Docket No.: **SA-510**
Exhibit No.: **9X-J**

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

737 Rudder Power Control Unit
Particulate Contamination Test
January 12-20, 1995

Test Report
737 Rudder PCU Particulate Contamination Test
January 12 through 20, 1995

Contents

Summary

In conjunction with Boeing's involvement in the investigation of USAir Flight 427 crash, Boeing performed a test to investigate the effects of hydraulic fluid heavily contaminated with small particulates on the performance of the 737 rudder Power Control Unit (PCU). A PCU (with its internal filters removed) was run, unloaded, on a small laboratory test stand. Particulate contaminants were added to the fluid, and the effect on PCU performance was determined. When tested with Class 12 particulate contamination and with fifty times Class 12, the PCU responded correctly to commands, and at no time was there an uncommanded movement of the PCU.

Personnel

Test direction and coordination: J. Curulla

Lab Engineers: M. Holbrook, T. Lowery

Instrumentation: B. Zawacki

Test EWA and overall direction: S. Hilby

Test dates

Buildup: December 16, 1994 to January 12, 1995

Test run: January 12 through 20, 1995

Test setup

The test EWA is appended as Attachment 1.

The test rig schematic is given as Figure 1.

A list of instrumentation is given in Table 1. Parameters were recorded on strip charts by an AstroMed real-time recorder. The flowmeter was initially deleted, but later reinstated during troubleshooting of the pumps.

A new rudder PCU was outfitted with a used servo in order to represent an in-service unit. The serial number of the PCU body was 2763A. The inlet filters were removed from the PCU. A copy of the acceptance test performed on this PCU after the installation of the used servo is appended as Attachment 3.

Input to the PCU was supplied by a small hydraulic cylinder powered by a separate hydraulic power supply. The cylinder was controlled by a separate closed-loop control system to provide a sinusoidal input to the PCU. Nine "slow" cycles were performed at 0.043 hz, providing a 0.48 in/sec maximum input rate, and then one "fast" cycle at 0.43 hz, for a 4.8 in/sec maximum input rate; this series (nine slow, one fast) was repeated for the duration of the test. Approximately thirteen hours into the test, the fast cycle was reduced to 0.22 hz, for a maximum input rate of 2.4 in/sec. The fast rate was reduced because the degraded pumps were unable to supply enough flow during the fast cycle, resulting in extremely high input forces as the input lever hit the PCU's manifold stops.

Discussion of particulate levels used

NAS 1638 assigns a Class to fluid contaminated with particulates, depending on the number of particles found in various size ranges. Numbers of particles double with each class; the highest level of particulate contamination specified in NAS 1638 is Class 12.

In the airplane, the PCU's dual-concentric servo valve is protected from fluid-borne particulates not only by the 15 micron absolute hydraulic system filters but by a 25 micron absolute filter in each inlet port of the PCU. "B" system fluid that is metered from the cylinder by the control valve to return is passed through the link cavity before exiting the PCU. The link cavity found in the USAir 427 PCU link cavity measured Class 12. This fluid was contaminated by particulates generated inside the link cavity and the PCU main cylinder. Backflow of contaminants from the link cavity into the servo, when the system is depressurized, is prevented by a check valve in the PCU inlet.

Despite the aforementioned reasons to doubt whether the servo would ever be exposed to Class 12 contamination in service, it was decided to begin the test with Class 12 fluid, and then move on to an exaggeratedly high level of particulates. The inlet filters of the PCU were removed to prevent them from trapping the contaminants and protecting the servo. The filter in the test rig was only used for initial cleanup and checkout of the system; it was removed before particulates were added to the fluid. Particulates representative of those found in PCU link cavities in service and on USAir 427 were mixed with a small amount of fluid to form a slurry, which was then poured into the rig's reservoir. A small centrifugal pump located in the reservoir kept the fluid and particulates well mixed.

Per the EWA test procedure, particulates were to be added in three steps. The first step contamination would be to NAS 1638 Class 12 levels, then to approximately 50 (fifty) times Class 12, then finally to approximately 100 (one hundred) times Class 12. Particulate composition is given in the test EWA, Attachment 1. As it turned out, the third batch of particulates was delivered from the vendor too late for the test, so only Class 12 and 50 times Class 12 ("50x") were tested.

Fluid samples

Fluid samples were taken at various times during the test, and particulates counted by the Boeing Quality Assurance Materials Analysis & Process Control Laboratory 9-4888. Results are given in Table 2. Only two samples (6P2 and 6R) of the 50x fluid were subjected to particle counts; the fluid clogged the automatic particle counter, and the particles refused to remain suspended long enough to count. The samples were eventually diluted 1000 (one thousand) times, filtered, and particles on the filter element counted manually. The fluid analysis report is appended as Attachment 2. Because of the extreme effort involved, no further samples of the 50x fluid were counted.

Test Log

The following is a log of the test, written afterward from rough notes. Boldface figure references refer to data appended to this report as Figures D1 through D11.

737 Rudder PCU Contamination Test Log Summary

12 January

Ran about twenty minutes with filter in system. Samples 1P & 1R taken after 17 minutes.

Removed filter, ran about twenty minutes, checking out input mechanism, etc. Samples 2P & 2R taken. **(Figure D1)**

Cycles: nine at about 0.48 in/sec peak rate, one at 4.8 in/sec peak rate; repeated

During uncontaminated run:

- Input force negligible during slow cycles
- Input force +5/-4 lb during fast cycles ("+" indicates extend direction)

Added contaminants to bring to approximately Class 12. Samples 3P & 3R taken after 20 minutes. **(Figure D2)**

Ran ten hours. Samples 4P & 4R taken at 323 minutes. Samples 5P & 5R taken at 590 minutes.

During Class 12 run:

- Input force irregular, peak about 1 lb, during slow cycles
- Input force during fast cycles +6/-4.5 at beginning of test, +7/-8 at end of Class 12 run.

13 January

Added contaminants to bring to approximately 50 (fifty) times Class 12.

Ran approximately three hours (614 cycles)

During 50xClass 12 run:

- Input force irregular, peak about 8 lb, during slow cycles
- Input force during fast cycles gradually increased, causing numerous high-input-force shutdowns. High-force protection was disabled. Saw input forces as high as 135 lb. **(Figure D3)**
- No phase lag between PCU input and output.

13 January continued

Reduced fast rate to 2.4 in/sec. **(Figure D4)**

Ran a short time. Fluid samples 6P, 6P2, and 6R taken.

Input forces were reduced for a time, but then began to increase again.

Also at this time, pressure began to sag (to approx 1800 psi) when PCU was moving, indicating degraded pump performance.

16 January

Pump replaced with another pump. Pressure sagged to about nothing during fast cycles.

Pump replaced again (#3). Still lots of pressure sag. Suspected high PCU internal leakage. Put flowmeter in rig, showed pump was bad (i.e., low flow when PCU high rate commanded)

17 January

Replaced pump again (#4). Pressure sag only about 300 psi (to 2600-2700 psi). Plenty of flow.

Produced expanded-scale data for fast (2.4 in/sec) cycle. **(Figure D5)**

Input force about 8 lb (slow cycle force was about 4 lb)

Shimmed PCU yaw damper piston to prevent movement.

Produced expanded-scale data for fast cycle **(Figure D6)**

Input force same as before shims

8 lb during high-rate, approx 5 lb during slow cycles

18 January

Continued test; pump showed signs of slow deterioration. Ran 10.2 hours. **(Figure D7)**

Input force +8.5/-9 lb at beginning of day, +27/-26 lb at end of day.

Pump output pressure 2900 at beginning, 2700 psi at end

19 January

Test shut down at end of shift; cumulative cycles 1675 at Class 12 (10 hours) plus 3350 at 50x (20 hours) **(Figures D8, D9, D10, D11)**

Fast rate 2.4 in/sec, Slow rate 0.48 in/sec

Input force +30/-28 at beginning of day, +48/-36 at end of day

Pump outlet pressure 2300 psi at end of day.

20 January

PCU removed from test rig, taken to EQA lab for teardown

Post-test teardown

The test PCU was partially dismantled at the Renton Equipment Quality Analysis (EQA) lab on 20 January.

The input lever was moved to its stop; the force required to do this was 35 lb. Prior to the test the force required was 26 lb.

The return cavity cover plate was removed. The bottom of the return cavity had approximately 0.2 inch of loose sediment **(Photo P1)**. Particles had settled on horizontal surfaces and in stagnant corners. The internal linkage was dismantled. The summing lever ball bearings were heavily contaminated with particles **(Photo P2)**.

The dual-concentric servo valve was removed. Loose blobs of viscous particle-fluid mixture, the consistency of cookie dough, were found in the grooves on the outside of the secondary spool, and hard-packed contaminants had accumulated in some sections of the annular passages **(Photo P3 upper photos)**. The primary spool took less than 2 lb to move; the secondary took 4.5 lb, both higher than normal. When the primary spool was removed from the secondary, the balance grooves were found to be packed full of particulates **(Photo P3 lower photos)**.

The metering edges of the primary and secondary spools were found to be heavily rounded, with polished-looking craters worn into the minor diameters of the spools below the metering edges **(Photo P4, primary, and Photo P5, secondary)**. The mechanism was almost certainly pure mechanical abrasion, the craters resulting from impingement of the particle-laden fluid stream. The inside surface of the secondary was not inspected.

Test Results & Discussion

The PCU responded correctly to every command given.

At no time was there an uncommanded PCU movement.

The valve metering lands showed heavy wear; this would be seen on an airplane as high leakage and sluggish response, making this performance degradation very detectable. Although the inside surface of the secondary was not inspected, one would expect matching wear of the metering edge on the port.

The test was not run at the planned 100x contamination level, due to difficulties in getting contaminants in time, however the 50x level served the intended purpose of saturating the PCU with contaminants. The PCU in general fared better than the pumps; in a highly contaminated aircraft system, pump failures are expected much sooner than severe rudder PCU degradation.

PCU input forces during fast cycles climbed as the test progressed, dropped when a new pump was installed, and then began to climb again. It is thought that the high input forces during fast cycles are due to two factors:

1) Packing of contaminant into the balance grooves caused higher forces internal to the servo valve (This also increased the force during slow cycles).

2) Reduced PCU inlet pressure (caused by pump wear) and reduced pressure gain (caused by servovalve wear) caused the PCU input linkage to move farther during fast cycles. This greater movement against both the high friction of the particulate-filled linkage bearings and the high resistance of the sediment in the bottom of the link cavity resulted in high forces. The greater movement also compressed the PCU internal springs further, another contribution to higher input forces. In the worst case, the linkage moved far enough to hit the PCU manifold stops, causing extremely high input forces (limited only by the capability of the hydraulic actuator supplying the input command).

The test was extremely conservative. As such, the test did not reflect expected in-service operating conditions. The PCU servo valve was subjected to a level of particulates far above that usually found in service; in-service fluid entering the rudder PCU usually runs about Class 8. The test rig hydraulic system filter and the PCU inlet filters were removed, depriving the servo of its protection against particulates.

Conclusions

The testing performed demonstrated that the 737 Rudder PCU operated acceptably when exposed to contamination levels far in excess of those found in the USAir 427 PCU link cavity. Under all conditions, the PCU output was consistent with the input command.

It is concluded that the 737 Rudder PCU design is tolerant of significantly higher particulate contamination levels than those present in service.

Table 1
Instrumentation List

		Transducer range	Signal uncertainty
1.	PCU input load	-100 to +100 lbf	± 0.22 lb
2.	Pump output pressure	0 to 5000 psi	± 8.3 psi
3.	Flow	0.3 to 5.0 gpm	± 0.02 gpm
4.	Fluid temperature	-436 to 2480 F	± 2.5 F
5.	PCU input stroke	0 to 6" (3" total stroke)	± 0.005"
6.	PCU output stroke	0 to 6" (3.944" total stoke)	± 0.005"
7.	Emergency shutdown:	Low pump output pressure	
8.	Emergency shutdown:	Pump output high temperature	
9.	Emergency shutdown:	PCU input high force*	
10.	Emergency shutdown:	Pump high amperage (>30 amps)	

*Later disabled

Tàble 2
Fluid Particle Count Results

Results given as "Number of Particles / NAS 1638 Class";
Counts in excess of Class 12 given as multiplier of Class 12: "XX.XX*12"

Sample No.	5 - 15 µ	15 - 25 µ	25 - 50 µ	50 - 100 µ	>100 µ	Overall Class
Barrel Sample	16124 / 7	15834 / 9	3956 / 9	296 / 8	32 / 7	**9**
1P	97625 / 9	11388 / 8	2426 / 9	72 / 6	61 / 8	**9**
1R	13778 / 6	1202 / 5	240 / 5	40 / 5	4 / 4	**6**
2P	90418 / 9	97610 / 12	11788 / 11	392 / 9	36 / 8	**12**
2R	31002 / 7	4558 / 7	1358 / 8	234 / 8	34 / 7	**8**
3P	35284 / 8	62824 / 11	52250 / "1.61*12"	1902 / 11	16 / 6	**"1.61*12"**
3R	63682 / 8	78082 / 11	25152 / 12	1168 / 10	8 / 5	**12**
4P						
4R						
5P	1.288E6 / "1.3*12"	344000 / "1.9*12"	192920 / "6*12"	31800 / "5.6 *12"	5880 / "5.7*12"	**"6*12"**
5R	2.172E6 / "2.1*12"	536000 / "3*12"	117440 / "3.6*12"	15560 / "2.7 *12"	6400 / "6.2*12"	**"6.2*12"**
6P						
6P2	52.7E6 / "53*12"	12.1E6 / "67*12"	7.742E6 / "242*12"	1.484E6 / "260*12"	0.248E6 / "243*12"	**"260*12"**
6R	93.9E6 / "93*12"	22.9E6 / "126*12"	11.474E6 / "358*12"	1.992E6 / "349*12"	0.372E6 / "364*12"	**"364*12"**

