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August 8, 1995
BXK01-15325-ASI

Greg Phillips
AS-10
National Transportation Safety Board
490 L'Enfant Plaza SW
Washington DC 20594

BOEING

Subject: USAir 737-300 N513AU Accident Near Pittsburgh, September 8, 1994

Reference: NTSB Letter dated June 27, 1995, Greg Phillips to Rick Howes

Dear Mr. Phillips:

The following is in response to the reference letter. Each numbered reply corresponds to the like numbered question in the letter.

1. Enclosure 1 shows 737 flight test data for a severe wake encounter. This data is from a 1970 test in which a 737 was deliberately flown through a 747 wake. The data shows that the rudder followed the rudder pedal commands except for the yaw damper commanded rudder deflections,which can be seen as small oscillations superimposed on the pedal commanded rudder.

   We are not aware of any Boeing or supplier data which shows the rudder PCU response to a large piston load. We have, however, used a computer model of the PCU to show its response to a 2000 lb. load. This is our estimate of the maximum possible load that could have been induced by the wake vortex associated with the flight 427 accident. The data is shown in enclosure 2. Note that the computer simulation does not include the effect of the yaw damper. This would require that the PCU model be expanded to include an airplane model and a yaw damper model and would require considerable time and engineering manpower. It should also be noted that the vortex load represents only 33 percent of the PCU capability and is a load that would be commonly encountered in normal airline service when the rudder is deflected by the pilot.

2. When a PCU is subjected to an external load there is a small amount of compression of the PCU and its support structure. Because the PCU input rod remains fixed while the PCU rod and manifold move slightly there is a small amount of dynamic valve movement followed by an even smaller steady state valve offset as shown in enclosure 2. This steady state valve offset generates the differential cylinder pressure to balance the external

load. Because the valve motion is so small there is no motion of the secondary valve slide.

A large aerodynamic side load on the vertical tail would likely generate an airplane yaw rate which would in turn generate a yaw damper command. The yaw damper has the capability to generate a nearly full input to the PCU control valve. The yaw damper induced valve motion is therefore much greater than the motion due directly to the air load acting on the rudder. The yaw damper tends to input commands to the rudder at the Dutch Roll frequency of the airplane which is about .3 Hertz. A sudden external air load on the rudder generates valve and piston motion at approximately 13 Hertz. Because these frequencies are so widely separated and because the motions due to air loads are so small there is no measurable interaction between the two.

3. The main rudder PCU has, to our knowledge, never been tested by applying a pulsed load to the actuator rod. It should be noted, however, that the inertia of the rudder surface provides a nearly pulsed load to the PCU after a rapid pedal or yaw damper command. Enclosure 3 shows the computer generated PCU response to a two degree rudder command. This situation (rapid surface commands) has occurred during testing and occurs on a regular basis in service. We are not aware of any reports of the PCU stopping motion, reversing motion or erroneously changing rate except for those instances, which the NTSB is already aware of, where the valve traveled beyond the external stop. Note also that this condition, which is well understood, could not be caused by the input of a pulsed PCU rod load.

4. A momentary increase in cylinder pressure can not cause a by-pass valve to shut off supply pressure. The bypass valve spool is held in place by system supply pressure and in the pressurized condition it is not subjected to an axial force by any of the cylinder pressures.

5. The only additional condition that can result in cross flow between cylinder extend and retract ports is if either the primary or secondary valve slide jams away from neutral. In this case the unjammed valve slide will open creating a cross flow condition to negate the jammed valve slide. This situation was demonstrated by the residual pressure testing which was witnessed by the NTSB.

6. We are unaware of any failure mode of the PCU input/summing lever mechanism, other than a jam of the PCU feedback linkage, that could result in yaw damper authority greater than 3 degrees or a rudder runaway, reversal or hardover. In support of the FAA CDR follow-up Boeing is currently accomplishing a new failure analysis of the rudder PCU. This analysis is expected to be completed by September 15, 1995.

If you have any questions please contact me.

