SIMULATED MULTIPLE LOADS TEST
OF
NCFI 24-124 FOAM APPLIED TO ET CONFIGURED INTERTANK THRUST PANELS
IN
SUPERSONIC WIND TUNNEL A
AT
ARNOLD ENGINEERING DEVELOPMENT CENTER

P.A. KOPFINGER

LOCKHEED MARTIN MICHOUD SPACE SYSTEMS

FINAL TECHNICAL REPORT 826-2000-47

JULY 22, 1999

LOCKHEED MARTIN MICHOUD SPACE SYSTEMS

NEW ORLEANS, LOUISIANA

FOREWORD

The research work reported herein was conducted by the United States Air Force at Arnold Engineering Development Center (AEDC), Tullahoma, Tennessee for Lockheed Martin, Michoud Space Division in New Orleans, Louisiana under Test Directive MMC-TDC-826-2000-17 Rev A. The effort was initiated under Project VA437-J4766, "NASA Shuttle Materials" by Sverdrup Technology, Arnold AFB, TN. The work was administrated under the direction of Philip A. Kopfinger, Lockheed Martin Michoud Space Systems Project Manager and Steve Holmes, NASA Marshall Space Flight Center Test Engineer. The report covers work performed during the period January 23 to January 25, 1999.

This technical report has been reviewed and is approved by:

P.A. Kopfinger, Staff Engineer
Materials Test Engineering

S.C. Copsey, Technical Lead
Materials Test Engineering

R.D. Steinbock, Staff Engineer
Aerodynamics

B.J. Nolan, Staff Engineer
Induced Environments Integration

S. Holmes,
MSFC-NASA

S. Sparks,
MSFC-NASA

C. Williams, Technical Lead
Materials Development Engineering

FOREWORD

The research work reported herein was conducted by the United States Air Force at Arnold Engineering Development Center (AEDC), Tullahoma, Tennessee for Lockheed Martin, Michoud Space Division in New Orleans, Louisiana under Test Directive MMC-TDC-826-2000-17 Rev A. The effort was initiated under Project VA437-J4766, "NASA Shuttle Materials" by Sverdrup Technology, Arnold AFB, TN. The work was administrated under the direction of Philip A. Kopfinger, Lockheed Martin Michoud Space Systems Project Manager and Steve Holmes, NASA Marshall Space Flight Center Test Engineer. The report covers work performed during the period January 23 to January 25, 1999.

This technical report has been reviewed and is approved by:

P.A. Kopfinger, Staff Engineer
Materials Test Engineering

Steve Holmes 7/29/99
S. Holmes,
MSFC-NASA

S.C. Copsey, Technical Lead
Materials Test Engineering

S. Sparks,
MSFC-NASA

R.D. Steinbock, Staff Engineer
Induced Environments Integration

C. Williams, Technical Lead
Materials Development Engineering

B.J. Nolan, Staff Engineer
Induced Environments Integration

FOREWORD

The research work reported herein was conducted by the United States Air Force at Arnold Engineering Development Center (AEDC), Tullahoma, Tennessee for Lockheed Martin, Michoud Space Division in New Orleans, Louisiana under Test Directive MMC-TDC-826-2000-17 Rev A. The effort was initiated under Project VA437-J4766, "NASA Shuttle Materials" by Sverdrup Technology, Arnold AFB, TN. The work was administrated under the direction of Philip A. Kopfinger, Lockheed Martin Michoud Space Systems Project Manager and Steve Holmes, NASA Marshall Space Flight Center Test Engineer. The report covers work performed during the period January 23 to January 25, 1999.

This technical report has been reviewed and is approved by:

P.A. Kopfinger, Staff Engineer
Materials Test Engineering

S. Holmes,
MSFC-NASA

S.C. Copsey, Technical Lead
Materials Test Engineering

7/26/99
S. Sparks,
MSFC-NASA

R.D. Steinbock, Staff Engineer
Induced Environments Integration

C. Williams, Technical Lead
Materials Development Engineering

B.J. Nolan, Staff Engineer
Induced Environments Integration

1.0 INTRODUCTION

This final report presents the results of testing conducted at Arnold Engineering Development Center (AEDC) in Tullahoma, Tennessee over the period of January 23 through 25, 1999. Sverdrup Technology, Inc., contractor for operation, maintenance and repair of the Propulsion and Aerospace Flight Dynamics test facilities, obtained the test results. The test was conducted in the von Karman Gas Dynamics Facility (VKF) Supersonic Wind Tunnel A.

The External Tank experienced a significant loss of thermal protection material from the intertank thrust panel region on Flight STS-87, the second flight to have NCFI 24-124 on the intertank (Figure 1). The material lost from the thrust panels has been implicated as causing damage to the thermal protection high temperature tiles on the lower surface of the shuttle. Subsequent modifications to the intertank to alleviate this problem for STS Flights-89, 90 and 91 did show improvements; however, these improvements did not eliminate the problem. This program was established to understand what effect multiple environments have on the NCFI 24-124 foam.

2.0 OBJECTIVES/SUCCESS CRITERIA

The objectives of this test program was to establish with calibration runs wind tunnel conditions that simulate the flight environments seen on the ribs on the intertank thrust panel which are coated with NCFI 24-124 foam. The test was designed to simulate flight internal and external stresses imposed on the external tank skin panels. Simulated loads applied during this test were high dynamic pressure, vacuum, substrate bending, axial loads, aeroshear and oscillating shocks.

The success criteria for this investigation was defined as debris (foam loss) generated on a consistent basis without the influence of extraneous environments not consistent with those experienced in flight.

3.0 APPROACH

All testing was performed per LMMSS document 826-2000-17 Rev. A, "In Flight Anomaly Investigation (IFA-87) for DOE B", dated January 19,1999.

4.0 TEST FACILITY

Tunnel A (Fig. 2) is a continuous-flow, closed circuit, variable-density wind tunnel with an automatically driven flexible-plate, convergent-divergent nozzle and a 40-in. by 40-in. test section. The tunnel can be operated subsonically at selected Mach numbers up to 0.8 and supersonically at Mach numbers from 1.2 to 5.5. With a test article fully immersed in the flow, the minimum supersonic Mach number is normally limited to 1.5. At subsonic Mach numbers, the maximum stagnation pressure is restricted to less than 1 atm; however, at supersonic Mach numbers, the maximum stagnation pressure varies from 24 to 200 psia as Mach number increases from minimum to maximum. Minimum operating pressures are approximately one-tenth of the maximum at each Mach number. The maximum stagnation temperature also varies as Mach number increases. Depending upon the Mach number, tunnel pressure level, and outside temperature, the maximum stagnation temperature in the tunnel may vary from about 90 to 260°F.

The tunnel is equipped with a flow visualization system that can be used to record shadowgraph and/or schlieren data through the tunnel sidewall windows (Figure 3). Additional information on Tunnel A and its airflow calibrations may be found in Ref. 6.