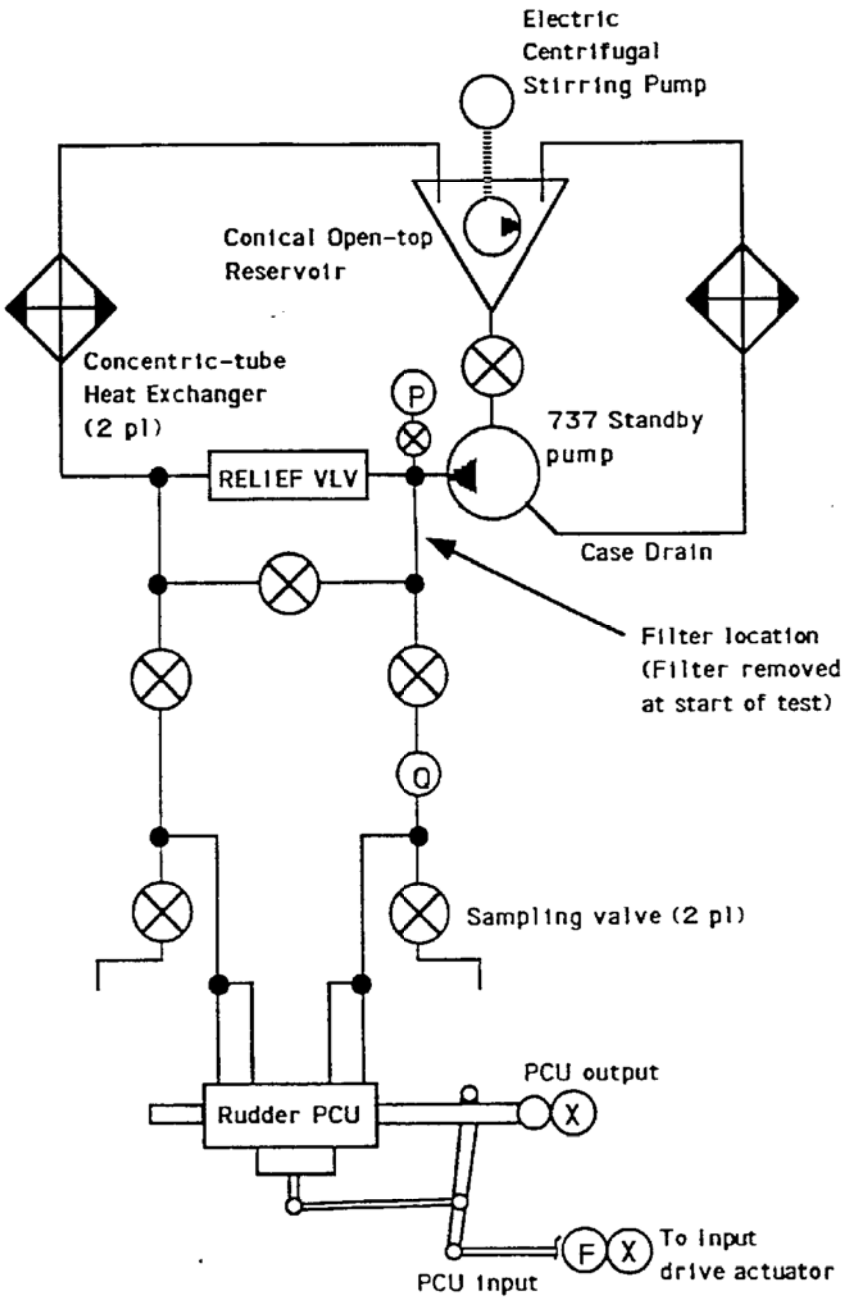
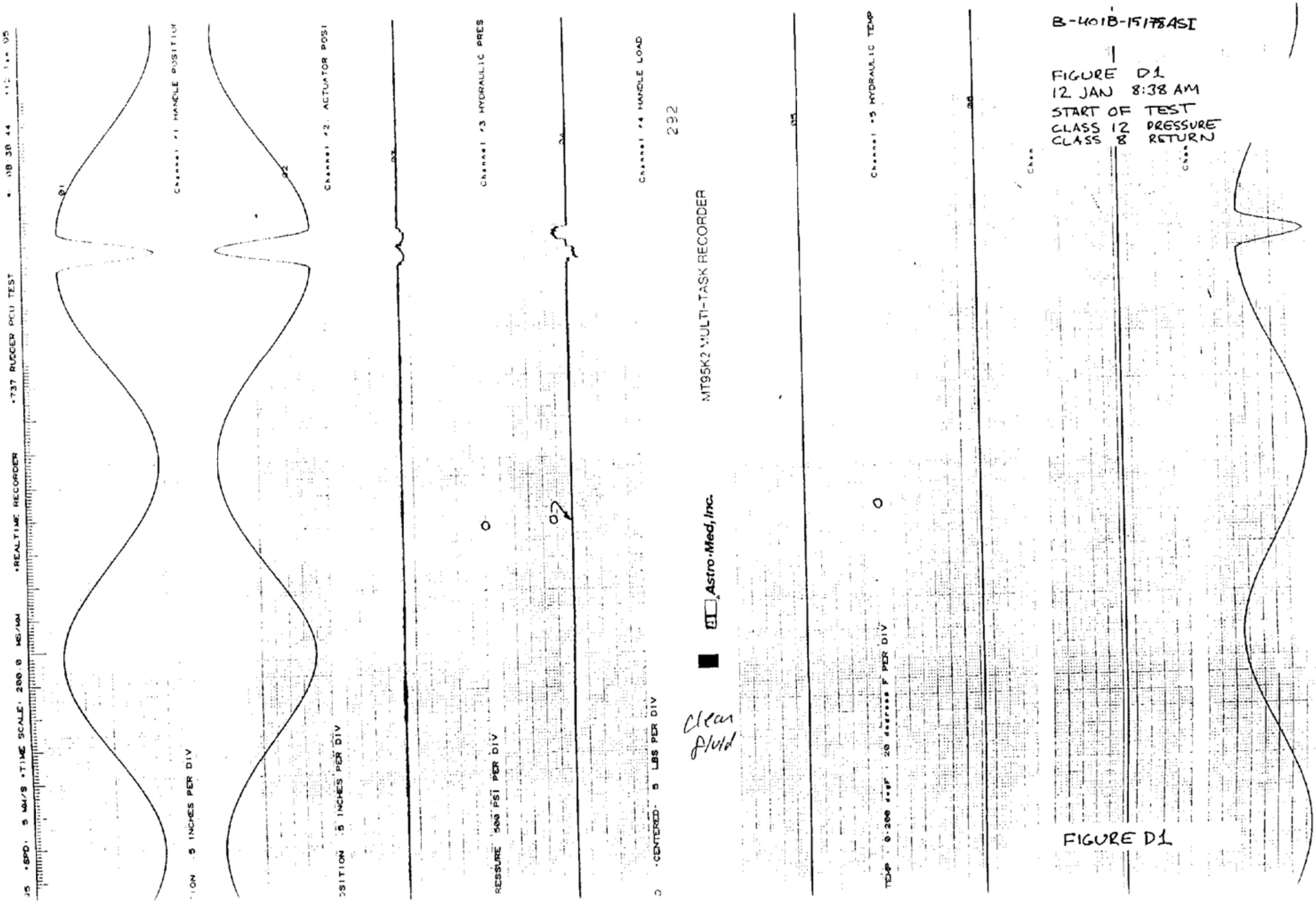
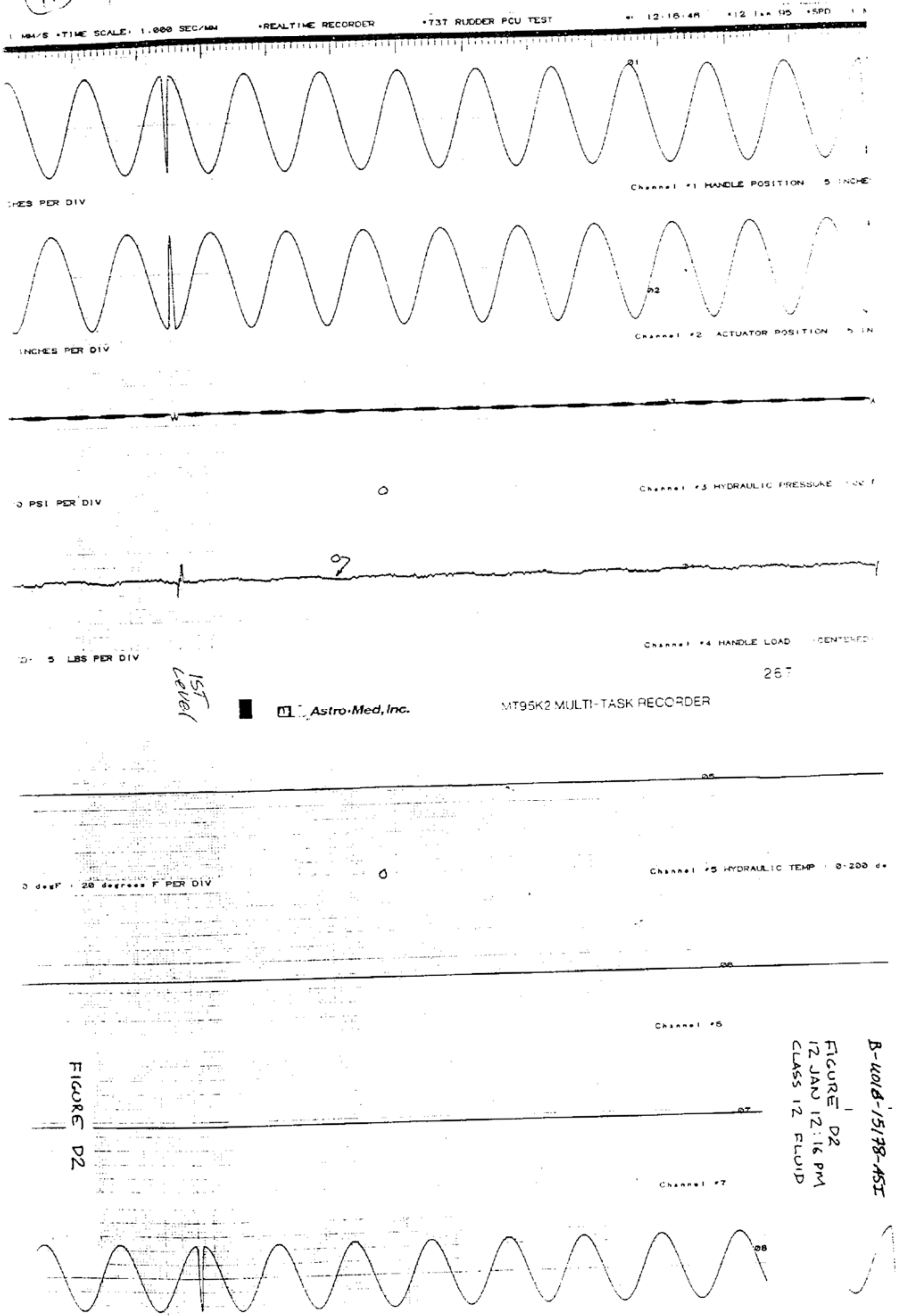


Figure 1
Test Rig Schematic


B-401B-15175ASI
FIGURE D1
12 JAN 8:38 AM
START OF TEST
CLASS 12 PRESSURE
CLASS 8 RETURN
FIGURE D1
Channel #1 HANDLE POSITION
Channel #2 ACTUATOR POSI
Channel #3 HYDRAULIC PRES
Channel #4 HANDLE LOAD
Channel #5 HYDRAULIC TEMP
ITION .5 INCHES PER DIV
OSITION .5 INCHES PER DIV
RESSURE 500 PSI PER DIV
·CENTERED· 5 LBS PER DIV
TEMP 0-200 degF 20 degrees F PER DIV
·SPD· 5 MM/S ·TIME SCALE· 200.0 MS/MM ·REALTIME RECORDER ·737 RUDDER PCU TEST · 08:38:44
232
MT95K2 MULTI-TASK RECORDER
Astro·Med, Inc.
Clean fluid

(11)



267

FIGURE D2

FIGURE D2
12 JAN 12:16 PM
CLASS 12 FLUID

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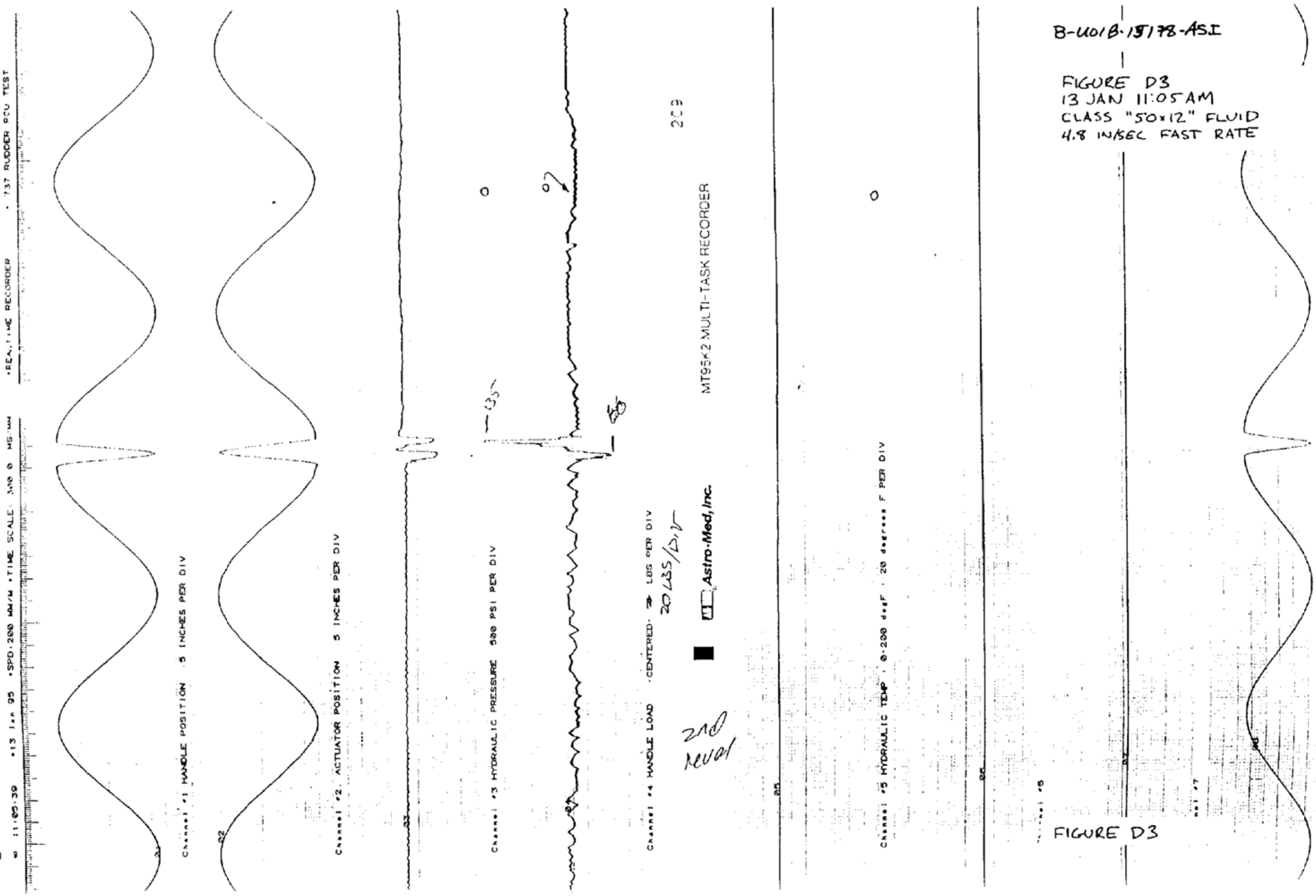
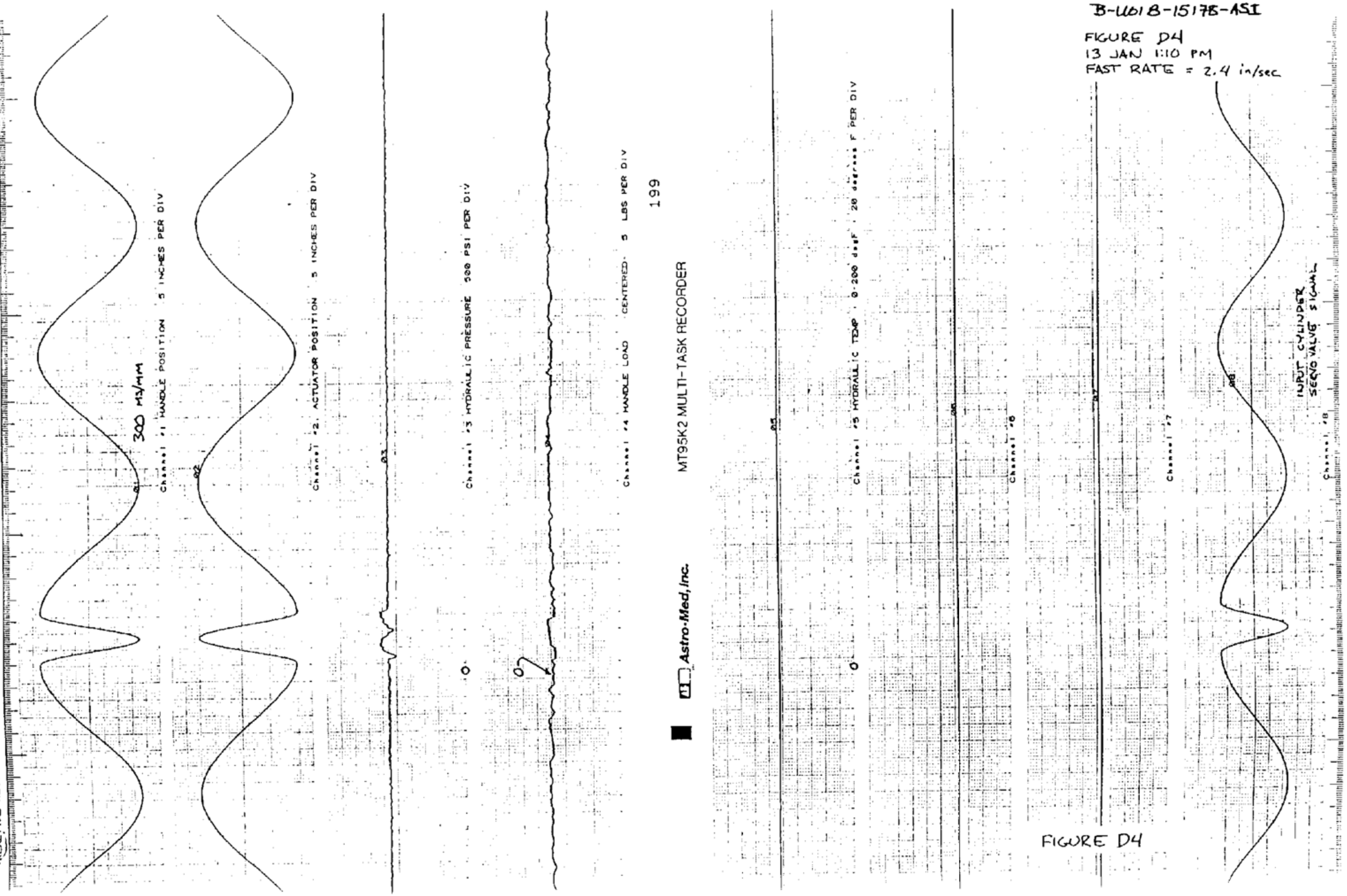

B-U01B-15178-ASI
FIGURE D3
13 JAN 11:05 AM
CLASS "50x12" FLUID
4.8 IN/SEC FAST RATE
11:05:39 •13 Jan 95 •SPD:200 MM/M •TIME SCALE: 3/10 0 MS/MM
•REAL-TIME RECORDER • 737 RUDDER PCU TEST
Channel #1 HANDLE POSITION .5 INCHES PER DIV
Channel #2 ACTUATOR POSITION .5 INCHES PER DIV
Channel #3 HYDRAULIC PRESSURE 500 PSI PER DIV
Channel #4 HANDLE LOAD ·CENTERED· LBS PER DIV
20 LBS/DIV
MT95K2 MULTI-TASK RECORDER
Astro-Med, Inc.
Channel #5 HYDRAULIC TEMP · 0-200 degF · 20 degrees F PER DIV
FIGURE D3

