a PCU rudder that come in, I understand, that Parker services about 30 percent of the marketplace. The other 70 percent is the airlines themselves, other outside third-party houses. Our data shows that it's about 75 percent of external, of the removal reason for coming in to our shop is to replace the worn seals on the main ram.

MR. PHILLIPS: So once the unit is removed from service and comes into your unit -- or into Parker, could you give us a brief summary of what would happen as it would be processed in for -- say, for instance, if the initial squawk was that it was leaking externally?

THE WITNESS: We go right -- there's a couple of ways of approaching it. If it's a severe squawk, we'll usually go right to it and try to determine the anomaly right off in hopes that earlier testing or other testing wouldn't destroy the evidence.

However, the norm is is we get a unit back in and we usually perform the standard functional maintenance manual that Boeing referred to earlier testing, which covers about 22 parameters. We run it through that test. We basically record that data and put it in file. Then based on what we find, we'll do repair work. We'll usually notify the airlines and then we'll do the repair work based on their approval.

MR. PHILLIPS: You said earlier that about 70 percent of the units are being worked on by airlines rather than Parker. Is that correct?

THE WITNESS: That's ballpark number, yes.

MR. PHILLIPS: Ballpark number. Do they follow the same procedures that you do when you bring it in for review?

THE WITNESS: I can't answer that.

MR. PHILLIPS: That's something that is worked out with Boeing then, the procedures they use to overhaul their rudder PCU?

THE WITNESS: This is true. The overhaul manual is a standard for the rudder PCU.

CHAIRMAN HALL: Just one quick question, and I hate to keep injecting, but I like to follow this logically. Do they come in only when they need repair or do they come in on some regular suggested interval?

THE WITNESS: Again, Chairman Hall, I believe I would refer that to the airlines. The norm that we see is either under warranty work or that they have some squawk. Whether that follows some routine check, the C-check or other.

CHAIRMAN HALL: What kind of warranty do you-all give if I go and buy me one of these things?

THE WITNESS: I guess I'm going to have to say that there is others at my table that are more versed in that. I really don't know.

CHAIRMAN HALL: Would anyone like to respond?

MR. SIMMONS: We don't have that data here. We can supply it later.

CHAIRMAN HALL: All right. They are going to supply the information later. Please proceed, Mr. Phillips.

MR. PHILLIPS: In regards to the main rudder PCU design, the original design, could you give us a summary of the genesis of that part, it's beginning, how it was designed, by who time frame?

THE WITNESS: I believe there's been some earlier testimony on some of the history on it, but I'll give you my best shot of it. Basically in the late '60s, mid '60s, I believe more closer to the mid '60s, Boeing was in a phase of designing the 37. At the time, they were in need of engineers. Parker, at the time, Bertea actually, supplied engineers as shop jobbers under the direction of Boeing Engineering.

The testimony given yesterday by Mr. Sheng indicated that he had linkage design -- had designed the linkage on the rudder PCU. We also know that this design is on Boeing paper and is under the design constraints of Boeing Engineer.

Basically, Parker or actually Bertea supplied job shopping engineers under the direction of Boeing. When it went into production in the late '60s, 1967, Bertea carried out the qualification and then production of it since that time. Basically that's where we are.

MR. PHILLIPS: Does anyone else manufacture a main rudder PCU for the Boeing 737, to the best of your knowledge?

THE WITNESS: No.

MR. PHILLIPS: Do they manufacture any components for the PCU, sub-level components?

THE WITNESS: I can't answer that.

CHAIRMAN HALL: Do we have how many have been manufactured in the record?

MR. PHILLIPS: I don't know if we have a total. We could get that.

THE WITNESS: We can give you that number. I think a rough number that we're working off of in regards to the airworthiness directive is roughly around 2800, but it's well above that when it comes to looking at spares and others.

CHAIRMAN HALL: Do you currently manufacturer new units?

THE WITNESS: You bet.

CHAIRMAN HALL: How many do you put out a year?

THE WITNESS: Well, depending on how many people are buying 737s, the shipment rate, at this time, I think is around eight ship sets. A rough ballpark number right now.

CHAIRMAN HALL: And what does one of them cost or is that proprietary?

THE WITNESS: I would decline to answer that.

MR. PHILLIPS: I doubt that we could afford one. In the eight units you speak of, are eight units per month?

THE WITNESS: That's correct.

MR. PHILLIPS: That's dependent upon the airplane manufacturer rate that would require a PCU. Is that correct?

THE WITNESS: Basically, it could be down to one or whatever quantity is demanded by their manufacturer.

MR. PHILLIPS: In your experience, in your position that you're in now, what significant changes have you seen made to the PCU package, design changes?

THE WITNESS: There's currently 11 different configurations of this rudder. The only significant change is are when we change from a dual yaw concentric or dual yaw system to a single yaw system, and when we change from 4 degrees, 2 degrees to 3 degrees. Those are all in different configurations and you could determine which configuration you're working with.

Then later on -- and that was very early on in the program, the '70 time frame, early '70s. Later on, as I stated, external leakage is nothing new to us and it's been something that's kind of inherent on this particular package.

We've been working towards trying different seals through the different seal manufacturers, have worked with Parker and Boeing to try to address premature or what we consider -- what we would like to see as an extended wear on any of these seals.

So the last few configuration changes have been based on seal changes and attempting to reduce the amount of external leakage.

MR. PHILLIPS: How would external leakage affect the performance of the package in relationship to the airplane?

THE WITNESS: External leakage when you're talking about one drop in 25 cycles or four drops in

100 cycles as we deliver it new and the service limits go up a little bit, I think it doubles. If you'll ask the airlines, I think the airlines will say it's more of a nuisance.

The fluid used in these packages is BMS-311 and it's very acoustic to paint, human hands, skin, whatever. It's not a very friendly fluid. In terms of performance, again, I think I would like to -- Boeing would be the better person to answer that.

MR. PHILLIPS: I guess I could ask, are you aware of any reported control difficulties of loss of control as a result of external leakage?

THE WITNESS: To my knowledge, the leakage that we see is usually a nuisance. It's not considered a performance problem.

MR. PHILLIPS: Any other regards in your experiences in this position, have you seen any other changes to the package, design changes?

THE WITNESS: It's been stated in earlier testimonies that we are currently in the process of carrying out an AD. That AD is against the servo valve. That is probably the most significant change that we've gone through in the last 20 years.

MR. PHILLIPS: Did you participate in the early phases of that AD process that define the changes that were required to the package?

THE WITNESS: Yes, I did.

MR. PHILLIPS: In regard to the accident investigations of the Colorado Springs airplane, USAir 427 and the other United airplane we've referred to in earlier testimony, were you involved in each of those?

THE WITNESS: Yes, I was.

MR. PHILLIPS: Could you briefly describe your involvement in the Colorado Springs' investigation?

THE WITNESS: I first got involved in April of '91 at the Irvine facility, the overhaul Irvine facility. The NTSB, United, and I believe the whole systems group at that time, came to our facility or came to the overhaul facility, and I was contacted to support the technical end of it.

At that time, I believe it's PCU serial number 833, was brought in in severely burned and what appeared to be impact damaged state and was in several pieces, many pieces. There was not anything intact that you would see go out of an overhaul facility or a new facility.

The servo valves were also detached and

carried in separately. In fact, the servo valve itself was missing the end cap and the spring in the back of the servo valve. So it had been pulled apart. That was my first involvement with the flight 585 or PCU 833.

Later in 1992, in the summer, there was earlier testimony, a unit came in. I believe that was PCU 2228. More commonly referred to as the Mack Moore unit. I think we've heard testimony on what was seen and what the results of that was.

We did several other PCU testing during that time. There seemed to be a -- well, basically we were going through quite a bit of testing on different units that they felt that I think we saw several United units come back. Then we also had the 585 valve reinvestigated or looked at, the servo valve.

I would like to comment, though, that the servo valve initially in April was ceased and placed due to fire damage. The fire had baked and frozen the primary and secondary together. It had to be removed forcefully and was later cleaned up in terms of what we call in the industry, was done as a light wipe so that the parts could slide in its normal fashion.

There's already documentation in the Colorado

Springs' docket as to the condition of the valve. We were able to test it, but there was damage in this valve. There are individual wafers. Those wafers were separated, which caused some problems in its performance. We believe the separation was due to impact.

We went through a rather extensive investigation with the Colorado Springs. However, for the phenomenon that later resulted in the AD.

MR. PHILLIPS: Do you recall whether that Colorado Springs' valve ever reversed on any of the testing that was performed at Parker?

THE WITNESS: No, it did not.

MR. PHILLIPS: And by reversing, you mean reverse flow or reverse porting of the fluid? Were we able or were you able in all cases to test the valve in its original as manufactured condition?

THE WITNESS: To the extent, we were able to test the valve, understanding that there was damage to the stacks and that it was not a perfect condition valve that you would see out of a new. That we were able to test it in that state.

MR. PHILLIPS: You stated that when you received the valve or you saw it the first time that it was in some state of disassembly, where was that done and who had done that?

THE WITNESS: I was not involved at the site or at the hanger in United. Mr. Walz of our organization, who is our DER or FAA representative, he was involved with a man from the quality organization. He was there present at the time. I would have to refer the questions to Mr. Walz on that part of the investigation. That was in April, several weeks later, that I was involved.

MR. PHILLIPS: Was it under the control of the NTSB at the time?

THE WITNESS: That's correct.

MR. PHILLIPS: The Mack Moore testing, the United airplane, was that under the control of the NTSB at the time also?

THE WITNESS: There was some confusion on that. United witnessed it, and they contacted Boeing and Parker. Parker representatives met up at United. To my recollection, they did not see the reversal up there after it happened the one time or they did see a stall. They brought it back down to Parker, at our facility. At that time, United and Boeing and ourselves were together.

It was a few days that lapsed that the NTSB was brought in. At that time, there was some feeling that the NTSB was being excluded and that was not the case. It was just a matter of lack of understanding on some of our parts that NTSB was still investigating the Colorado Springs.

There had been a fair amount of time lapsed between that event and the Colorado Springs.

MR. PHILLIPS: Could you describe your participation in the investigation of the USAir flight 427 accident?

THE WITNESS: I guess, based on lessons learned or some experience that we have gained in getting educated on the 585 investigation, we were contacted. Mr. Walz was contacted as being our FAA representative, I believe, on September 13th, and was asked if we would like to participate under the auspice of NTSB to help in removal of the rudder or witness the removal of the rudder.

So on September 14th, we appeared in Pittsburgh and on September 15th, we aided in assisting the systems group in trying to prevent any loss of evidence on this valve. Because of 585, we were aware that the things that were of concern were in the thousandth of inch category or .001, and when you look at an airplane, it's in the scales of feet. We felt it was important that if this valve was going to be scrutinized, that we maintain as much evidence as possible.

So we came in through the hanger after it had been removed from the site. That's where we proceeded to get involved.

MR. PHILLIPS: Did you feel -- Mr. Cline testified earlier this morning that the possibility that some of the initial data may have been compromised by handling. Do you share that feeling?

THE WITNESS: Yes, I do.

MR. PHILLIPS: So more specifically in regards to the position of the actuator at the time of removal from the accident site until the time that you were involved, could the position of the valve have been changed?

THE WITNESS: That's a possibility.

MR. PHILLIPS: Would that have affected any of the investigations or examinations that we've done to this point?

THE WITNESS: Yes.

MR. PHILLIPS: How so?

THE WITNESS: Well, when we secured the unit and brought it back to Boeing and as already testified by Mr. Cline, we were able to determine the position of the main ram PCU at impact. On this particular case, because the piston rod was bent, I believe that we can give an honest calculated position of the rudder at impact.

However, had that unit not been bent in that position and in picking up the vertical fin and people touching the actual rudder surface, there would be the possibility of pushing the rudder, retract or extend, and we would, therefore, lose possible positioning of the rudder.

Since we don't have flight data recordings as to where the rudder electronically is determined to, we only have this somewhat archaic way. Therefore, anything can be possible.

MR. PHILLIPS: I understand your point. How confident are we or are you in the position that's been determined as the position of the rudder at impact?

THE WITNESS: I think we took every precaution possible once it was in the hanger to secure it. I think from the witness marks on the piston and realizing that it had to be cut out of there and there was no movement of any type when we were cutting it out. It was in there pretty good. Meaning, it was in its normal position as it would have been installed and was secured between the strut and the horn arm, that I believe that it is a good representation of where it was at impact.

MR. PHILLIPS: So the reported position of approximately 2 degrees right rudder is, in your opinion, an accurate position of the rudder at impact?

THE WITNESS: Yes.

MR. PHILLIPS: Based on the witness marks?

THE WITNESS: Yes.

MR. PHILLIPS: I guess, the point of your testimony is that had we not had a bent rod, we stood the chance in handling the wreckage of losing that position in the absence of having a recorded position by flight data recorder?

THE WITNESS: That's correct.

MR. PHILLIPS: So then can I go one step and say that you would recommend additional flight parameters or position parameters for flight data recording?

THE WITNESS: As an engineer, I think you heard earlier testimony that all of us in the technical world would benefit. I think being in the sustaining engineering area, not related to the airlines, but even in our field where we get a lot of information based on squawks, it's very difficult to analysis what that means in PCU terms.

If we had flight data recordings that showed specific positions of the rudder, we could probably go to the anomaly quicker than what we are doing at this time.

MR. PHILLIPS: Backing up a little bit to the point where we picked up the rudder and began the testing, could you take us through the chronology of the testing that was accomplished at Parker and your involvement at testing at Boeing?

THE WITNESS: I'll pick it up from where we left Boeing and were down at Parker. We, again, because of the experience that many of us who were there had gone through with 585, we were very cautious in allowing any of the parts to move, any links, the ram, that sort of thing. We very slowly disassembled the unit.

To get fluid samples was one of our first things that we did. We also did a dialectic. Essentially in a nutshell, we did the full acceptance test procedure. When we eventually got down to witnesses the actual state, we video it. We took many, many pictures to verify the condition before we disturbed anything.

Then we went through and checked forces, input forces on the pilot input point. As Mr. Cline earlier testified, that we went through and took lots of fluid samples in different areas under the NTSB's direction. We had to replace parts. The main ram was damaged. The H-link and the pilot input link was damaged.

We had to put in -- we had to disassemble the unit enough to get the main ram out of there and put in a new ram. It was under the members' consensus that we didn't feel that that would damage any of the internal summing linkage or any of that.

At that time, the crank arm was still secured, as I believe, and my recollection is fading a little bit. But I believe that the main ram was -- or the external crank arm was still shimmed while we put in these different components so we wouldn't disturb that.

Then we went back and had a new piston in there and a new H-link, a new pilot summing arm. We believe that that information, there was no way around testing, unless we replaced that.

So we went through that procedure and then diligently went through and checked the summing lever arms. We opened up the cap. Looked at the summing lever arm to determine their position. When we took some measurements that normally aren't taken and it was somewhat difficult to do, but it was a first shot at it to determine where the primary and secondary slides were.

We proceeded on to do all the functional testing on the top level. Then at that time, we had a caucus and tried to determine what we should do next. One of the things we did is similar to what we had tried and what we had performed in the case of 228. That was that in order to get it to dual reversal, you take the pilot input arm and you cycle it at probably a rate beyond what the pilot could do.

You cycle it back and forth, as fast and as hard as you can in an attempt to make it reverse. We did this until everybody had an opportunity to do it amongst the members, until their hands got sore, and we didn't see any sort of reversal.

At that time, I believe we came down to

disassembling it. The scrutiny would go towards the servo valve. Am I getting too detailed?

MR. PHILLIPS: I'm going to jump in and give you a rest here for a minute. Mr. Cline testified earlier that as a result of the testing, although there were anomalies found, there was a summary conclusion by the group that the unit was capable of functioning for the purpose it was designed. Were you part of those discussions and did you agree to that?

THE WITNESS: Yes, I did. Yes, in both cases.

MR. PHILLIPS: You believe that his testimony this morning was accurate?

THE WITNESS: Yes.

MR. PHILLIPS: After the disassembly, examinations and testing at Parker during that phase, was there any additional testing performed that you participated in?

THE WITNESS: I think it's been recorded that we have met seven times in different locations under the NTSB's direction. So we've done numerous, different tests beyond the normal performance parameters that we check on PCUs that go out.

MR. PHILLIPS: I guess more specifically, I would like to address the two issues of the chip shear testing that was done at Boeing and your participation in that. Also, the residual pressure, differential tests that were discussed this morning in some detail that were performed at Parker.

I think first we'll go in the order of the tests. The residual pressure test on the servo valve, did you participate in those tests?

THE WITNESS: Yes, I did.

MR. PHILLIPS: Could you describe to us the Parker facility that was used for that testing and the test set up?

THE WITNESS: We, in this occasion, worked at the OEM facility. On the other occasions where we gathered, we were usually doing it at the CSO facility. But OEM and CSO are mere images, are one in the same for that part.

We have hydraulic test boards that extent that have flow capacity up to 80 GPM. On the servo valve is what we did the residual pressure at. It wasn't at the PCU level. We extracted the PCU or the PCU was separated. We tested the PCU separately in a fixture that we use for production to test the 13 different parameters that this valve is made to.

In this case, we deviated from those 13 tests and we performed a test where we simulated different failure modes of the valve. Basically, I think those are stated in 9-AH. I'm not sure which docket.

At that time, we pressurized it to 3,000 psi, which is inlet pressure, and we performed the different positions of the slide and we read the gages. These are gages that are plugged. It doesn't have the line losses that are normal for a PCU. So these pressures would be not 100 percent, but close enough.

CHAIRMAN HALL: Mr. Phillips, my understanding is there was a design review conducted by the FAA and Parker after the Colorado Springs' accident. Is that correct?

MR. PHILLIPS: I'm not aware of an FAA design review. The board wrote a safety recommendation asking the FAA and Boeing to review Parker manufacturer dual concentric valves in light of the secondary over travel jamming or reversing. If you're speaking to that, we can address that issue.

CHAIRMAN HALL: Well, I'm referring to the recommendation 92-121, which asks the FAA to conduct an exam review of servo valves manufactured by Parker Hannifin, which are similar in design to the Boeing 737 rudder power control unit servo valve.

MR. PHILLIPS: Okay.

CHAIRMAN HALL: That's it?

MR. PHILLIPS: That's it.

CHAIRMAN HALL: My question is are any of these tests related? Do they do the same test over again or not? Are we talking about a different part of the rudder?

MR. PHILLIPS: We'll ask Mr. Weik to address that question, if he can.

THE WITNESS: That request came from Boeing. The FAA, I believe, requested it of Boeing, and Boeing came to us. We reviewed all our servo valves, both dual concentric and single system or all our single valve slide sleeve arrangement. The condition we checked for, we checked all, I believe, it was nine valves for a specific case of the valve that we saw on flight 585.

So, yes, we did, and we found, I believe -- and it's strictly off memory, that document is available. There was only one unit and it was out of production and it was on a military airplane, and it was not a big production. I think it was a limited production on a 707, but that's strictly by memory. We can qualify that. But we check all line valves that are currently in production and there was no reversal anomalies.

MR. PHILLIPS: So the testing was done specific to the reversal condition. Were there any other failure conditions or modes considered during that review?

THE WITNESS: No, there were not.

MR. PHILLIPS: Was the direction for that review just the specific requirement of the recommendation of the FAA's goals and objectives or, I guess, what set the objectives for that review?

THE WITNESS: Well, it was primarily based on what we knew and we had gone through with the 10-91 which is off of the 585 valve.

CHAIRMAN HALL: Well, again, it says here that they were going to look at flight control malfunctions or reversals. So they looked at reversals or they looked at both or --

MR. PHILLIPS: I think they selected the or, the reversal condition.

CHAIRMAN HALL: Only?

MR. PHILLIPS: That's the answer that I'm hearing. Is that correct, Steve?

THE WITNESS: Again, we supplied analytic data that showed those specific servo valves to Boeing and that's as far as I can go with that.

MR. PHILLIPS: Mr. Chairman, I would suggest that in later testimony with the FAA, we will have people involved who were involved in that.