Very truly yours,

FLIGHT TEST

[redacted]

BOEING

for J.W. Purvis, Director
Air Safety Investigation
BXK01, M/S 14-HM
[redacted]

cc; Tom Haueter, AS-10

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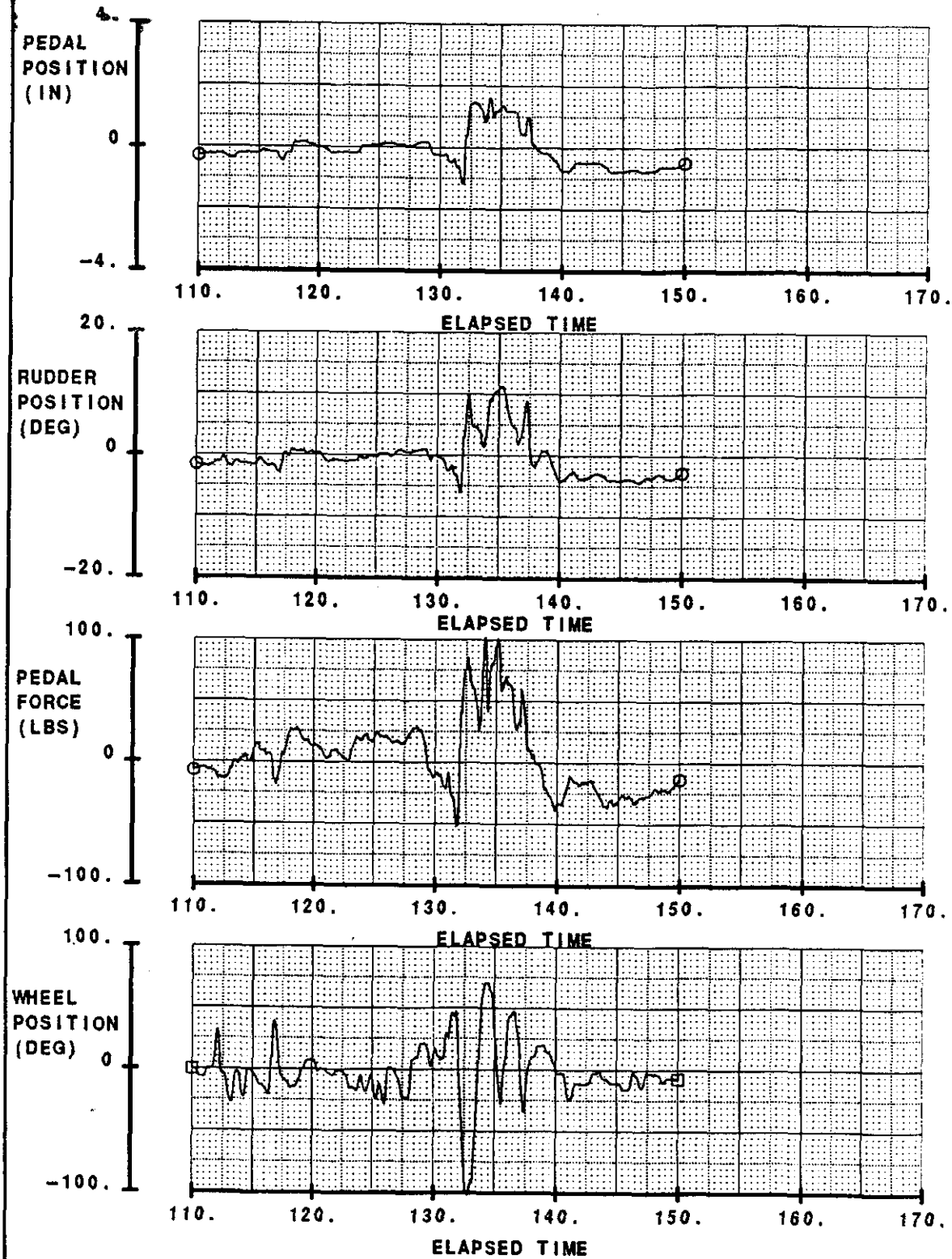
ATTACHMENT 1