B-U018-15178-ASI

FIGURE D4
13 JAN 1:10 PM
FAST RATE = 2.4 in/sec



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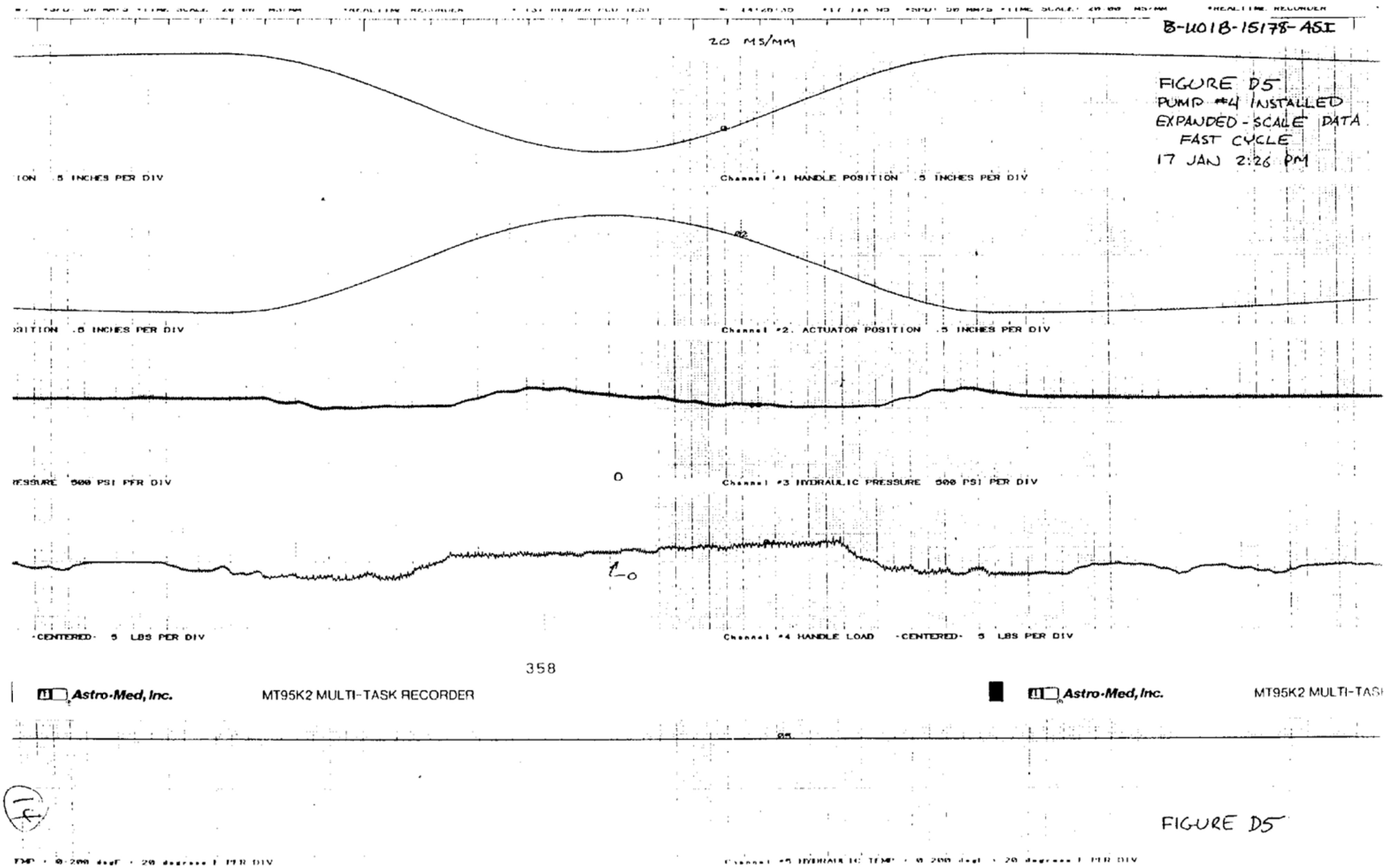
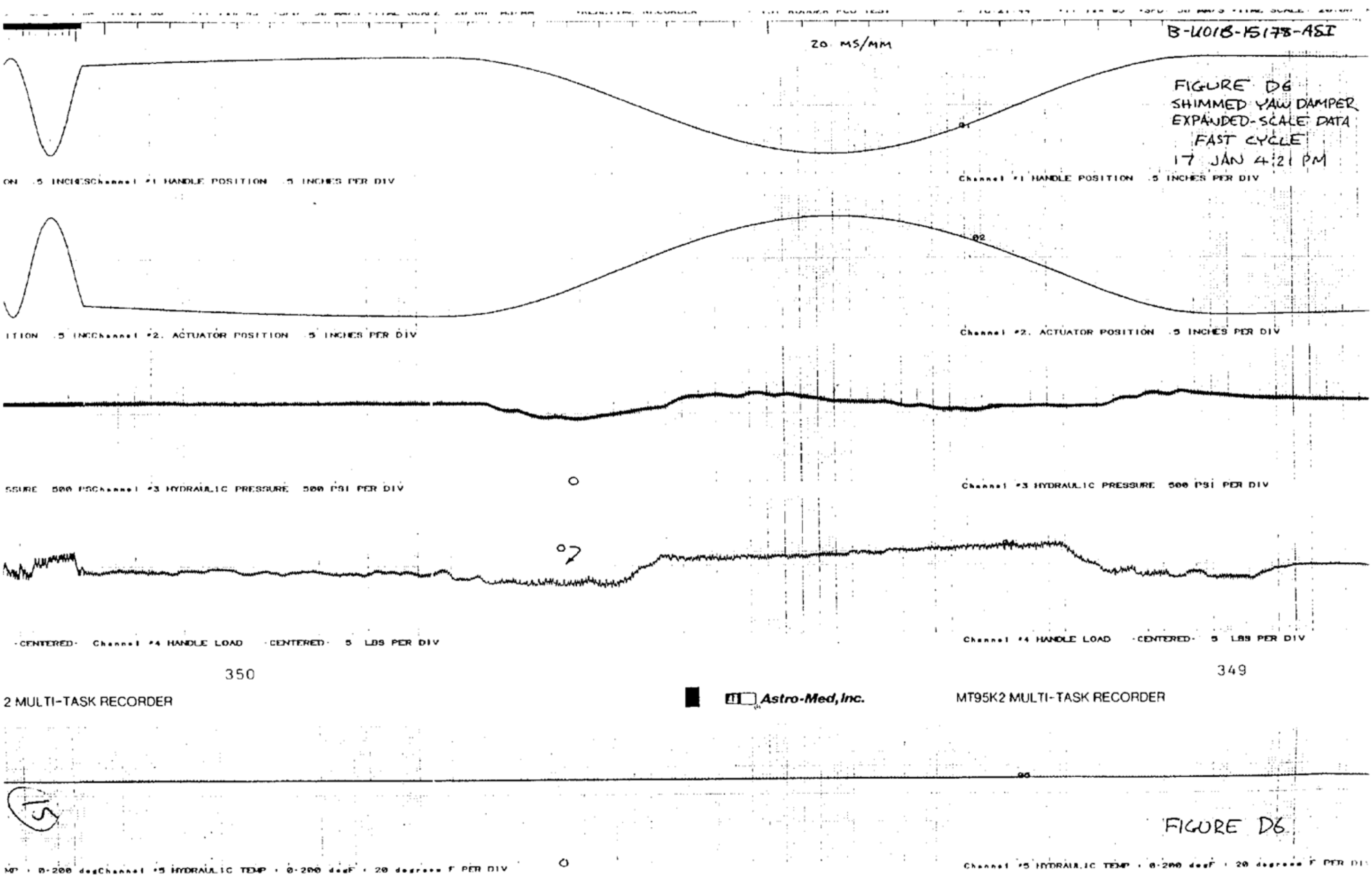
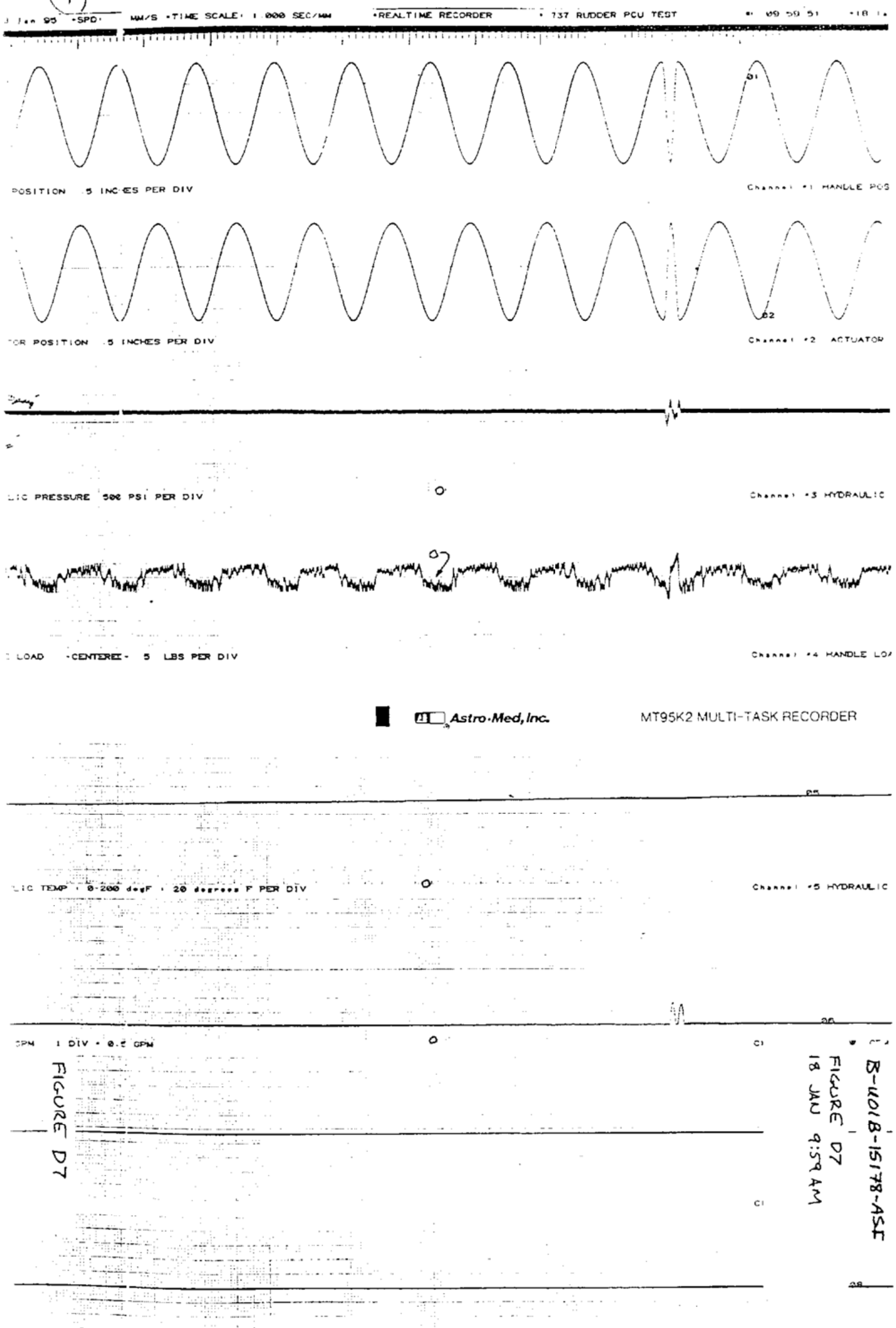

B-401B-15178-ASI
20 MS/MM
FIGURE D5
PUMP #4 INSTALLED
EXPANDED-SCALE DATA
FAST CYCLE
17 JAN 2:26 PM
Channel #1 HANDLE POSITION .5 INCHES PER DIV
Channel #2. ACTUATOR POSITION .5 INCHES PER DIV
Channel #3 HYDRAULIC PRESSURE 500 PSI PER DIV
t_0
Channel #4 HANDLE LOAD -CENTERED- 5 LBS PER DIV
Astro-Med, Inc.
MT95K2 MULTI-TASK RECORDER
FIGURE D5

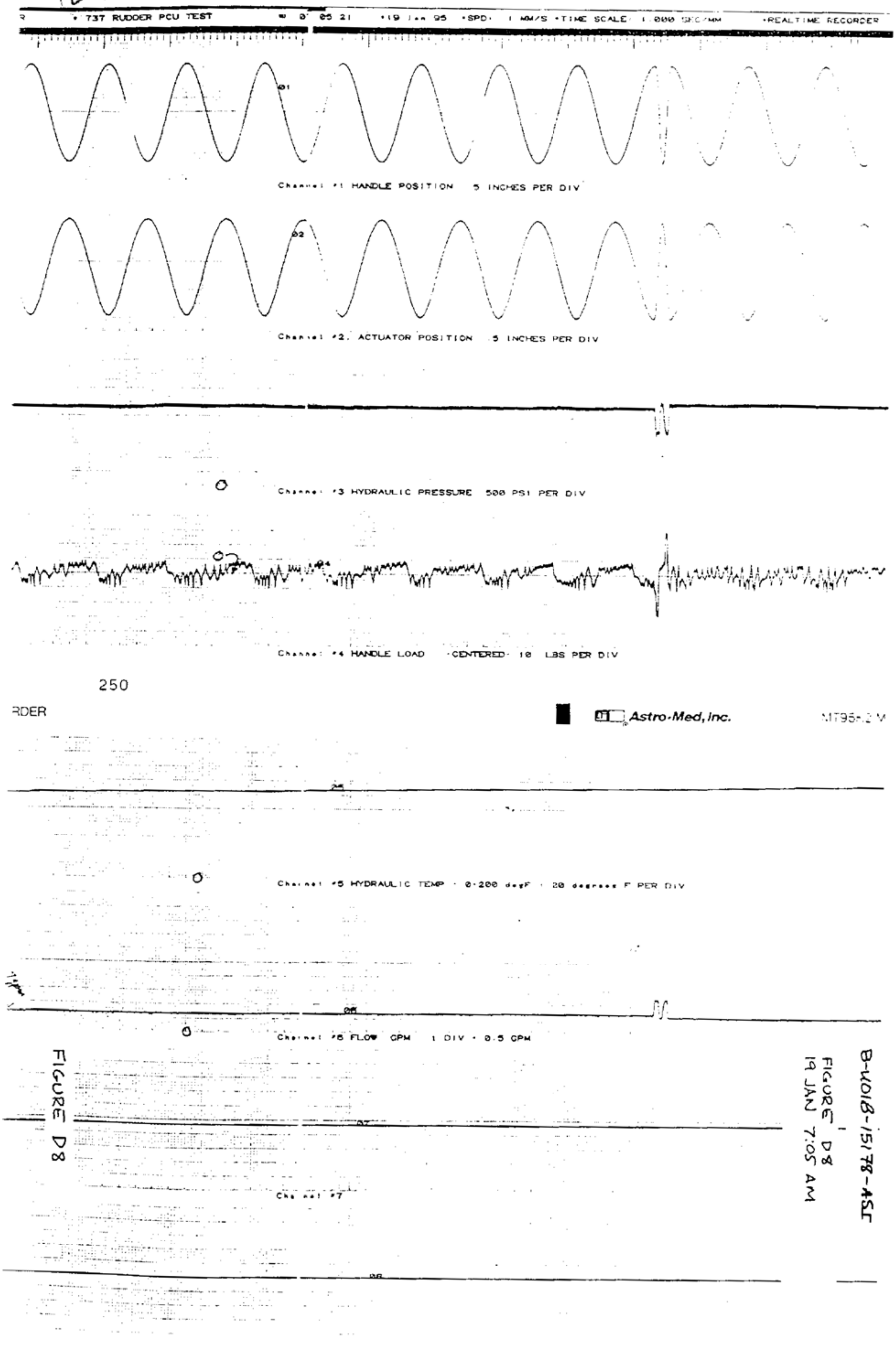
358


B-U01B-15178-ASI
20 MS/MM
FIGURE D6
SHIMMED YAW DAMPER
EXPANDED-SCALE DATA
FAST CYCLE
17 JAN 4:21 PM
ON .5 INCHESChannel #1 HANDLE POSITION .5 INCHES PER DIV
Channel #1 HANDLE POSITION .5 INCHES PER DIV
ITION .5 INCChannel #2. ACTUATOR POSITION .5 INCHES PER DIV
Channel #2. ACTUATOR POSITION .5 INCHES PER DIV
SSURE 500 PSChannel #3 HYDRAULIC PRESSURE 500 PSI PER DIV
Channel #3 HYDRAULIC PRESSURE 500 PSI PER DIV
-CENTERED- Channel #4 HANDLE LOAD -CENTERED- 5 LBS PER DIV
Channel #4 HANDLE LOAD -CENTERED- 5 LBS PER DIV
350
349
2 MULTI-TASK RECORDER
Astro-Med, Inc.
MT95K2 MULTI-TASK RECORDER
15
FIGURE D6
MP · 0-200 degChannel #5 HYDRAULIC TEMP · 0-200 degF · 20 degrees F PER DIV
Channel #5 HYDRAULIC TEMP · 0-200 degF · 20 degrees F PER DIV

(91)


Jan 95 •SPD• MM/S •TIME SCALE• 1.000 SEC/MM
•REALTIME RECORDER
• 737 RUDDER PCU TEST
09 59 51
POSITION .5 INCHES PER DIV
Channel #1 HANDLE POS
TOR POSITION .5 INCHES PER DIV
Channel #2 ACTUATOR
LIC PRESSURE 500 PSI PER DIV
Channel #3 HYDRAULIC
LOAD •CENTERED• 5 LBS PER DIV
Channel #4 HANDLE LOA
Astro-Med, Inc.
MT95K2 MULTI-TASK RECORDER
LIC TEMP • 0-200 degF • 20 degrees F PER DIV
Channel #5 HYDRAULIC
GPM 1 DIV • 0.5 GPM
FIGURE D7
B-4018-15178-ASI
FIGURE D7
18 JAN 9:59 AM