CHAIRMAN HALL: That's fine with me, as long as Steve's going to be here in case we want to ask any more questions about this, because in all seriousness, the taxpayers paid for a lot of tests after Colorado Springs. What I'm trying to do is find out what tests were made then and what's been done now. I think that's a reasonable question.

THE WITNESS: I agree.

CHAIRMAN HALL: Please proceed.

MR. PHILLIPS: In the testing that was done, I believe the second week of January in regards to the over travel conditions that Mr. Cline spoke of this morning, were there any additional tests performed during that meeting of the systems group?

THE WITNESS: As Mr. Cline has stated and I think the members of your system team can testify, we've done a rather extensive look at this overall PCU and the servo valve understanding that it's of high profile.

MR. PHILLIPS: More specifically, the over pressure test or the high pressure test?

THE WITNESS: Correct. We looked at a condition that because of the nature of the servo valve and the understanding that all valves have very close clearances that they are designed to, there was one scenario that would leave no witness marks that might have caused the jam and that would have been what we would refer to as clamping, deflection of the inter ID to the OD.

Actually, OD clamping on the ID of the slide -- primary slide bore on the secondary slide being clamped by the valve body. That is something that in the initial design and the initial testing of the valve, we go through and we have to hand fit each of these valves to the type of clearances that have been discussed earlier.

In light of that, we thought that to show that there was no clamping, we took pressures that was determined to be the maximum amount of pressure that a pump could put out without kicking a check valve. Again, that I will have to refer more to Boeing to give you information on it. But we took a pressure of 3850 or 3,850 psi in a normal 3,000 psi system to see if we had any restriction of movement on the primary or secondary slide different from that of the 3,000 psi that normally would be in there.

I think you'll look in that docket or in exhibit -- what is it, 9. I think basically you'll see information in there showing you that whether it was 3,000 psi or 3,850 psi, the forces to move the primary slide and the secondary slide were the same. That we felt strong that clamping could not be an issue here that would have caused that valve to jam.

MR. PHILLIPS: Are you aware of any other events where clamping has happened, occurred?

THE WITNESS: No, I am not.

MR. PHILLIPS: So the question was raised or the test was done more out of curiosity than a requirement that's specified anywhere?

THE WITNESS: That's true.

MR. PHILLIPS: In earlier testimony, we discussed the effects of contamination. In particular, particulate contamination on PCUs. Could you comment generally on your experiences with contamination and its effects on the rudder power control unit?

THE WITNESS: I really don't believe I can add much more to what's already been testified. We rely on the filtration system. Parker in 1971 -- like all companies, we have an internal specifications.

We have a specification that's called the BMF, which is a Bertea manufacturer specification that we created to maintain a class 5 -- worse case class 5, best case 2 on our test boards. We have a contamination lab that monitors that on a daily basis. So our hydraulic boards are maintained at a worse case is class 5.

MR. PHILLIPS: More specifically, are you aware of any main rudder Parker manufacturer Boeing 737 main rudder power control unit, that's operated in an other than intended direction as a result of a jam?

THE WITNESS: Could you repeat that, please?

MR. PHILLIPS: Boy, that will be tough. Are you aware of a jam ever -- have you ever heard, have you ever tested, have you ever read at Parker about a jam main rudder PCU from a 737?

THE WITNESS: I personally have not witnessed any. I know there is -- being in part of the 585 and I'm familiar with the documentation in there of the different cases. All those were before my time. The one that was stated was the corrosion one that happened in the '90 time frame, I believe.

The origin of where that came from never reached us. So to answer your question, no, I have never personally seen a jam.

MR. PHILLIPS: Are you aware of any testing that's been conducted without the NTSB's presence in regards to either the Colorado Springs' accident or the USAir 427 accident?

THE WITNESS: No, I'm not.

MR. PHILLIPS: Have you been involved in any failure modes and effects analysis of the main rudder PCU in your time with the unit?

THE WITNESS: Only in recall in the airworthiness directive. We performed a functional qualification test on that valve to assure us that we had remedied the anomaly.

MR. PHILLIPS: So then you're saying as a result of the airworthiness directive, the valve was looked at again for its performance capabilities?

THE WITNESS: Not in its entirely.

MR. PHILLIPS: Specifically, what was changed for the AD?

THE WITNESS: I think earlier talked that we restricted some of the travel between the linkage stops

and the internal stops. We went back once. We
incorporated the design change. We went back in. We
tested. I believe you have that data in your
possession.
MR. PHILLIPS: In the process of reviewing
those stops and modifying the design, did you uncover
or did you come up with any data that would say that
Parker had ever or a PCU had ever been reported to
Parker that had reversed?
THE WITNESS: Not to my knowledge.
MR. PHILLIPS: Do you know whether the
question was asked or not or was that specifically
examined?
THE WITNESS: Again, as to whether Parker --
any Parker employee had seen a reversed rudder?
MR. PHILLIPS: I was looking more
specifically for a data that had been provided to
Parker from an operator that said that they had
experienced a reversal of a main power control unit?
THE WITNESS: I guess, I'm at loss on how to
-- we've so many units. We have not experienced any
reversal other than the 2228 Mack Moore unit. It's the
only one that anybody at Parker is familiar with.
MR. PHILLIPS: Recently a PCU was sent to

Parker under the NTSB control that was removed from a Sahara India -- I believe Sahara India Airlines airplane. Do you have any knowledge of that unit, the squawk that it came in on and the test findings, just in general terms?

THE WITNESS: That valve, the PCU came in under the direction of the NTSB with the FAA present. We ran the full functional test on the PCU and then disassembled down the servo valve. I guess, in answer to your question before, that one showed a reversal in the -- I guess it would be both directions extend and retract on the main PCU.

MR. PHILLIPS: That was experienced at Parker or was that reported to you from another source?

THE WITNESS: That was verified by running a test on the servo valve that simulates the earlier testimonies that talk about the three conditions that you need in order to achieve a reversal.

We, as a result of the AD, have a test on the rudder top PCU and at the servo valve level to assure ourselves that we will never have a reversal in any condition if any of those three conditions align themselves to occur.

So we took the Sahara India valve and

subjected it to that failure mode. All three of those conditions do exist. And at that time, we saw that in both directions, retract or extend, the valve would reverse if you had those three conditions.

MR. PHILLIPS: Was there a determination made during that testing as to what the cause of those reversals was?

THE WITNESS: As far from our experience and seeing the valves that are coming back and from the dimensional analysis, if you have a retract rudder, there's rarely a problem with the reversal. That even with adverse tolerances and the other two conditions aligning, you usually would not see a reversal. However, in the other condition, you would.

This particular Sahara unit showed a reversal in the direction that we least expected to occur. The low percentage of occurring. It surprised me as to how that could be so. In disassembling it, what we found was some improper parts in the spring guides.

MR. PHILLIPS: Has there been any determination made as to how those improper parts were installed into the unit?

THE WITNESS: That unit was from the Middle East, and a trace on the overhaul of that valve shows that there were seven different times that that unit was in for some sort of maintenance. There were, I believe, three or four different maintenance shops that worked on that valve.

We, in our facility, are unaware of all that took place. In fact, the serial number on that unit does not match any of the current records that we are holding, and we hold all records from day one on the PCU. Every unit we shipped, we have a record package of the original data that it went out on and all of its components.

We were unable to find that one in our -- it had a serial number, but that was not a Parker serial number.

MR. PHILLIPS: So then that would give us two PCUs that have reversed. Both the United Mack Moore with the summing lever condition, and the Sahara India Airlines with the discrepant parts. Is that correct?

THE WITNESS: That's true.

MR. PHILLIPS: Were there any discrepant parts found in the United 585 component or the USAir flight 427 component?

THE WITNESS: The 585, my memory is that there was not any. But as I recall, again, as I stated, the 585 was in pretty poor shape as compared to the valve on the 427. In terms of the 427, there were no -- we didn't perform any dimensional analysis on any of the components, but we did determine by acceptance test procedure and the extensive testing outside of that, that there was no hardware anomalies or tolerance problems.

MR. PHILLIPS: Is it your opinion that any additional testing should be performed on USAir flight 427 PCU? Should dimensional checks be made of those parts to verify their condition?

THE WITNESS: To my knowledge, the procedures of the tests that we've so far performed are indicative of the valve, and I don't believe that there would be anything gained by running dimensional checks on any of the components.

The final say of this PCU is its ability to meet the performance requirements. Understand that each subcomponent goes through anywhere from eight to 12 different individual tests. Then they are brought together and integrated at the top level where there it goes through 22 different individual tests, checking its performance.

The parameters are rather stringent

parameters and difficult. If they weren't met there, they show up very easily.

MR. PHILLIPS: So that on the performance test, any one failure of the performance test would fail a complete unit?

THE WITNESS: That is true. If any one of those 22 or down at the sub-level requires the valve to or the PCU to be removed from the hydraulic bench and determine the problem and the part replaced, if there's something to that effect and then retested. So until the unit passes the acceptance test procedure, it is not released.

CHAIRMAN HALL: Mr. Phillips, we are nearing time for a break. Do you want to continue and finish? Do you have a few more questions or would you prefer we break and come back? It's your call.

MR. PHILLIPS: I actually have about probably about ten minutes more questions for myself.

CHAIRMAN HALL: We'll continue then.

MR. PHILLIPS: The next area I wanted to get into just briefly was the yaw damper system and your experience with the yaw damper operation. We've heard testimony from Mr. Cline this morning about the condition of USAir 427's yaw damper system. But once again, could you describe to us what you saw in testing of this unit?

THE WITNESS: All rudder PCUs, the 22 different performance parameters we checked in that is extensive testing of the yaw system that's part of that PCU package. One of the test that we do is simulate a hard over electro-hydraulic valve or an open solenoid. Basically, that would cause the yaw piston to travel over to its extreme position, which is, as testified earlier, has mechanical stops.

Understand that our test fixture is very similar to what it would look like in the aircraft. We have a wheel on the test fixture that shows zero degrees through the plus or minus 26 degrees. When we turn on and basically do that failure, we watch where the yaw takes the rudder PCU. And in that case, we all witnessed that it went 3 degrees depending on what direction the failure would have been.

So based on that, there would have been no physical way other than to travel -- it could not travel any further than 3 degrees.

MR. PHILLIPS: To the best of your knowledge, have you ever seen a rudder PCU travel beyond its limits, its design limits?

THE WITNESS: No. Understand again, there are units out there with 2 degrees and 4 degrees. So there can be ones with 4 degrees still roaming out there. But as far as meeting those parameters, I have never seen one that goes outside of the design parameters.

MR. PHILLIPS: You would be in a position to be aware of one if it had?

THE WITNESS: Yes, I am definitely contacted of any anomaly that does occur, that would be that significant.

MR. PHILLIPS: You would also be the best person at Parker to ask if there's ever been a jam PCU servo valve which caused a runaway or hard over condition?

THE WITNESS: Well, I would probably be a runner up. I think the testimony of Mr. Sheng, who's been with the company for 30 plus years, he's strictly our technical lead and he's a very practical minded, besides being very intelligent, and he's seen a lot, and he's somebody we consult with and has consulted throughout the years. I think he's given testimony that to what his experience was.

So between Sheng's testimony and my

testimony, I think you can get Parker's input as to we have not, to our knowledge, seen any jams on the rudder, 737 rudder PCU.

MR. PHILLIPS: One more time for the record, did you see any evidence of a jam of the USAir 427 package?

THE WITNESS: No, I did not.

MR. PHILLIPS: That's all the questions I have, unless you would like to add something that I've omitted?

THE WITNESS: No.

MR. PHILLIPS: Thank you.

CHAIRMAN HALL: I want to correct an item that I mentioned a few minutes ago. Mr. Laynor, who is our senior and most respected aviation accident investigator, informed the Chairman that these tests that had been requested after Colorado Springs and had been conducted by the FAA and by Parker Hannifin and Boeing, the majority of costs of those tests were borne by Boeing and Parker Hannifin and not by the American taxpayers. I apologize to you gentlemen.

I merely want to be sure that on the record we have two accidents which are linked in the public's mind, and that we inform them and are sure and clear everything that has been done in that interval period of time, regardless of who it was paid for, in order to look for the cause of the problem.

With that, we will take a 15 minute break.

(Whereupon, a short recess was taken.)

CHAIRMAN HALL: The hearing will come back in session. I believe we are now proceeding with the party questions for this witness. Would you please indicate which parties have questions? I see the FAA and the Airline Pilots Association, International Association of Machinists and Boeing. We will proceed fir with the International Association of Machinists, Mr. Wurzel.

MR. WURZEL: Good afternoon, Mr. Weik.

THE WITNESS: Good afternoon.

MR. WURZEL: Were you aware that all possible documentation, both photographic and measurement wise, were taken in the field by the NTSB systems group of the main rudder power control unit and its relationship to the rudder before the vertical fin and rudder removed from the accident scene to the hanger?

THE WITNESS: I was not present at the site. So I'm not aware of that.

MR. WURZEL: How would you characterize the difficulty in removing the main rudder power control unit in the AI hanger under the much better conditions than at the accident scene? I think you were present there.

THE WITNESS: It was a rather difficult endeavor. It required once we secured any -- as long as the unit was intact the way it was, it had all the torque tubes and rods connected to it. Once we started disassembling, we'd lose position and we took precautions to secure the position of it.

Once we did that and started connecting -- disconnecting the connecting rods, from there because of the damage to the piston rod, we were forced to cut the PCU out so as not to disturb it. It would have required retracting the piston rod in order to get the PCU out of there. Obviously, that would take away any evidence that it was there.

So it was a very difficult task, and it required a lot of input from a lot of people.

MR. WURZEL: Have you ever come across any bogus parts in the overhaul, the servo or the main rudder power control unit at your overhaul headquarters?

THE WITNESS: I don't know what you mean by "bogus" parts. But parts other than being manufactured from Parker, there has been one or two instances that we are aware of.

MR. WURZEL: Are you familiar with the term "silting," and could you explain its effects in relation to the servo?

THE WITNESS: Silting is a common term in the hydraulic fields. I don't know if it's a real term or something that we hydraulic engineers use. Basically, it's phenomenon that the electro-hydraulic valve people I think first saw. That is if a slide stays in one position while fluid is -- for instance, if it's an underlap valve porting by it or it just hasn't been exercised in a while, the fluid builds up a little bit of a surface tension.

All fluids have a surface tension. Basically, it increases the force to break that surface tension, but we are all familiar with water. Not too many of us can walk on water. So the bottom line is it's just that sort of thing. It's maybe an ounce of increased force to break it out. It's nothing that's a big issue unless it's something like an electro-hydraulic valve and the way they prevent it from being an issue in performance. They just put a little bit of a cycle -- input around neutral to prevent friction in terms of this valve.

I don't think it's an issue.

MR. WURZEL: That concludes my questions. Thank you, Steve.

CHAIRMAN HALL: Airline Pilots Association.

CAPTAIN LeGROW: Thank you, Mr. Chairman. Good afternoon, Mr. Weik. Could you tell me in your involvement with the USAir 427 accident airplane, how much time was on the main PCU?

THE WITNESS: In our investigation, I believe that number came out, but I don't believe it's in the public docket. I think I would prefer to have USAir provide you with that number of the NTSB.

CAPTAIN LeGROW: Does 22,000 hours refresh your memory?

THE WITNESS: Again, those were numbers that I've heard. Unless they are in the public docket, I don't know if I can say that's true or false.

CHAIRMAN HALL: Is it in the public docket, Mr. Phillips?

MR. PHILLIPS: I believe that would appear in the maintenance records report. We'll take a look and see. My recollection is it is on the order of 22,000 hours for approximate discussion.

CHAIRMAN HALL: Since the issue has been raised, would someone please go through the exhibits and if it's in the docket, let's give the page number and the correct exhibit.

MR. PHILLIPS: We'll do that.

CHAIRMAN HALL: Please proceed, Captain.

CAPTAIN LeGROW: Thank you, Mr. Chairman. When the 737 PCU was originally put in service, did it have a time life on it?

THE WITNESS: I'm not sure if I understand. Let me just clarify that our acceptance test procedure when it goes out, besides doing -- it takes about two hours to run through the performance parameters. Then it goes through an eight-hour duty cycle. Most units that leave the factory to the OEM have that type of time on it.

CAPTAIN LeGROW: I guess my question was did it have a suggested time to overhaul when the unit first went in service?

THE WITNESS: I'm not aware that there's anything out there that states when to overhaul these units. That's something I'm not familiar with.

CAPTAIN LeGROW: I'm asking when the unit first went in service in 1967 or whatever date that was?

THE WITNESS: There's definitely in-service performance parameters. A lot of those performance parameters in the world of hydraulics is determined on how clean the fluid is. Fluid does cause wear which causes larger clearances, which leads to increased leakage. Most of our performance parameters revolve around leakage requirements, but there is no time limit that is specified. There's only requirements once it's removed to assure that it's within its performance parameters, to my knowledge.

CHAIRMAN HALL: Excuse me one moment, Captain. Do we have the information now?

MR. PHILLIPS: Yes, Mr. Chairman, Exhibit 9-A, I believe page 45, is the receiving paperwork that we took to Parker on the initial test of 9-21-94. I believe the accident unit at that time had 21,077.33 hours.

CHAIRMAN HALL: An answer to your question, Captain. Thank you.

CAPTAIN LeGROW: Thank you, Mr. Chairman. When the 737 PCU was originally certified, did the specs call for type 3 fluid?

THE WITNESS: I believe that's correct. We maintain to the specification of what we call the SCD, source control dine. I believe at that time it was BMS 3-11 type 3 fluid.

CAPTAIN LeGROW: Today it uses type 4 fluid; is that correct?

THE WITNESS: That's correct.

CAPTAIN LeGROW: Were there any additional tests done between the time it went from type 3 to type 4 fluid?

THE WITNESS: I don't think I'm the qualified person to answer that.

CAPTAIN LeGROW: You made reference in your earlier testimony about the AD on the servo valve. Could you explain exactly what that AD was?

THE WITNESS: In earlier testimony, there's been discussion as to the travel of the primary and the secondary slide. The AD affects the travel of the secondary slide in the event that you have three conditions that occur in line with one another.

The AD, in simple terms, just restricts the amount of travel that the secondary can move in the event that these three conditions align to prevent any cross-porting fluid.

CAPTAIN LeGROW: So is my understanding correct that it's an internal stop for the slide. Would that be correct?

THE WITNESS: That's correct.

CAPTAIN LeGROW: On the original design of the servo, did it have those stops on the original design?

THE WITNESS: Yes, those stops are there and have been there present from day one.

CAPTAIN LeGROW: What was the reason for the AD if it had been there all along?

THE WITNESS: Basically, the valve was intended to stop on its linkage stops. It was not intended to stop on its internal stops. The internal stops are your spring guides that in the event that you have a mistolerance part, a jam and a full rate command such that the external stops do not perform, then you are reliant on the internal stops. And basically, we have reduced the travel to hit the internal stops, but they have always been present.

CAPTAIN LeGROW: So there's been no design change in the servo valve since it went into service?

THE WITNESS: Other than the ability to now limit the travel of the secondary slide, no, there has not.

CAPTAIN LeGROW: That's been there since the original design?

THE WITNESS: That's correct.

CAPTAIN LeGROW: Could you tell me when Parker Hannifin or Parker modifies a PCU, how long it takes?

THE WITNESS: Well, in this instance, again, it's -- we're the manufacturer. So this case it's a function of the design engineering on the Boeing side and dependent on what the issues are, there's no particular time. Things can happen quick or things can happen -- it's really dependent upon what the actual change is and what it has to do with performance.

CAPTAIN LeGROW: Are the users able to get the units modified as rapidly as they request?

THE WITNESS: To my knowledge, the AD that is taking place -- I'll give you some numbers. Roughly we figure there's 2800 PCUs that fall under this AD that are in operation today. To date, Parker has serviced about 1250 PCUs with the retrofit. We're doing them at about a rate of 50 per month. It's basically when the airline gets it into us, we will turn it around.

CAPTAIN LeGROW: So am I to understand that less than half the fleet has been modified to this date?