5.0 TEST ARTICLE FABRICATION

6.0 CALIBRATION PANELS

6.1 0° and 90° Calibration Panel Configuration

The calibration panel was machined from aluminum (Figure 7) and subdivided into two sections so that the aft unit could be rotated 90 degrees and reinstalled in a cross-flow configuration with slight modifications to the forward section of each configuration. The aft section was a 24-inch by 24-inch simulated rib section that duplicated the outer mold line of net-sprayed foam. The model encompassed a total of five rib tops and four valleys. This piece was instrumented with forty pressure taps, three aeroshear gages, one thermocouple and thirteen dynamic pressure gages (kulites). Again this panel was used for both the 0° and 90° test configurations. For the 0° configuration (Figure 8) an additional 18" long by 24" wide piece of aluminum was machined to the outer mold line configuration and then instrumented with forty pressure taps, one thermocouple and one dynamic pressure gage (kulite). The leading edge of this panel was machined to a 21° angle to allow for a smooth transition onto the calibration model. The 90° calibration plate had a flat forward spacer plate installed followed by a forward transition ramp (Figure 9). This section had one dynamic pressure gage (kulite) and one thermocouple. For detailed drawings of each calibration plate configuration see Figures 10 and 11. The calibration plates were mounted to the injection sting for insertion into the tunnel.

6.2 Shock Generator Configuration

The shock generator was fabricated to simulate the SRB bolt catcher at the ET/SRB forward attach point. Due to the limitations of the tunnel, the attach fittings and associated hardware were not simulated. Similar limitations restricted the length and width of the SRB bolt catcher thus it was fabricated to roughly half scale (Figures 12, 13 and 14). The SRB bolt catcher configuration was mounted to the Captive Trajectory System (Figure 15) for insertion and travel in the test section (Figure 16). In addition to simulating the bolt catcher, a portion of the SRB wall was also duplicated but limited in size due to blockage concerns.

6.3 Calibration Panel Instrumentation

A total of 80 static pressure measurements were obtained from the calibration panels using two 15-psid, 48-port Electronically Scanned Pressure (ESP®) transducer modules. The 80 static pressure ports were divided evenly between the two modules, and six psia was chosen as the reference pressure.

The calibration panel for the 0° and 90° panel also contained three skin friction gages (Figure 17). One of the gages was located in a flat area between ridges, and the other two were situated along the crest of one of the corrugations. The locations of these gages are also noted in Figure 18. To minimize measurement errors from erroneous static loads, vibration dynamics, and zero drift from temperature changes, gage developers advised that the gage internal volumes be kept filled with oil. Since the filling operation was somewhat time consuming and tedious and the gages were considered experimental, their data were relegated to a secondary level of importance. Economy of testing was deemed more important than skin friction measurement accuracy.

Thermocouples were attached to the skin friction gages and to the test article support frame to verify that the surface of the calibration plate was at or above room temperature. In addition to the standard tunnel instrumentation system pressures and temperatures from which test condition information was obtained, a video tape system was employed to document the panel condition and the air-flow shock structure (shadowgraph, Figure 19).

7.0 CALIBRATION RUNS

For the 0° rib panel the ET/SRB shock generator was positioned 6" from the top ribs of the panels. For the 90° rib panel the ET/SRB shock generator was moved up an additional two inches due to shock out concerns at Mach 1.5. For the Mach 4.0 condition the ET/SRB shock generator was repositioned to 6" from the rib tops. Three different sets of calibration runs were performed. The first was with the SRB shock generator at a stationary location at the aft end of the tunnel in a fully up position, which was about 20.8 inches above the panel to obtain pressure information without the influence of a shock generator. The second was with the shock generator moving down the centerline of the calibration panel from downstream to upstream. The third set of calibration runs were with the SRB shock generator moving diagonally from a downstream left most position to an upstream right-most position to obtain variances on cross-flow across the ribs. The shock generator movement covered about 38 inches in the stream-wise direction and about 16 (plus and minus 8) inches laterally

8.0 TEST DESCRIPTION

8.1 Test Conditions

Test conditions at each Mach number were nominally as follows:

M	PT	TT	QINF	PINF	RE x 10^{-6}
1.5	11	100	4.7	3.0	3.2
4.0	20	100	1.5	0.13	1.8

8.2 Panel Mounting

The following procedure was performed on all test panels whether 0° or 90° orientation. Sequentially, each foam test panel was positioned over the appropriate radius anvil matching leading edge of panel to leading edge of fixture. Radius blocks were positioned along the outer edges of the panel and held lightly into place by two equally spaced c-clamps on each side (Figure 20). The c-clamps were then simultaneously torqued down very slowly until the outer edges of panel came into contact with the radius block. The panel was then bolted into place and the c-clamps removed (Figure 21). All of the 77 and 99-inch radius panels in the 0° and 90° orientation experienced cracks in the NCFI 24-124 when torqued down.

8.3 Mounting into Insertion Fixture

The radius panel with the test panel bolted into place was placed into the test chamber and bolted down to the insertion fixture. A metallic air dam was fabricated for each panel radius for a smooth transition over the panel. This air dam, simulating the contour of the outer mold line of the net sprayed or machined panels, was then bolted to the leading edge of the panel (Figure 22). The leading edge of the foam that butted up against the air dam was then sanded to meet the air dams contour so as not to induce any forward facing steps during testing. Any foam residue was removed and the panel inspected for any damage prior to insertion.

8.4 General Testing Procedure

For this test installation, the model injection system was modified so that the leading edge of each test article was coplanar with the lower wall of the tunnel at the end of the injection stroke length. In the injected position, the leading edge of each test panel was located about 12 inches aft of the end of the nozzle. A list of panel configurations is presented in Table 1.

The test article was mounted on a sting support mechanism in the model injection tank (Figure 2) located directly underneath the tunnel test section. A pair of fairing doors and a safety door separate the injection tank from the tunnel while the model is in the retracted position. When closed, the fairing doors comprised part of the floor of the tunnel, and the safety door sealed the tunnel from the tank area. After the model was prepared for testing, the personnel access door to the installation tank was closed, the tank was vented to the tunnel flow, the safety and fairing doors were opened, and the model was injected into the air-stream boundary layer. Normally the model is fully injected into the air-stream and the fairing doors are closed at this point in the sequence. For this installation, however, the models were not fully immersed in the air-stream, but positioned level with the tunnel floor. Due to the model location, the fairing doors remained in the open position while data were acquired for about one minute. Following data acquisition, the model was retracted into the tank and the fairing and safety doors were closed. Two sequential runs were required with each test panel, the first at Mach number 1.5 and the subsequent run at Mach number 4.0. Between runs, in order to keep the test panel load magnitude and sequence as realistic as possible, the pressure level in the model injection tank remained at or near the tunnel free-stream pressure level while the nozzle contour was changed from Mach number 1.5

to Mach number 4.0. Once test conditions were established at Mach number 4.0, the sequence noted above for the Mach number 1.5 run was re-executed except when the model was once again retracted, the injection tank was vented to the atmosphere to allow personnel access for the model change. A summary of the runs acquired is presented in Table 2.

The calibration panels were tested first to acquire a record of the pressure levels to which the foam test panels would later be exposed. To keep the load realistic for the entire test period of each panel, the time during which each panel was subjected to pre-stress and flight dynamic loads was strictly controlled and kept as short as possible. While any given panel was being tested, the next panel in the test sequence was attached to its appropriate mandrill, conformed to the proper shape (and stress level), and photographed so that it would be ready for installation as soon as the current test panel's test period ended. While each panel was subjected to air-stream loads, the shock generator produced additional loads. After each panel had experienced a complete test cycle, which constitutes a Mach 1.5 and Mach 4.0 run, the test panel was retracted and photographed. Then the model and mandrill were removed together. During removal, the nozzle contour was returned to Mach number 1.5 for the next panel test sequence. As soon as the next panel/mandrill combination was installed, photographed, and testing had begun, the previously tested panel was removed from its mandrill, and the succeeding mandrill/panel combination was assembled and photographed to get ready for the next test sequence.