(21)



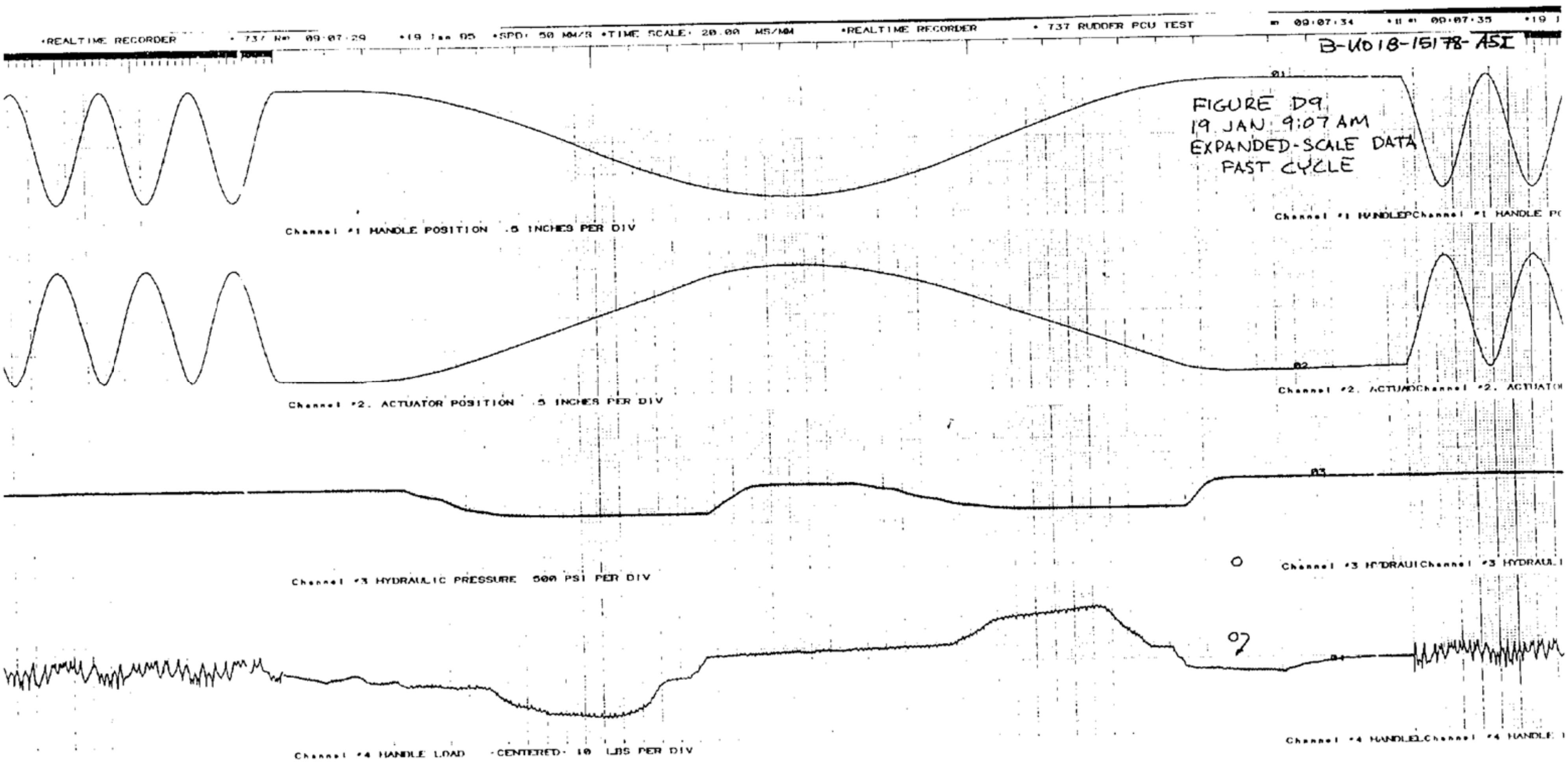
250

RDER

Astro-Med, Inc.

FIGURE D8

B-6018-15178-45I
FIGURE D8
19 JAN 7:05 AM



Astro-Med, Inc. MT95K2 MULTI-TASK RECORDER

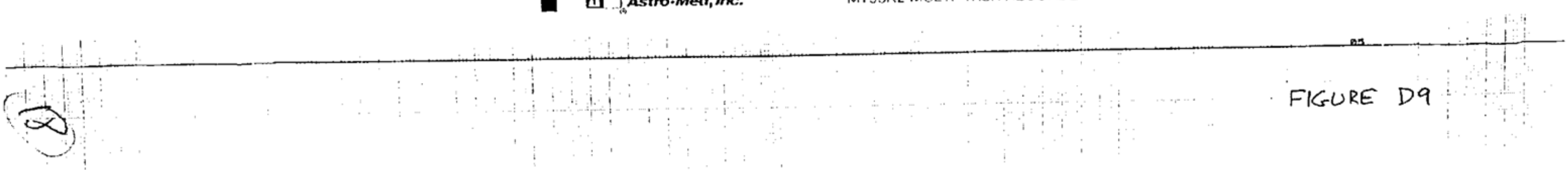
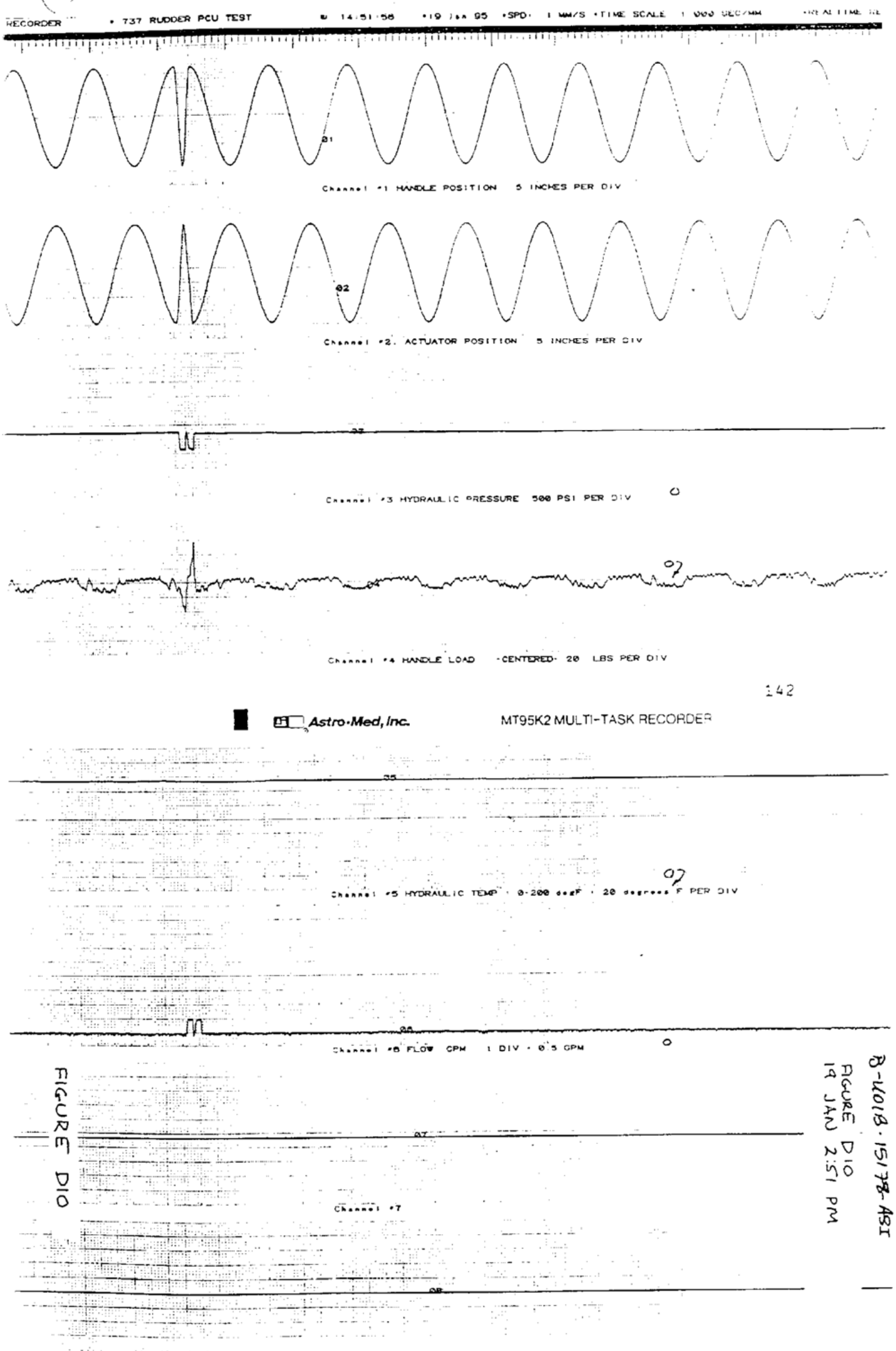


FIGURE D9

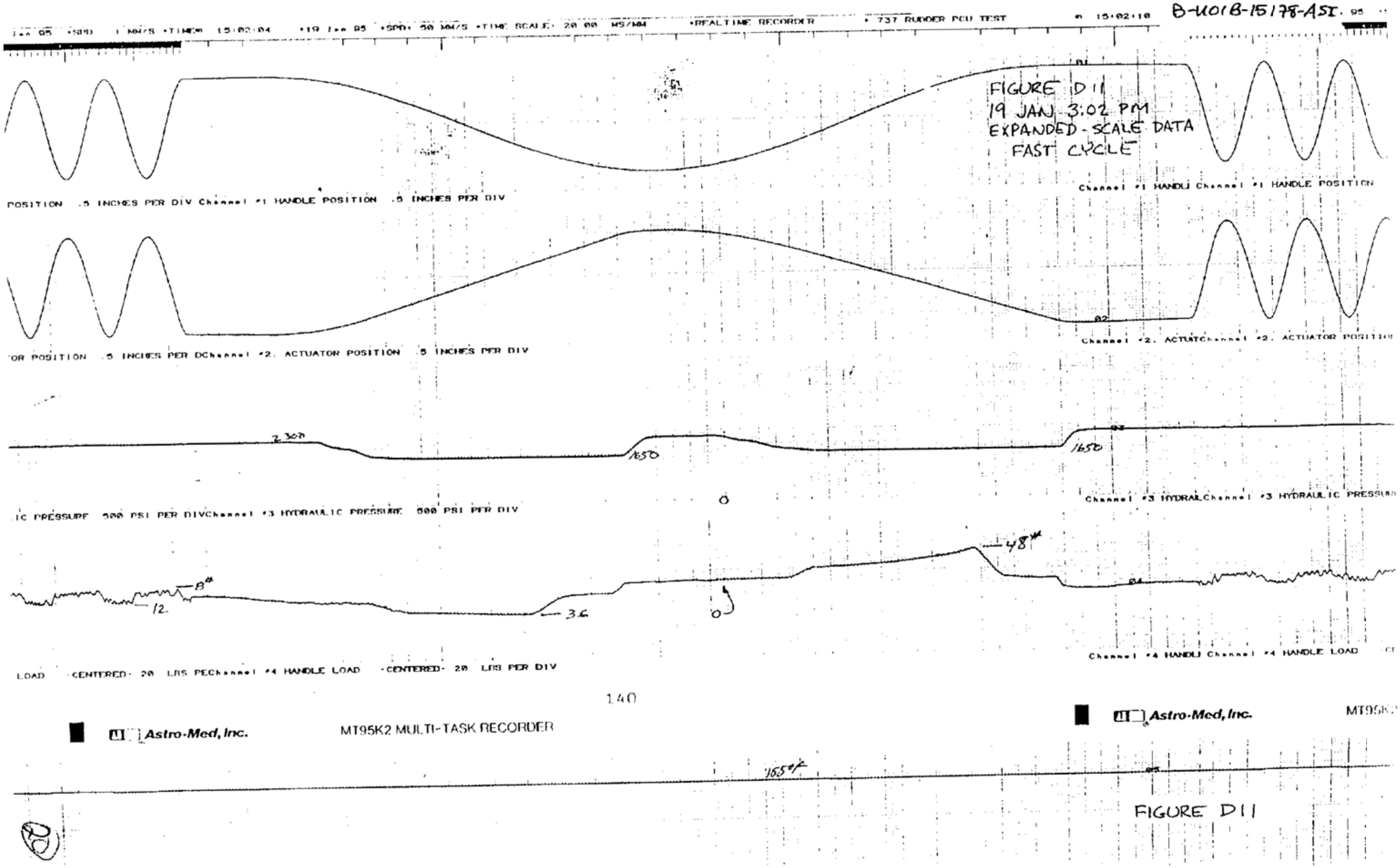
(51)



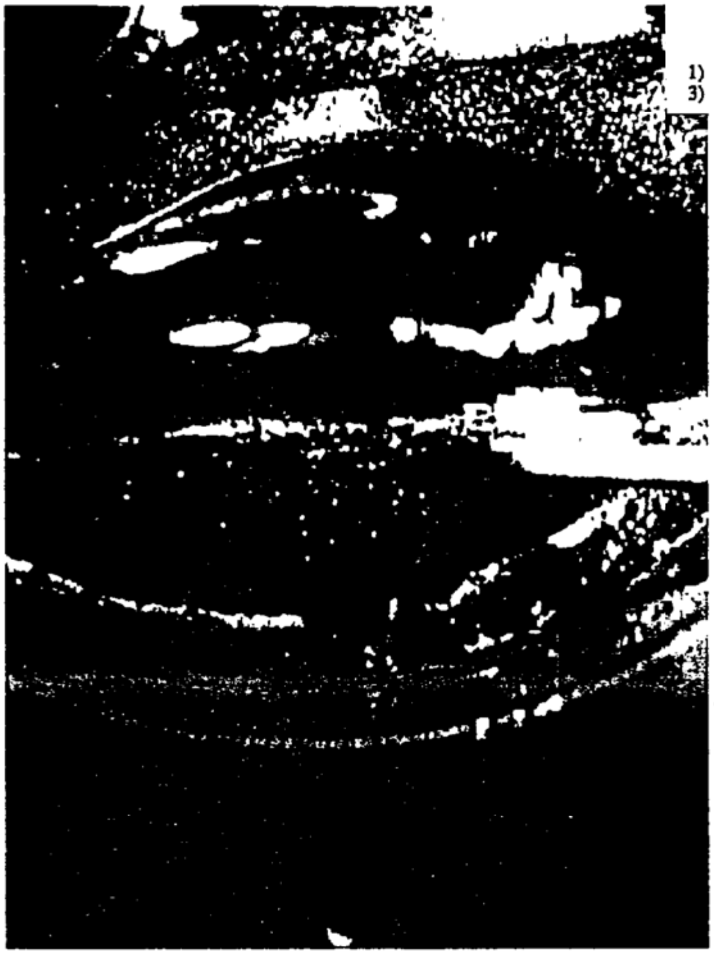
142

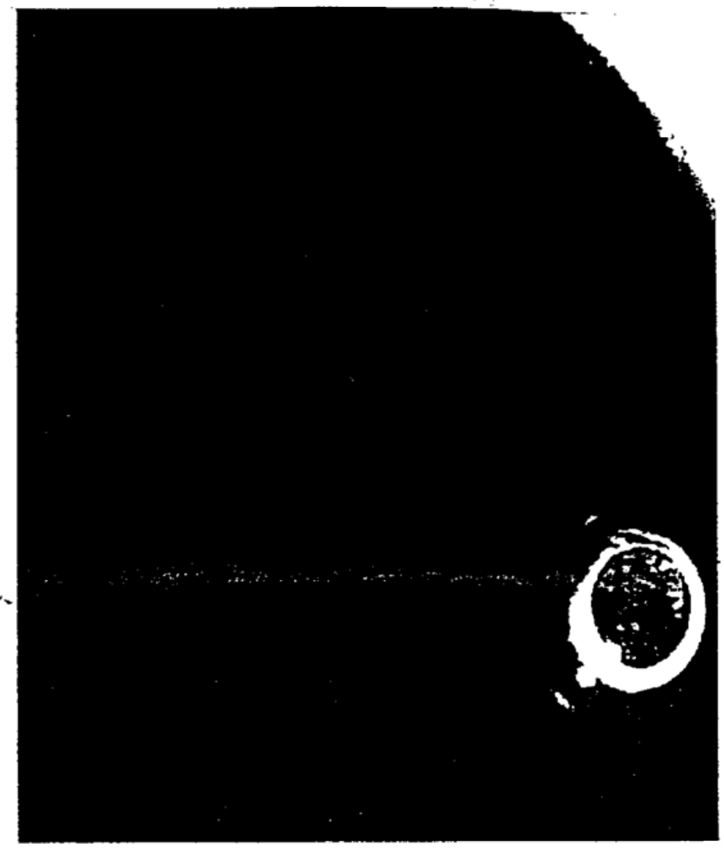
FIGURE D10

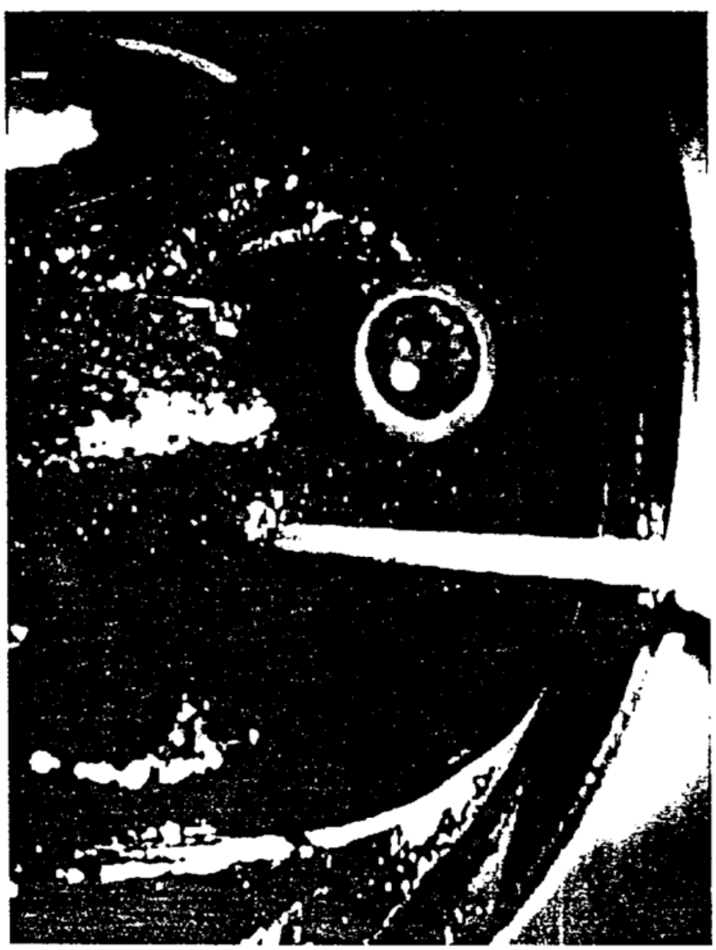
B-U018.15178-ASI
FIGURE D10
19 JAN 2:51 PM