THE WITNESS: To my knowledge, those are the numbers that I just gave you, the most up-to-date numbers. There's probably a plus or minus range of 20 in there.

CAPTAIN LeGROW: Does Parker have the capacity to increase that time?

THE WITNESS: At this current time, 50 is a taxing load on our organization, but we will comply with whatever the industry or the FAA feels is necessary.

CAPTAIN LeGROW: Parker produces other servo valves. Is that correct?

THE WITNESS: That's correct.

CAPTAIN LeGROW: Has any other servo valve that Parker produces ever been under the scrutiny that this valve has been under?

THE WITNESS: I think all valves have. Just probably is one of the more complex valves. The other valves -- all of them go through scrutiny at design and are tested through qualification. This particular valve has received a lot more attention than what would be normally.

Valves that we make today are very similar to what we made 35 years ago until we've gotten into this more electrical driven servo valves. But to answer your question in short --

CAPTAIN LeGROW: But the point is Parker Hannifin or Parker -- excuse me -- does produce other dual concentric servo valves. Is that correct?

THE WITNESS: That's our line of work, yes.

CAPTAIN LeGROW: It just appears that this valve has been under a lot more scrutiny than other valves that Parker produces. I guess my question is what makes this valve so unique?

THE WITNESS: I don't know if -- that's the question that I have. It's not unique in terms. It's a dual concentric. We make single slide valves, too. That's probably the more predominant ones we make. But the dual concentric is a very good design, and it fulfills certain specific parameters that would not be filled by a single valve.

I think the exposure to this valve has basically been derived from the incident of 585 and now the flight 429.

CAPTAIN LeGROW: Thank you. Could you tell me -- we had some discussion earlier on chip shear.

Could you tell me what the chip shear is on the accident airplane? What the chip shear was on the accident airplane?

THE WITNESS: Basically, it can be determined by looking at the functional test data that we ran. Specifically on -- this is in Exhibit 9-A. If you'll look in the functional data sheet at page 63, from that graph, there's a ratio that you have to use in order to term off that graph, but the Y axis is pounds.

If you take the pound rating and to be honest with you, I don't know -- I don't recall the ratio off the top of my head. I have it written down. It's probably within the 40 -- it's better than 44 pounds.

CAPTAIN LeGROW: I think we heard some testimony yesterday that it was around 44 pounds. My question is how does this compare with other dual concentric valves?

THE WITNESS: In terms of what other dual concentric valves? I'm not sure?

CAPTAIN LeGROW: Would the chip shear be higher or lower, about average?

THE WITNESS: Each valve is designed differently. I think the dual concentric valve chip shear is not as serious a consideration, because you do have the other slide to compensate for any single jam, that the other slide will give you half rate but full authority.

CAPTAIN LeGROW: I understand that, but all dual concentric valves will do that. Is that correct?

THE WITNESS: That's correct.

CAPTAIN LeGROW: My question is how does this compare with valves in other controls that Parker produces?

THE WITNESS: To my knowledge, there's ones that are higher in the 50. Some as high as 100.

CAPTAIN LeGROW: Is there some as high as 200?

THE WITNESS: I guess, I would have to do some research before I gave you that number for sure.

CAPTAIN LeGROW: Do you know if this is the lowest?

THE WITNESS: Again, without going back and looking at all of our valves with specific intentions of looking at what chip shear requirements are for each of those valves, I can't tell you where it is in the scale of things.

CAPTAIN LeGROW: Thank you. Can you explain to me how a PCU could be sent to Parker Hannifin or

Parker -- again, excuse me -- to be overhauled, be requalified or qualified for service, then sent back to Parker within a month, and found that because of pilot squawks and found to have worn summing levers and fail a dielectric test?

THE WITNESS: Well, if you want to take it in a sense that I think we've all had personal experiences where you take the car down for a specific failure and drive out and two days later something else fails. Understand that you do diagnostic testing and one of the things that we do is we do as the airlines directs us to do and fix only that. Everything we do obviously has a price attached to it.

The airlines tells us specifically what they want done. We obviously have the ATP requirements to meet. But if they meet the requirements with arms that are worn and a month later that wear turns in to mean reducing or not being able to meet the performance requirements, we have no control over that.

CAPTAIN LeGROW: So you're telling me that it's possible for something to go through Parker's facility, be qualified for service and have worn summing levers?

THE WITNESS: I guess, the question is is what do you define as worn? If you look at your units and you look at them and you determine that these parts meet all the performance requirements, do we go through and do a dimensional check on every single part, I guess that would be at the expense of the airlines if we did that.

My answer to that is if we see anything that's excessively worn, we would notify the airlines and tell them that we believe this is not something that should go back out.

CAPTAIN LeGROW: Is Parker the only facility that overhauls this power control unit?

THE WITNESS: We basically have 30 percent of the market share. The other 70 percent is out there amongst the airlines and the third parties.

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

CHAIRMAN HALL: Boeing, Mr. Purvis.

MR. PURVIS: Thank you. I have some questions for Mr. Weik.

I would like to go back to the Sahara unit, please. Did the PCU that came from the Sahara airplane as a top assembly actually reverse on the Parker test bench?

THE WITNESS: No, sir, it did not. It met all functional test requirements.

MR. PURVIS: So when you said the unit reversed, you were referring to the control valve as a component. Is that correct?

THE WITNESS: That's true. We were testing the servo valve when we saw -- in fact, we tested the servo valve for what we call the failure condition. At that time, we saw that the servo valve if it failed, would go in reverse, but the PCU did not reverse.

MR. PURVIS: The test that caused the servo valve as a component to reverse, was that a normal mode of operation or was it a failure mode being simulated?

THE WITNESS: That is correct also. It is a failure mode that we simulated, as I said, to indicate the worse condition that occurred.

MR. PURVIS: Could that valve then have reversed in flight?

THE WITNESS: Only in the event that all of those parameters necessary for a reversal came together at the right time.

MR. PURVIS: I would like to go to your involvement on the 427 PCU. Based on your close connection with all the phases of the 427 investigation, did you find any evidence of a jam on the primary or secondary flight?

THE WITNESS: I did not see anything that was out of the normal of what we produce on the new valve.

MR. PURVIS: Was there any evidence that this PCU could have reversed?

THE WITNESS: From every test that I witnessed and outside of the normal functional testing, the other test that we did to try to create failure modes, no, there was no evidence.

MR. PURVIS: Was there any evidence from the chip shear, the residual pressure or the fluid particle test that would have affected the intended performance of the 427 PCU?

THE WITNESS: No.

MR. PURVIS: I missed an item on the Sahara PCU that I wanted to ask you. Was there any evidence that the dual spring guide had been so-called "remachined" after delivery?

THE WITNESS: That was the case. In our opinion, there was some remanufacturing of that part. We believe, as I said before, that it had gone through, I believe, four to five different maintenance houses within its life span, which we can't even define what it's life span was, because we can't identify the serial number to one of our serial numbers.

MR. PURVIS: That's all the questions I have. Thank you.

CHAIRMAN HALL: Do any of the parties have additional questions? If not, I am going to turn it over to Mr. Marx. At this point, I must excuse myself briefly to make a phone call. I'm going to leave the gable in Mr. Laynor's hands if for any reason the questioning is concluded and we need to move forward before I can return.

Mr. Marx.

MR. MARX: Mr. Weik, I realize that you've been on the stand for quite a long time. It's quite grueling up there. I've been there myself. I wanted to clarify two things. Do you recall back in early November when I came to Parker Hannifin?

THE WITNESS: Yes.

MR. MARX: At that particular time, was there any dimensional checks that were made on the main rudder PCU? That would be the servo valve itself.

THE WITNESS: The servo valve was in the possession of the NTSB after every meeting that we were together. There had been no dimensional inspection at

Parker until the time that you --

MR. MARX: Right. But, I mean, at that particular time, we did do dimensional checks. It was under my authority to do the dimensional checks, but I wanted to just clarify that there had been some dimensional checks that were made on the particular servo valve. They are not part of the public record.

Do you recall any of those dimensions that would indicate that this valve was not manufactured as to the requirements of Parker Hannifin? In other words, were there any possibility of any parts being in there that were not Parker Hannifin's and to their specifications?

THE WITNESS: No, there was not.

MR. MARX: Now, you also spoke of there wasn't any significant changes made to the PCU. That would be maybe when we're talking about dimensional changes. Could there have been some manufacturing changes, such as the subcontracting out primary spools, manufacturing primary spools?

THE WITNESS: All designs are controlled by the Boeing Company and then from those designs, we construct route sheets that basically define how the parts will be manufactured that's under Parker's control. Within the guidelines of the SCD that I've spoken of, that we use the right materials, the right speed feeds, and we also outside vend our parts depending on load capacity and our company.

So, yes, it could have been done on a lays or it could have been crushed ground. Basically, as long as the product meets the end requirements in terms of material, the hardness, the surface finish and the dimensional parameters, where it's made is inconsequential.

MR. MARX: I understand that. I just wanted to clarify the design on the servo valve. I'm a little bit confused. To your knowledge, is the design of the servo valve a Boeing design or a Parker Hannifin design?

THE WITNESS: The design is on Parker paper. I understand that there's some sort of patent going on with it, and to be honest with you, I can't say much further.

MR. MARX: Are you familiar with the overhaul procedures when a PCU comes into the shop for overhaul?

THE WITNESS: Yes, I am.

MR. MARX: Are there any written procedures that you know of for disassembly of the primary from the secondary and the secondary from the housing?

THE WITNESS: I'm not familiar with any.

MR. MARX: Or any procedures for reassembly?

THE WITNESS: In the overhaul manual, it does describe -- the Boeing overhaul manual does describe disassembly and assembly procedures. That manual is used. So I stand corrected that we do not have our own internal procedures on that. Actually, we do create internal procedures off of the Boeing overhaul manual that describe areas of caution.

For instance, the materials on the primary and secondary slide are a very high aesthete and are brittle, much like glass. If you drop them, they'll chip. That sort of problems. So you definitely have to do special handling on those things.

We have rubber mats on our benches to prevent that. There are quite a few internal standards on how to perform disassembly and assembly on all units. There's a lot of generic practices. The specifics on the servo valve are spelled out very clearly in the overhaul manual.

Specifically, after the 585, there are some very specific -- there's not a lot left that isn't described on how to assemble that servo valve and test it.

MR. MARX: Well, this would be on the overhaul. My understanding is that this particular PCU has been overhauled within a couple of years of the accident. Is that correct, do you know?

THE WITNESS: No, that is not correct. The PCU is overhauled for external leakage when a unit comes in and it's squawked as external leakage. We replace all the software. We replace all the filters. There's a standard procedure. The servo valve was not taken down to the sub-level and checked.

It was checked at the top level, which we consider catches all the parameters and it met that requirement. It was shipped out. There was no work done to the servo valve.

MR. MARX: So it was never disassembled?

THE WITNESS: That there is not definition. There are several ways of disassembling the ram. One is to take out all the linkage and --

MR. MARX: I'm just speaking of the servo valve.

THE WITNESS: The servo valve was not disassembled. Understand, depending on how you take the PCU apart, if you take the PCU apart, you have to disassemble the servo valve in some cases and not all cases. It depends on where you go to do your work.

If you do it on the internal linkage, you have to remove the servo valve to do any work on the summing levers. Down on the piston level, as we did in this investigation on flight 427, we did not have to disturb the internal summing levers or the main servo valve.

So I don't have record as specifically there was written on the receiving card or the overhaul card, there was no work done to the servo valve. Only software which we call all the seals and then the filters were replaced at the time.

Then it was tested to the functional top assembly ATP and passed all those and sent out back to the customer.

MR. MARX: Just to make sure I understand you. As far as the record showing and as far as your understanding is, the servo valve since it was originally manufactured, had not been taken apart and put back together again?

THE WITNESS: I cannot say that.

MR. MARX: Up until the time of the accident?

THE WITNESS: There was no work done to the servo, but in terms of whether it was taken apart or not, I cannot definitively answer that.

MR. MARX: You were also talking about different methodologies in which to produce a jam in a servo valve. You were mentioning something about clamping forces. The clamping forces would be those produced between an outside diameter say of the primary and the inside diameter of the secondary or the outside diameter of the secondary to the inside diameter of the housing.

Could this be because of dimensional problems? That is that the overall dimensions are not properly or uniformally along the lengths of the spool. Is this what you were talking about?

THE WITNESS: The valves, the hand-fit valves. Again, we have an internal requirement on all of our servo valves for roundness and straightness call out throughout the board that deals in the millionths which is basically -- it's about ten millionths roundness and straightness.

If you know that, that's five zeros to the right of the decimal place and then a one or a five. That's kind of roundness and straightness that we try to maintain on these valves. You need special gages and sorts. Then for performance sake, you have to keep the clearances within the 150 millionths to 200 millionths, as already testified to.

Material properties, you have yield. All material has yield to it. Basically we go through a very extensive testing to what we call stabilize the valve. We stabilize the valve so that this yield is already pre-yielded, that you will not see any more yield.

Then you fit the valve to make sure that you will not have any further conditions where pressure would cause this to clamp, i.e., we stabilize this at 6,000 pounds of pressure several different times to make sure that we have no clamping. Then we come back when we fit the valve and then we go through the normal functional ATP of the servo valve.

We, therefore, check to see if we have any binding or sticking of that valve, and then you open up the clearances basically to meet your friction requirements that were earlier discussed that are in the ounces on the primary slide, roughly around 12 ounces. The secondary is a little higher because it has the effects of the detents springs.

MR. MARX: Could particulate matter or some debris also reduce the diametrical clearances in certain areas of the valve that could increase to clamping forces?

THE WITNESS: Understand the way the servo valve is designed. It's much like in your garage you've got dikes or wire snips, and that's the way the servo valve is designed. You've got two pieces that act like scissors or wire dikes.

Like anything, if you have scissors -- if you have a pair of scissors that are a little worn and the nut's basically backed off and you get a bigger gap in there and you go to cut something, it will get jammed up in between there.

Well, when you're talking about 150 millionths to 200 millionths, that doggone thing is just about on top of the other blade. The materials we use are 52-100, which holds a very high Rockwell hardness in the 62 RC category and the nitroloid that the primary slide is made of is a 58 RC. They act like any very high strength dikes.

If there's anything that would fall in there, as the chip shear test shows, it would be severed. The particulate small in the micron level that you're talking about, there is probably nothing that has that kind of shear strength to withstand that kind of --

MR. MARX: Is it possible to get a very soft material stuck that would not leave a mark against the outside diameter of the spool in reference to the ID of their main surfaces?

THE WITNESS: Are you asking me to speculate that?

MR. MARX: Yes. I mean, is it possible to get soft material in there?

THE WITNESS: I'm sure it's possible. I don't believe that that would be the case based on the clearances that we're dealing with here.

MR. MARX: Well, the clearances are being in the neighborhood of 1.5 to 2 microns on each side, as was testified by, I think, Mr. Turner was the one that gave us that. It was in the neighborhood of 4 to 5 microns throughout the whole diameter, which is a very small distance.

I just wanted to clarify about this clamping. The clamping that we are speaking of is one in which we have a reduced ID or an expanded OD or something that's in between it that could do the same thing. This still would be an active scenario for clamping or for sticking of the valve, wouldn't it?

THE WITNESS: We tested for that as we spoke earlier. Two weeks ago, we checked to see if clamping was an issue. Clamping had no effect on this valve.

MR. MARX: During the last test that you're talking about, you specifically did put materials between the IDs and the ODs, or did you just do shear tests?

THE WITNESS: No, we didn't do -- what I'm speaking to is the fact that when I was speaking of clamping, I am talking about the effects of higher pressures coming into the servo valve.

MR. LAYNOR: Mr. Weik, I think Mr. Marx is deferring to me to ask a question that he's been trying to ask the previous witness.

Were you present during the test where the pressure differentials were measured between the pressure and return for the A and B systems to determine residual pressures under different jamming positions?

THE WITNESS: Yes, I was.

MR. LAYNOR: The tests were conducted with the -- if you can refer to Exhibit 9-AH, page 2, I guess it is. I think there's another exhibit that also discusses these tests, but we'll use this one. Now, the tests were conducted with four different conditions. Two of which involved the secondary spool jammed to the housing in both directions with the left rudder input and the right rudder input, and assuming that the jam occurred with the secondary spool at the full travel to the external stop and the primary spool or slide free to move. Is that correct, are they the first two conditions?

THE WITNESS: I believe I heard you correctly.

MR. LAYNOR: The other two conditions assumed that the -- or actually were conducted with the primary slide jammed to the secondary with both a left and a right rudder command, and the secondary free to move to control the fluid flow through the servo valve. Is that correct?

THE WITNESS: Yes.

MR. LAYNOR: I think what Mr. Marx was trying to establish in questioning Mr. Cline earlier is that if we were to assume that the secondary slide for some reason, perhaps something like contamination in the secondary slide pick up area, were to move prematurely and move to the internal stop rather than the external stop and then become jammed, what would the residual pressure be or the residual percentage of rudder, and what travel would the rudder be able to go with power command?

THE WITNESS: Let me first off say, that when you start getting into the system, that's not my area of expertise. That's Boeing's. So my answering would have to be based on just what the gages read and where we put the positioning of the slides.

In terms of references to what the rudder would do and that sort of thing, you've had testimony and I'm sure you can get Boeing to come back up here and explain it. I'd be glad to answer to you on where what pressure of readings we got at certain specific positions of the slide.

MR. LAYNOR: I think that that would be sufficient for our purposes. What we're trying to ascertain is if the secondary were to travel beyond the external stop to the internal stop, what would these first two conditions have produced as far as available rudder travel and residual position with the best null available?

THE WITNESS: Are we working with number one?

MR. LAYNOR: If we are working with number one, and I'll perhaps go a little further into that in the questioning. In our examination of these conditions, it appeared to us, at least, that the relative primary and secondary slide positions for number one if the left rudder command and the maximum opposite travel of the primary spool would be the same condition, that you would have in condition number four the same relative position for the primary and secondary spool when the secondary spool was fully driven to the internal stop.

THE WITNESS: Could we have a definition of left rudder? I guess, left rudder is extend ram or retract ram?

MR. LAYNOR: I think left rudder is retract. I'm told it's extend.

THE WITNESS: The left rudder is extend command?

MR. LAYNOR: Yes. Is that correct?

MR. MARX: The actual pressure measurement for those tests are in Exhibit 9-R, page 3.

THE WITNESS: That's probably the better language for me. Again, Mr. Laynor, understand that I am somewhat familiar and I have learned a lot through this investigation and what it does on the airplane, but my knowledge is basically extend or retract on the main PCU.

When it's integrated into the system, that goes into the line of questioning for Boeing.

MR. LAYNOR: The number one scenario is secondary retract linkage stop. I suppose instead of linkage stop, we would say what would that be if it were on the internal stop?

THE WITNESS: Are we in test condition one now?

MR. LAYNOR: Test condition one.

THE WITNESS: If you have a secondary retract against the linkage stop, that would create an extend command on the PCU rudder. Basically, a 12 percent residual pressure says that if the secondary was against its linkage stops and held there, it would be basically getting an extend PCU command and you tried to go retract on the RAM, you would reduce the ability load output to within 12 percent.

MR. LAYNOR: Basically, the ram would neutralize within 12 percent of its output force. That's the closest to the null position that you could achieve by full movement of the primary slide. Is that true?

THE WITNESS: That's true.

MR. LAYNOR: Now, if in condition three -- and I know there's some problem with the signs in this exhibit when you look at it in the terms we are now. But condition three would be placing the secondary retract to the internal stop rather than the linkage stop. The residual pressure appears to be 58 percent in the same direction as it does in test condition one.

THE WITNESS: In this case assimilating that the primary --

MR. LAYNOR: Well, my question is could that condition be comparable to a secondary spool, a secondary slide jam at the internal stop?

THE WITNESS: The physical positions are the same, but the condition of failure is different and the ability to get output force is different. Basically, you have a 12 percent reduction within -- I'm trying to find the words, Mr. Laynor, to explain this.

MR. LAYNOR: Maybe we can let it go, but what it appeared to us, at least, is that if you moved the secondary slide to the internal stop, beyond the external stop to the internal stop and jammed it, you would have the conditions that you had in condition three when you moved the primary slide full stroke in the opposite direction.