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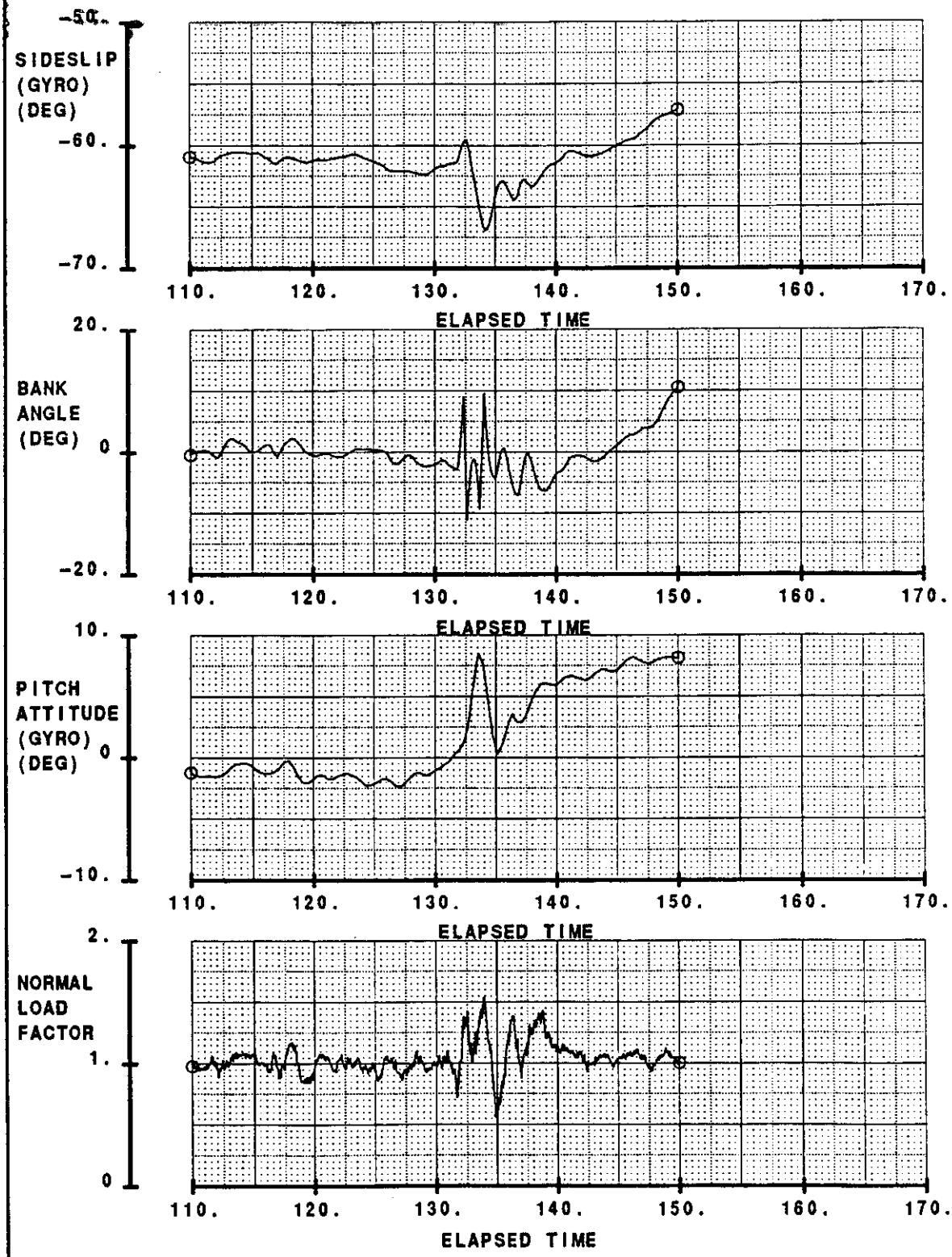
747 / 737 WAKE VORTEX ENCOUNTER
FLIGHT TEST