8.5 Data Acquisition

During testing of the calibration panels, a portable 16-channel transient data system was employed to acquire fluctuating pressure data. The static pressure data obtained from the calibration panels were used to estimate the local Mach number in the vicinity of each pressure port. This was done by first obtaining a total pressure measurement from a pitot tube situated at the leading edge of the assembly supporting the shock generator. The local static pressures and the total pressure data were then applied as inputs to a data reduction scheme based upon the Rayleigh-Pitot formula. It should be noted that the Mach number estimates thus acquired are reasonably accurate for all orifices except those orifices that are downstream of the impingement of the shock generated by the shock generator. A sample of the data acquired in this phase of the test is presented in Table 3.

Continuous video coverage was maintained on each foam test panel from the start of injection until shutter door closure. Photographic coverage was for each Mach number. Video coverage was initiated in order to capture any failure of the foam.

9.0 RESULTS

9.1 Visual Observation

For all panels tested in the net sprayed, machined vented and non-vented test configuration, there were no indications of any material loss during the test run. No visual cracks or material degradation was observed during the runs or at post-test inspection. As noted earlier, all of the 77-inch and 99-inch radius panels in the 0° and 90° orientation had cracked NCFI 24-124 when torqued down.

9.2 Plug Pull Data

Plug pulls were performed only on the 337-inch radius panels since these were the only radii that did not produce cracks in the foam. All plug pulls were performed per OP13M50FT. The following panels were tested:

Panel Number	Foam Configuration	Test Orientation
3155	Machined-Vented	0°
3159	Machined-Vented	90°
3157	As Sprayed-Vented	0°
3158	As Sprayed-Vented	90°
3151	As Sprayed	0°
3154	As Sprayed	0°
3161	As Sprayed	90°

Sixteen plug pulls were performed on each zero-degree-oriented panel and fourteen on each ninety-degree panel at locations noted on Figures 23 and 24. The plugs pulled on the zero-degree-machined panels were all 0.50" thick and not the typical one-inch core heights called out in OP13M50FT. This data was normalized to a typical one-inch core height specimen by performing a log normal fit from GVTA, AEDC, DOE-B, TP-06, TP-14, TP-23 and all NCFI 24-124 intertank (88-104) plug pull data. The initial thickness, plug pull values and normalized data can be found in Table 4. Figures 25 through 28 are plots of normalized plug pull values versus plug location for net sprayed and machined foam panels tested at zero and ninety degrees. All normalized plug pull values met the minimum acceptance limit of 30 psia.

9.3 Local Pressure Data

This test was designed to match the actual freestream dynamic pressure for the high q regime of a typical STS launch (STS-87). Three plots are provided in Figures 29, 30 and 31. All plots exhibit the local skin pressures as a function of panel length by percent. For the design data, length (L) equals 277.58 inches and the length used for the AEDC calibration panels were 42.0 inches and 30.067 inches for the zero degree and ninety degree rib orientations, respectively. The first plot (Figure 29) is a comparison between two design cases, SWLT versus zero margin. The SLWT design case was derived by using Boeing North America (BNA) supplied pressure coefficients (IVBC3 PE) with NASA/JSC supplied SLWT design trajectory environments. The zero margin design case was derived by using the same BNA supplied pressure coefficients (C_p's) (IVBC3 PE) with the zero margin environments. It should be noted that C_p's are a function of Mach Number, vehicle attitude and location. The BNA supplied C_p matrix ranges from Mach 0.60 to 2.50, therefore Mach 4.0 data were not presented. The purpose of the Mach 4.0 runs were to decrease the static pressure to less than 1.0 psia to obtain a near one-atmosphere pressure differential across the foam cell wall structure, which was attained at AEDC. The second and third plots (Figures 30 and 31) compare the AEDC zero and ninety-degree rib data versus the SLWT design case. For the zero degree case, calibration runs 18 and 19 were selected because the foam panels were tested to these environments. Runs 28 and 30 were chosen for the ninety-degree rib case for the same reasons.

In absolute terms ignoring X/L, the AEDC data falls within the design cases. The design cases account for the ET/SRB attach fitting (i.e. stagnation), which is the reason why the local pressures are higher at X/L of 0.50 or less. Other than the ribs and shock generator, protuberances were not modeled on the AEDC panels.

9.4 Aeroshear Data

The aeroshear portion of this test was developed based on the STS-87 BET derived environments and tested accordingly (i.e., tested Mach 1.5 first, then Mach 4.0 for each panel). Comparison charts between AEDC test results and "design" shear stress values are provided in Figures 32 through 34. The design shear stresses were from aero data provided in the "Space Shuttle Transportation System Operational Aerodynamic Design Data Book", (STS85-018), in conjunction with the environments from the four SLWT "design" trajectories provided by NASA/JSC. The shear stresses obtained from the clean skin calibration panel were equivalent to or exceeded maximum "design" requirements as shown in Figures 32 and 33. In essence, viscous effects in themselves were over tested and no detrimental effects were observed. It should be noted that in Figure 33, the AEDC data is actually for Mach 3.95 while the "design" data is for Mach 3.50 (skin friction data from Reference STS85-0118 stops at Mach 3.50). In general, viscous effects decrease with Mach number in the supersonic/hypersonic regime as the trend between Figures 32 and 33 portrays. For comparisons, pre-test computations are provided in Figure 34 for the Mach 1.5 case and considering the magnitude of the shear stress data relative to the total drag, the data are consistent.

9.5 Dynamic Pressure Data

Kulite dynamic pressure data were taken for 20 runs on the calibration plate. Time history plots from these runs are shown in Figures 35 through 54, with test descriptions for the run numbers in Table 5. Actual run data is available from compact discs found in References 1-3, and 10. Kulite pressure sensor placement is shown on Figures 8 and 9. The 0° and 90° cases were obtained by rotating the cal plate rib orientation 90° to the flow as shown in Figure 11. Kulites were placed on two sets of profiles consisting of adjacent valley, rib side, rib top, rib side, and valley (10 total) along with individual placements (5 total) for a total of 15 measurements. Run parameters are shown in Tables 5, 6 and 7.

Table 8 contains a high amplitude expanded time clip of the time record data from Figure 54 (Recording 20, Channel 9). Total data in this clip is available from the disc in Reference 4. Figure 55 is a plot of the data from Table 8. It can be seen from this expanded time plot that the primary nature of these data is wide-band random noise.

This data comprises a database from which information will be drawn to provide enhanced insight with respect to aerodynamic and vibroacoustic phenomena relative to foam loss. Vibroacoustic flight data from STS-95/ET-98, STS-96/ET-100, and STS-93/ET-99 will be primarily targeted for these comparisons. Anticipated usage will be to spectrally correlate Kulite data, related to specific run parameters, and further relate it to flight data. An additional usage will be the definition of octave band acoustic levels also related to specific run parameters. These will be compared to flight acoustics. Attempts to generate one-third octave band data from the Kulite pressure data have not been successful up to the present due to problems inherent in the commercial software. The vendor is currently generating a fix to the software problem. When the software problem is resolved, we will perform an acoustic assessment and report on this assessment, if any unexpected results occur.

10.0 CONCLUSION

The objective of this test was to establish with calibration models the wind tunnel conditions that simulated local free stream dynamic pressure and vacuum and these were substantiated by the calibration data.

The induced simulated environments achieved in this test caused no degradation to the machined vented or non-vented panels in either the 0° or 90° orientation. Neither did it cause degradation to the net-sprayed panels tested at the 0° or 90° orientation.