In that case, a residual pressure would result in a 58 percent of load down or maximum pressure condition rather than 12 percent. The available travel would be between 58 percent and 100 percent in one direction, but it could not go in the other direction.

THE WITNESS: The difficulty that comes in this data is the way it's presented is it's taken through two different levels. There's a servo level and then there's a PCU level, and then there's the airplane and what it does in the airplane. I think this is where we are running into some problems in trying to interpret what it says.

It says the same thing. I think, in testimony given earlier that, again, the residual in the first two cases show that you can't reduce the effects of the secondary being jammed against the linkage stops.

In the case three and four, in the event that the primary slides become jammed at full rate, you have full authority with the secondary slides, no matter how far they travel, that's against the internal stop. At that rate, you'll have the authority of wherever the secondary slide goes. In actuality, you would have authority in both directions of the extend, retract or load output.

MR. LAYNOR: I'm not going to pursue it any farther. I'm going to turn it back to Mr. Marx, and hopefully he won't either, but --

MR. MARX: I just merely looked at the pressures and we went through this once before with Mr. Cline, and it had to do with the C2, C1 pressures versus the C4, C3 pressures. Looking at that, I believe he testified, and I concur with his testimony, that the rudder would be going left at that position.

THE WITNESS: Which case are we speaking to?

MR. MARX: This is number three, test condition number three, Exhibit No. 9-R, Romeo, on page 3.

THE WITNESS: Okay.

CHAIRMAN HALL: Mr. Clark?

MR. CLARK: I have no questions.

CHAIRMAN HALL: You have no questions. Mr. Schleede?

MR. SCHLEEDE: Just a couple here, hopefully brief.

Mr. Marx asked you about the design of the dual concentric servo valve, and I was confused about your answer. Who was primarily responsible for the design of the 737 servo valve? Was it Boeing or Parker?

THE WITNESS: I think we can get that information to you. I'm probably not the right one to ask. That time frame was, obviously, a little before my time.

MR. SCHLEEDE: Just, as you know, we have in the exhibits some documents that pertain to an incident involving a 747-400. I don't want to go into great depth, because the exhibits speak for themselves. I just want to know if you have reviewed -- I know you have worked on this case, but have you reviewed the report of the 747 incident involving a British Airways airplane?

THE WITNESS: I have participated and am still participating in an investigation with the Boeing Company, where the Boeing Company has been a lead in this investigation, and we have provided services to them. We have seen the report, and we are basically just now in the process of going through the report and evaluating what it is.

MR. SCHLEEDE: This is the report we're speaking of it's Exhibit 9-Q, the Air Accident Investigation Branch Report from the United Kingdom?

THE WITNESS: That's correct.

MR. SCHLEEDE: I was going to ask you if you could comment on the findings, whether you agreed or not. Do you have a position at this point?

THE WITNESS: I think we would like to defer until we've looked at it further.

MR. SCHLEEDE: One little question about the Sahara Airlines or the 737 incident. I know you clarified the record about the servo valve under a test condition reversed, not the full up PCU. But my question was if the servo valve, control valve does reverse -- and I realize it's a simulated situation when it did reverse -- can you explain why since it is a control valve that it wouldn't reverse the PCU in a full up unit?

THE WITNESS: I guess the understanding is that you have to understand in order to have a reversal, you have to have three things occur simultaneously. Those three things don't happen except for out here in space, there's probably a probability number for it. But it is a remote line up of conditions in order to have that reversal.

So under normal operation that happens as we have -- it's taken us this long to come to the recognition that this condition existed, you can see that the remote possibility is remote. So for the Sahara one, it's basically one of those cases that you have to go to that remote condition and test for that remote condition before you can get the reversal. That's what we do now with the AD is we go to lining up three of those issues that need to occur simultaneously and then check it to see.

In that failure mode, the Sahara would do it. But the Sahara unit at the top level, at the top level PCU, does not have those three elements in the failure mode. So it cannot happen.

MR. SCHLEEDE: I understand now. Thank you. One other question on the standby rudder actuator. I know you were here during Mr. Turner's testimony regarding a jam in the standby rudder actuator. I wanted your comments. Do you agree with his testimony about the compliance in the PCU that will allow normal operation of the continued operation of the rudder with a fully jammed standby?

THE WITNESS: Our responsibility stops right around the pilot input point on the PCU. In terms of anything back from that point is out of our jurisdiction or out of our technical expertise. We're just a PCU manufacturer.

MR. SCHLEEDE: Well, within the PCU itself, are you aware of any occasions of jams that may have been caused by external foreign objects other than what we've talked about already within the servo valve or in the summing levers? How about external interference with the operation of the PCU?

THE WITNESS: Not to my personal knowledge, no.

MR. SCHLEEDE: Thank you.

THE WITNESS: Could I clarify one thing, Mr. Hall?

CHAIRMAN HALL: Surely.

THE WITNESS: At break, I think there was some misunderstanding by some of the NTSB people in my testimony about the Pittsburgh accident in the hanger. I want to make it clear that it's only a possibility that in the future that if this tragedy ever happens, hopefully never, that participation from, i.e., the Boeing systems group or something come in to assure that there is no movement.

However, I want to state for the record, that I do not believe that there was any movement to the unit in the handling from the accident site to the hanger. That the bent rod in itself secure that the rudder was in the position that it was when it impacted or just slightly off that, depending on the progression of the impact on the vertical fins.

So for the record, please understand that the rudder PCU information available to us at two degrees right, I believe, that is the case.

CHAIRMAN HALL: Mr. Weik, I appreciate that comment, but I want to be sure you understand and all the parties understand that if there's anything that the NTSB needs to be doing better, tell us. That's the process here. Everybody has invested a lot of time and effort into this investigation. Everybody is coming here wanting to find the cause.

If there's something that wasn't done properly and it was the NTSB that didn't do it properly, then as the head of the NTSB, I want to know. You have mentioned in a lot of your questions here that you have to defer to your customers. Well, the board has customers too we've got to report to. I want to be sure that the report we give is a full one.

Now, if you could help me and I'm not going to get into technical questions about the slides or anything, but I want to go back and ask you if you could give me an overview and an understanding from the Colorado Springs' accident. What has been done in terms of looking at that rudder, whether it was the FAA, the study that's going on right now, the study that was -- and if it was just limited to reversals, it was just limited to reverses.

But could you tell me what's happened between Colorado Springs and now that Parker Hannifin has participated in in regard to looking at that rudder? I would like to lay that on the record. I think the American people ought to know what's been done. I think a lot's been done, but I would like to get it out in the way people can understand it.

THE WITNESS: As it was testified earlier by Mr. Cline, once there was an understanding of the condition that resulted out of the extensive investigation Mack Moore unit 2228, we felt that there needed to be some improvement on this remote failure, that it needed to be eliminated.

So we, therefore, redid the internal stops on the primary around the secondary slide to restrict valve, and that's basically the AD that has gone on. We believe that that in itself, along with scrutiny of the rudder in determining its performance just in terms of the performance parameters, we felt that they were still in line. That we have covered these sort of things that were failure modes. As I said, this was a remote one. We have eliminated this remote failure mode.

Let me add to the fact that in precautions, one of the things that we did learn is that there has to be some very specific guidelines on how to put this thing together and how to manufacture it.

Due to the nature of the product, it is very performance oriented to the aircraft that it has to have high standards in the quality world, and we have put numerous additional steps within our route sheet on how to manufacture and how to assemble this that has to be bought off by a quality organization, which is different from your manufacturing organization.

Therefore, you have another set of eyes that are looking at this and determining that it's not deviating from blueprint or performance requirements. So, basically, I think the manufacture in itself has tightened down its standards and left no room for guesswork or just the hand me down attitude of giving journeyman and then working them into technical experts. We now have a documented procedure on how to put this together and disassemble it and manufacture it.

CHAIRMAN HALL: Thank you for that report. Now, if you just help me on one little item here so I can again understand. The rudder on the 737 is moved by what?

THE WITNESS: By this PCU.

CHAIRMAN HALL: By the PCU. And it has what two or three major parts. Is that correct?

THE WITNESS: I'm sorry?

CHAIRMAN HALL: Components. What are the major components of the PCU?

THE WITNESS: There is bypass. There's a mod piston. There is a main PCU -- or the main control valve. There's an electro-hydraulic servo valve. There's a solenoid. There's some inlet checks and some filters. Each one of those are individually checked, plus some connectors.

CHAIRMAN HALL: How many of those items have been looked at as part of you-all's work? All of them? Some of them?

THE WITNESS: Well, when they're integrated at the top assembly, all of them are looked at in terms of how they interact with one another. Then down at the detailed level, we've look at the servo valve. We've looked at the solenoid a little closer. We've done some external tests on that.

CHAIRMAN HALL: Now this PCU is manufactured to certain specifications, I assume?

THE WITNESS: That is true.

CHAIRMAN HALL: Are those specifications approved by who? They come from Boeing and you-all do the manufacturing?

THE WITNESS: That's correct.

CHAIRMAN HALL: Is there an FAA requirement on that unit or is that a Boeing item?

THE WITNESS: Yeah, it's a Boeing item. Yes.

CHAIRMAN HALL: Now, the particular unit that was on the accident aircraft, had you-all done all the service on that particular unit since manufacture?

THE WITNESS: That's correct.

CHAIRMAN HALL: How many times had it been in for service?

THE WITNESS: One time after original manufacturing.

CHAIRMAN HALL: Did you have, I assume, in your computer what it came in for at the time it was serviced previously?

THE WITNESS: That's correct.

CHAIRMAN HALL: What was that, please?

THE WITNESS: External leakage.

CHAIRMAN HALL: External leakage. Now the filters on these units, how often are they supposed to be changed?

THE WITNESS: Parker's policy is anything that comes in is replaced, we replace that as a standard item.

CHAIRMAN HALL: No, I'm talking about is it changed in the field at all by the company?

THE WITNESS: When it comes under our roof, yes, we replace it. It's up to the airlines as to when they remove it.

CHAIRMAN HALL: How often should the filters be replaced?

THE WITNESS: I think there is some requirements within a Boeing standard, but I don't know if I can answer that.

CHAIRMAN HALL: I mean, I'm trying to get this. I can understand, I have to change my oil every 3,000 miles. It used to be 10,000. Now they tell you to do it every 3,000. Is there somewhere somebody knows how to properly maintain this thing? I'm sure there is. USAir coming on that. Okay.

Do you-all have a recommended interval that filters are supposed to be changed?

THE WITNESS: I think we would follow in the line of what Boeing recommended.

CHAIRMAN HALL: Well, I guess we'll have to piece everything together as we go. We would like to -- Mr. Weik, you are going to stay with us this week, right?

THE WITNESS: Yes.

CHAIRMAN HALL: I appreciate, you've been up here for a long time, and I appreciate your time up here. We may want to recall you, but since you'll be here with us, that wouldn't be a problem.

I would like to recall at this point in time from Boeing -- you are excused.

THE WITNESS: Thank you, Mr. Chairman.

(Witness excused.)

CHAIRMAN HALL: I would like Mr. Cline to please come up if he could just for five minutes. I hate to have a situation where somebody says I don't have the answer, somebody else does and they're sitting in the room. So, Mr. Cline has graciously agreed to come up here for five minutes.

Mr. Laynor is going to handle the questions. You are already sworn, and, Mr. Laynor, I will give you the microphone.

(Witness testimony continues on the next page.)

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

Whereupon,

PAUL CLINE,

was recalled for examination by the NTSB and, having been previously duly sworn, was examined and testified further as follows:

MR. LAYNOR: Welcome again, Mr. Cline. Mr. Cline, I think you understand the question I wanted to recall you for. But if we can refer to Exhibit 9-AH, page 2 or Exhibit 9-R where we have the pressure differential measurements across the servo valve during the test where we jam the spools in various positions. You're familiar with that test, are you not?

THE WITNESS: Yes, I am.

MR. LAYNOR: The question is that if the secondary slide over traveled for whatever reason to the internal stops and jammed at the internal stop instead of the external stop, what would the available rudder travel be and what would the point at which the rudder stalled or the residual position be?

THE WITNESS: The condition you're talking about with the positions of the slides is the same as those positions represented in condition three. In condition three, we're simulating a primary jam, and that's why you see the number as a positive 58 percent.

If you look at this assimilating a secondary jam, so that the secondary jam is at the internal stop and we're trying to overcome that with the primary, you have to consider that a minus value, a negative 58 percent.

So, what that really means is that in this case, once you've got the secondary to the internal stops and you've jammed it there, that was a left rudder command that got it there and now you try to bring it back with the primary, you will only be able to bring it back to 58 percent of the blow-down value.

I have to point out that in order to get the secondary jammed at the internal stops, it really takes three series of events or failures. First of all, you have to have something that can overstroke the secondary to get it to the internal stop. That would be something like a primary or secondary jam.

Once you get the secondary to that internal stop, then you have to jam the secondary and unjam the primary. So that's three separate events to get there. If you do that, you will be left with a 58 percent residual pressure, which is 58 percent of the hinge moment.

I would like to also point out that that 58 percent hinge moment on the case of the USAir flight 427 airplane, it would be consistent or inconsistent with the full rudder blow-down deflection required to produce the yaw moment that Mr. Kerrigan has previously testified to.

MR. LAYNOR: Let's revisit just a little bit the conditions it would take to get the secondary jam to over travel. Is there any possibility that contamination in the slot in which the roller picks up the secondary slide could cause a premature pick up of that slide without having a jam of the primary?

THE WITNESS: Yes, that would cause a premature pick up and it would cause additional stroke of the secondary equal to the magnitude or whatever piece of material that was in that slot.

MR. LAYNOR: So if there were 100 micron particle, it might over travel a certain distance of twenty thousandths?

THE WITNESS: Yes, it would over travel. If the particle was incompressible, it would over travel 100 microns.

MR. LAYNOR: Just for clarification, under those conditions, if the pilot tried to introduce right rudder that's jammed after a left rudder command, his pedal would effectively be jammed by the feedback mechanism through the pilot control linkage?

THE WITNESS: Now, this is after we've completed the three events to get to this?

MR. LAYNOR: Yes.

THE WITNESS: Yes, his pedals would come up against the external manifold stops and he would -- to him, they would feel like they were jammed in the one direction.

MR. LAYNOR: So he would have left pedal to control the rudder from this 58 degree or 58 percent, I'm sorry, residual position to full travel to the blow-down limit, but he could get nothing less than the 58 percent left rudder. He could get nothing to the right?

THE WITNESS: That's correct.

MR. LAYNOR: Thank you, Mr. Cline.

CHAIRMAN HALL: Thank you very much for your willingness to come up and you're excused.

THE WITNESS: I would like to say that I apologize for the initial confusion on that when Mr. Clark was on the right line of questioning and I thought we understood each other in our answers and he really didn't. Thank you.

CHAIRMAN HALL: Well, thank you.

(Witness excused.)

CHAIRMAN HALL: Do we need a break? Are we at a break point or not? Well, who is next? Mr. Jakse. We will be calling Mr. Jakse, but before we call Mr. Jakse, there seems to be sentiment at the table and stirring in the audience, so we'll take another 15 minute break and return, please, promptly in 15 minutes.

(Whereupon, a recess was taken.)

CHAIRMAN HALL: We will reconvene this hearing. The witness previously called is Mr. Frank Jakse. He is a senior research specialist with the Monsanto Company in St. Louis, Missouri.

Welcome, Mr. Jakse.

(Witness testimony continues on the next page.)

FRANK JAKSE, SENIOR RESEARCH SPECIALIST, MONSANTO
COMPANY, ST. LOUIS, MISSOURI

Whereupon,

FRANK JAKSE,

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: How long have you been with the Monsanto Company?

THE WITNESS: I've been with Monsanto for 15 years.

MR. SCHLEEDE: Could you give us a brief description of your education and background that qualifies you for your present position?

THE WITNESS: Yes. I have a bachelor's of science, master of science in chemistry. I've been in research and development in the industry for 15 years.

In the last three years, I've been devoting my time to Skydrol technology and technical support.

MR. SCHLEEDE: Thank you. I believe Mr. Sasser is going to begin the questioning or Mr. Phillips.

MR. PHILLIPS: Mr. Jakse, in your duties at Monsanto, what are your responsibilities and what do you do on a day-to-day basis for Monsanto?

THE WITNESS: I am senior research specialist responsible for Skydrol marketing technical service. I assist the sales people in explaining the technical aspects and performance characteristics of our Skydrol fire resistant aviation hydraulic fluid.

I am also technology team leader for Skydrol for new product developments and also oversight of our fluid analysis service.

MR. PHILLIPS: What is Skydrol?

THE WITNESS: Skydrol is a synthetic fire resistant hydraulic fluid used exclusively in aviation hydraulics. It consists of a phosphate ester base stock which in partes the fire resistant characteristics to it. They are blended up with a precise mixture of performance additives that in parte certain performance characteristics to the fluid.

MR. PHILLIPS: Do other companies other than Monsanto manufacturer hydraulic fluid?

THE WITNESS: Yes. Chevron is a competitive of ours. They also supply a fire resistant phosphate ester based hydraulic fluid to the commercial aviation industry.

MR. PHILLIPS: To the best of your knowledge, what type of hydraulic fluid was in the accident airplane, the USAir flight 427?

THE WITNESS: The Boeing 737-300 was serviced with fire resistant hydraulic fluid.

MR. PHILLIPS: Would that have been Skydrol, your product?

THE WITNESS: Actually, it would be a mixture. It is predominantly Skydrol, but as part of the certification of the hydraulic fluids, they must be mixable and miscible and compatible with other fluids, other phosphate esther fluids in any and all proportions. So there was a mixture of our product and the Chevron product in flight 427.

MR. PHILLIPS: Could you characterize the percentage concentrations of Skydrol versus Hyjet, ballpark figures?

THE WITNESS: In ballpark figures, I think it was, if I recall the numbers correctly, it was 84 percent Skydrol, 16 percent Hyjet.

MR. PHILLIPS: Have you participated in the investigation of the USAir 427 accident?

THE WITNESS: Yes, I have.

MR. PHILLIPS: In what capacity?

THE WITNESS: The NTSB requested of Monsanto support in the investigation and analysis of the hydraulic fluid from the accident aircraft. We have been a manufacturer of Skydrol for over 40 years to the industry.

Now, naturally we have a vast history of experience with the fluid and understanding the chemistry involved. We also operate an in-service fluid analysis program for our customers. So we have experience in analyzing hydraulic fluid.

MR. PHILLIPS: As part of the investigation, you were called upon or Monsanto was called upon to assist in the examination of the accident airplane's hydraulic fluid. Is that correct?

THE WITNESS: That's correct.

MR. PHILLIPS: I believe you also were involved in sampling or testing some other samples of hydraulic fluid removed from other aircraft, 737 aircraft. Could you briefly describe the process and the findings for that testing?

THE WITNESS: Are you talking specifically about what analyses we have performed?

MR. PHILLIPS: Yes, first of all, I would like to have a general overview of what samples were taken and what the process was for analyzing the samples?

THE WITNESS: At the direction of the NTSB, samples were collected from the in-service operating fleet of 737 aircraft. These fluids were collected from the A and B reservoir and A returned and B returned on each aircraft. Aircraft selected were from Southwest Airlines, United Airlines and USAir. That was one category of samples.

Another category of samples were collected from rudder PCU units that were returned to Parker for servicing or maintenance. I don't know the details of why they were returned. Fluid was collected from these rudder PCUs, from the B link cavity, A return yaw damper, B large filter, I believe, were the four locations. That was the second category of samples.

The third category of samples were fluid samples collected at various locations from the accident aircraft.

MR. PHILLIPS: These samples were tested where?

THE WITNESS: These samples were first tested in our laboratory in St. Louis as part of a -- it was what would be categorized as a wet chemical analysis. These fluids, if we had sufficient volume, and in many cases we did not have sufficient volume, we subjected the fluids to our standard analysis program, which consists of just a physical appearance and observation of color and clarity of the fluid, water content, acidity, chlorine content, specific gravity, and then gas chromatography.