FIGURE

ATTACHMENT 1



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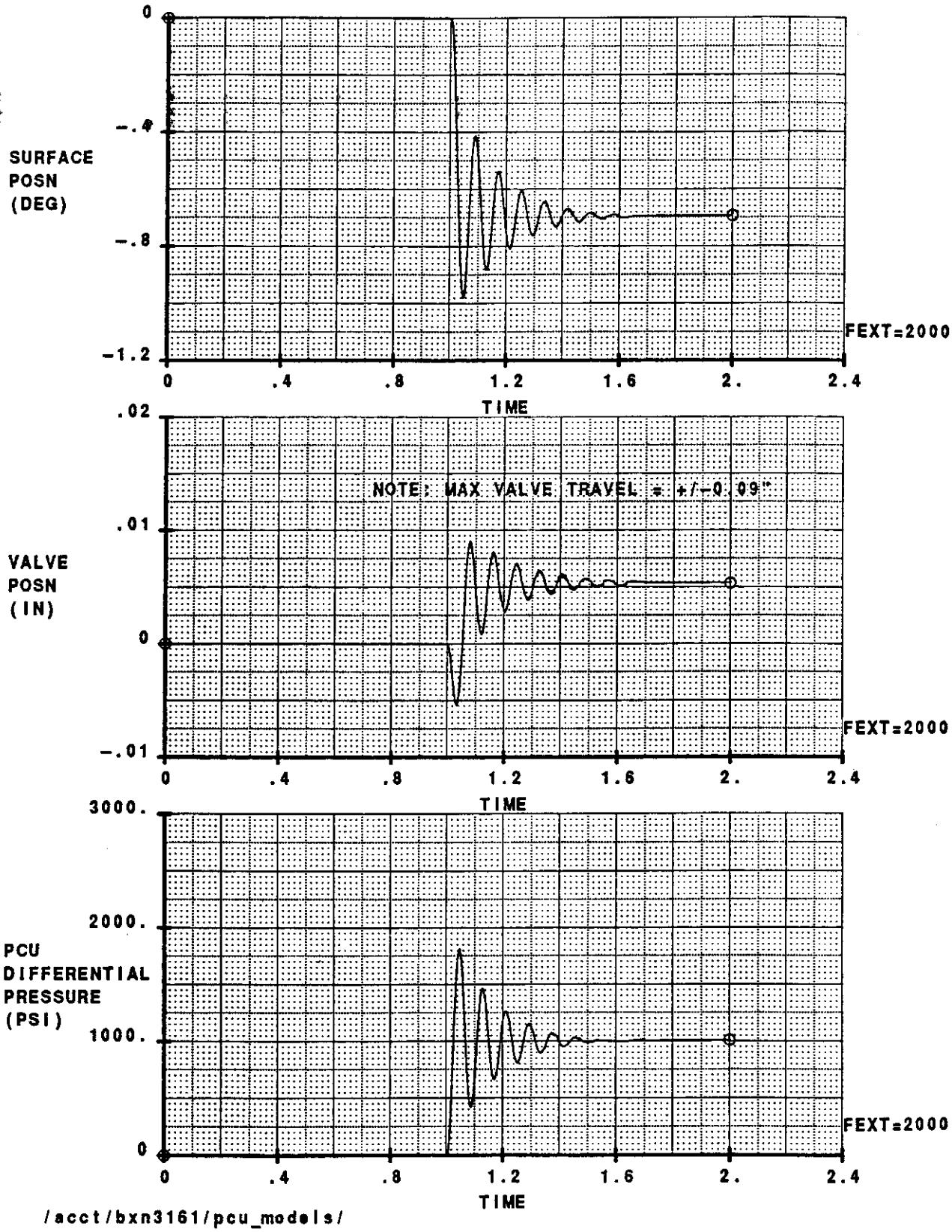
747 / 737 WAKE VORTEX ENCOUNTER
FLIGHT TEST