In summary, the combination of high dynamic loads, substrate bending, aero-acoustics, aero-shear, oscillating shocks and vacuum effects do not cause foam loss.

1.0 REFERENCES

1. AEDC VKF Tunnel A CD 1 of 3, "NASA Shuttle Materials Test, Acoustic Data, Recordings 2 - 9", 1/23/99

2. AEDC VKF Tunnel A CD 2 of 3, "NASA Shuttle Materials Test, Acoustic Data, Recordings 10 - 17", 1/23/99

3. AEDC VKF Tunnel A CD 3 of 3, "NASA Shuttle Materials Test, Acoustic Data, Recordings 18 - 20", 1/23/99

4. AEDC VKD Tunnel A Disc 1 of 1, NASA Shut tle Materials Test, Acoustic Data, High Amplitude Clip of Time Record Data (Rec. 20)", 1/23/99

5 AEDC VKF Tunnel A CD, "VA437 J4766 NASA Shuttle Material Test, Final Data, Dwg., Photos & TSR Files", June 1, 1999

6. AEDC VKF Tunnel A CD, "VA437 J4766 NASA Shuttle Material Test, Photos", February 5, 1999

7. AEDC VKF Tunnel A CD, "Test Facilities Handbook", January 1, 1999

8. AEDC VKF Tunnel A, A Wind Tunnel Test Attempt to Duplicate the Failure Mechanism(s) of the Shuttle External Tank Foam Coating", May 1999

9. AEDC VKF Tunnel A, "NASA Shuttle Data Package: Test and Evaluation Facility", Job 4766, January 1999 Runs 11-55

10. AEDC VKF Tunnel A CD 1 of 1, "NASA Shuttle Materials Test, Acoustic Data, Recordings 1", 1/23/99

Panel No.	Panel Orientation	Foam Configuration	Vented Non-Vented	Freestream Mach No.	Panel Radius (inches)	CTS Schedule	Run Duration (seconds)
3150	0°	Net Sprayed	Non-Vented	1.55	77	A,B	60
3150	0°	Net Sprayed	Non-Vented	4	77	A,B	60
3151	0°	Net Sprayed	Non-Vented	1.55	337	A,B	60
3151	0°	Net Sprayed	Non-Vented	4	337	A,B	60
3152	0°	Net Sprayed	Non-Vented	1.55	77	A,B	60
3152	0°	Net Sprayed	Non-Vented	4	77	A,B	60
3154	0°	Net Sprayed	Non-Vented	1.55	337	A,B	60
3154	0°	Net Sprayed	Non-Vented	4	337	A,B	60
3156	0°	Net Sprayed	Non-Vented	1.55	99	A,B	60
3156	0°	Net Sprayed	Non-Vented	4	99	A,B	60
3160	90°	Net Sprayed	Non-Vented	1.55	77	A,B	60
3160	90°	Net Sprayed	Non-Vented	4	77	A,B	60
3161	90°	Net Sprayed	Non-Vented	1.55	337	A,B	60
3161	90°	Net Sprayed	Non-Vented	4	337	A,B	60
3162	90°	Net Sprayed	Non-Vented	1.55	99	A,B	60
3162	90°	Net Sprayed	Non-Vented	4	99	A,B	60

Table 1: List of Panel Configurations and Run Schedule

Panel No.	Panel Orientation	Foam Configuration	Vented Non-Vented	Freestream Mach No.	Panel Radius (inches)	CTS Schedule	Run Duration (seconds)
3153	0°	Machined	Non-Vented	1.55	337	A,B	60
3153	0°	Machined	Non-Vented	4	337	A,B	60
3155	0°	Machined	Vented	1.55	337	A,B	60
3155	0°	Machined	Vented	4	337	A,B	60
3157	0°	Machined	Vented	1.55	337	A,B	60
3157	0°	Machined	Vented	4	337	A,B	60
3158	90°	Machined	Non-Vented	1.55	337	A,B	60
3158	90°	Machined	Non-Vented	4	337	A,B	60
3159	90°	Machined	Vented	1.55	337	A,B	60
3159	90°	Machined	Vented	4	337	A,B	60

Table 1 (cont.'d): List of Panel Configurations and Run Schedule

Config Number	Radius of Curvature		Mach No.	1.5				4.0		Remarks
			PT	5.0	10.0	11.0	13.0	10.0	20.0	
			BC TRK	Run Numbers						
101	77	0	0	17		18	16	20	22	Calib.
101	77	0	¦		11/12/13			21	23	Calib.
101	77	0	¥		14/15	19			24	Calib.
102	77	90	0			28			25	Calib.
102	77	90	¦			29			26*	Calib.
102	77	90	¥			30			27*	Calib.
3150	77	0	¥			31			32	Net
3151	337	0	¥			52			53	Net
3152	77	0	¥			35			36	Net
3153	337									Not Tested
3154	337	0	¥			48			49	Net
3155	337	0	¥			37			38	Machined
3156	99	0	¥			39			40	Net
3157	337	0	¥			33			34	Machined
3158	337	90	¥			44			45	Machined
3159	337	90	¥			50			51	Machined
3160	77	90	¥			42			43	Net
3161	337	90	¥			54			55	Net
3162	99	90	¥			46			47	Net

0 – Bolt Catcher fully aft and up in tunnel, stationary during run, ~20.8 separation distance from panel

¦ - Bolt Catcher traverse from downstream to upstream in vertical plane of symmetry of tunnel, separation between bolt-catcher and panel ~8 in.

¥ - Bolt Catcher diagonal traverse from downstream left side to the upstream right side of the traverse envelope, usual separation between bolt-catcher and panel ~8 in.

* - Separation between bolt-catcher and panel ~6 in.

Table 2: Run Number Summary

SVERDRUP TECHNOLOGY, INC
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE BASE, TENNESSEE

DATE COMPUTED 17-MAR-99
DATE RECORDED 23-JAN-99
TIME RECORDED 17:57: 9
TIME COMPUTED 07:27:14

NASA SHUTTLE MATERIALS TEST
JOB NO 4766 TEST NO VA437

PAGE 9

RUN	CONFIG	TESP1	TESP2	M	PT	TT	QINF	PINF	TINF	RE	PT2	VINF	PK01	PK32
12	101	567.7	572.7	1.50	10.00	559.7	4.292	2.725	386.0	0.291E+07	9.302	1444.664	1.942	1.958

FOREBODY

PN	ELPT	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9	PS10
1	0.000	3.172	2.982	3.104	3.114	3.142	3.037	3.062	3.121	2.985	3.088
31	6.265	3.157	2.993	3.161	3.177	3.191	3.105	3.119	3.162	3.045	3.152
61	12.530	3.224	3.027	3.169	3.200	3.205	3.096	3.117	3.180	3.050	3.148
91	18.795	3.227	3.115	3.274	3.320	3.352	3.243	3.255	3.318	3.202	3.299
121	25.059	3.187	3.000	3.148	3.155	3.181	3.088	3.083	3.137	3.022	3.108
151	31.324	3.209	3.063	3.238	3.268	3.281	3.158	3.163	3.203	3.073	3.191
181	37.589	3.215	3.105	3.246	3.319	3.344	3.220	3.230	3.286	3.152	3.249
211	43.854	3.149	3.011	3.153	3.215	3.263	3.123	3.177	3.227	3.089	3.198
241	50.118	3.222	3.051	3.192	3.236	3.275	3.153	3.166	3.226	3.102	3.188
271	56.383	3.232	3.024	3.174	3.214	3.242	3.123	3.152	3.208	3.081	3.188