Of these tests, all of them, except for acid number, were addressing the potential contamination of the hydraulic fluid. Water, chlorinated solvents are all -- I don't want to say routine, but are found quite often in used hydraulic fluid.

Specific gravity also addresses the issue of contamination. The phosphate ester hydraulic fluids have a distinctive specific gravity. The introduction of other fluids that may be used around in service of the aircraft, if they were introduced inadvertently into the hydraulic fluid, specific gravity would pick that up.

Gas chromatography is even more sensitive to detecting the presence of soluble impurities in the fluid, contaminants in the fluid.

MR. PHILLIPS: Could you summarize your findings concerning the USAir flight 427 samples?

THE WITNESS: The samples that we analyzed as part of the in-service fluid program, they all met the in-service limits as specified in the Boeing 737 service manual. If they were characterized or they did have a high particle count, the service manual does not specify an in-service limit for particle count.

We revert back to an NAS 16-38 class 9 specification as far as an in-service limit. That is defined in a Boeing document discussing hydraulic fluid contaminants for hydraulic fluid in new delivered aircraft.

MR. PHILLIPS: Could you describe the class of fluid that you found in the USAir airplane PCU?

THE WITNESS: We found rather high concentrations of particle counts in the rudder PCU fluid samples taken from the accident aircraft. Specifically, the B link cavity had what I would characterize as a very high count level in terms of particulates.

MR. PHILLIPS: Was there any attempt to do further analysis of the fluids beyond the systems that were available at Monsanto?

THE WITNESS: In the case of the hydraulic fluid, per se, no, we didn't pursue the analysis of particulates in terms of what their composition was.

MR. PHILLIPS: In the other fleet samples that were taken, I suppose were taken as a baseline to compare against the USAir 427 sample?

THE WITNESS: That's correct. That was the intent. It was to determine what the baseline fluid characteristics were at these various points on the aircraft.

MR. PHILLIPS: Could you generally characterize the differences between the accident airplane's fluid sample and those of the other samples taken?

THE WITNESS: In terms of what I would call the wet chemistry, we didn't see any difference between the 427 fluid and in the baseline fluid. Essentially, all fluid samples that we analyzed met the in-service limits as specified in the 737 service manual.

In terms of particle counts, we did see some high levels of particle counts in the in-service fleet. There's really not a direct comparison you can make between samples that were pulled from the rudder PCU of the accident and aircraft and the in-service samples, because they were collected at different locations.

MR. PHILLIPS: Could you give us an idea of the sensitivity of the sample method, the variability and results depending on the cleanliness and the methods used in sampling the fluid?

THE WITNESS: Yes, our experience has been that particle counts are very sensitive to the sampling technique and handling of the sample. Specifically, we supply clean sample bottles for our customers who wish to sample their fleet. These bottles are certified to be clean to a class 1 or zero level. So we are certain that on the collection of the fluid into the bottle, the bottle will not introduce particulates.

The 737 service manual gives a technique for collecting a proper sample. They indicate that some fluids should be drained prior to catching a midstream sample, because of the possibility of settling in the reservoir and getting a nonrepresentative sampling as far as particle counts is concerned.

I would also add that in terms of the

collection of samples from the rudder PCU, we heard testimony this morning regarding samples collected by pouring fluid out of the filter bowl. Once again, that's not a -- that's a non-standard method, if you will, of collecting fluid sample for particle counts.

The location of where you take the sample on the aircraft, how you collect the sample, and what type of bottle, all play a role in what your ultimate counts will be on that sample.

MR. PHILLIPS: We heard earlier testimony relative to the size of the micron and how small some of these particles are that we're speaking of. Could you briefly describe the equipment used to identify and even count particulates in hydraulic fluid?

THE WITNESS: We do have a slide show of some of the analyses, analytical techniques we use. Perhaps I could go through that, if you don't mind?

MR. PHILLIPS: It would be fine with me.

THE WITNESS: Could I have the first slide, please?

(Slide shown.)

THE WITNESS: This laboratory here is our in-service fluid laboratory. It is dedicated exclusively to the analysis of fluid samples submitted by our customers. There are a number of techniques. I'll go through some of them individually.

Essentially, when we receive a sample, we log it in, establish a log number, and then the sample goes through a number of stations to determine the different quality measures that were taken on the fluid.

Can I have the next slide, please?

(Slide shown.)

THE WITNESS: In 1994, we did over 7500 fluid samples for our customers in the industry. Needless to say, we have to adopt some automated techniques. This is an auto-type reader to measure acidity in the fluid.

Next slide, please?

(Slide shown.)

CHAIRMAN HALL: Mr. Jakse, I believe those slides are submitted as exhibits, are they not?

THE WITNESS: That's correct.

CHAIRMAN HALL: If you would not mind, Mr. Phillips, I guess, for the record, they are not from Exhibit No. 9-Z.

MR. PHILLIPS: That's correct, 9-Z.

CHAIRMAN HALL: Please proceed.

THE WITNESS: Shown here is our gas chromatograph. We use gas chromatography, like I said earlier, to detect the presence of other fluids that may be present. We also can determine the concentration of our product versus the competitions. A very accurate, very sensitive method for detecting contaminants, volatile contaminants.

Next slide, please?

(Slide shown.)

THE WITNESS: This addresses Mr. Phillips' question. This is a highyac automated particle counter. This allows us to do particle counts on a sample. It's a laser light scattering method. We can do an analysis of particle counts in the fluid in a matter of a few minutes.

The alternative is a manual particle counting method, whereby a laboratory person would filter the fluid, collect the micron-sized particles on a filter, put that filter under a microscope, and then visually manually count the particles in a specified grid area. That method takes on average an hour and a half to two hours per sample versus a couple of minutes for this technique.

There are differences between the two methods; manual versus automated. The laser light scattering method has been determined to be more sensitive to smaller particles. That is in the range of five to 15 microns. The manual particle count method appears to be more sensitive regarding larger particles and fibers, as well.

Can I have the next slide, please?

(Slide shown.)

THE WITNESS: We have now switched venues. I've gone through the wet chemistry analysis of the fluid. The NTSB requested that we do a chemical composition of the particles in the fluid to determine, if we could, the origin of these particles. I must say right at this point that we have never, to my knowledge, undertaken such a study. We do have the equipment and the personnel and the expertise to work with micron-sized specimens, but we have never worked with micron-sized particles from aircraft hydraulic systems.

What we're looking at here is a 48 transform infrared spectrometer with a microscope. In this method, essentially we collected the particles on a filter. Then our scientists picked out by hand selected particles from that filter pad, placed them on a salt flat and then placed them under the infrared microscope.

She then positioned the sample into the infrared beam and took an infrared spectrum. The infrared spectrum is, in many instances, a fingerprint for the material you're looking at.

It's not fool proof, however. In that, if you do not have a library of spectra to compare against or pure compounds to compare against, you will still get an infrared spectrum, but in many cases, you may not be able to conclusively identify what the material is.

May we have the next slide, please?

(Slide shown.)

THE WITNESS: The second phase of identifying the composition of the particle was electron microscopy. It's a scanning electron microscope technique. We took the same filter pads that were used in the infrared investigation, took a pie wedge out of that filter pad, mounted it on a specimen platform, and then took three views of that sample in the electron microscope.

This particular technique allows us to identify elemental contaminant -- I'm sorry -- elemental composition of the particles. It's particularly good for identifying metals. Those were the techniques we used to characterize the composition of the particles in the samples.

MR. PHILLIPS: So you used literally everything that was available to your company within your knowledge as a research specialist with Monsanto to categorize the fluid and also identify the particles where possible?

THE WITNESS: That's correct.

MR. PHILLIPS: Based on those tests, do you have any general statements to make about the quality of the fluid, the condition of the fluid?

THE WITNESS: Yes. Like I said earlier, the quality of the fluid that was available to us from flight 427 was what I would characterize as good service condition. I would not, if that sample had been received as a normal in-service fluid sample, there would be no action necessary by the operator in terms of correcting any deficiencies in the fluid.

The moisture content was moderate, but it was not beyond the in-service limit. We might point that out to the customer, but like I said, the condition of the fluid from an in-service quality aspect was good.

The particle counts were high. We provided the information as far as infrared spectra and what we call element maps that come out of the electron microscope to the NTSB.

In the cases with the infrared spectroscopy, we were only successful in identifying only a couple of compounds. Most notably, teflon, which has a very characteristic infrared spectrum.

In the case of the element maps, we saw metal. We also saw fluorine, which would be consistent with the teflon. We were not involved in further characterization as far as identifying where the particles came from.

MR. PHILLIPS: Are you aware of any other test methods available that would have been able to do additional analysis to the fluids?

THE WITNESS: No, not really. I think in terms of what know as far as what provides good long-term service of hydraulic fluid, we captured that in our wet chemical method.

MR. PHILLIPS: One final area of questioning. You stated in earlier testimony that Monsanto maintains a database for customers or relates with customers relating to fluid samples. Could you briefly describe the use of this database and why would an operator want to use your services?

THE WITNESS: We have been providing a service to our customers, the in-service fluid analysis, since 1987. In that time period, we've analyzed over 30,000 samples from various aircraft models, various operators.

What we include in that database is essentially the information that's provided to us by the operator. We request aircraft model, the carrier, the tail number, flight hours, and the date the sample is taken and any other comments that the operator may want to include in that particular fluid sample.

All the data that we generate as far as analyzing the fluid, that being water, specific gravity, acid number, chlorine, and gas chromatography, as well as our particle count are entered into that data base. That allows us to do trend analysis on fleet models, individual aircraft, particular carrier's fleet, compare that to the industry fleet performance, as well as provide us some information regarding our product's performance versus the competition.

MR. PHILLIPS: Has USAir used those services in sampling their hydraulic fluid?

THE WITNESS: Yes, they have.

MR. PHILLIPS: I have no further questions, unless you would like to add a comment.

CHAIRMAN HALL: Do the parties have questions for this witness? I see three. I see Boeing, Machinists and Monsanto. We'll begin with Mr. Purvis from the Boeing Corporation.

MR. PURVIS: Thank you. Can you tell me if it's true that the only sample from 427 that was subjected to particle counting was from the link cavity. That the others were too small or diluted with test stan fluid to be sampled or -- I'm sorry -- to be subjected to particle counting?

THE WITNESS: That's a good point. That requires clarification. It appears that any samples that were designated as A system appeared to be containing some test stan fluid. We have two samples. We have the B link cavity and the standby rudder sample, as well.

Both samples, as I recall, had high particle count, but the B link cavity was the highest level.

MR. PURVIS: Wasn't the 427 link cavity articulate level similar to the level obtained in the link cavities of the other six in-service PCUs that came to you?

THE WITNESS: That's correct. Virtually

every one, if not every one of the B link samples from the rudder PCUs that were provided to us by Parker, did have high particle counts, as well.

MR. PURVIS: Thank you very much. No more questions.

CHAIRMAN HALL: Thank you. Mr. Wurzel with the IAM.

MR. WURZEL: Mr. Jakse, good afternoon.

THE WITNESS: Good afternoon.

MR. WURZEL: You stated the sampling of fluid from flight 427's PCU was done in a non-standard way. Did this explain the higher level of contaminants in the samples taken?

THE WITNESS: I, myself, did not witness the sampling that you referred to. The explanation that was provided this morning gave an indication of perhaps some concern. Keep in mind also that we're not accustomed or we have not had the occasion to analyze samples from accident aircraft.

I'm speculating at this point, but I don't think you can rule that out, given the sensitivity of particle counts to the sampling procedure.

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

CHAIRMAN HALL: Of course, Mr. Jakse is the designated representative for Monsanto. Since he is a witness, who is going to be questioning, please?

MR. SIEGEL: I am, Mr. Chairman, Jim Siegel.

CHAIRMAN HALL: Mr. Siegel, please proceed.

MR. SIEGEL: Thank you. Mr. Jakse, we have a couple of questions for you. Specifically, how high were the particle counts in the accident aircraft flight number 427 in terms of NAS 16-38 and can you put those classes in perspective for us?

MR. SIEGEL: Sure. NAS 16-38 defines fluid cleanliness levels in five categories. That's determined by size ranges. The five size ranges are five to 15 microns, 15 to 25 microns, 25 to 50 microns, 50 to 100 microns, and then greater than 100 microns.

In our high particle count method and also in the manual particle count method, the particles are counted in those classifications. So for every sample, you get five numbers.

You compare those numbers to a scale as defined by NAS 16-38. That will define the -- then there's a numerical class designation, dependent upon what's the maximum levels. The class designation defines the maximum particles within that class.

For every class increase, you're essentially doubling the counts of particles. So, for example, if you have a class 5 fluid, a class 5 fluid versus a class 6 fluid, a class 5 fluid would be twice as clean, if you will, as a class 6. A class 7 would be four times as dirty as a class 5.

Every class increase doubles the concentration of particles.

MR. SIEGEL: What was the highest classification that was seen on the accident aircraft?

THE WITNESS: The highest classification that is designated by NAS 16-38 is class 12. I don't recall the numbers exactly, but in the five to 15 microns range, it's a little over a million particles in the five to 15 micron range.

The fluid from the B link cavity from flight 427 was a class 12.

MR. SIEGEL: What's the purity of Skydrol as sold to our customers?

THE WITNESS: The purity of Skydrol or the specification is really defined by Boeing material specification, BMS 3-11. That specification defines the cleanliness levels for new fluid. Their specification is class 7 per NES 16-38. Our production and quality control on our Skydrol fluid typically delivers class 6 or better.

In layman's terms, then we are at a minimum twice as clean as required by the BMS 3-11.

MR. SIEGEL: In your examination of the fluids on flight number 427, can you confirm as part of the particle identification process, whether you found any corrosion products, rust, et cetera?

THE WITNESS: In the samples we looked at, we saw no evidence for corrosion products. The condition of the fluid would be consistent with that in terms of low acidity and low water contamination.

MR. SIEGEL: I have no further questions.

CHAIRMAN HALL: Are there any other questions from the parties?

(No response.)

CHAIRMAN HALL: If not, Mr. Marx?

MR. MARX: In your terminology of 100 plus or greater than 100 micron particles, could these be anything say 300, 500 microns in size when you classify those as greater than 100?

THE WITNESS: Yes, they could. I think in those cases, the manual particle count would identify those as a fiber. The highyac, since it's a laser light scattering method, takes the mean diameter of a tumbling particle.

So the highyac, if anything, would tend to downsize the particles. But our channels can't distinguish between 100 and 300 microns or whatever. We just classify it as greater than 100 microns.

MR. MARX: Well, did you look at any of these particles to see what they were and how big they were in the B link cavity of the accident airplane?

THE WITNESS: In the process of identifying the composition of the particles, there were several particles that we focused our infrared beam on. I'm speaking generally now, but I think the larger particles tended to be teflon, teflon flakes, teflon film.

MR. MARX: How big were those, do you have any idea?

THE WITNESS: The biggest that I recall seeing was in the 150 micron range.

MR. MARX: Thank you.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HALL: Just one question, I guess, Mr. Jakse. Is there anything that -- this is the first time that you-all have participated in an accident investigation. Is that correct?

THE WITNESS: Yes, sir, it is.

CHAIRMAN HALL: Have you learned anything in this investigation that would lead to any changes in your-all's procedures or standards?

THE WITNESS: No, sir, I believe the NTSB has worked very diligently. In our team, I have been very impressed.

CHAIRMAN HALL: Do you have anything else to add that you feel would be pertinent, please feel free to do so?

THE WITNESS: Well, I know there's been an issue associated with standards established in terms of in-service limits. Our literature recommends annual sampling or per the airplane manufacturer's recommendations. It's been our experience that, in general, that's an appropriate time frame as far as annual sampling of hydraulic fluid.

However, I would caution that there are instances out there were annual sampling may not be appropriate.

CHAIRMAN HALL: Does that mean that you need to do it more frequently?

THE WITNESS: Actually, either way. There is some aircraft -- some systems out there that would -- as newer aircraft come on board, they are running hotter and putting greater stresses on the hydraulic fluid. The sampling may be warranted in those cases. In other cases, there are situations where the hydraulic fluid operates just fine.

So what I am cautioning is the establishment of a standard must take into consideration improved system performance and reliability across the spectrum.

CHAIRMAN HALL: Do you-all participate in setting these in-service limits?

THE WITNESS: The in-service limits that we quote in our brochure, now, I don't know if we were involved in it. Those were established before I came on board. I don't know.

CHAIRMAN HALL: All right. Well, Mr. Jakse, thank you very much for your testimony. You're excused.

(Witness excused.)

CHAIRMAN HALL: Our next witness if Michael Cohen. He is the senior vice president for Engineering and Maintenance with USAir, Inc. here in Pittsburgh, Pennsylvania. Mr. Cohen, if you would please come up.

(The witness testimony continues on the next page.)

MICHAEL COHEN, VICE PRESIDENT, LINE MAINTENANCE,
USAIR, INC., PITTSBURGH, PENNSYLVANIA

Whereupon,

MICHAEL COHEN,

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:

CHAIRMAN HALL: Welcome, Mr. Cohen. Mr. Schleede will begin the testimony.

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

THE WITNESS: My name is Michael Cohen. I'm with USAir at Pittsburgh International Airport.

MR. SCHLEEDE: And your position?

THE WITNESS: My position is vice president of line maintenance.

MR. SCHLEEDE: Give us a brief description of your background and education that qualifies you for this position?

THE WITNESS: Certainly. My education is a bachelor of science degree in aeronautical engineering with a major in structural analysis and a minor in aerodynamics and mathematics. I hold a commercial pilot's certificate with an instrument rating. I hold a flight instructor's certificate and an airplane and power plant mechanic's license.

MR. SCHLEEDE: How long have you been employed for USAir?

THE WITNESS: It would probably be easier for me to explain my background and my employment with USAir. I have over 20 years experience in the aerospace industry. The majority of it being with the airlines and other time with manufacturers. I started out as a stress engineer for North American Aircraft, and continued as a stress engineer for the Northrup Corporation. I joined Pacific Southwest Airlines in 1977.

At Pacific Southwest Airlines, I held a number of positions there. I started out there as a mechanical engineer for the company, and progressed through the organization having responsibility at various times for the manager of the engineering organization, the director of engineering and the quality organization.

Towards the end of the PSA era, I was the director of maintenance. At which time, I was responsible for all the maintenance that took place on the USAir fleet; the overall maintenance, the line maintenance, the shops, and all the productive personnel that worked the aircraft.

In my tenure with PSA, I had responsibility at one time for every department within the maintenance department. In 1988, we merged with USAir and my initial position after the merger was that of regional director of line maintenance.

I remained based in San Diego, California, where I had responsibility for six line stations and the San Diego base. At that time, the San Diego base was completing heavy overhaul maintenance work on MD-80 and British Aerospace 146 aircraft. We had the shops that were based there, and then the various line operations throughout California.

Subsequent to that, I became the vice president of operations for Pacific Southwest Air

Motive, which was a subsidiary of USAir. It was an engine overhaul facility where we did USAir engines and third-party work.

After my job there, I continued on to Pittsburgh where I became assistant vice president of engineering and quality. In that job, I had responsibility for the engineering department, the quality control and quality assurance and audit department.

Then most recently in June, I became vice president of line maintenance where I have responsibility for 36 line maintenance stations and an excess of 3500 mechanics.

We handle all the day-to-day operation of the aircraft that are operational. We take care of the C-check, the B-check, the A-check, the transit check, all of the overnight work load that takes place on the fleets.

MR. SCHLEEDE: Thank you very much. Mr. Sasser will continue.

MR. SASSER: Good afternoon, Mr. Cohen. Mr. Cohen, can you please describe the process used by USAir to develop and maintain their aircraft maintenance program?

THE WITNESS: Yes, sir. USAir develops their maintenance program through a fairly complex operation. The cornerstone of our maintenance program is the MRB document, which is the maintenance review board document that is established when the aircraft is certified, and the maintenance planning document, which is the recommended items that should be accomplished throughout the maintenance program when the airplane is placed with the operator.