FIGURE

ATTACHMENT 2



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rud_2mains_345.esb

CALC	b. nguyen	01AUG95	REVISED	DATE	Main rud PCU response to 2000# rod load	737-300
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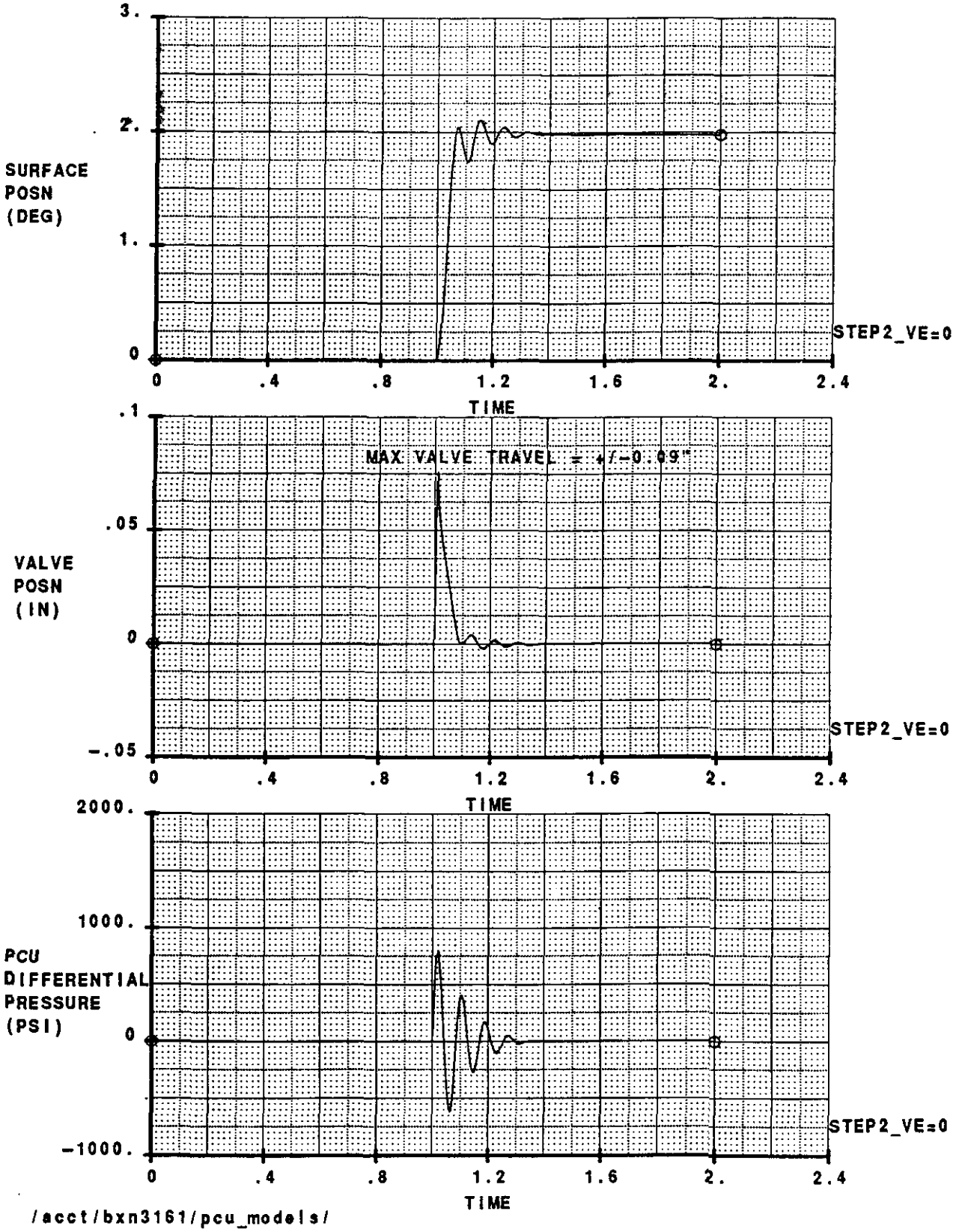
ATTACHMENT 3



/acct/bxn3161/pcu_models/
rud_2mains_345.esb

CALC	b. nguyen	01AUG95	REVISED	DATE	Main rudder pcu step response Command = 2 deg at time=1 No airload	737-300
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