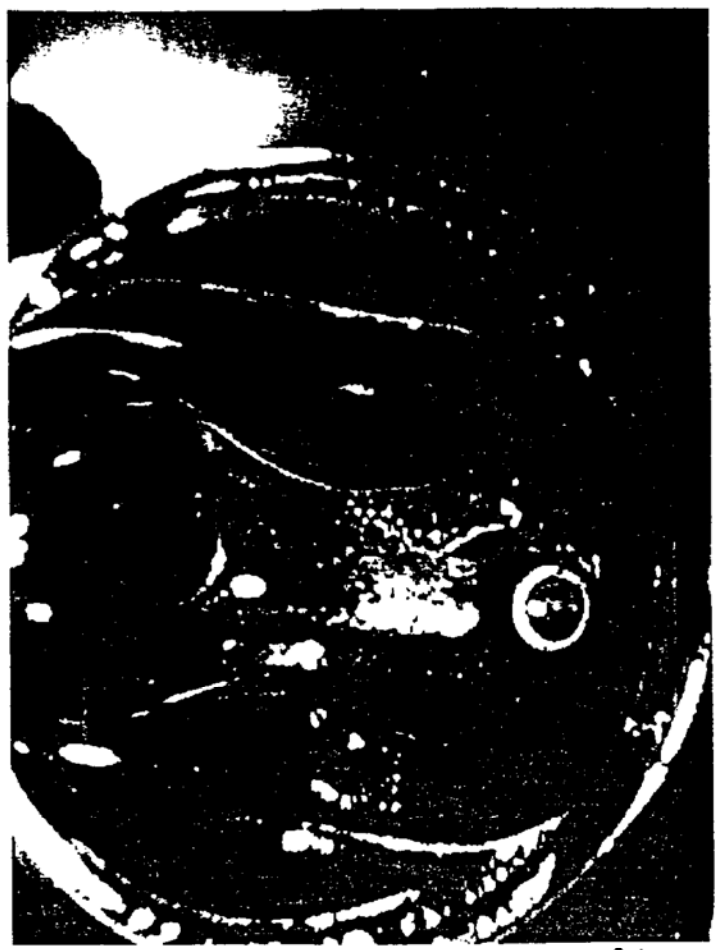

B-U01B-15178-ASI
19 Jan 95 *SPD* 50 MM/S *TIME SCALE* 20.00 MS/MM *REALTIME RECORDER * 737 RUDDER PCU TEST 15:02:10
FIGURE D11
19 JAN 3:02 PM
EXPANDED-SCALE DATA
FAST CYCLE
Channel #1 HANDLE POSITION .5 INCHES PER DIV
Channel #2. ACTUATOR POSITION .5 INCHES PER DIV
2300
1650
1650
Channel #3 HYDRAULIC PRESSURE 500 PSI PER DIV
48#
8#
12
3.6
0
Channel #4 HANDLE LOAD -CENTERED- 20 LBS PER DIV
Astro-Med, Inc.
MT95K2 MULTI-TASK RECORDER
155#
FIGURE D11

1) Sediment in bottom of link cavity
2) Link cavity full of dirty fluid
3) "Snowdrift" on link
4) "Snowdrift" on link





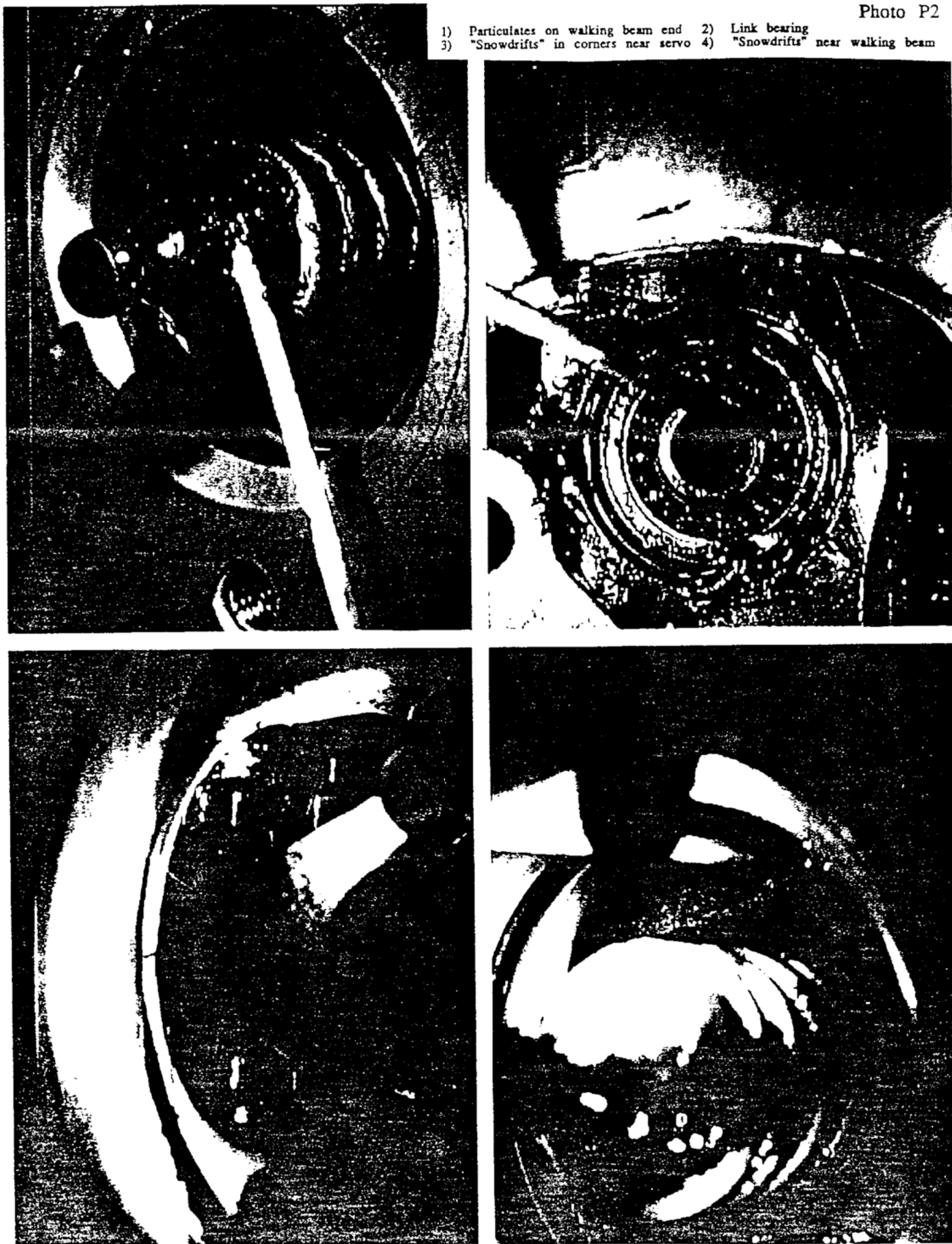




B-U018-15178-ASI

Photo P2

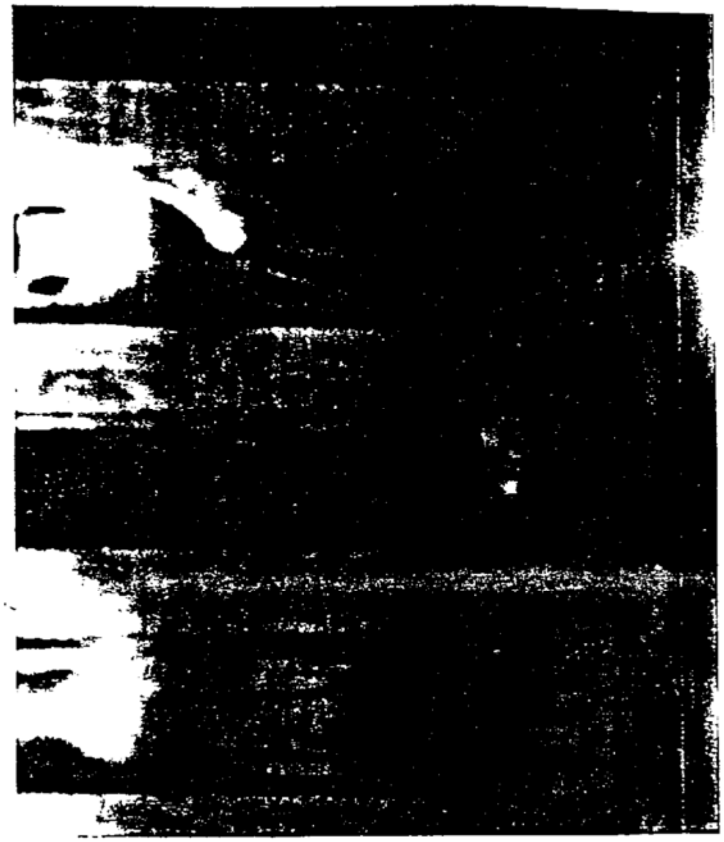
1) Particulates on walking beam end 2) Link bearing
3) "Snowdrifts" in corners near servo 4) "Snowdrifts" near walking beam



B-U018-15178-ASI

Photo P3

1) Sludge in passages, OD of secondary 2) Sludge in passages, secondary OD
3) Goo adhering to primary 4) Goo adhering to primary

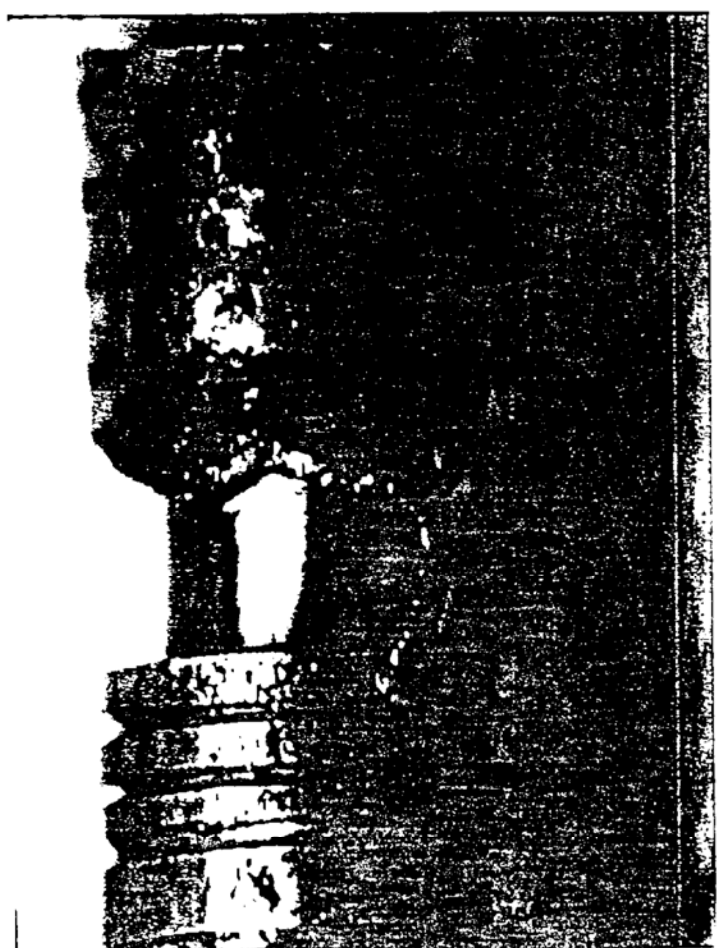
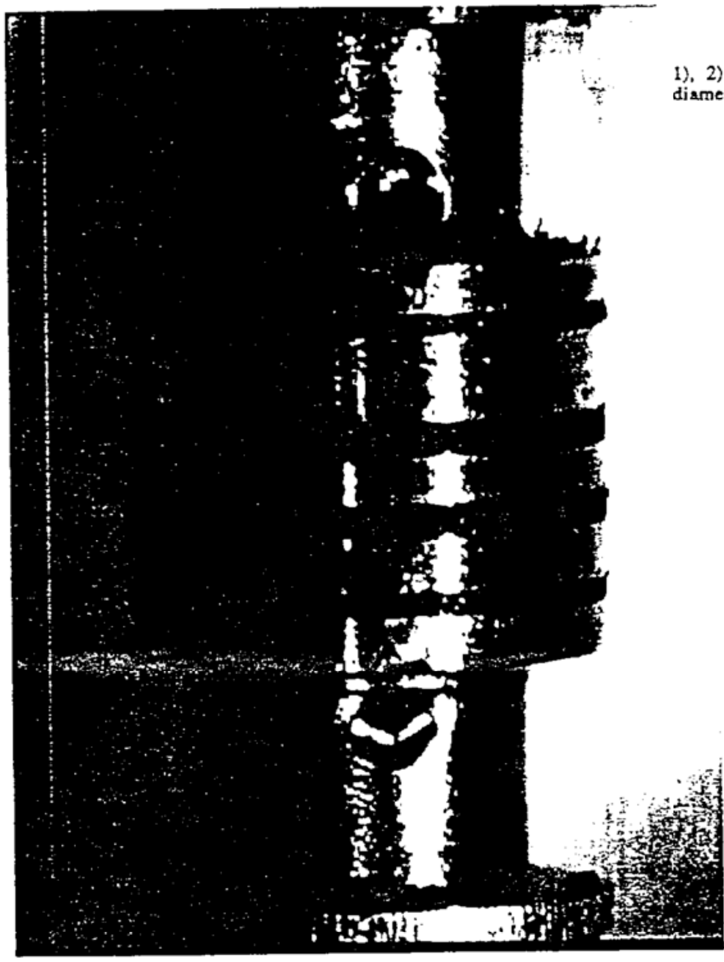
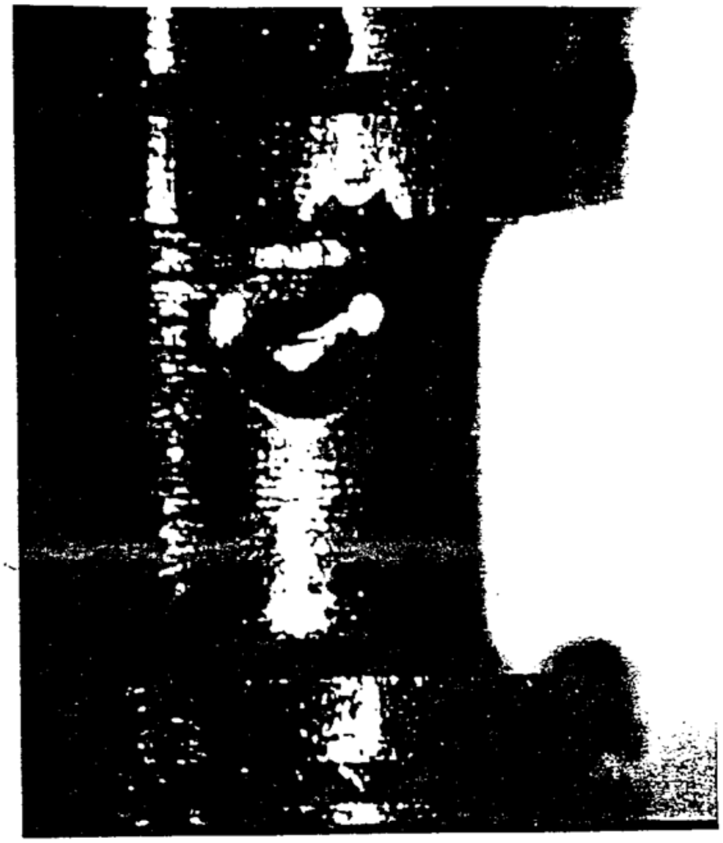