The maintenance review board document handles the mandatory items and is established for a new operator of the aircraft. It does not take into consideration the experience that an operator may have in operating that fleet or a similar fleet of aircraft.

Once those documents are received in addition to the task cards that come with the document, we establish a task force at our company. That task force is made up of personnel from various departments; the engineering department, the quality department, the planning department, the production department and our program management people.

The reason this is so important to us is USAir with the size that it is and the diversity of the fleet and the experience it's had with the various products, brings to the maintenance program a lot of its experience over the years.

So we take the documents, together with this task group, and we evaluate all of the items in the MRB documents and in the maintenance planning document, and we determine whether that item is right for the maintenance that's going to take place at USAir.

By doing that, we review it with our technical people and we start to establish a matrix. That matrix is shown to take the MRB item, the maintenance planning item, and the USAir item. This gives us a history of the development of the program so that when we are through and we audit this program, we can insure ourselves through a matrix that we have not missed any items.

Now in the case of the 737, which we're speaking of with this hearing, USAir had had experience with the 737 prior to the 300 coming on board the property. We had operated the 737-200 for quite a time, and we were also the kick-off customer for the 300 aircraft.

So our personnel from our engineering department and production department were involved in the development of the MRB document. As I'm sure you're aware, the MRB document is developed through a consortium of FAA personnel, the manufacturing personnel, various airlines that have operated similar products, and everybody gets together to determine what the proper maintenance to be done is and what the frequency of that maintenance should be done at.

Again, I want to be sure to stress the fact that when the MRB document comes out, it is developed from the Boeing stand point for the lowest common denominator. When I say that, it refers to a maintenance organization that could be very small, possibly do all of their maintenance through a third-party operation, and not have the sophistication of some of the larger airlines. So we have to take that into consideration in the development of the program.

The next item that we do with this task force is after the cards have been written and the matrix has been established, we now validate the work through all the groups independently. Instead of meeting as a task force, we route the program through the various groups so that they can bring all of their personnel together to validate any concerns that they may have and bring back to the panel or just to be insured that everything has been covered.

Then the final step after it has been bought off by all the internal USAir personnel would be to send it to the FAA for their review and approval. This is our local office where it would go to. We send them the entire package; the work cards, the matrix, and obviously the MRB document and all the planning documents.

I should also note that the FAA throughout the development of the program, takes part in some of our development. While they don't necessarily designate or dictate what should be done, there's questions that arise and rather than wait till it gets to the end and send it back and forth for revisions, as a question comes up in USAir's mind, we will solicit comments from the FAA to get their thoughts and beliefs on how they would like to see it handled.

That's how we establish the program. Now, the program is a very dynamic program. It's in constant revision. The revisions take place for many reasons. Primarily they take place for two reasons. One is revisions to the MRB document as a new aircraft is developed. It's only the initial starting point when these documents are released. But as various airlines gain experience with the aircraft and its systems and components, we then take that back to the MRB, reconvene this MRB and make revisions to the program.

In some cases, they only may be once or twice. In some cases, they may be in excess of ten times. It really depends on the sophistication of the systems and the aircraft.

The other method that has the program in constant change is the reliability program that is operated within the airline. Our airline operates a reliability program where we collect data constantly on the tasks that we do, on the component reliability, and on the effects of delays and everything that could possibly affect the airplane.

In some cases, we will learn that an item we are doing it too frequently and it does not need to be accomplished that frequently. So we will modify our program to do an extension. In other cases, we will find that the task we're doing or the frequency we are doing it at may be too long term and we will shorten that frequency. But it's all driven by the reliability of the aircraft and how the aircraft performs in our operation.

It's very difficult to take the information that the industry has with this aircraft and apply it to a particular airline. Because, as I'm sure you're aware, the environment with which you operate it in, the level of maintenance you do, how often the aircraft visits a maintenance station, all these things have an effect on the maintenance program and we revise it as these things change.

I should also add that any revision to the maintenance program, whether it be through the MRB process or through our internal process, is done by a strict set of guidelines, which is referred to as the MS-3 document.

This is a maintenance steering group document that was developed years ago and has been revised over the years to bring into account the various maintenance actions, the maintenance processees and all the validation of the work that you do.

It's done through a group of decision trees. Where you can take an experienced reliability person and let him work through decision diagrams, getting yes or no answers and making determinations of where that program should be.

MR. SASSER: All these changes that you've referred to that come as a course of the program being dynamic in nature, all of those changes, are they all coordinated with the manufacturer and the local FAA office?

THE WITNESS: The majority of the changes are coordinated with the manufacturer. There's a lot of things in the maintenance program that are USAir internal that really do not have a requirement in the maintenance program or the aircraft.

It's just things that we have learned by doing our business, things that we prefer to do where we won't get caught with a minor delay by doing a grease shop a little bit earlier or having different limits on various components. But anything that requires an extension of a component that is under the control of the MRB, they are all coordinated through the manufacturer of that component and the OEM of the airplane. In this case, being Boeing.

MR. SASSER: And the FAA, in addition to that? The FAA is also in on that?

THE WITNESS: The FAA is also brought on board. We advise them of all the items that we are doing. There are certain items that don't require FAA approval. The majority of them, especially when you come to extensions or changes in your processees, they all require FAA approval and the document is sent to them for their review and approval before we implement.

MR. SASSER: This kind of brings us into our next area. Can you tell us how USAir communicates with the various manufacturers and uses them in the resolution of problems that arise during the operation of the fleet?

THE WITNESS: Yes. USAir, like most large aircraft or airlines, have many of the manufacturer's representatives on the property. We have a very expensive engineering department that is our direct communication link with our manufacturers and vendors, but we do have reps on the property.

As an example with the Boeing Company, we have their reps on our property in the Pittsburgh Airport, in the Charlotte facility and in the Winston facility. These are three of our major bases where we do both overhaul work and line work. The Pittsburgh office gets most of the inquiries because that is where the majority of our engineers are located.

We use them as a clearinghouse, if you will, for the information to go to the manufacturer and from the manufacturer. We are in constant contact with these people. They attend most of our daily meetings.

We have a daily operational meeting where we go over the operation from the day before and any items that need to have corrective action. They sit in on that meeting. They sit in our reliability meetings. Quite honestly, their offices are located right next to our engineering department. We treat them as they're one of our staff.

We very rarely even think of them as Boeing personnel. I can give you a better analogy here. If you were taking your car in to be worked on and you happen to be driving a Ford and you had the Ford rep living in the extra bedroom of your house. That's really what it's like with these representatives.

We have representatives from Boeing. We have representatives from CFMI, who is the engine manufacturer and other manufacturers who are not associated with this hearing, such as the Douglas Corporation, the Foker Corporation, and even some of our component people.

The reps spend an enormous amount of time on the floor. They solicit comments and questions from our maintenance personnel and our maintenance personnel do the same from them. Also, any of the inquiries that go into the Boeing Company are returned not only to the rep, but they are returned by an E-mail. We have an E-mail system within USAir throughout our 36 maintenance stations.

We have a mailing list on that E-mail where all of the responses and questions come through E-mail. So most of our personnel -- certainly in the management ranks and the foreman ranks -- are aware of the conversations that are going on back and forth.

MR. SASSER: In testimony earlier today, a question was raised about the compliance of the Boeing 737, known as flight 427, compliance with an FAA AD 94-01-07. I refer you to Exhibit 9-F, page 32 through 46. Can you tell us if the rudder PCU used on USAir flight 427 had been tested for proper operation in accordance with this AD?

THE WITNESS: Yes, actually, USAir has a little bit of a unique history with this AD, and I would like to take a moment to explain that to you. After the Colorado Springs' accident, there was a lot of speculation as to the cause and determination of that accident, and there was a lot of questions being asked, as you are aware, in regards to the PCU.

Prior to that AD coming out, USAir, through its engineering department and in coordination with

Boeing and some of the other operators of the aircraft, developed an engineering order. Where we went out in late '92 and early '93, we completed all the airplanes within a 60 day period. Essentially, we had performed the check that subsequently became the AD.

We did not write the AD, but we had knowledge of what was going into the development of that AD. So we had gone out and complied with that on all of our 300 fleet. When the AD came out, there were some changes, but it was only for the 200 fleet.

After the AD came out, which came out March 3, 1994, the functional test that was required to be done initially was complied with on the accident aircraft on 3-21-94. It was done a second time on 6-14-94, and it was done a third time on 8-8-94.

Now, the interval between those times is 750 hours. In case you're asking yourself it seems like a short time in between that, we frequently do a lot of our checks early as a result of our scheduling process. With 450 fleets, you can't always put your hands on the airplane that you want. So we take the opportunity when we have that aircraft in maintenance to do the required maintenance that's coming up.

Also, earlier in some of the testimony, there was a question of when that PCU was installed on that aircraft. That PCU was installed on the accident aircraft on January 21, 1993.

MR. SASSER: In your testimony, you talk about your engineering department in compliance with the AD and their interface with the manufacturer. Can you describe your engineering organization and how that interfaced between the manufacturers and the FAA work?

THE WITNESS: Yes, I can. I have a little bit of a unique advantage coming from a production department. If you hadn't picked up on it, prior to June, I was responsible for the engineering department and the quality department at USAir. We are quite proud of our engineering department.

We have a group of over 70 degree engineers that work with us. We have a group of 12 engineers that are DPRs authorized by the FAA. We have them in various disciplines. We have them in the structures group. We have them in the interiors group. We have them in the systems group. We also have engineering personnel in the power plant organization and in the avionics group.

We also have within our engineering department a DAS authority. I believe there are only handful of airlines in the U.S. that have DAS authority. This authority gives us the authorization through the FAA to be able to authorize supplemental type certificate changes on behalf of the FAA. We have a staff of personnel that have been trained and certified to carry on that action.

Again, they are our primary communication with our vendors and with our reps. We use them as a clearinghouse, because for any of you that have worked on the floor, the language we use on the floor isn't the same language we use as an engineer, isn't the same language we use as a manufacturer. And we try to get a clear message across by putting in the proper terminology as we transfer the message.

MR. SASSER: From your perspective, can you tell us what the relationship between your office and the Flight Standards District Office of the Federal Aviation Administration here that has your certificate for maintenance? What is that relationship like?

THE WITNESS: Well, as you might expect with an airline the size of USAir, there is a lot of activity between the local office and USAir. I would simply classify it as a very businesslike, arm's length, very communicative relationship.

Our local FAA spends an enormous amount of time at our facility doing spot checks, doing ram checks. They participate in a lot of our meetings, our reliability meeting that takes place within USAir. Frequently, they are asked to come in and discuss concerns that they might have with our maintenance management staff, so that there's no surprises out there.

We try to keep open communication going all the time. We also have a numerous amount of scheduled meetings that take place on a regular basis. For one, we attend a monthly meeting with all of the inspection personnel and management personnel and the maintenance department, along with the various groups within USAir maintenance. We get together monthly and discuss issues from both sides.

We typically hear from the inspectors things that they're seeing that certainly are not a dangerous situation, a safety issue or a regulatory situation, but just things that they think we should take another look at and possibly reconsider the way we do business. We are also given the opportunity from the airline side to raise issues that we have regarding the FAA and the dealings that go back and forth.

We also have a quarterly meeting that is not just the maintenance area, but it is the maintenance area and the operation's area as well. It's the PTRS system and we have a quarterly meeting to review the trends that are being established.

If you're not familiar, the PTRS system is a tracking system that the FAA uses with not only the local personnel, but it's used with all the geographic personnel throughout the USAir system. They analyze that data on a regular basis and develop trends. We meet together with our operation's groups to go over these trends, whether they be negative or positive, to develop corrective action, if needed, or just to bring them to the surface so everybody knows what we're dealing with on a regular basis.

There's also a tremendous amount of one on one with the FAA. Frequently, I will probably not go a day without having a phone conversation with somebody in the FAA office, whether it be initiated by me or initiated by the FAA. I see it as a very open relationship and a very businesslike, arm's length relationship.

Not to give them a compliment, because I hate to do that, but they have a staff that has a lot of exairline personnel. And you bring into that people who that have had hand-on experience. They can bring a lot to the table for the airline.

MR. SASSER: The FAA does inspections on your organization, and I understand that you an internal audit program that you operate at USAir, as well. Can you explain your internal audit system and how that's utilized in the operation of the maintenance program?

THE WITNESS: Yes, I can. Again, this is a department that I really look to for guidance internally. They have a tremendous amount of responsibility. They have the responsibility and it's based on the premise that USAir is primarily responsible for continuously monitoring the operation to be safe, to be within the regulatory requirements, and to meet all of the federal air regulations.

This organization bypasses all lines of authority at USAir and it reports within the maintenance department directly to our most senior officer, which is the senior vice president of engineering and maintenance operations.

This program was initiated in 1989. As you're aware, the advisory circular for internal evaluation programs came out in 1992. USAir participated in a lot of industry meetings and participated in the development of this advisory circular. We felt so strong about it, we started to develop our program as the development of the advisory circular was going on.

So our program really kicked off in 1989. Some of the things that are people to look at, just to give you some examples, they are responsible for the continuing analysis and surveillance program throughout the entire maintenance organization; the line maintenance, the shops, the engineering. They do audits for every one of our facilities and do spot checks on personnel to see how a department is developing and working.

They have the responsibility for oversight of the continuous airworthiness maintenance program. As I indicated earlier with the development of the program, a lot of the groups take place in it. They are really the final say before it goes out the door to give us assurance that it's satisfies all the requirements of the regulations.

They monitor our required inspection program. They are responsible for the AD compliance program. They are responsible for oversight of the maintenance training program, the deferred maintenance program. They insure that all the items fall within the requirements that it takes to allow an item to be deferred. They keep oversight of our weight and balance program, our major repair and alteration program, our fueling program.

They have a special group that just has oversight of all our fueling vendors. We do all our fueling with third-party vendors, and they have oversight responsibility for all of them. Then they, of course, look over our stores and material control program.

In addition to that, we have some internal programs that we have established that we find to be extremely helpful within the USAir facility. One of them is a hot-line program. We determined that it's very difficult to receive input from the mechanics that are working on the line, the people that are out there on the third shift, the people that are really getting the job done.

Frequently, if they are approached by management personnel, as you might expect, they might be hesitant in raising an issue. They may not be available when the management personnel are available.

It's a very difficult task to get their concerns, their inputs. These are the people that do the work every day. They have tremendous input to the maintenance program and to issues within USAir.

So we established a hot line for a couple of reasons. One, so that it could be manned 24 hours a day and receive input 24 hours a day, seven days a week. And also so that if a maintenance personnel had a concern that he thought might jeopardize his standing in the company, he could do it without reporting who he is or where he works, just being able to raise the issue.

Every one of these items that comes into the hot line is responded to. I must tell you, there's some great items that come in and there's also some garbage that comes in. But we make it a point to address each and every item. If the people want to have a response back as to our actions or our findings, we will do that. If they do not have a desire to do that, we do have a file on every item that comes in the door.

We also have established in coordination with the FAA an MRM program. I'm sure you are all aware of the cockpit resource management program, the CRM program. We are working towards a maintenance resource management program. There has been some assistance from the FAA.

We have been one of the subject airlines where personnel that they have had on grants to do some studies for them have participated in meetings within USAir and worked with our personnel trying to determine causes for poor communication, concerns for how we develop work cards. So that there's not anything in there that's going to lead people astray. And working together in a team concept just like the cockpit is working.

Now this program is in the development stages right now. The FAA has been a participant in it. We expect it to develop very quickly from this point on, and hope it to be the kick-off program for the airline industries.

That really summarizes what takes place in our quality control, our audit program. We have an inspection program, which I can talk to later as we get into some of the other items.

MR. SASSER: Can you describe for us the requirements for hydraulic fluid testing utilized at USAir?

THE WITNESS: Yes. First of all, let me say that hydraulic fluid testing, if you will, I would prefer to break it into two categories; one is aircraft and one is ground support equipment, GSE equipment. The reason I do that is obviously the GSE equipment is what we install the hydraulic fluid into the aircraft with.

On the aircraft side of it, we follow all the standards that are established through the manufacturer of the aircraft and establish within the maintenance planning and MRB documents.

The quality of fluid is primarily audited through the change of filters throughout the system. The 737-300, I believe, has 17 hydraulic filters on the aircraft. We have a regular schedule of filter changes in our maintenance program for all of these filters.

Should we find any contamination or particles in the filters or anything that would lead us to believe that there is suspect for the fluid, we would take a sample of that fluid and send it out to our engineering department for evaluation.

If we would have a failure in the system, if we would fail a component, primarily if we would a hydraulic pump, an engine driven hydraulic pump, we will flush that system, change the filters, with the change of the pump, and insure that we have clean fluid going back into the aircraft.

The bottom line of our aircraft program is we follow all the prescribed actions required by the manufacturer. From our GSE side, we have a considerable amount of various maintenance programs for that equipment.

To give you some examples, our GSE equipment comes in various sizes. One, we refer to as a Bowser, which is a service cart. It's typically a cart that contains anywhere from five to 15 gallons of fluid and it's typically activated with a hand pump used to service the hydraulic system on an aircraft.

When we do maintenance on the system and break it and we lose some fluid or if there would be a leak or any reason to service the system, we use these carts to service those systems.

Now there's two levels of maintenance with those carts. One is a monthly check where it is looked at to be sure that it is intact and it's not dirty and everything is working and the hose is intact. We also remove the filter screen, evaluate it, and replace it if necessary.

Then on an annual basis, we take those service carts, we flush them out and replenish them with all brand new fluid, replace the filter on there with a brand new one, and, again, validate the hoses and all the components of that system.

Our next group of units and they really come in two sizes, but I'll describe them as one. They are an external power cart used to either power an aircraft when it's in the hanger so that we do not need to use the engine driven pumps or the electric pumps on the airplane.

It is actually an external hydraulic system that has a reservoir, a pump and valves where maintenance personnel can operate the entire hydraulic system at 3,000 psi as if it was operating on engine pumps or electric pumps.

We also have a smaller version of that that we use in our shops, where we do various component work so that we can power those components with 3,000 psi and use them during the test process within the shops.

Now those components are both on a similar program. On a monthly basis, they have a visual inspection for general condition and we look at all the hoses and the connections and insure the cleanliness and insure that everything is intact on that unit.

Then on an annual basis, we actually have a work card similar to that with which we work on an aircraft with, that lays out all the required items. Everything from looking at all the valves on the interior to the paint condition, to the valve condition, to the glass condition.

We inspect all the controls. We inspect the reservoir for any leaks. We drain and flush the reservoir. We evaluate all the hardware on there. There's a tremendous amount of placards on there that give directions on how to operate the equipment on the safety procedures, on hook-up procedures, and we assure that those are intact and certainly readable.

Then we replace all filter elements. Most of these larger units have large filters, small filters, almost as sophisticated as an aircraft. They don't have 17, but most of them have two to five filters installed on them.

They have kaystrain filters. They have pressure filters, return filters. All of those are replaced on an annual basis and then the reservoirs are refilled.

MR. SASSER: Mr. Cohen, during the course of the investigation, an issue was raised about the life limit of the aircraft engine from the 737 program and USAir's derating of engines. Can you briefly describe the system used by USAir for this program?

THE WITNESS: I'm not sure that I can briefly do it, but I'll try my best. First of all, a lot of things were alluded to in the various articles that came out, which I'm sure you are all aware of. The bottom line of the project is I must tell you is that during the aircraft certification in 1984 when this aircraft was certified and as part of the type data certification of the aircraft, there was a requirement to be able to operate the aircraft with two power level engines.

Let me go back and tell you that this aircraft is certified to operate with an engine that we refer to as a B-2 engine, which is certified to operate at 22,100 pounds of thrust. The same aircraft is also certified to operate with B-1 power, which is 20,100 pounds of thrust.

The obvious reason for the difference in the thrust levels is the mission that the aircraft is going to fly and the payload that you wish to carry with this aircraft. As the aircraft was being certified, there were carriers, such as USAir, that we're going to have a mixed fleet of airplanes.

While USAir has a large fleet of 737-300s, we really break it into two fleets. One which we call the long-range aircraft, which we fly missions coast to coast or those which we refer to as our short-haul airplanes, which typically fly a mission of two and half hours or less.