PS11	PS12	PS13	PS14	PS15	PS16	PS17	PS18	PS19	PS20	PS21	PS22	PS23	PS24	PS25
3.031	3.038	3.058	2.967	3.091	3.124	3.152	2.959	3.224	3.057	3.080	2.584	3.087	2.802	3.034
3.074	3.095	3.118	3.006	3.143	3.170	3.132	2.967	3.230	3.040	3.124	2.637	3.144	2.855	3.136
3.095	3.104	3.112	3.027	3.151	3.189	3.217	3.015	3.239	3.090	3.154	2.639	3.145	2.867	3.107
3.239	3.257	3.271	3.160	3.275	3.271	3.289	3.054	3.222	3.166	3.264	2.760	3.249	2.987	3.284
3.042	3.066	3.078	2.977	3.095	3.134	3.163	2.961	3.222	3.043	3.111	2.601	3.121	2.828	3.119
3.112	3.131	3.157	3.036	3.153	3.176	3.180	2.961	3.211	3.070	3.163	2.650	3.167	2.875	3.161
3.205	3.216	3.230	3.150	3.256	3.265	3.254	3.089	3.229	3.124	3.242	2.732	3.250	2.980	3.260
3.157	3.145	3.163	3.081	3.192	3.176	3.172	3.009	3.175	3.083	3.165	2.646	3.180	2.891	3.172
3.130	3.144	3.153	3.064	3.175	3.162	3.162	3.016	3.209	3.098	3.170	2.635	3.183	2.896	3.180
3.126	3.123	3.151	3.064	3.175	3.224	3.246	3.021	3.289	3.154	3.165	2.653	3.185	2.895	3.163

PS26	PS27	PS28	PS29	PS30	PS31	PS32	PS33	PS34	PS35	PS36	PS37	PS38	PS39	PS40
2.865	3.083	3.038	3.045	3.121	3.160	3.037	2.945	2.967	2.973	2.977	2.544	2.763	2.749	2.742
2.936	3.158	3.130	3.120	3.212	3.292	3.142	3.047	3.056	3.027	3.027	2.681	2.785	2.811	2.759
2.911	3.138	3.093	3.127	3.186	3.196	3.077	2.973	2.995	2.987	2.981	2.609	2.767	2.773	2.755
3.080	3.275	3.241	3.298	3.379	3.364	3.231	3.045	3.078	3.046	3.059	2.694	2.861	2.890	2.892
2.893	3.132	3.094	3.116	3.187	3.211	3.088	2.997	3.013	3.004	3.018	2.602	2.792	2.798	2.779
2.935	3.161	3.136	3.182	3.240	3.252	3.129	3.020	3.043	3.030	3.036	2.645	2.831	2.835	2.913
3.079	3.311	3.256	3.282	3.398	3.402	3.279	3.025	3.047	3.031	3.036	2.690	2.866	2.876	2.908
2.991	3.211	3.159	3.208	3.322	3.337	3.220	3.025	3.038	3.014	3.000	2.681	2.794	2.818	2.747
2.972	3.206	3.165	3.186	3.286	3.310	3.185	3.063	3.063	3.054	3.056	2.709	2.844	2.859	2.823
2.961	3.213	3.152	3.163	3.239	3.256	3.140	3.018	3.042	3.043	3.024	2.625	2.832	2.797	2.783

Table 3: Sample Data

SVERDRUP TECHNOLOGY, INC
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE BASE, TENNESSEE

DATE COMPUTED 17-MAR-99
DATE RECORDED 23-JAN-99
TIME RECORDED 17:57: 9
TIME COMPUTED 07:27:14

NASA SHUTTLE MATERIALS TEST
JOB NO 4766 TEST NO VA437

PAGE 10

RUN	CONFIG	TESP1	TESP2	M	PT	TT	QINF	PINF	TINF	RE	PT2	VINF	PK01	PK32
12	101	567.7	572.7	1.50	10.00	559.7	4.292	2.725	386.0	0.291E+07	9.302	1444.664	1.942	1.958

PANEL

PN	ELPT	PF41	PF42	PF43	PF44	PF45	PF46	PF47	PF48	PF49	PF50
1	0.000	2.939	2.526	2.487	2.482	2.512	2.677	2.940	2.837	2.725	2.631
31	6.265	2.955	2.529	2.499	2.488	2.517	2.706	2.957	2.833	2.723	2.627
61	12.530	2.947	2.522	2.485	2.489	2.519	2.702	2.909	2.802	2.706	2.625
91	18.795	2.938	2.513	2.487	2.503	2.585	2.816	2.927	2.821	2.714	2.609
121	25.059	2.973	2.553	2.511	2.491	2.517	2.687	2.952	2.862	2.762	2.653
151	31.324	2.955	2.538	2.506	2.484	2.527	2.724	2.953	2.850	2.749	2.642
181	37.589	2.929	2.510	2.472	2.493	2.571	2.790	2.910	2.799	2.695	2.611
211	43.854	2.935	2.506	2.469	2.474	2.535	2.733	2.913	2.808	2.709	2.623
241	50.118	2.956	2.529	2.489	2.488	2.549	2.746	2.933	2.838	2.727	2.634
271	56.383	2.983	2.537	2.504	2.511	2.533	2.718	2.950	2.852	2.740	2.661

PF51	PF52	PF53	PFS5	PF55	PF56	PF57	PF58	PF59	PF60	PF61	PF62	PF63	PF64	PF65
2.603	2.556	2.472	2.487	2.452	2.483	2.484	2.441	2.437	2.571	2.660	2.823	2.863	2.219	2.597
2.591	2.549	2.459	2.479	2.458	2.493	2.479	2.452	2.441	2.571	2.681	2.862	2.897	2.202	2.587
2.594	2.538	2.463	2.474	2.443	2.482	2.484	2.448	2.446	2.598	2.707	2.881	2.912	2.191	2.571
2.584	2.543	2.441	2.470	2.458	2.481	2.485	2.475	2.500	2.660	2.794	2.982	3.031	2.184	2.567
2.623	2.582	2.476	2.499	2.475	2.500	2.484	2.454	2.441	2.575	2.679	2.841	2.865	2.215	2.606
2.602	2.566	2.471	2.481	2.466	2.496	2.480	2.455	2.462	2.596	2.715	2.897	2.918	2.196	2.586
2.582	2.536	2.445	2.467	2.441	2.469	2.474	2.460	2.478	2.659	2.793	2.986	3.036	2.182	2.542
2.582	2.530	2.447	2.469	2.427	2.464	2.457	2.420	2.446	2.601	2.724	2.917	2.958	2.190	2.568
2.602	2.550	2.462	2.485	2.462	2.483	2.488	2.458	2.451	2.607	2.723	2.904	2.940	2.203	2.592
2.623	2.557	2.472	2.503	2.466	2.509	2.504	2.460	2.461	2.602	2.694	2.880	2.926	2.198	2.590