Photo P4

1), 2), 3), & 4) Primary spool: Erosion of metering edges, "craters" on base diameter, sludge packed into balance grooves





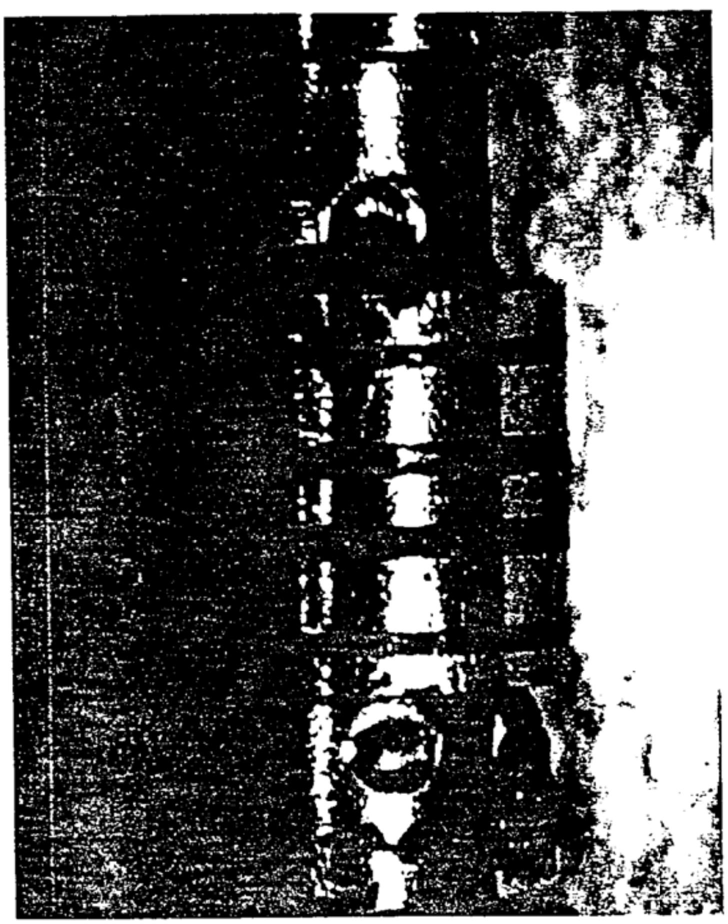
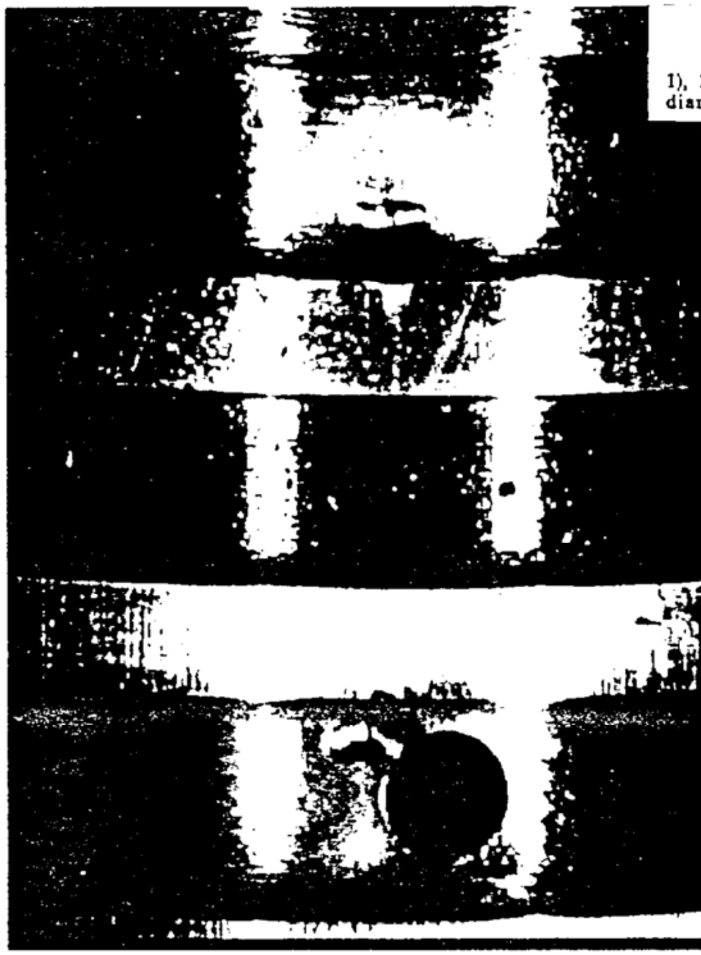
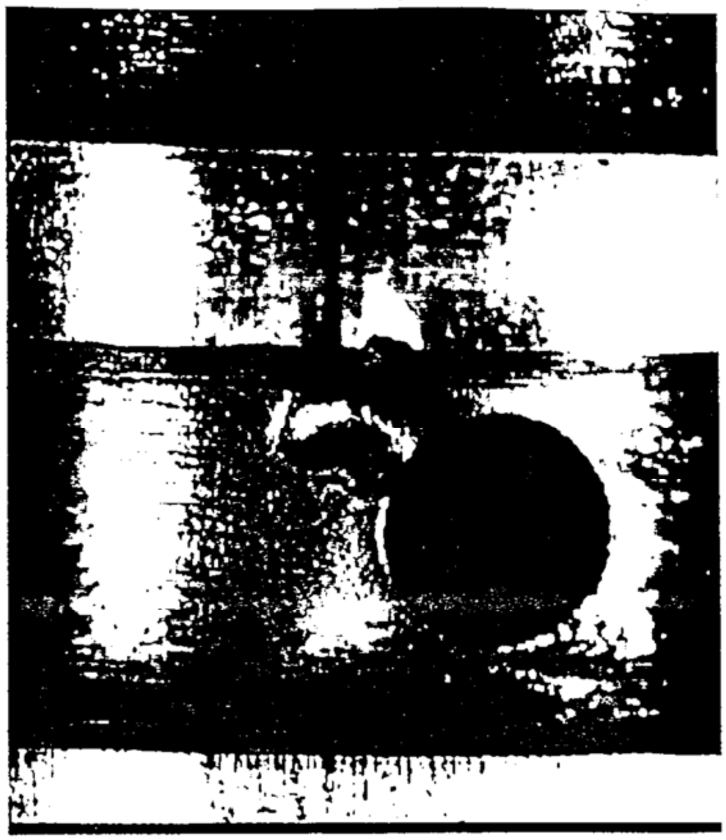
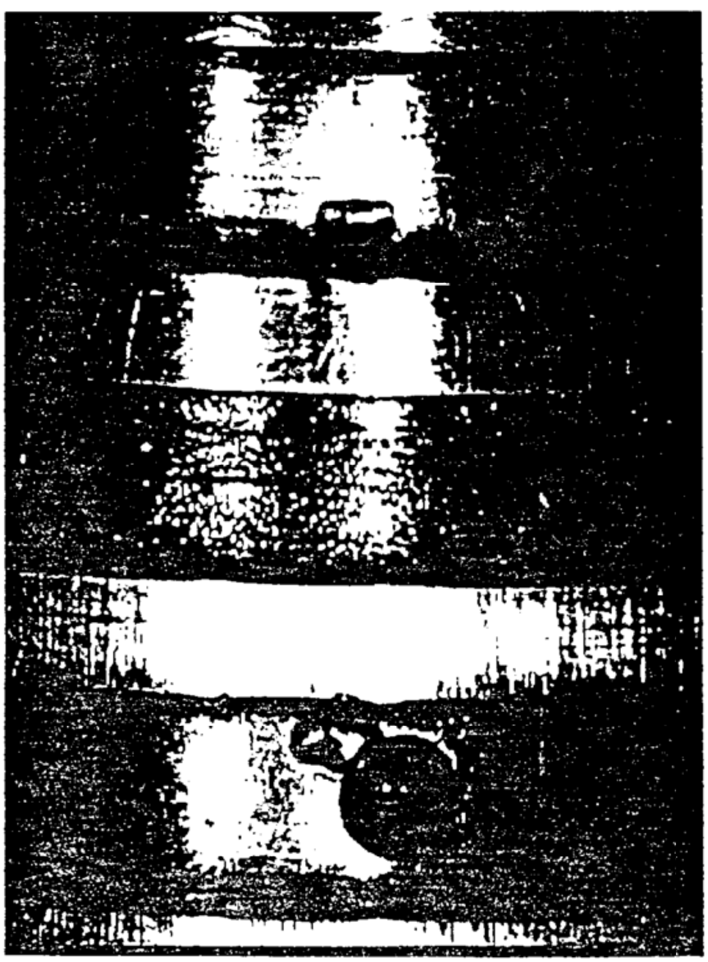


Photo P5

1), 2), 3), & 4) Secondary spool: Erosion of metering edges, "craters" on base diameter







ATTACHMENT 1 TO
B-U018-15178-ASI
PG 1/5

ROUTING WRITE IN NAME NOT INITIALS	DATE	MAIL STOP
[redacted] S. N. Hilby	12/20/94	67-61
[redacted] R. J. Noges	12/20/94	67-61
[redacted] E. D. Robinson	12/20/94	67-61
[redacted] J. J. Metzer	12/21/94	67-61
[redacted]		70-47
RETURN ORIGINAL TO Test Integration 70-47		
G. Engberg		19 MC
RETURN ORIGINAL TO		

737 ENGINEERING WORK AUTHORIZATION NO.

EWA NO.	DASH NO'S.
32 4 0 0 8 9 F	

TO: J. Metzer
(ENGINEER RESPONSIBLE FOR PROGRAM)

PAGE 1/ 6

DATE 12/22/94

REVISIONS

REV./AUTH.	LTR.	DATE

TITLE: 737 Rudder PCU Contamination Demonstration

PURPOSE: Demonstrate characteristics of 737 Rudder PCU when exposed to high levels of particulate contamination.

PRIORITY: Mandatory

GENERAL DESCRIPTION: A test circuit will be set up in the Mechanical Systems Lab, consisting of a reservoir, a 737 Standby pump, and a 737 rudder PCU. Particulate contamination will be introduced in stages into the circuit. The pump will be run while applying a command to the PCU. PCU input force will be monitored. Test duration will be 150 hours. See pg 2 for further details.

PHASE NO.	NAME OF PHASE	UNITS DOING WORK	SEE PAGES
1	Test setup	B-H43B, A-23XX	
2	Test run	B-G61R, B-H43B, 9-4888, R-6710	

Prepared by: Steve Hilby, 965-0708, M/S 67-61

EWA Coordinator: Jack Nickerson, 237-4926, M/S 70-47

CONTRACTUAL AUTHORITY FOR EXPENDITURES:

SCHEDULE AND COST ESTIMATE AUTHORIZED BY: [redacted]
J. J. Metzer

CHARGE NO. 5-R4521-3240-089F00 (Salco# 7296355 for LAB USE ONLY)

	SCHEDULED	ACTUAL
TOTAL COST $	79,269 (Burdened Materials)	Hours Including
TEST COMPLETION DATE		
REPORT COMPLETION DATE		

MFG. SCHED. OR AUTHOR

MFG. MGR. AUTHORIZATION

PROGRAM AUTHORIZED BY: [redacted] 12/22/94
(ENGINEER RESPONSIBLE FOR AUTHORIZING WORK UNDER APPLICABLE CONTRACT)
J. McGrew

26

(This page is to be used when additional space is required for basic EWA information)

A. Test Objective:
This test will demonstrate that the 737 Main Rudder PCU functions properly when operating using hydraulic fluid with up to one hundred times the particulates found in the average in-service rudder PCU linkage cavity.

B. Test configuration required:
A test circuit will be fabricated per the schematic given in Figure 1. Pump will be part number 10-61292-4 (737 Standby pump). Rudder PCU will be p/n 65-44861-11 with inlet filters removed. A crank mechanism, driven by a hydraulic or electric motor, will be required in order to provide the correct input to the PCU.

B1. Equipment required:
737 Standby pump 10-61292-4 provided by B-G61R.
737 Main Rudder PCU 65-44861-11 provided by B-G61R. Inlet filters to be removed.
Laboratory Hardware/Test Buildup provided by B-H43B.
Standard fine air cleaner test dust, or equivalent, with the following particle size distribution: 0-5 microns, 39% ± 2%; 5-10 microns, 18% ± 3%; 10-20 microns, 16% ± 3%; 20-40 microns, 18% ± 3%; and 40-80 microns, 9% ± 3%. Amount required will be about 1/2 lb. Provided by B-H43B.
Steel particles, 10 micron or less diameter, 4340 CRES, about 1/2 lb req'd. Provided by B-H43B.
Aluminum-Nickel-Bronze particles, 10 micron or less diameter, about 1/2 lb req'd. Provided by B-H43B.
Teflon particles or flakes, 50 to 100 micron largest dimension, about 1/2 lb req'd. Provided by B-H43B.
(Suggested source for contaminants: Fluid Technologies, Inc., 1016 E Airport Rd, Stillwater, OK, 74075. Rod Webb, phone 405-624-0400, FAX 405-624-0401)

C. Measurements and information required:
For instrumentation requirements, see Section H.
Color photos of test setup.
Videos of test running, addition of contaminant (at least once)

D. Test Procedure:
1. Run the pump with the pressure filter in the system for 20 minutes, PCU bypassed. Close the bypass valve, open the PCU loop valves, and run with the PCU in the circuit, while cycling the PCU input, for another 20 minutes.
2. Shut down the pump and PCU input mechanism.
3. Open valve 5 and close valve 6 to take the filter out of the active circuit.
4. Mix an amount of contaminant per Table 1 into a slurry using a small amount of BMS 3-11 hydraulic fluid.
5. Shut the contaminant tee isolation valves, remove the contaminant tee cap, siphon out some fluid, and pour the slurry in. Replace tee cap and open valves.
6. Start the pump and PCU input mechanism. Run the system for 20 minutes.
7. Open the sampling valve. Let approximately one pint of fluid run out, then insert a clean fluid sample bottle into the stream without touching the valve. Take two samples. When each bottle is full, remove it from the stream without touching the valve. When sampling is complete, shut the sample valve. Send the samples out for automatic particle counting.

ATTACHMENT 1 TO
B-U01B-15178-ASI
PG 3/5

Document No ______
ENGINEERING WORK AUTHORIZATION NO 32-40089F
Page 3
Date ______
Rev ______

(This page is to be used when additional space is required for basic EWA information)

8. Run the system for 10 hours. Input to PCU will be roughly sinusoidal, with the following stroke/rate schedule:

2 inch stroke	2 inch/sec maximum rate	1 hour
2 inch stroke	1 inch/sec max rate	9 hours

Replace pumps as necessary. After pump or other component failures, sample the system fluid again as in (7) above and add contaminant as necessary to regain original contaminant level.

9. Shut down. Repeat from (4) above, adding more contaminant per Table 1.
10. Continue Round 3 for 130 hours until 150 hours total test time is reached. Sample fluid again. Remove PCU, disassemble, inspect, document condition.

E. Units responsible for test:

Mechanical Systems Lab, B-H43B (C. Nelson, 655-9606): Design of test fixture, coordination of assembly with Shop.

737 Hydraulics, B-G61R: Overall test direction.

Lab Manufacturing, A-23XX: Fabrication and assembly of test rig.

Fluid Analysis Lab, 9-4888 (S. Bencel, 657-3833): Analysis of fluid samples (automatic particle counts)

EQA Lab, R-6710 (K. Jacobs, 237-3831): Disassembly, inspection, documentation, and reassembly of Rudder PCU.

F. Observers required:

Steve Hilby 965-0708, John Curulla, Paul Cline 234-5834

G. Personnel required:

Mechanical Systems Lab will perform the test. See (E) above for other support required.

H. Instrumentation required:

1. PCU input load	-100 to +100 lbf	± 0.5%
2. Pump output pressure	0 to 3500 psi	± 2%
~~3. Flow~~	~~0 to 3.5 gpm~~	~~± 5%~~ Ed Hayes
4. Fluid temperature	0 to 250 F	± 2% (Tube wall temp okay)
5. PCU input stroke	3" total stroke	
6. PCU output stroke	3.944" total stoke	

7. Emergency shutdown: Low pump output pressure
8. Emergency shutdown: Pump output high temperature
9. Emergency shutdown: PCU input high force
10. Emergency shutdown: Pump high amperage (>30 amps)

Record PCU input load, input stroke, output stroke, and pump output pressure continuously during the test using HSPCM or equivalent. Real time display of PCU input load and pump output pressure will be required for checkout.

I. Test Report:

A report will be generated by B-G61R.