The aircraft has the same air frame. The primary difference between the two aircraft is the fact that one operates with B-2 power and one operates with B-1, and the long-range airplanes has an auxiliary fuel tank mounted in the cargo hold to carry the extra fuel to carry the load.

During the certification, as I said earlier, it was important that the airlines had an opportunity to operate with an inter-mix of engines. Not unique to the Boeing aircraft, but very consistent with any aircraft that has multiple engine models certified for use.

The reason for that is that if you find yourself one day where you only have a spare engine available that is not of the higher thrust level, you can install the engine with the lower thrust level and then also derate the other engine so that they are both operating at the same power level. But it gives you an opportunity to use the aircraft instead of have it sitting on the ground for lack of spares.

This enables us -- we certainly can't fly the mission that we would if we had the two higher rated engines, but we can use the aircraft in other circumstances. So during the certification, Boeing certified the aircraft to operate with either two B-2 engines, two B-1 engines or an inter-mix of both.

Now, what USAir has determined to do because we have a limited number of long-range airplanes, we are taking the majority of our airplanes were delivered with B-2 power. So we really have an excess of B-2 engines, if you will.

We use those B-2 engines on short-haul airplanes. If we were to operate those engines consistently at B-2 power at the 22,000 pound thrust level, obviously the wear and tear on the engine would take place in a faster manner than it would if you operated at a lesser level.

Two great analogies for that is -- one, is a box fan. You've got a box fan that has a motor on it. That motor is capable of running that fan at a low speed, a medium speed or a high speed. If I operated all the time at a low speed, it doesn't take a rocket scientist to figure out it's going to last us a longer period of time.

So we elect to use those B-2 engines in a derated form on the B-1 aircraft, and, thus, we extend our maintenance requirements for a longer period of time because we operate them at a lower power setting. But the issue of time limits on the engine, I must tell you we're talking about maintenance requirements now and not time limits.

When that engine is certified, there are time limits established for various components of that engine. Most of them are rotating parts. Regardless of whether that engine is operated in B-2 power, whether it's operated at B-1 power, or, in fact, if you operated it on a smaller aircraft, the 500 at 18,000, when it receives those time limits and those are in cycles -- a cycle being a take off and a landing -- those engines need to come off regardless of what stage they are in the maintenance program.

The time limit is a drop dead time when the engine must be removed. There are various components to drive it. As soon as one component reaches that time limit, the engine must be removed from service. So the bottom line of our program at USAir was we extended the life on the wing, but we did not extend the life of the engine.

The airline nor our local FAA, not even Boeing, has the authority to extend that life. That life has to come through very expensive testing and analysis through the engine certification branch of the FAA and the manufacturer of the engine.

MR. SASSER: Mr. Cohen, that's all the questions I have. Do you have anything to add that we failed to talk about here this evening?

THE WITNESS: No, sir.

MR. SASSER: Mr. Chairman.

CHAIRMAN HALL: Thank you, Mr. Sasser. Do the parties have questions for this witness?

(No response.)

CHAIRMAN HALL: I see no hands. Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Clark?

MR. CLARK: No questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Just a couple areas.

Mr. Cohen, when you were describing the

hydraulic fluid testing program, I want to make sure it was clear that that program you described was that in effect at the time in September of 1994? You were describing your sampling program and your fluid testing program?

THE WITNESS: Yes, it was. To give you a little bit more on it, since the accident aircraft, we have taken a sample of our fleet just to go through the fleet on an ad hoc basis to see the condition of the fleet. But the requirement of the program is, in fact, the same as it was from the day we start operating the aircraft, which is totally in compliance with the Boeing program.

MR. SCHLEEDE: I was going to ask you, other than the sampling, are there any other changes in your hydraulic fluid programs since the accident?

THE WITNESS: No, sir.

MR. SCHLEEDE: I wanted to ask you just briefly about service difficulty reporting or defect reporting. What type of items are normally required to be reported to the FAA by an airline maintenance type items, just general?

THE WITNESS: The typical items that get reported are major structural defects found during an inspection program or in service. Failures or service difficulties with major components of the aircraft in appliances, engines, avionics. Things that would cause an interruption in the operation of the aircraft during its intended flight, whether it would be a return to field for a failure of an item or things like this.

MR. SCHLEEDE: So any item that causes an interruption of the flight would have to be reported to the FAA?

THE WITNESS: That's correct.

MR. SCHLEEDE: How about during scheduled maintenance? You mentioned these major components. Is there a clear definition of major components malfunctions that would be reported?

THE WITNESS: Well, if you look at the FARs, it's a laundry list that you can wear down both sleeves. It goes on and on and on. Typically, it handles all the components that could affect the safety of flight or any structure that could affect the safety of flight.

MR. SCHLEEDE: Do you as an airline make reports directly to the Boeing Company or let's say the manufacturer of the air frame?

THE WITNESS: We, as an airline, make reports directly to the manufacturer through the reps at our facility. As I explained earlier, the reps sit in on our daily meetings, our operational meetings. In some cases, I hate to admit it, but they're aware of the problem before I am. But all the difficulties that we have are reported through the manufacturers.

Actually, also USAir being the kick off customer with the 737-300, a lot of development work for the maintenance program, for improvements in the aircraft and the engine really were done in coordination with USAir. There was a lot of close work done with the two groups.

I would also like to comment on the service difficulty reports. USAir when I responsible for quality, I would be less than honest if I didn't tell you one of my concerns was the amount of items that we did report. While there are a set of regulations out there that say, you as an airline report this, this and this, there's a whole matrix of what goes on in the industry, and I'm sure you are aware of that.

When we took a sample of the industry, and we have not changed our procedures since that time, but we have taken a survey of the industry, USAir does more reporting than any other airline out there. I believe it's USAir and Northwest that are the two highest in reporting items. That raises a difficult balance, because we report a lot of things that are not necessarily required, but we feel that the industry should be aware of it.

We, as an airline, review the responses from service difficulty reports just so we know what's going out on the industry. We don't want to have our head buried in the sand and say USAir is the only carrier out there. So because we're interested in what's going on out there, we feel that other people are interested with what goes on with our fleet, because we have a large fleet. So we do an extensive amount of reporting.

MR. SCHLEEDE: Do you have on-line capability to the FAA's SDR system, computer on-line?

THE WITNESS: No, we send it over to the local office. Actually, I'm going to tell you I'm not 100 percent sure on that. I know it was in a changeover. We have a form that we fill out through our maintenance control and tech center. When I was responsible for it, they were being hand carried over and sent through the mail.

I can't tell you for sure honestly if we have transformed into the electronic.

MR. SCHLEEDE: Well, I was actually referring to searching this database itself?

THE WITNESS: No, we will go on over to the FAA if we have an inquiry and go through them to get the response.

MR. SCHLEEDE: I think you characterized it, but could I ask you could you characterize the usefulness of the SDR program?

THE WITNESS: We find them very useful. We throw out a lot of data because if we find a carrier that's operating in a very different environment or operating the airline on different flight segments, we will tend to toss that information out. We will look for similar airlines with similar equipment and then make a determination from that.

Yes, we find it valuable. A lot of times we have to take the description that's given and we will make a follow on phone call to the carrier, because we know who it is, and get further data on it to see if it's something that would impact us.

MR. SCHLEEDE: One last item, sir, and to the left of that pile they gave you Exhibit 11-A-1. I know 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. Look in the upper right-hand corner. It's addendum 1, I guess.

THE WITNESS: Yes.

MR. SCHLEEDE: Have you seen this before? It's an addendum to the Maintenance Records Group Chairman's report for this particular accident. It's an expansion of some history on the main rudder PCU that was removed and replaced in January of '93 on the accident airplane. Are you familiar with that?

THE WITNESS: No, I am not.

MR. SCHLEEDE: Well, the one thing I was interested in is in the third paragraph along the lines of our -- just to help me understand service reporting. The third paragraph talks about the bolt that attaches the PCU main rod to the rudder was worn and replaced and shipped back. Is that something that you would expect some type of a report to either Boeing or to the FAA or even to your own -- into some kind of a database or an SDR?

THE WITNESS: Well, when we do the change on the component, as you're aware in the Boeing maintenance manual, there are limits that the bolt can be worn to. The requirements of our paperwork require the inspector to go in and take the proper dimensions and record it.

If the bolt is worn beyond limits, typically unless it was almost to a catastrophic point, if it was just at the limits or beyond the limits, we would not report it. If it was really an extreme case where the bolt was worn significantly through, we would certainly report that. But on a normal day-to-day basis if we exceeded it by a couple of thousandths, no, we would not report that.

MR. SCHLEEDE: The third paragraph on the bottom, our investigators looked at your reliability department's computer printout for the work card, the job cards specified here and determined if they were reoccurring defects. We note here that PCU leaks were found to be common, which we've already had other testimony on. That's understandable.

It said no other case of bolt deformation or damage was found. This would be in your system. Would this other particular finding up here in paragraph 3, would that have been put into your computer? Is that something that would be put in so that if we wanted to find it later, we could retrieve it?

THE WITNESS: I guess I'm not sure. Can you restate your question again?

MR. SCHLEEDE: Well, I guess, in the third from the bottom paragraph, we say we found no cases of bolt deformation in your system, in your computer printout. But would we find it? Would the one that's cited up there in paragraph 3 be entered in there? If we didn't find anything, they're not entered. I'd understand why we didn't find them.

THE WITNESS: Yes, it would. In our inspection program, every time an inspection finding or discrepancy is found during the evaluation of the aircraft, an OM-26 which is an internal form -- it's a non-routine discrepancy form -- is filled out by the inspection personnel.

Then the corrective action is added to that card and it goes into our permanent records. Typically, these are found during our Q-check which is our overhaul maintenance. Those packages stay intact and could be found in that system.

MR. SCHLEEDE: Thank you very much.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HALL: Mr. Cohen, this particular aircraft, when was it delivered and was it USAir at the time that accepted this particular aircraft, the accident aircraft?

THE WITNESS: To be perfectly honest with you, I don't have the exact date. I believe it's part of the record. I believe the airplane was delivered in 1988, if I'm not mistaken.

CHAIRMAN HALL: Was it delivered to USAir or to who?

THE WITNESS: I can't tell you that for sure, but I can tell you it was either delivered to USAir or to Piedmont. Piedmont became another airline that merged into the USAir system and we combined the fleets.

CHAIRMAN HALL: The PCU was installed on the accident aircraft you say January 21, 1993? That's what you mentioned.

THE WITNESS: Yes, just let me find it. Yes, it was installed January 21, 1993.

CHAIRMAN HALL: And was that a new PCU?

THE WITNESS: No, it was a PCU that had just come back from Parker, who does our repair work. It was removed from another aircraft in our fleet on September 9, 1992 for an external leak.

CHAIRMAN HALL: The flight records on that aircraft that were initiated, I guess, is there a planning document for that aircraft, specific aircraft?

THE WITNESS: Do you mean for the maintenance program?

CHAIRMAN HALL: Yes.

THE WITNESS: The planning document is for the series of airplanes. They don't issue a planning document for a particular tail number aircraft.

CHAIRMAN HALL: So you have the planning document for all your 737-300s?

THE WITNESS: Absolutely.

CHAIRMAN HALL: This aircraft was covered under that document, but we're not sure whether it was a Piedmont or USAir. I'm just trying to wonder how that was merged into the system when all these airlines came together?

THE WITNESS: The fleets as far as the maintenance program are identical. There is no difference in the maintenance requirements for either aircraft. When the merger took place, the Piedmont aircraft were merged into the USAir maintenance program. The USAir maintenance program was a more intensive maintenance program, and we elected to transition these aircraft in.

There was a transition check that was developed and approved by our local FAA to transition the aircraft that were presently on the Piedmont program into the USAir program. So the bottom line of that was there was certainly no maintenance missed. We probably did more maintenance than we ever needed to do to transition it in.

CHAIRMAN HALL: Now when do you-all decide to repair a PCU yourselves and when do you decide to send it back to Parker-Hannifin to repair?

THE WITNESS: We do not repair any PCUs in house. That's one component that goes out all of the time.

CHAIRMAN HALL: Routinely, how long do you-all keep one in service or do you have any service interval for them or it's just when they need to be serviced?

THE WITNESS: There is no service interval for the PCU. It's on condition. That's the maintenance process for it, which would tell you that it would only come off when there's a reason for it to come off.

CHAIRMAN HALL: You said an engine had a life to it, that you then stopped using that engine. Does the PCU have a life to it?

THE WITNESS: No, it does not. Let me explain that if you don't mind. A component that is on condition goes for a period of time. As it deteriorates over a time scale, it starts to develop a discrepancy, whether that discrepancy be an external leak, which the majority of them are, or some sort of a mechanical item. As soon as it is squawked or found to be leaking by our maintenance personnel, we take an action.

We send it back to Parker to be reworked and, in fact, what happens is it is restored and recertified back to its original condition. So if I were to draw a scale of it for you, you could take the reliability of it or the deterioration of it and draw a straight line down. I'm sorry, not a straight line down. A diagonal line down and then it goes in for restoration.

You take it up to its original level of reliability and operation. Then it deteriorates again and it's like a saw tooth chart. It's constantly restored as the requirement it. But there is no requirement for a life limit on it.

CHAIRMAN HALL: What has been your experience with this PCU? Do you keep a computer printout? Has it been a dependable unit? Is it something that you have more problems with than you would have with maybe another hydraulic operation in the plane or what's your experience with these PCUs? How many 737s do you-all operate, by the way?

THE WITNESS: We have 235.

CHAIRMAN HALL: So you-all are pretty big in that. So, okay, what is your experience then? I guess, you would have a pretty good idea of what experience you had with that PCU?

THE WITNESS: I would not classify it any worse than any other hydraulic actuator on the aircraft. It's very similar. The major reason that we take the actuator off the aircraft is for external leaks. It's a sensitive unit up there and it does have a tendency to develop some leaks, but from a mechanical standpoint, I wouldn't consider it any different than any other actuator on the aircraft.

CHAIRMAN HALL: I assume, sir, that you are aware of the accident involving that we've referred to numerous times in Colorado Springs?

THE WITNESS: Correct.

CHAIRMAN HALL: Have you read the accident report the NTSB issued on that?

THE WITNESS: No, I have not.

CHAIRMAN HALL: Do you know what actions USAir might have taken in regards to their 737 fleet or was there any concerns that came out to you from either the FAA or your Boeing person that stays there with you-all in regard to anything you should be doing in regard to that rudder?

THE WITNESS: Well, we are taking those actions. The concerns that were raised at USAir and they were raised internally through our engineering department, the concerns were from the issues that came out of the Colorado Springs accident. I'm telling you I did not personally read the report, but it was gone over in detail with our engineering folks.

The engineering folks, in coordination with our flight department, issued what turned out to be the AD prior to the AD ever coming out. It was complied with on the USAir fleet.

In addition, USAir has accelerated the replacement program and we anticipate having 235 aircraft retrofitted with the reworked PCUs by the end of 1995. The restricting factor right now is how fast we can turn them at the vendor. But we are constantly -- we not waiting for a leak or any other discrepancy to take place. When we get a PCU in our hands, we replace it on an aircraft.

CHAIRMAN HALL: Let me, sir, applaud that aggressive action. Are you aware that the National Transportation Safety Board was unable to find a probable cause in the Colorado Springs' accident?

THE WITNESS: Yes, sir, I am.

CHAIRMAN HALL: Are you aware of the items, I guess, you have on your planes, called flight data recorders?

THE WITNESS: Yes.

CHAIRMAN HALL: Do you-all have any plans as a result of these two accidents to upgrade your flight data recorders on your 737 fleet to provide the National Transportation Safety Board, if regrettably if we ever had another accident, there would be some information on rudder movement and other flight control information that might be beneficial to determining the cause of an accident and preventing future accidents?

THE WITNESS: Well, let me answer that in a couple of ways if I can. First of all, we are still taking delivery of new aircraft. And those new aircraft are coming with upgraded flight recorders.

CHAIRMAN HALL: How many parameters do they have, do you know, sir?

THE WITNESS: If I'm not mistaken, there are 18. I would have to get you that answer to be absolutely sure. That's not a positive. That's my guess. But USAir is presently in a program of getting the 11 parameter flight recorders on, which is the present requirement. Do we have plans to retrofit those up to the higher ones? Nothing has been determined yet that we are for sure going there.

It is under consideration by the management of USAir and the engineering department. We are still in the development process. Obviously with every project you do, there are things that you have to look at. And that is, whose recorder are you going to use, what modifications need to be done to get there, and what's the reasonable time frame.

All that is under consideration right now, but no decision has been made.

CHAIRMAN HALL: What type of recommendation would you make to your company in that regard?

THE WITNESS: I'm not sure that's a fair question.

(General laughter.)

CHAIRMAN HALL: Well, I believe, I have been impressed with how fast you have risen in the business and your presentation. Since you're the senior vice president for engineering and maintenance, if I were the president of USAir, I would pay attention to what you recommended to me.

THE WITNESS: I will pass that message on.

(General laughter.)

CHAIRMAN HALL: Well, let me say without putting you further on the spot, that I hope that you will at least recommend to your chairman that they give serious consideration to looking at upgrading the flight data recorders on the existing 737 fleet that is operating throughout this country in a very fine fashion.

THE WITNESS: It is being considered at a very high level. Not to make just of it, but obviously USAir is very concerned with this accident, not only the Colorado Springs' accident. A lot of things could be resolved by knowing what caused this and if that's what would help us get there, we're certainly going to be part of that.

So it is getting a high level consideration.

CHAIRMAN HALL: The accident aircraft, could you tell me and just walk me quickly through in your position what you did to look at the maintenance history and follow that aircraft through all its checks and everything and trying to -- I assume you-all independently have tried to determine yourselves what happened. Right?

THE WITNESS: Correct. We have engineering personnel on all the teams that are involved in the maintenance and technical side of it. We have dumped the records. We have been trying to go out and make sure that even the AD test is the right thing to do. We have an entire engineering staff going over this program daily.

We are just as concerned as anybody out there to a resolution, so that we can get on with our life and take the corrective action, if there's any needed, and certainly put this one to sleep.

CHAIRMAN HALL: Well, I know that your company has received a lot of publicity as regard of this. Anything that you want to say or walk me through in terms of what you-all have done to put on the record, I would be glad to do so, because I think that you know this board is very interested.

A lot of people are interested in the things that you-all have done. I know that we're going to hear later from your -- I believe we've got the director of training from USAir. We've got your new vice president for corporate safety and regulatory compliance we're going to also hear from.

But since we have the senior vice president for engineering and maintenance, anything that you want to put on the record or if the record may already been adequately documented in terms of your investigation, I would offer you this opportunity to do so.

THE WITNESS: Well, first of all, let me correct the record in case there's a confusion. I am not the senior vice president of engineering and maintenance. I am the vice president of line maintenance. I report to the senior vice president of engineering and maintenance.

However, if you would like to recommend to my chairman my promotion, I would be more than gracious.

(General laughter.)

THE WITNESS: To be quite honest with you, to add any additional --

CHAIRMAN HALL: Well, I apologize. That was an error in our --

THE WITNESS: Oh, I enjoyed it.

CHAIRMAN HALL: I can understand why.

THE WITNESS: I don't have any additional comments or requests. Quite honestly, we're on a meeting on a weekly basis with the investigation, and we get everything we need to say in on those meetings. I would only like to compliment the board on their activity on this. I know that they share the same frustrations that we do in coming up with a resolve and hope that we get there soon.

CHAIRMAN HALL: Well, that is why the Chairman's frustrations go at least to being sure that we upgrade flight data recorders. That's a decision obviously of this full board -- of the full board of the National Transportation and Safety Board, but it is certainly something we're looking at. I'm pleased to hear that you're looking at it.

Hopefully, that will get the same type of aggressive action that you mentioned in the other category.

Does anyone else have any other questions for this witness?

(No response.)

CHAIRMAN HALL: Parties?

(No response.)

CHAIRMAN HALL: Sir, we appreciate very much your presence and your testimony. You are excused.

THE WITNESS: Thank you.