PF66	PF67	PF68	PF69	PF70	PF71	PF72	PF73	PF74	PF75	PF76	PF77	PF78	PF79	PF80
2.675	2.614	2.596	2.567	2.525	2.484	2.476	2.455	2.440	2.461	2.473	2.511	2.643	2.792	2.953
2.646	2.608	2.616	2.557	2.523	2.478	2.469	2.462	2.438	2.456	2.483	2.509	2.626	2.810	2.976
2.655	2.609	2.583	2.551	2.515	2.474	2.468	2.451	2.433	2.461	2.483	2.525	2.671	2.848	3.013
2.626	2.588	2.586	2.535	2.504	2.463	2.455	2.454	2.431	2.460	2.513	2.589	2.774	3.001	3.174
2.672	2.631	2.633	2.577	2.541	2.493	2.481	2.476	2.446	2.460	2.487	2.503	2.619	2.785	2.949
2.649	2.601	2.595	2.552	2.512	2.474	2.464	2.462	2.436	2.451	2.488	2.524	2.663	2.853	3.024
2.615	2.571	2.572	2.540	2.501	2.464	2.459	2.437	2.423	2.460	2.510	2.605	2.808	3.025	3.194
2.640	2.597	2.581	2.542	2.499	2.455	2.444	2.423	2.407	2.428	2.463	2.521	2.690	2.871	3.051
2.669	2.624	2.604	2.570	2.529	2.480	2.468	2.461	2.433	2.461	2.487	2.522	2.678	2.869	3.031
2.673	2.617	2.621	2.577	2.534	2.502	2.488	2.469	2.463	2.480	2.497	2.543	2.686	2.863	3.042

Table 3 (cont.'d): Sample Data

SVERDRUP TECHNOLOGY, INC
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE BASE, TENNESSEE

DATE COMPUTED 17-MAR-99
DATE RECORDED 23-JAN-99
TIME RECORDED 17:57: 9
TIME COMPUTED 07:27:14

NASA SHUTTLE MATERIALS TEST
JOB NO 4766 TEST NO VA437

PAGE 11

RUN	CONFIG	TESP1	TESP2	M	PT	TT	QINF	PINF	TINF	RE	PT2	VINF	PK01	PK32
12	101	567.7	572.7	1.50	10.00	559.7	4.292	2.725	386.0	0.291E+07	9.302	1444.664	1.942	1.958

FOREBODY

PN	ELPT	PS1/P	PS2/P	PS3/P	PS4/P	PS5/P	PS6/P	PS7/P	PS8/P	PS9/P	PS10/P
1	0.000	1.164	1.094	1.139	1.143	1.153	1.114	1.123	1.145	1.095	1.133
31	6.265	1.150	1.090	1.151	1.157	1.162	1.131	1.136	1.152	1.109	1.148
61	12.530	1.169	1.097	1.149	1.160	1.162	1.122	1.130	1.153	1.106	1.141
91	18.795	1.172	1.131	1.189	1.206	1.217	1.178	1.182	1.205	1.163	1.198
121	25.059	1.147	1.080	1.133	1.136	1.145	1.112	1.109	1.129	1.088	1.119
151	31.324	1.165	1.112	1.175	1.186	1.191	1.146	1.148	1.162	1.115	1.158
181	37.589	1.161	1.121	1.172	1.198	1.207	1.162	1.166	1.186	1.138	1.173
211	43.854	1.139	1.089	1.140	1.183	1.180	1.129	1.149	1.167	1.117	1.157
241	50.118	1.173	1.111	1.162	1.178	1.192	1.148	1.153	1.174	1.129	1.161
271	56.383	1.164	1.089	1.143	1.157	1.167	1.125	1.135	1.155	1.109	1.148

PS11/P	PS12/P	PS13/P	PS14/P	PS15/P	PS16/P	PS17/P	PS18/P	PS19/P	PS20/P	PS21/P	PS22/P	PS23/P	PS24/P	PS25/P
1.112	1.115	1.122	1.089	1.134	1.146	1.157	1.086	1.183	1.122	1.130	0.948	1.133	1.028	1.113
1.120	1.127	1.136	1.095	1.145	1.155	1.141	1.081	1.177	1.107	1.138	0.961	1.145	1.040	1.142
1.122	1.125	1.128	1.097	1.142	1.156	1.166	1.093	1.174	1.120	1.143	0.956	1.140	1.039	1.126
1.176	1.183	1.188	1.148	1.189	1.188	1.194	1.109	1.170	1.150	1.185	1.003	1.180	1.085	1.193
1.095	1.104	1.108	1.071	1.114	1.128	1.138	1.066	1.160	1.095	1.120	0.936	1.123	1.018	1.123
1.129	1.136	1.146	1.102	1.144	1.153	1.154	1.075	1.165	1.114	1.148	0.962	1.149	1.044	1.147
1.157	1.161	1.166	1.137	1.175	1.179	1.175	1.115	1.166	1.128	1.170	0.986	1.173	1.076	1.177
1.142	1.138	1.144	1.114	1.154	1.148	1.147	1.088	1.148	1.115	1.145	0.957	1.150	1.045	1.147
1.139	1.145	1.148	1.115	1.156	1.151	1.151	1.098	1.168	1.128	1.154	0.959	1.159	1.054	1.158
1.126	1.125	1.135	1.103	1.143	1.161	1.169	1.088	1.184	1.136	1.140	0.955	1.147	1.043	1.139

PS26/P	PS27/P	PS28/P	PS29/P	PS30/P	PS31/P	PS32/P	PS33/P	PS34/P	PS35/P	PS36/P	PS37/P	PS38/P	PS39/P	PS40/P
1.051	1.131	1.115	1.117	1.145	1.159	1.114	1.081	1.089	1.091	1.092	0.933	1.014	1.009	1.006
1.069	1.150	1.140	1.136	1.170	1.199	1.145	1.110	1.113	1.103	1.103	0.977	1.015	1.024	1.005
1.055	1.138	1.121	1.133	1.155	1.159	1.116	1.078	1.086	1.083	1.081	0.946	1.003	1.005	0.999
1.119	1.189	1.177	1.198	1.227	1.222	1.173	1.106	1.118	1.106	1.111	0.979	1.039	1.050	1.050
1.041	1.127	1.114	1.122	1.147	1.156	1.111	1.079	1.084	1.081	1.086	0.936	1.005	1.007	1.000
1.065	1.147	1.138	1.155	1.176	1.180	1.136	1.096	1.105	1.100	1.102	0.960	1.028	1.029	1.057
1.112	1.195	1.175	1.185	1.227	1.228	1.184	1.092	1.100	1.094	1.096	0.971	1.035	1.038	1.050
1.082	1.161	1.143	1.160	1.201	1.207	1.164	1.094	1.099	1.090	1.085	0.970	1.011	1.019	0.994
1.082	1.167	1.152	1.160	1.196	1.205	1.159	1.115	1.115	1.112	1.112	0.986	1.035	1.041	1.028
1.066	1.157	1.135	1.139	1.166	1.173	1.131	1.087	1.096	1.096	1.089	0.945	1.020	1.007	1.002