J. Test Inspection:

None

ATTACHMENT 1 TO
B-U01B-15178-ASI
PG 4/5

Document No ____________

ENGINEERING WORK AUTHORIZATION NO 32-40089F

Page 4
Date ____________
Rev ____________

(This page is to be used when additional space is required for basic EWA information)

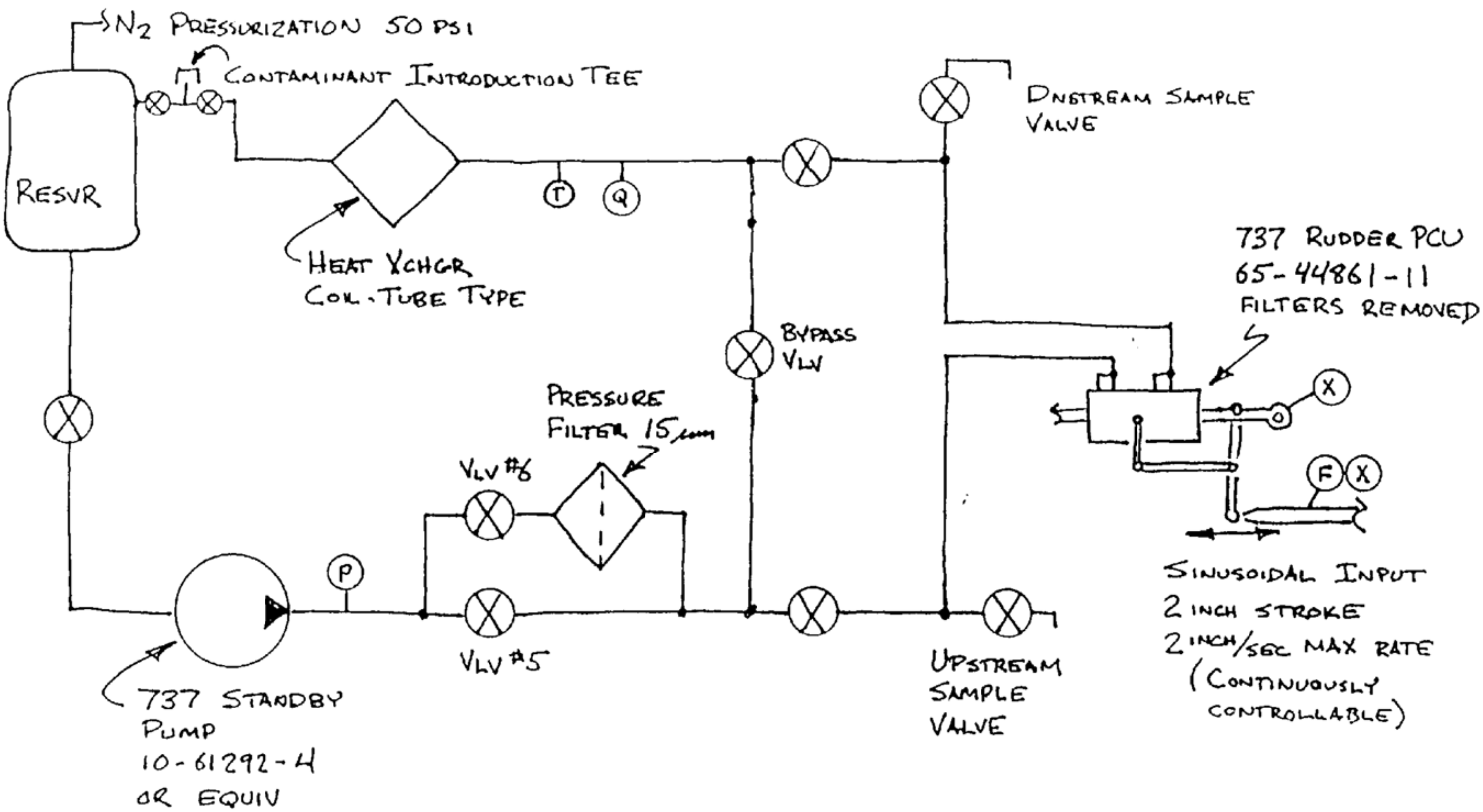
K. Capital resources:
No new required.

Table 1

Contaminant additions per gallon of test rig volume

Round	Steel, mg/gal, and Al-Ni-Bronze, mg/gal	Road dust, mg/gal	Teflon, mg/gal	Goal, NAS 1638 Class (Ref only)
1	88 (each)	18	43	
2	4400	900	2150	
3	4400	900	2150	

ATTACHMENT 1 TO
B-U01B-15178-ASI
PG 5/5
ATTACHMENT TO
EWA # 32-40089F
PAGE 5



737 RUDDER PCU CONTAMINATION
DEMO SETUP
FIG 1

(29)

ATTACHMENT 2 TO
B-U01B-15178-ASI
PG 1/3

9-4888-CSM95-010
January 19, 1995

To:	Steve Hilby	B-G61R	m/s 67-61
	John Curulla	B-G61R	m/s 6H-TR

cc:	Jean Ray	B-Z54B	m/s 73-47
	Brad Steele	9-4858	m/s 8P-04

Subject: Manual Particulate Count in BMS 3-11 for Rudder Test

Background:

Eight BMS 3-11 hydraulic fluid samples were forwarded to us on January 16th. Four of the samples were requested to be tested using manual particle counting. Conversations with Jean Ray of BMT and Steve Hilby gave us history and sample preparation techniques. Due to the anticipated level of contaminants present in the samples, multiple dilutions were necessary.

Analysis:

Each sample was ultrasonically vibrated for approximately 15 minutes, then shaken prior to dilution. Samples were diluted with filtered BMS 3-11 hydraulic fluid.
Samples were then filtered through 0.8 μ filter membrane and counted by microscope. One of the filtered membrane samples was witnessed by Jean Ray and taken to her laboratory for microphotography.

Results:

See attached.

ATTACHMENT 2 TO
B-U01B-15178-ASI
PG 2/3

Summary:

Due to the extremely high level of contaminants spiked into the BMS 3-11, large dilutions with clean fluid were required to allow the use of manual microscopy to count the samples. The results indicated that the fluids were many times higher than would normally be seen in an operating system. Dilution of the samples (on the order of 1:1000) and statistically counting of the membrane filter probably introduced variations which may be on the level of orders of magnitude. Used as trend data, these numbers are meaningful; used as absolute numbers, these particle counts not highly relevant.

For further information or evaluation, please contact the undersigned.

[redacted]
Dennis G. McKillip
Process Control Lab Lead
9-4888, m/s 8Y-57
phone: [redacted]
pager: [redacted]

[redacted]
Christine S. Moy
Process Control Engineer
9-4888, m/s 8Y-57
phone: [redacted]

Concurred by:

[redacted]
John W. Bethel
MA & PC Laboratory Supervisor
9-4888, m/s 8Y-57
phone: [redacted]
pager:

RUDDER TEST - PARTICLE CONTAMINATION

Sample I.D.	Sample Description	Particle count/100 ml by Microscope				
		5–15 μ	15-25μ	25-50μ	50–100μ	>100μ
6R	Contamination level #2, 610 min.,Pressure	52700000	12100000	7742000	1484000	248000
6P2	Contamination level #2, Manual, Pressure	93300000	22900000	11474000	1992000	372000
5P	Contamination level #1, 593 min., Pressure	1288000	344000	192920	31800	5880
5R	Contamination level #1, 593 min., Return	2172000	536000	117440	15560	6400

NOTES: All samples had been ultrasonically vibrated for ~ 15 min., shaken then diluted with filtered BMS-311
All four samples particulate contamination are catagorized as NAS 1638 >12 class
6R - most of particles >25μ were teflon
6P2 - metallic particles(25μ) appeared to be rounded by abrasion
5P - metallic particles appeared jagged; high concentration of silt (< 5 μ)
5R - >100 μ particles appeared to be teflon clumps with shiny metal fragments inbedded into structure

ATTACHMENT 2 TO
B-U018-15178-ASI
PG 3/3

(32)

ATTACHMENT 3 TO
B-UCIB-15178-ASI
PG 1/13

Parker TEST DATA RECORD

Customer Support Operations

Rev. G

Drawn [illegible] Date 4-20-93

Test Approval [redacted] Date 4-20-93

Eng. Approval [redacted] Date 4-29-93

Overhaul Manual 27-20-01 ☐ Overhaul ☑ In-Service Work Order 706-0515-1C

PART NO. 65-44861-9/65~~G37052~~ **SERIAL NO.** 2765-4 **DATE OF TEST** 1-9-95

PART NAME RUDDER ACTUATOR PCU **INSPECTOR** [redacted]

☒ **PHOSPHATE ESTER** ☐ **MIL-H-5606** ☐ **MIL-H-83282** ☐ **AIR** ☐ **PD680**

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
11.A. Continuity Check	Check Continuity per wiring diagram (Fig. 403, Fig. 403A).	OK		
11.B. Pin to Pin Resistance	Check pin to pin resistance at 70°F and record. Must comply with noted valve.			
	Pins / **Resistance**	**Sys "A"** / **Sys "B"**		
	1-2 / 71-87 OHMS (Solenoid PN 59600)	___ / 78		
	1-2 / 49-62 OHMS (Solenoid PN 45080 @ 77°F)	___ / ___		
	1-2 / 79-115 OHMS (Solenoid PN 45080-1 @ 77°F)	___ / ___		
	5-6 / 900-1100 OHMS	___ / 981		
	7-8 / 900-1100 OHMS	___ / 1000		
	1-4 / 0 OHMS (Short)	___ / Ø		
	9-10 / 80-165 OHMS	___ / 103		
	11-12 / 60-135 OHMS	___ / 83		
	3-Other / Infinite (No Connection)	___ / ∞		
11.C. Dielectric Strength	Slowly apply noted voltages and hold for a period of 5 seconds (Fig. 403), 1 min (Fig. 403A). There must be no arcing or insulation failure.			
	1500 VAC Body to Pin 2 (Fig. 403)	OK		
	1500 VAC Body to Pin 1 (Fig. 403A)	OK		
	1000 VAC Body and Pins 2,5,7 connected to common lead to Pin 9 (Fig. 403)	OK		

ATTACHMENT 3 TO
B-U01B-15178-ASI
PG 2/13

Parker TEST DATA RECORD (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☒ In-Service Work Order 7N6-0515-Y...

PART NO. 65-44861-9/6~~5037052~~- SERIAL NO. Z763A DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS		ACC	REJ.
11.C. Dielectric Strength (Continued)	1000 VAC Body and Pins 2,5,7 connected to common lead to Pin 11 (Fig. 403)	OK			
	1000 VAC Body and Pins 1,5,7 connected to common lead to Pin 11.	OK			
	1000 VAC Body and Pins 1,5,7 connected to common lead to Pin 9.	OK			
	800 VAC between Pins 5 and 7	OK			
	800 VAC between Pins 9 and 11 (Fig. 403A)	OK			
11.D. Insulation Resistance	500 VDC between noted pins 100 Megohms min resistance 10 megohms min in-service. (Fig. 403)				
	Pins	Sys "A"	Sys "B"		
	1,5,7,9 & 11 to Body				
	1 to 5,7,9 & 11				
	5 to 7,9, & 11				
	7 to 9 & 11				
	9 to 11				

ATTACHMENT 3 TO
B-U01B-15178-ASI
PG 3/13

Parker TEST DATA RECORD (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☑ In-Service Work Order 706-0515-

PART NO. 65-44861-7/~~65C37052-~~ SERIAL NO. 2763 AF DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.B. Return Pressure	No external leakage or permanent set, each test. No intersystem leakage.	3000 3 ± 2 Sys A ____ ____ Sys B ____ ____		
12.C.3 & .4 Secondary Stroke/Flow Test	Measure and record leakage at open ports Ra and Rb. The unit shall not move after 25 lbs. is applied to lever TF83300-53, and leakage at each return port must not exceed the following: (a) 300-700 cc/min for overhauled unit. (b) 300-1085 cc/min for unit in service.	Extend (12.C.3) Ra ______ cc/min Rb ______ cc/min Retract (12.C.4) Ra ______ cc/min Rb ______ cc/min Movement _____ in.		
12.D. Proof Pressure	No external leakage or permanent set, each test. No intersystem leakage.	5400 3 ± 2 Sys A ____ ____ Sys B ____ ____		
12.E. Rig Neutral Cylinder Stroke and Clearance Test	Output Rig Pin must fit. (27.46 - 27.54 Ref.) No binding or interference at 3000 PSI. Stoke 26° ± ½° each direction. Visual snubbing. No binding or interference at 0 PSI.	Rig Pin OK Surface Indicator at 0° 0° Binding Yes (No) Ext. 26° Ret. 26° Snubbing ✓ OK ✓ OK		

35

ATTACHMENT 3 TO
B-U01B-15178-ASI
PG 4/13

Parker **TEST DATA RECORD** (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☑ In-Service Work Order 706-0515-100

PART NO. 65-44861-9/~~65C37052~~ SERIAL NO. 27631A DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.F. Linkage Breakout Friction	19 oz. maximum to start extend. 1 oz. minimum in extend direction to start retract.	Ext. 12 Oz. Ret. 6 Oz.		
12.G. Input Force vs. Input Travel	Force plot must fall within limits shown on Fig. 723.	✓ OK		
12.H. Cylinder Rod Leakage	1 drop/25 cycles max at each End Gland (In-Service 1 drop/5 cycles) 2 drops/25 cycles max. at Center Gland (In-Service 2 drops/5 cylces) 1 drop/100 cycles max at Input Shaft (In-Service 1 drop/25 cycles)	Rod Gland 0 drops Aft Gland 0 drops Center Gland 0 drops Input Shaft 0 drops		
12.J. Internal Leakage	(1) Rig neutral leakage at RA & RB. 300 cc/min - overhaul. 3000 cc/min - In-Service. (2) & (3) Input lever at extend & retract stops 300-700 cc/min - overhaul. 300-1085 cc/min - In-Service.	Neutral RA RB 210 220 RA RB Ext. 410 410 Ret. 420 370		

(36)

ATTACHMENT 3 TO
B-W01B-15178-ASI
PG 5/13

Parker **TEST DATA RECORD** (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☒ In-Service Work Order 7060-0515-100

PART NO. 65-44861-9 ~~65C37052-~~ **SERIAL NO.** 2763A **DATE OF TEST** 1-9-95

PART NAME RUDDER ACTUATOR PCU **INSPECTOR** [redacted]

☒ **PHOSPHATE ESTER** ☐ **MIL-H-5606** ☐ **MIL-H-83282** ☐ **AIR** ☐ **PD680**

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.J. Internal Leakage (Continued)	(4) 65-44861 and 65C37052 System A energized 1370 cc/min - overhaul 2000 cc/min above leakage measured in step (1) (b) In-Service	Neutral RA ___ RB ___		
	(5) 65-44861 and 65C37052 System A energized 1370 cc/min - overhaul 2000 cc/min above leakage measured in step (1) (b) In-Service	RA RB Ext. ___ ___ Ret. ___ ___		
	(6) 65-44861-5 thru -9,-11 and 65C37052-5 thru -9 System B energized 1370 cc/min - overhaul 2000 cc/min above leakage measured in step (1) (b) In-Service	RB Neutral 640		
	(7) 65-44861-5 thru -9,-11 and 65C37052-5 thru -9 System B energized 1370 cc/min @ RB 2000 cc/min above leakage measured in step (1) (b) @ RB for In-Service	RB Ext. 610 Ret. 600		

ATTACHMENT 3 TO
B-401B-15178-ASI
PG 6/13

Parker

TEST DATA RECORD (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☑ In-Service Work Order 706-0515-10

PART NO. 65-44861-9/~~65C37052~~ SERIAL NO. 2263A DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.K. Intersystem Leakage	Combined leakage from PB and RB 10 cc/min maximum.	0 cc/min		
12.L. Transducer Output	4.2-4.8 VAC 65-44861-2 and 65C37052-2 (Sys A & B) 1.95-2.55 VAC 65-44861-3,-4 and 65C37052-2,-3,-4 (Sys A & B) 1.95-2.55 VAC 65-44861-5,-8 and 65C37052-5,-8 (Sys B) 3.07-3.67 VAC 65-44861-6,-7,-9,-11 and 65C37052-6,-7,-9 (Sys B)	"A" Extend ____ VAC Retract ____ VAC "B" Extend 3.45 VAC Retract 3.55 VAC		
12.M. Transducer Null	50 MV maximum at null for each system - Overhaul. 150 MV maximum at null for each system In-Service.	"A" Null ______ VAC "B" Null .024 VAC		

ATTACHMENT 3 TO
B-U01B-15178-ASI
PG 7/13

Parker TEST DATA RECORD (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☒ In-Service Work Order 706-0515-700

PART NO. 65-44861-9/~~65C37052-~~ SERIAL NO. 2763A DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.N. Yaw Damper Authority	Per Figure 1, Ref. Test Data Sheet 10. Actuator must be stable and within .050" of neutral.	Ext. Ret. Sys "A ______ Sys "B" .232 / .236 Sys "A & B" ____ Stable Yes No Position from "ZERO" ______ Ext. Ret. Stable Yes No Position from "ZERO" ______ Ext. Ret.		
12.P. Manual Hysteresis 4.3.14	Hysteresis shall not exceed .004 inch each direction - Overhaul. .006 inch each direction In-Service	Extend .003 Inch Retract .001 Inch		
12.Q. Yaw Damper System Phase Lag	Phase shift to be: 25 degrees (Sin Ø, 0.423) 30 degrees (Sin Ø, 0.500) for in-service units. No crossover in plot.	"A" sin Ø ____ "B" sin Ø .287 Crossovers: Yes (No)		

ATTACHMENT 3 TO
B-U01B-15178-ASI
PG 8/13

Parker **TEST DATA RECORD** (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☑ In-Service Work Order 706-0515-100