CHAIRMAN HALL: The next witness of Mr. David Cann or Conn. Is it Cann?

THE WITNESS: Cann.

CHAIRMAN HALL: Thank you, David. David, please listen to what title I give you. If I'm not correct, let me know, so I won't repeat it two or three times. The principal maintenance inspector for USAir, for the Federal Aviation Administration here in Pittsburgh.

(The witness testimony continues on the next page.)

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. Cann, 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 FAA?

THE WITNESS: Currently, I am the principal maintenance inspector assigned to USAir.

MR. SCHLEEDE: Could you give us a brief description of your education and background that brings you to that position?

THE WITNESS: I started out as an aircraft mechanic in the Air Force on transport category aircraft. After that, I subsequently went to work for an airline as a mechanic in flight engineer. Following that, I worked for a 135 mechanic on leer jets and Mitsubishi MU-2 aircraft. Following that, I became a civilian employee of the Department of Defense as a flight engineer on transport category aircraft.

In 1986, I came on with the FAA. The first position with the FAA was that of a geographic inspector responsible for 121 air carrier aircraft and operators over a geographic area, including Pittsburgh, Erie, Elmora, Ithica, Syracuse, Buffalo, Rochester and Toronto.

I then assumed a position of assistant principal maintenance inspector, USAir. Later I became a partial program manager or fleet manager with responsibility for the Boeing 767 aircraft and the BA-146 aircraft. Then in February of 1990, I became the principal maintenance inspector of USAir.

MR. SCHLEEDE: Thank you. What FAA rating certificates do you hold?

THE WITNESS: I currently hold a mechanic certificate with air frame and haul plant ratings, and a flight engineer certificate with turbo propeller rating.

MR. SCHLEEDE: Thank you. Mr. Sasser.

MR. SASSER: Good evening, Mr. Cann. Mr. Cann, could you explain to us your role or rather the role of the FAA in the development of USAir's maintenance program and its continuing operation as well?

THE WITNESS: As previous testimony stated, when a new aircraft originally comes into a fleet of a particular operator, with that, you have the maintenance review board or the MRB document. That document specifies the minimum requirements for a maintenance program for a scheduled or routine maintenance.

Additionally, the maintenance planning document or MPD which is produced by the manufacturer is also utilized. Specifically to the 737-300 Boeing task cards are also associated which correspond to that maintenance planning document.

Along with that, you have the maintenance manuals that come with the appropriate aircraft. All of these things are reviewed by the operator. After review, the operator develops their own maintenance program. It's obvious that there is more to it than the MPD or MRB specifies, because there's non-routine maintenance to be considered.

So each operator is somewhat different, because of the operating environment, maybe the configuration of the aircraft, modification status to the aircraft, et cetera. All those things have to be considered in the development of the maintenance program, which is the responsibility of the operator at that point.

MR. SASSER: You operate here in Pittsburgh. And the terminology for your organization here that handles USAir's maintenance is the certificate management unit or CMU. Can you explain to us, give us some explanation of the organizational structure of the maintenance part of the CMU, please?

THE WITNESS: I'm the supervisor of the

maintenance portion of the certificate management unit. I currently have ten inspectors. One being my assistant or the assistant principal maintenance inspector. I'll explain what acronyms we use. One is a PPM or a partial program manager, which is common to a fleet manager and an assistant partial program manager.

I have a partial program manager and an assistant partial program manager assigned to the DC-9 MD-80 fleet. I have a partial program manager and assistant partial program manager assigned to the Boeing 737-200 fleet.

I have a partial program manager and assistant partial program manager assigned to the Boeing 737-300/400 combined fleet. I have a partial program manager and assistant partial program manager assigned to the Boeing 757 an Boeing 767 fleet.

A partial program manager assigned to the Foker F-100 fleet. And a partial program manager assigned to the Foker F-28 and the Boeing 727 aircraft fleet.

MR. SASSER: In the course of your operation, you are required to do certain surveillance operations on the air carrier. In planning the activity of the people in the CMU and your personnel, can you explain to us how you go about setting up a work plan for these people for the type of inspections and number of inspections that they'll accomplish during the year?

THE WITNESS: What we have to consider first is what we call environmental or environment for USAir. That consists of what work USAir currently does. What kind of heavy checks. Those being D-checks or USAir refers to them as Q. C-checks, B-checks, A-checks, transit checks, et cetera, which are all different intervals.

What kind of shop work they do, what kind of overhaul, be it seats, components, engines, et cetera. We also look at addition to components, facilities, line stations, heavy maintenance, hangers, et cetera. After considering all of these environmental characteristics, we plug that into the database.

We also look at any trends that we've seen over the previous year. We look at any emphasis areas which could be new FAA policy, newly implemented regulations. Deicing would be a perfect example. With that, we focus our attention or our staffing in those areas.

Additionally, we have the routine

surveillance that doesn't fit any of the categories above. We work on this program. We put it into the database, and then it's assigned to the office. This program also encompasses those -- what we refer to as R-items or required items which are put out nationally at the direction of Washington and our region in New York.

Those are items that they track specifically. Those are duly noted on our work program. The work programs are then sorted and selected and given to the respective partial program manager or assistant partial program manager by fleet.

MR. SASSER: Are these programs accomplishable and have they been accomplished in the last couple of years? In other words, are a large percentage of the program being accomplished that were planned for that year?

THE WITNESS: Our goal is always 100 percent accomplishment. Sometimes we're at 98 percent, 99 percent, 97 percent. But we will always strive for 100 percent.

MR. SASSER: When we talk about surveillance, what are we talking about? When we say you're going to do a surveillance operation on an air carrier or an operator, what does that mean?

THE WITNESS: Surveillance is made up of a lot of different inspections. We have one type of inspection called a ramp inspection. That's an inspection of an aircraft that we refer to as being in-service, an aircraft that's on the gate. Perhaps just came in with passengers and is waiting to board to go out.

In that situation, we would go to that aircraft and using what we call a job aid or a checklist, accomplish that inspection to denote or detect any mechanical irregularities. If any are found, we communicate it to the flight crew or to the management personnel or a mechanic.

We also do in route inspections, which are flight inspections to observe the operation of the aircraft systems for system irregularities during flight.

Another particular inspection is what we call a spot inspection. That's a real hands-on inspection. That's an inspection where a mechanic is doing a job and we'll really go up to the mechanic to watch and observe he or she doing a job. Make sure that they have the knowledge. They have the required publications, work task card or work instructions to properly accomplish a task, and actually watch them, observe them do it.

Other inspections are structural inspections. The aging aircraft is a big consideration. We do a lot of hands on there in that we observe the inspection, the NDT inspections associated with aging aircraft.

Airworthiness directive compliance. AD compliances is another very important work task. We have obviously reliability evaluations. We have records reviews, et cetera.

MR. SASSER: Could you give us some estimate of how many of these surveillance inspections were accomplished during the fiscal year in 1994?

THE WITNESS: I don't have the data for fiscal year '94. I can tell you calendar year '94.

MR. SASSER: Calendar year '94.

THE WITNESS: The total, I believe, inspections on USAir exceeded 3600. That's FAA wide. Of that number, our office or my staff accomplished approximately 41 percent or slightly under 41 percent of those total inspections.

MR. SASSER: In accomplishing these inspections, the reports are filled out and data is collected and then you said was put into the system. Can you tell us what's done with that data once it's collected?

THE WITNESS: Upon completion of the inspection, the inspector will return to the office and enter into the computer or have entered into the computer system what's called PTRS, a program tracking and reporting system. It's the FAA database for data collection of inspections.

We enter comments. We enter a description of the inspection and number of aircraft location, pertinent statistics like that, and any comments associated with a comment code. Be it informational, a potential problem or unacceptable. That data is then input. We download this data weekly.

One reason we look weekly is for any significant trends that need a quicker reaction than any long-term trend. We also download this data monthly and do a snapshot trend of this data.

Then quarterly, additionally we download all the data. We do a trend analysis of that data. We have a meeting with USAir, and share that data with them for their corrective actions. I'll tell you that this analysis is done by either me personally or by my assistants.

MR. SASSER: Do you know of any surveillance operations that are performed by other parties other than your CMU or geographic units around the country outside of your organization and any other surveillance operation?

THE WITNESS: Outside of our office, there's a program called the National Aviation Safety Inspection Program or NASIP program within the FAA. This program is generally made up of inspectors from outside of the certificate holding region, which in this case is the Eastern Region. A team will be generated in the airworthiness and in the operations area.

They will come in for a period of time to do an inspection and sort of give a different set of eyes, so to speak, to the inspection of the assigned operator. In this case, USAir got a NASIP -- received a NASIP inspection in 1993, I believe it was.

In addition to the NASIP program, the Department of Defense has a responsibility for periodic audits. That's conducted by the United States Air Force out of Scott Air Force Base, Illinois. They came in I believe in 1994 and did an audit on USAir, as well.

MR. SASSER: The results of these NASIP inspections and DOD audits are, I assume, given to you and that is also put into your data for the now system and implementation of corrective measures for USAir?

THE WITNESS: The NASIP information is entered into the PTRS system. It's also a matter of record. The Department of Defense gives us a written report that we respond to, any findings that they so note.

MR. SASSER: What method is used to insure that the in-service problems are adequately addressed by USAir?

THE WITNESS: In-service problems or what we would refer to as trends or concerns, as I mentioned, we trend weekly, monthly and quarterly. As previously stated, quarterly we have a meeting with USAir to share that information.

Additionally, monthly we have a meeting with the USAir quality assurance and engineering departments who come to our office and we go over any short-term snapshot trends or any concerns that may not be a trend, but they are concerns.

Additionally, our continuance surveillance would verify any problems that we so noted and were tracking. Also quarterly, we put out what we refer to as a geographic newsletter. That's a newsletter that's sent out through the FAA mail system to all the other Flight Standard's District Offices throughout the world. We request their assistance.

We give them specific emphasis items. We give them codes to use. So that if they use those codes and do the surveillance, it will help us better in our trending. All of this together helps us to follow up on any in-service problems or in-service concerns that we have raised with USAir.

MR. SASSER: Mr. Cann, from your perspective, what is the relationship between USAir and the FAA, and what is USAir's attitude toward compliance with the Federal Aviation Regulations?

THE WITNESS: My impression or my opinion of their attitude regarding compliance is that they are pro-active. As Mr. Cohen had been previously testified, they initiated an internal evaluation program three years prior to the advisory circular being issued.

They used voluntary or self-disclosure program that's covered by an advisory circular to report discrepancies and violations that they do. They are pretty up front with that. So I think my impression of their attitude regarding compliance is good based on that.

As well, we know historically that they have brought in independent audit firms to assist in the audit of their own company. To me, that's an indicator of a pro-active approach to compliance.

MR. SASSER: Mr. Cann, are you aware of any requirements to routinely collect and test hydraulic fluid samples from the Boeing 737 fleet?

THE WITNESS: Specifically for the Boeing 737-300, I believe that the maintenance manual refers to taking hydraulic samples when the operator's experience determines that they are necessary to be taken. Beyond that, I know of no requirement as such.

MR. SASSER: There's no hourly or yearly requirement. I believe we heard testimony earlier from Mr. Cohen that they did that on a regular basis. At least annually, but there is no requirement that you're aware of from Boeing.

THE WITNESS: No.

MR. SASSER: I have no further questions, Mr. Cann. Do you have anything that you would like to add that we failed to talk about?

THE WITNESS: No, sir.

MR. SASSER: Mr. Chairman.

CHAIRMAN HALL: Thank you, Mr. Sasser. Do any of the parties have questions of this witness?

(No response.)

CHAIRMAN HALL: Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Clark?

MR. CLARK: No questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HALL: Well, the Chairman has some questions, so. To just get a feel, you have ten people that work for you, are employed with you, sir?

THE WITNESS: Yes, sir.

CHAIRMAN HALL: You all perform, what, about 1400 inspections a year? I was trying to take 40 percent of 3600. So roughly 1400, 1500?

THE WITNESS: Roughly, yes, sir.

CHAIRMAN HALL: Could you tell me routinely in regard to the hydraulic systems on planes, what type of inspection you would routinely run, if any, that would impact the checking the proper maintenance of the hydraulic systems?

THE WITNESS: Routinely, we would -- for instance, we know that USAir issued a CD or what's referred to as a campaign directive to sample hydraulic fluid. We would take the initiative to go look to see that they're sampling and sampling the fluid properly in accordance with the maintenance manual requirement.

Another issue we know is the PCU, the power control unit. The opportunity arises to observe a power control unit replacement. We will obviously put particular emphasis on that.

Other than that, we would observe routine maintenance, including the use of the hydraulic round test hands or hydraulic mules. Other than that directly relative to the 737-300 hydraulic system maintenance, it would be just a continuous oversight. It would be hard to schedule. If somebody's working on that system, obviously we observe the maintenance on it.

CHAIRMAN HALL: Well, my understanding is that FAA in its letter I referred to yesterday stated that there were problems with the systems, the power control system, et cetera, and I need to look to get that correspondence in front of me. That could be detected by manual checks that are taking place before each flight.

Are you familiar with what I am talking about or should I try and get that letter out?

THE WITNESS: I'm not familiar with the letter. I don't know if you're referring to a check that's done by the flight crew or not.

CHAIRMAN HALL: Yes, the ground check.

THE WITNESS: That's not done by maintenance personnel. I believe that's done by the flight crew on the originating flight, I believe, if I'm following you correctly.

CHAIRMAN HALL: So if the flight check found a galling condition that was then reported to the maintenance crew, would that be a document that you-all would review as part of your inspection?

THE WITNESS: That would be documented in the log book. If it was a pilot discrepancy, the pilot would obviously initiate an entry in the log book. We routinely review log books. It's a big part of our program. That's one of the ways that we detect trends.

CHAIRMAN HALL: Since the Colorado Springs' accident, has there been any direction to you in terms of your inspection of the rudder systems on the 737s?

THE WITNESS: If you're asking whether there was any particular emphasis placed on us by higher headquarters, I don't believe so. I know that we have personally placed -- made it an emphasis item as a result of 427.

CHAIRMAN HALL: But nothing prior to the 427?

THE WITNESS: No, sir, not to my knowledge.

CHAIRMAN HALL: Fourteen hundred inspections is a lot of inspections for ten people, I would think. How long does it take you to do an inspection and how do you decide on a great big plane like that with lots of things to inspect, how do you decide what you look at?

THE WITNESS: As I said, if we are doing a ramp inspection, we have a check list or a job aid that we use. It may or may not be possible to accomplish everything on the job aid because there could be passenger boarding, et cetera.

Spot checks are quite easy, because the aircraft is out of service. We have a significantly more amount of time to spend. We can review the maintenance material that the mechanics are using and observe the work task being accomplished. Deicing surveillance is somewhat different in that we can actually get out and watch the deicing. We can get out into the elements and observe those.

So each inspection that we do has different hourly requirements. I use word requirements in that it's really not a requirement. We know what we have as far as a work rate for planning purposes, but we really don't track the total work activity as such in man hours.

CHAIRMAN HALL: You say that generally your experience in relationship with USAir has been good. How long have you been in this position, sir?

THE WITNESS: I've been the principal maintenance inspector in USAir since February of 1990. So, I'm coming up on five years.

CHAIRMAN HALL: An item such as the auxiliary fuel tank that was referred to in the earlier testimony that was installed on some of the 737s, I gather, that go on the longer trips, and I understand that was a modification that was made by the airline rather than Boeing. What oversight do you have or what role does the FAA play in that at all, if anything?

THE WITNESS: Sir, I think you're referring to the PATS tank installation. That was an STC that was issued to PATS which is the company manufacturers the installation and that was done by Tramco in Seattle. I don't think -- to the best of my knowledge, USAir did not do any of those installations themselves. It was done generally prior to delivery of the aircraft in Seattle.

CHAIRMAN HALL: But did you-all have any role in that, the FAA?

THE WITNESS: No, sir, we have after the fact, because we knew that there were -- it was a trend item that we looked at, and we knew it was a new installation. So, we created an emphasis item to pay attention to that once it was initially installed.

CHAIRMAN HALL: You-all were notified by USAir of it before or after it was installed?

THE WITNESS: We were notified before the aircraft came on board, because there were AFM or flight manual revisions that were necessary, as well. I mean, that also included pilot handbook changes, a well as maintenance procedures. So, we were aware of that.

CHAIRMAN HALL: Is there anything else that you feel that you could add in your testimony that would assist us in our investigation of this accident?

THE WITNESS: No, sir. The only thing I might add was that in the previous testimony, to the best of my knowledge, the accident aircraft, M-513-AU, was a Boeing 737-3B7, which indicates that it was delivered to USAir, if that would help clarify the previous testimony.

CHAIRMAN HALL: Good. Good. Mr. Conn, I don't believe -- Cann, I'm sorry. Right?

THE WITNESS: Yes, sir.

CHAIRMAN HALL: It's getting late. I don't believe I have any other questions. Are you going to be with the table for the rest of the week?

THE WITNESS: I will be here for the rest of the week, sir.

CHAIRMAN HALL: Well, good. So if we get into anything else, that would be helpful to us. But thank you very much for your -- well, I did have one other questions. Do you have an adequate number of people to do the job that the FAA asks you to do?

THE WITNESS: Yes, sir. Obviously, I look at quality rather than quantity. We look at doing quality inspections. That's paramount. If I had more people, I could do a higher quantity. If I had less people, I could probably do a smaller quantity. But I'm worried about the quality as opposed to the quantity.

CHAIRMAN HALL: And the experience of the people that are employed there with FAA that you have responsibility for, what type of previous federal service -- what type of service do they have generally?

THE WITNESS: As far as airline service experience?

CHAIRMAN HALL: Yes.

THE WITNESS: They are quite experienced. One member is a member of PAN American Airlines for 20 some years. Others have been in the industry with other airlines, Eastern Airlines, in fact, repair stations, smaller airlines. So I believe I don't have a person that's got less than 20 years experience in the aviation industry.

CHAIRMAN HALL: Very good. Well, I wanted to put that on the record because a lot's written about everyone's roles here. Obviously, there's an important role that the Federal Aviation Administration plays. They have a number of dedicated employees, and you certainly have represented them well today. Thank you, sir. You're excused.

THE WITNESS: Thank you.

CAPTAIN SHARP: Excuse me?

CHAIRMAN HALL: I'm sorry, Captain. You had a question? I'm sorry. Would you mind remaining, please, Mr. Cann?

THE WITNESS: Yes, sir.

CHAIRMAN HALL: The microphone for USAir, please?

CAPTAIN SHARP: Mr. Cann, could I just maybe ask you one question about the PATS tank. There seem to be a little bit of a point that maybe we need to clarify on that.

Was it not your understanding that that PATS tank was installed at the factory as an option from other than Boeing, but installed while the airplane was still a new airplane and owned basically Boeing property before it was delivered to USAir?

THE WITNESS: It was my understanding, I don't think, Captain Sharp, that that was ever raised. The point that was raised to me that the aircraft was new. It went from Boeing to Tramco to have the PATS tank installed. I don't think we ever had question of ownership or anything. That was never an issue that we raised.

CAPTAIN SHARP: But the installation was done by PATS, the company that had an STC, which had been approved by the FAA for installation of the tank?

THE WITNESS: Yes, sir.

CAPTAIN SHARP: Thank you.

CHAIRMAN HALL: Does that conclude? Thank you very much. You are excused this time.

(Witness excused.)

CHAIRMAN HALL: We are sitting here trying to debate whether we should go one more time or whether we should just adjourn and proceed in the morning. Are we far enough along, Mr. Haueter, on this witness list that we can wait and proceed in the morning?

MR. HAUETER: The next witness will probably take an hour, an hour and a half, sir.

CHAIRMAN HALL: Well, I appreciate very much the parties' willingness to stay this late and assist us in working through this testimony. This is a long hearing, but I want to be sure that everyone has adequate time to ask whatever questions and put on the record whatever needs to document our investigation at this point.

We will, therefore, now recess until 8:30 in the morning.

(Whereupon, at 7:26 p.m., the hearing was adjourned. To be reconvened on Thursday, January 26, 1995, at 8:30 a.m.)

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