Table 3 (cont.'d): Sample Data

Panel No./Loc.	Core Height (inches)	Plug Pull Value (psi)	Normalized Value (psi)	Panel No./Loc.	Core Height (inches)	Plug Pull Value (psi)	Normalized Value (psi)	Panel No./Loc.	Core Height (inches)	Plug Pull Value (psi)	Normalized Value (psi)
3151/1	0.88	48.90	47.66	3154/1	0.87	58.80	57.18	3161/1	0.95	52.50	51.96
3151/2	0.86	45.90	44.53	3154/2	0.90	53.60	52.47	3161/2	0.75	47.50	44.87
3151/3	0.85	56.10	54.30	3154/3	0.88	53.80	52.43	3161/3	0.85	42.70	41.33
3151/4	0.88	41.60	40.54	3154/4	0.92	46.80	46.02	3161/4	1.05	59.50	60.10
3151/5	0.91	47.30	46.41	3154/5	0.90	56.00	54.82	3161/5	0.98	56.20	55.97
3151/6	0.83	46.60	44.90	3154/6	1.00	53.20	53.20	3161/6	0.87	53.60	52.12
3151/7	0.83	52.50	50.58	3154/7	0.95	55.30	54.73	3161/7	1.06	53.30	53.94
3151/8	0.90	44.20	43.27	3154/8	0.95	57.40	56.81	3161/8	1.04	62.00	62.50
3151/9	0.90	46.50	45.52	3154/9	0.95	66.20	65.52	3161/9	1.06	55.00	55.66
3151/10	0.90	53.10	51.98	3154/10	1.00	61.60	61.60	3161/10	1.00	46.90	46.90
3151/11	0.90	47.70	46.70	3154/11	0.85	67.60	65.43	3161/11	1.03	40.70	40.95
3151/12	0.90	48.50	47.48	3154/12	0.80	64.80	61.98	3161/12	0.95	47.20	46.71
3151/13	1.05	42.20	42.62	3154/13	0.95	63.20	62.55	3161/13	0.95	48.70	48.20
3151/14	1.10	46.90	47.83	3154/14	0.95	66.30	65.61	3161/14	1.10	41.70	42.53
3151/15	0.92	47.60	46.81	3154/15	0.90	57.70	56.49				
3151/16	0.95	53.10	52.55	3154/16	1.00	56.00	56.00				
Minimum	**0.83**	**41.60**	**40.54**	**Minimum**	**0.80**	**46.80**	**46.02**	**Minimum**	**0.75**	**40.70**	**40.95**
Average	**0.91**	**48.04**	**47.11**	**Average**	**0.92**	**58.64**	**57.68**	**Average**	**0.97**	**50.54**	**50.27**
Maximum	**1.10**	**56.10**	**54.30**	**Maximum**	**1.00**	**67.60**	**65.61**	**Maximum**	**1.10**	**62.00**	**62.50**
Std. Deviation	**0.07**	**3.99**	**3.75**	**Std. Deviation**	**0.06**	**5.83**	**5.63**	**Std. Deviation**	**0.10**	**6.55**	**6.86**

Table 4: Normalized Plug Pull Data – Net Sprayed Foam

Panel No./Loc.	Core Height (inches)	Plug Pull Value (psi)	Normalized Value (psi)	Panel No./Loc.	Core Height (inches)	Plug Pull Value (psi)	Normalized Value (psi)	Panel No./Loc.	Core Height (inches)	Plug Pull Value (psi)	Normalized Value (psi)
3157/1	0.50	40.10	35.14	3159/1	0.50	53.90	47.23	3158/1	0.50	60.40	52.93
3157/2	0.50	64.80	56.78	3159/2	0.50	43.80	38.38	3158/2	0.50	43.60	38.21
3157/3	0.50	56.00	49.07	3159/3	0.50	55.20	48.37	3158/3	0.50	46.10	40.40
3157/4	0.50	67.20	58.89	3159/4	0.50	54.80	48.02	3158/4	0.50	50.90	44.60
3157/5	0.50	56.80	49.77	3159/5	0.50	59.40	52.05	3158/5	0.50	51.20	44.87
3157/6	0.50	50.00	43.81	3159/6	0.50	66.80	58.54	3158/6	0.50	59.00	51.70
3157/7	0.50	55.40	48.55	3159/7	0.50	57.50	50.39	3158/7	0.50	65.00	56.96
3157/8	0.50	57.20	50.12	3159/8	0.50	49.10	43.03	3158/8	0.50	59.60	52.23
3157/9	0.50	67.80	59.41	3159/9	0.50	48.60	42.59	3158/9	0.50	62.30	54.59
3157/10	0.50	60.70	53.19	3159/10	0.50	61.70	54.07	3158/10	0.50	62.40	54.68
3157/11	0.50	55.80	48.90	3159/11	0.50	54.30	47.58	3158/11	0.50	48.00	42.06
3157/12	0.50	51.40	45.04	3159/12	0.50	53.60	46.97	3158/12	0.50	55.60	48.72
3157/13	0.50	50.20	43.99	3159/13	0.50	61.40	53.80	3158/13	0.50	59.10	51.79
3157/14	0.50	56.20	49.25	3159/14	0.50	57.40	50.30	3158/14	0.50	48.20	42.24
3157/15	0.50	58.70	51.44								
3157/16	0.50	61.60	53.98								
Minimum	**0.50**	**40.10**	**35.14**	**Minimum**	**0.50**	**43.80**	**38.38**	**Minimum**	**0.50**	**43.60**	**38.21**
Average	**0.50**	**56.87**	**49.83**	**Average**	**0.50**	**55.54**	**48.67**	**Average**	**0.50**	**55.10**	**48.28**
Maximum	**0.50**	**67.80**	**59.41**	**Maximum**	**0.50**	**66.80**	**58.54**	**Maximum**	**0.50**	**65.00**	**56.96**
Std. Deviation	**0.00**	**7.01**	**6.14**	**Std. Deviation**	**0.00**	**5.93**	**5.20**	**Std. Deviation**	**0.00**	**6.95**	**6.09**

Table 4 (cont.'d): Normalized Plug Pull Data – Machined Foam

0° case

Recording No.	Run No.	M	P_t	T_t	CTS Schedule	Span (Volts)	Comments
1	11	1.5	5	100	Home	4	Started recording late
2	12	1.5	10	100	Home	4	
3	13	1.5	10	100	1	10	
4	14	1.5	10	100	2	10	
5	15	1.5	10	100	2	4	Repeat run
6	16	1.5	13.3	100	Home	4	No signal on Ch. 13
7	17	1.5	5	100	Home	4	Repeat run – No Ch. 13
8	18	1.5	11	100	Home	4	No Ch. 13
9	19	1.5	11	100	2	4/10	10 V span Ch. 13,14 - No Ch. 13
10	20	4.0	10	100	Home	4	No Ch. 13
11	21	4.0	10	100	1	4	No Ch. 13
12	22	4.0	20	100	Home	4/10	10 V span Ch. 13,14 - No Ch. 13
13	23	4.0	20	100	1	4/10	10 V span Ch. 13,14 - No Ch. 13
14	24	4.0	20	100	2	4/10	10 V span Ch. 13,14 - No Ch. 13

90° case

Recording No.	Run No.	M	P_t	T_t	CTS Schedule	Span (Volts)	Comments
15	25	4.0	20	100	Home	4	No Ch. 13
16	26	4.0	20	100	1	4/10	10 V span Ch. 9,13,14 - No Ch. 13
17	27	4.0	20	100	2	4/10	10 V span Ch. 9,13,14 - No Ch. 13
18	28	1.5	11	100	Home	4/10	10 V span Ch. 9,13,14 - No Ch. 13
19	29	1.5	11	100	1	10	OVL on some Ch. – No Ch. 13
20	30	1.5	11	100	2	10/20	20 V span Ch. 4,9