PART NO. 65-44861-9/~~65C37052~~ SERIAL NO. 2763A DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.R. Yaw Damper System Repeatability and Linearity	Pattern must repeat within 0.8" (.008" at actuator) - Overhaul. 1.2" (.012" at actuator) In-Service	"A" ____ in max "B" .225 in max		
	Overshoot after reversal must be 0.2" maximum (.002" at actuator)	"A" ____ in max "B" .190 in max		
	Average input/output slope of any 10% segment must fall within the slope limits shown.	"A" Yes No "B" (Yes) No		
12.S. Phase Check	Manual control "extend", actuator must extend.	Extend "A" OK "B" OK		
	Manual control "retract", actuator must retract.	Retract "A" OK "B" OK		
	Operation smooth and stable for A and B.	Stable: (Yes) No		
12.T. Yaw Damper Engage 4.3.17	.004" maximum movement-overhaul .010" maximum movement-In-Service.	"A" ____ in "B" .002 in		
12.U. By-Pass Valve Operation	(4) No piston movement at 250 PSI differential for either system.	"A" Yes (No) "B" Yes (No)		
	(6a) Noticeable decrease in flow at less than 460 PSI differential.	"A" 395 PSI "B" 400 PSI		
	(8) Piston rod movement of 1.00 inch or more in either direction.	Ext. ✓ OK Ret. ✓ OK	40	

ATTACHMENT 3 TO
B-U01B-15178-ASI
PG 9/13

Parker

TEST DATA RECORD (CONTINUATION)

Customer Support Operations

Rev. G

Overhaul Manual 27-20-01 ☐ Overhaul ☑ In-Service Work Order 706-0515-100

PART NO. 65-44861-9/65C37052- SERIAL NO. 2763A DATE OF TEST 1-9-95

PART NAME RUDDER ACTUATOR PCU INSPECTOR [redacted]

☒ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

TEST & REF.	REQUIREMENT	RESULTS	ACC	REJ.
12.V. Duty Cycle (optional) Not Required for In-Service Unless Actuator Seals Were Replaced	3.0 cc/8 hours maximum at each piston rod seal. 6.0 cc/8 hours at center gland - Overhaul. 1.8 cc/hr maximum at each piston rod seal. 3.6 cc/hr at center gland - In-Service.	Output End _____cc_____hrs Fixed End _____cc_____hrs Center _____cc_____hrs		
12.W. Low Pressure Leakage (not same as 12.V.)	No external leakage in 8 hours - overhaul. No external leaks in one hour In-Service.	_____cc_____hrs		

Parker **TEST DATA RECORD** (CONTINUATION)

Customer Support Operations

Rev. 6

Overhaul Manual 27-20-01 ☐ Overhaul ☐ In-Service Work Order ________

PART NO. 65-44861- /65C37052- SERIAL NO. ________ DATE OF TEST ________

PART NAME RUDDER ACTUATOR PCU INSPECTOR ________

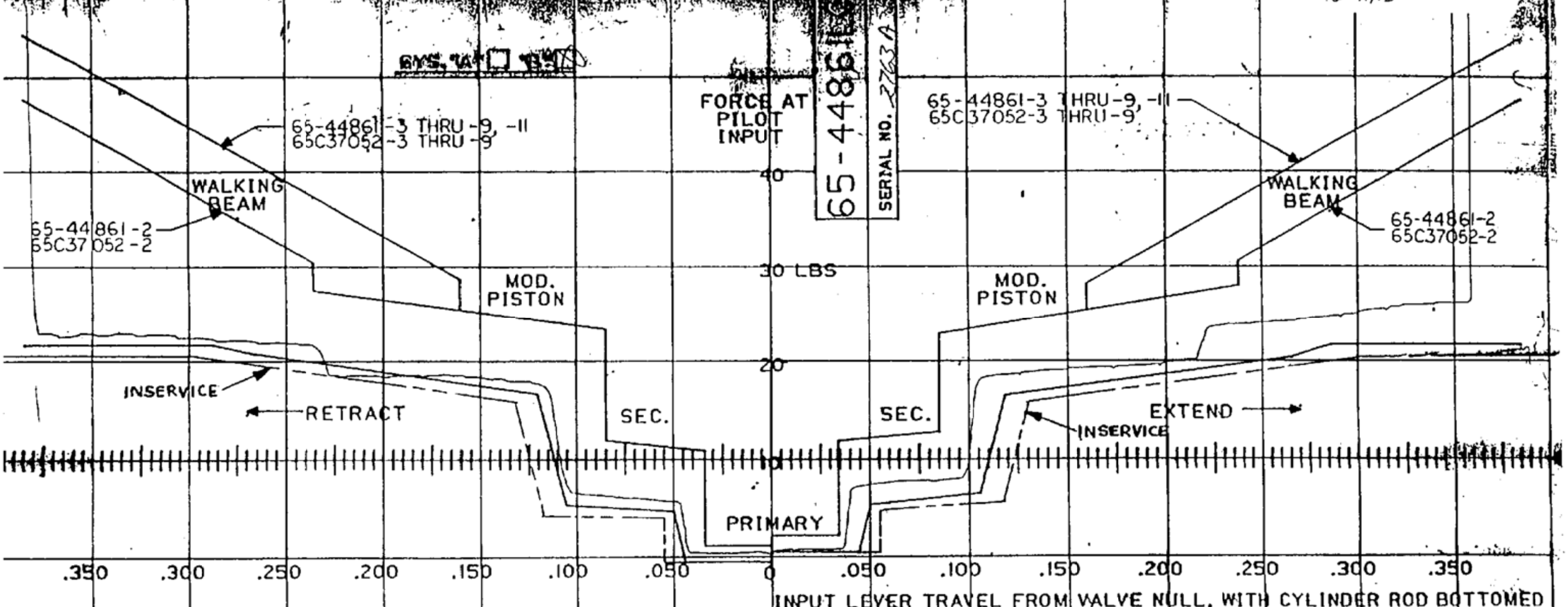
☐ PHOSPHATE ESTER ☐ MIL-H-5606 ☐ MIL-H-83282 ☐ AIR ☐ PD680

OVERHAULED UNIT			
PCU Assembly	Actuator Output Stroke (inches)		
	System A	System B	System AB
65-44861-2 65C37052-2	0.294 to 0.334	0.294 to 0.334	0.335 to 0.375
65-44861-3,-4 65C37052-3,-4	0.137 to 0.177	0.137 to 0.177	0.294 to 0.334
65-44861-5,-8 65C37052-5,-8	--------	0.137 to 0.177	--------
65-44861-6,-7,-9,-11 65C37052-6,-7,-9	--------	0.215 to 0.255	--------

IN-SERVICE UNIT			
PCU Assembly	Actuator Output Stroke (inches)		
	System A	System B	System AB
65-44861-2 65C37052-2	0.274 to 0.354	0.274 to 0.354	0.315 to 0.394
65-44861-3,-4 65C37052-3,-4	0.117 to 0.197	0.117 to 0.197	0.274 to 0.354
65-44861-5,-8 65C37052-5,-8	--------	0.117 to 0.197	--------
65-44861-6,-7,-9,-11 65C37052-6,-7,-9	--------	0.196 to 0.276	--------

Actuator Output Stroke Limits
Figure 1

ATTACHMENT 3 TO
B-661R-C95-037
PG 11/13



INPUT FORCE VS INPUT TRAVEL
TEST12G

PAGE 8 OF 10 ACCEPTANCE TEST DATA SHEETS			
DATE TESTED: 1-9-95	SIZE B	BERTEA/CORPORATION IRVINE, CALIFORNIA	
INSP: [redacted] 706-0515-100	FSCM NO. 82106	65-44861LG (1)	
PART NO. & DASH NO. 65-44861-9	PROJECT 737	PAGE 743	

ATTACHMENT 3 TO
B-661R-15176-46
PG 11/13

(43)

DRAWN: [signature] DATE: 10-2-80 ENG. APPR [signature] DATE: 10-2-80 | TEST APPR:

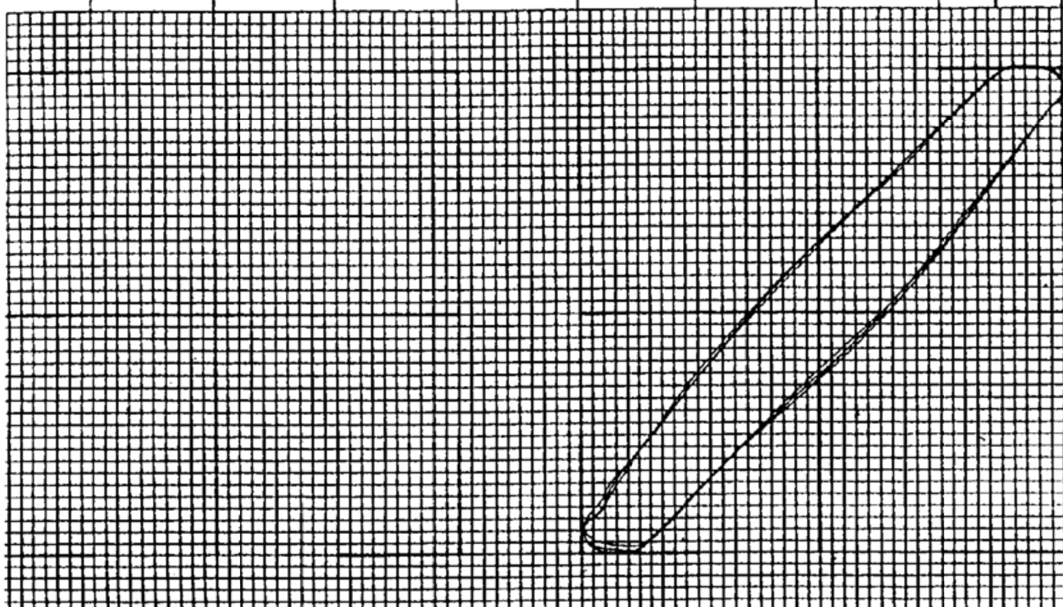
ATTACHMENT 3 TO B-G61R-C95-037 PG 12/13

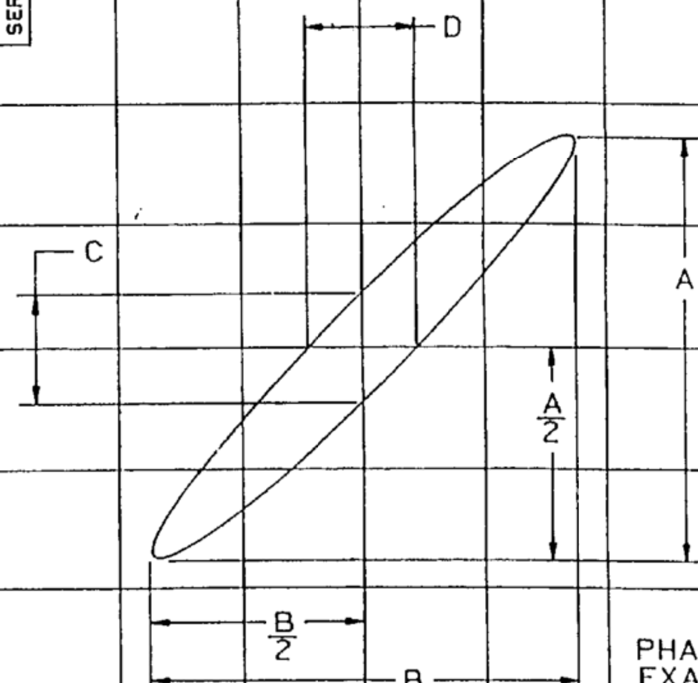
65-44861LG SERIAL NO. 27637A

SINE Ø MAXIMUM PER TEST REQ'MT .423 OVERHAUL .500 INSERVICE

$$2\left(\frac{C}{A}+\frac{D}{B}\right) = \text{SINE } Ø$$

CALCULATION





PHASE LAG EXAMPLE

SYS A

TEST 12Q

PHASE LAG

SYS B

SINE Ø .

SINE Ø .287

(-5 ASSY, 1 SYSTEM ONLY)

PAGE 9 OF 10 ACCEPTANCE TEST DATA SHEETS

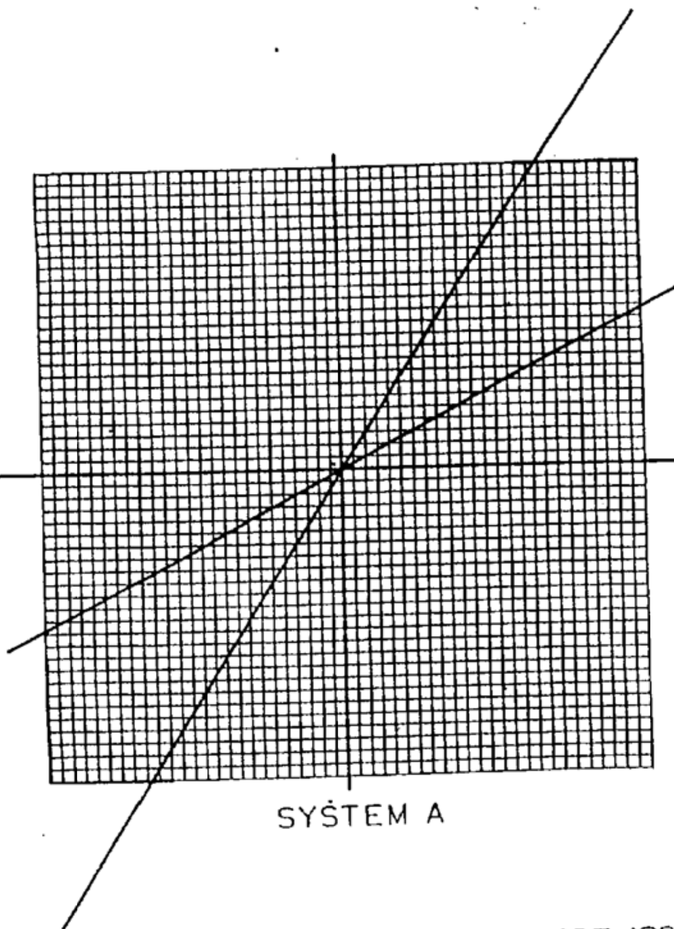
DATE TESTED 1-9-95	SIZE B	BERTEA/CORPORATION IRVINE, CALIFORNIA
INSP [redacted] 786-0515-100	FSCM NO. 82106	65-44861LG (2)
PART NO.	PROJECT 737	PAGE 750

ATTACHMENT 3 TO B-6018-15/75-A51 PG 12/13

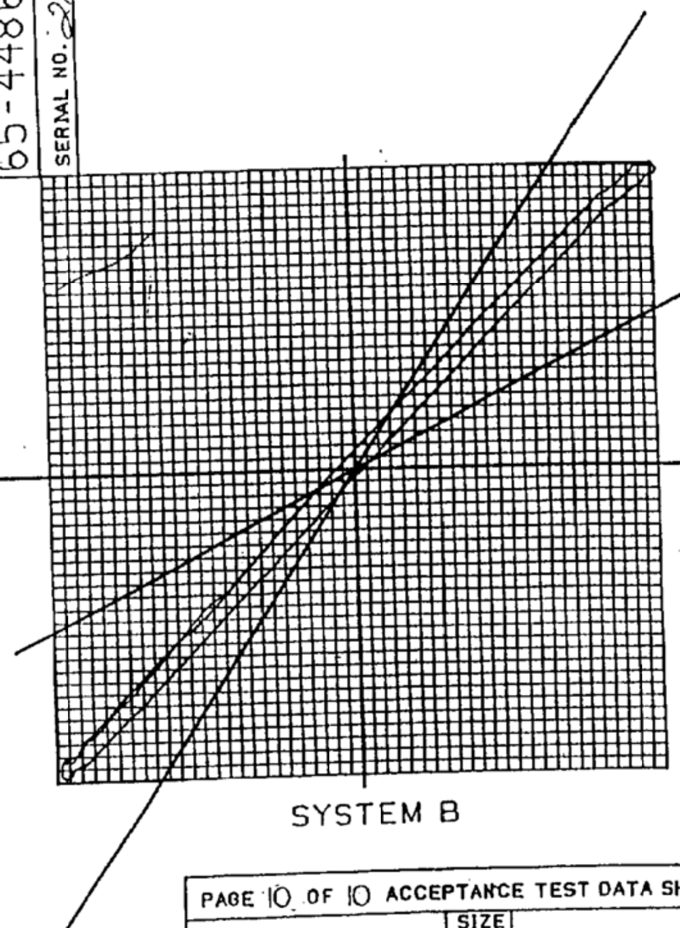
DRAWN: [illegible] DATE: 10-2-80 ENG. APPR: [illegible] DATE: 10-2-80 | TEST APPR:

ATTACHMENT 3 TO
B-G61R-C95-037
PG 13/13

65-4486ILG
SERIAL NO. 2763A



SYSTEM A



SYSTEM B

TEST 12R
REPEATABILITY AND LINEARITY
(-5 ASSY, 1 SYSTEM ONLY)

PAGE 10 OF 10 ACCEPTANCE TEST DATA SHEETS			
DATE TESTED: 1-2-95	SIZE B	BERTEA/CORPORATION IRVINE CALIFORNIA	
INSP [redacted]	FSCM NO. 82106	65-4486ILG (3)	
706-0515-100			
PART NO. [illegible]		PROJECT 737	PAGE 751

ATTACHMENT 3 TO
B-4018-1517-8-A01
PG 13/13

(47)