Table 5: Run Numbers and Test Conditions for Recordings

Channel No.	Location No.	Serial No.	Signal Conditioning Amplifier	12 VDC Excitation Sensitivity (mV/psi)	Gain	Technical Units (psi/V)
1	1	5957-1-207	AEDC	9.106	200	0.5491
2	2	5957-1-208	AEDC	9.120		0.5482
3	3	5957-1-209	AEDC	9.011		0.5549
4	4	5957-1-210	AEDC	9.062		0.5518
5	5	6048-3-240	AEDC	7.210		0.6935
6	6	6048-3-241	AEDC	7.320		0.6831
7	7	6048-3-242	AEDC	7.206		0.6939
8	8	6048-3-243	AEDC	7.449		0.6712
9	9	6048-3-245	AEDC	7.128		0.7015
10	10	6048-3-246	AEDC	7.138		0.7005
11	11	6163-1A-126	AEDC	9.202		0.5434
12	12	6163-1A-127	AEDC	9.035		0.5534
13	13	6163-1A-128	Pacific	9.015		0.5546
14	14	6163-1A-129	Pacific	8.951	200	0.5586

Table 6: Channel Parameters for 0° Case

Channel No.	Location No.	Serial No.	Signal Conditioning Amplifier	12 VDC Excitation Sensitivity (mV/psi)	Gain	Technical Units (psi/V)
1	1	5957-1-207	AEDC	9.106	200	0.5491
2	2	5957-1-208	AEDC	9.120		0.5482
3	3	5957-1-209	AEDC	9.011		0.5549
4	4	5957-1-210	AEDC	9.062		0.5518
5	5	6048-3-240	AEDC	7.210		0.6935
6	6	6048-3-241	AEDC	7.320		0.6831
7	7	6048-3-242	AEDC	7.206		0.6939
8	8	6048-3-243	AEDC	7.449		0.6712
9	9	6048-3-245	AEDC	7.128		0.7015
10	10	6048-3-246	AEDC	7.138		0.7005
11	15	5957-1-199	AEDC	9.113		0.5487
12	12	6163-1A-127	AEDC	9.035		0.5534
13	13	6163-1A-128	Pacific	9.015		0.5546
14	14	6163-1A-129	Pacific	8.951	200	0.5586

Table 7: Channel Parameters for 90° Case

Time (sec)	Pres (psi)	Time (sec)	Pres (psi)	Time (sec)	Pres (psi)	Time (sec)	Pres (psi)	Time (sec)	Pres (psi)
33.3195	-0.134922	33.32041	1.0754	33.32133	2.9145	33.32226	-0.072020	33.32318	-0.367118
33.319519	-0.024786	33.32043	1.02442	33.32136	2.51885	33.32228	-0.175843	33.3232	-0.488946
33.319538	0.167658	33.32046	0.913119	33.32138	2.25556	33.3223	-0.297904	33.32321	-0.559096
33.319561	0.414353	33.32048	0.771416	33.3214	1.97379	33.32231	-0.621529	33.32323	-0.552782
33.31958	0.646315	33.32049	0.763232	33.32141	1.76848	33.32233	-0.829875	33.32326	0.158071
33.319599	0.73447	33.32051	0.948662	33.32144	1.66092	33.32236	-0.409208	33.32328	0.416925
33.319618	0.656604	33.32054	1.12521	33.32146	1.56481	33.32238	0.136792	33.32329	0.092364
33.319641	0.727455	33.32056	1.55032	33.32148	1.49349	33.32239	0.327834	33.32331	0.18847
33.31966	0.81865	33.32058	2.17021	33.32149	1.33799	33.32241	0.394711	33.32334	0.319416
33.319679	0.613813	33.32059	2.34441	33.32152	1.14321	33.32244	0.312167	33.32336	0.246928
33.319698	0.3898	33.32062	2.54668	33.32154	1.04453	33.32246	0.061264	33.32338	-0.223311
33.319721	0.203903	33.32064	2.90327	33.32156	1.04874	33.32247	0.027124	33.32339	-0.639067
33.31974	0.05612	33.32066	2.70943	33.32157	1.09528	33.32249	0.189873	33.32342	-0.575698
33.319759	0.231729	33.32067	2.14261	33.32160	1.10229	33.32252	0.275222	33.32344	-0.735874
33.319778	0.194549	33.32070	1.45561	33.32162	1.1362	33.32254	0.283406	33.32346	-0.914756
33.319801	-0.257217	33.32072	0.846944	33.32164	1.2468	33.32255	0.240848	33.32347	-0.726754
33.31982	-0.461119	33.32074	0.480527	33.32165	1.3429	33.32257	0.319182	33.32350	-0.698928
33.319839	-0.504145	33.32075	0.112006	33.32167	1.37541	33.32260	0.506951		
33.319859	-0.503911	33.32078	-0.15737	33.32170	1.25405	33.32262	0.533374		
33.319881	-0.528697	33.32080	-0.192211	33.32172	0.987946	33.32263	0.448025		
33.319901	-0.643743	33.32082	-0.250436	33.32173	0.943985	33.32265	0.117618		
33.31992	-0.54226	33.32083	-0.467901	33.32175	0.89184	33.32268	-0.368755		
33.319939	-0.43797	33.32086	-0.49409	33.32178	0.49105	33.32270	-0.424174		
33.319962	-0.609604	33.32088	-0.167425	33.3218	0.276859	33.32272	-0.244122		
33.319981	-0.821223	33.3209	0.038582	33.32181	0.308894	33.32273	-0.261192		
33.32	-0.73751	33.32091	0.099613	33.32183	0.192913	33.32276	-0.399154		
33.320019	-0.417392	33.32093	0.214893	33.32186	0.080672	33.32278	-0.541558		
33.320042	-0.236873	33.32096	0.345138	33.32188	0.115747	33.3228	-0.627842		
33.320061	-0.072020	33.32098	0.49409	33.32189	0.061030	33.32281	-0.634857		
33.32008	0.071319	33.32099	0.499468	33.32191	-0.037179	33.32284	-0.492687		
33.320099	-0.025020	33.32101	0.452468	33.32194	0.009821	33.32286	-0.266336		
33.320122	0.126971	33.32104	0.585285	33.32196	0.05612	33.32288	-0.178181		
33.320141	0.555822	33.32106	0.811168	33.32198	0.048169	33.32289	-0.228221		
33.32016	0.811402	33.32107	1.04851	33.32199	0.046766	33.32292	-0.31778		
33.320179	0.882955	33.32109	1.34103	33.32202	0.088155	33.32294	-0.301177		
33.320202	0.917796	33.32112	2.00746	33.32204	0.220037	33.32296	-0.157837		
33.320221	1.03612	33.32114	2.95215	33.32206	0.212321	33.32297	-0.303516		
33.32024	1.20681	33.32115	3.31786	33.32207	0.057523	33.32300	-0.84788		
33.320259	1.28117	33.32117	3.58654	33.32210	0.18543	33.32302	-1.24329		
33.320278	1.24961	33.32120	4.01515	33.32212	0.309361	33.32304	-1.11118		
33.320301	1.31274	33.32122	3.74157	33.32214	0.069916	33.32305	-0.819352		
33.32032	1.37354	33.32123	3.19697	33.32215	-0.002104	33.32307	-0.893477		
33.320339	1.37167	33.32125	2.83827	33.32218	0.158773	33.32310	-1.25288		
33.320358	1.61251	33.32128	2.7742	33.32220	0.097274	33.32312	-1.47946		
33.320381	1.69599	33.32130	3.07491	33.32222	-0.041388	33.32313	-1.04921		
33.3204	1.3249	33.32132	3.22082	33.32223	-0.039751	33.32315	-0.369924		

Table 8: Expanded Time (Figure 54, Recording 20, Channel 9)

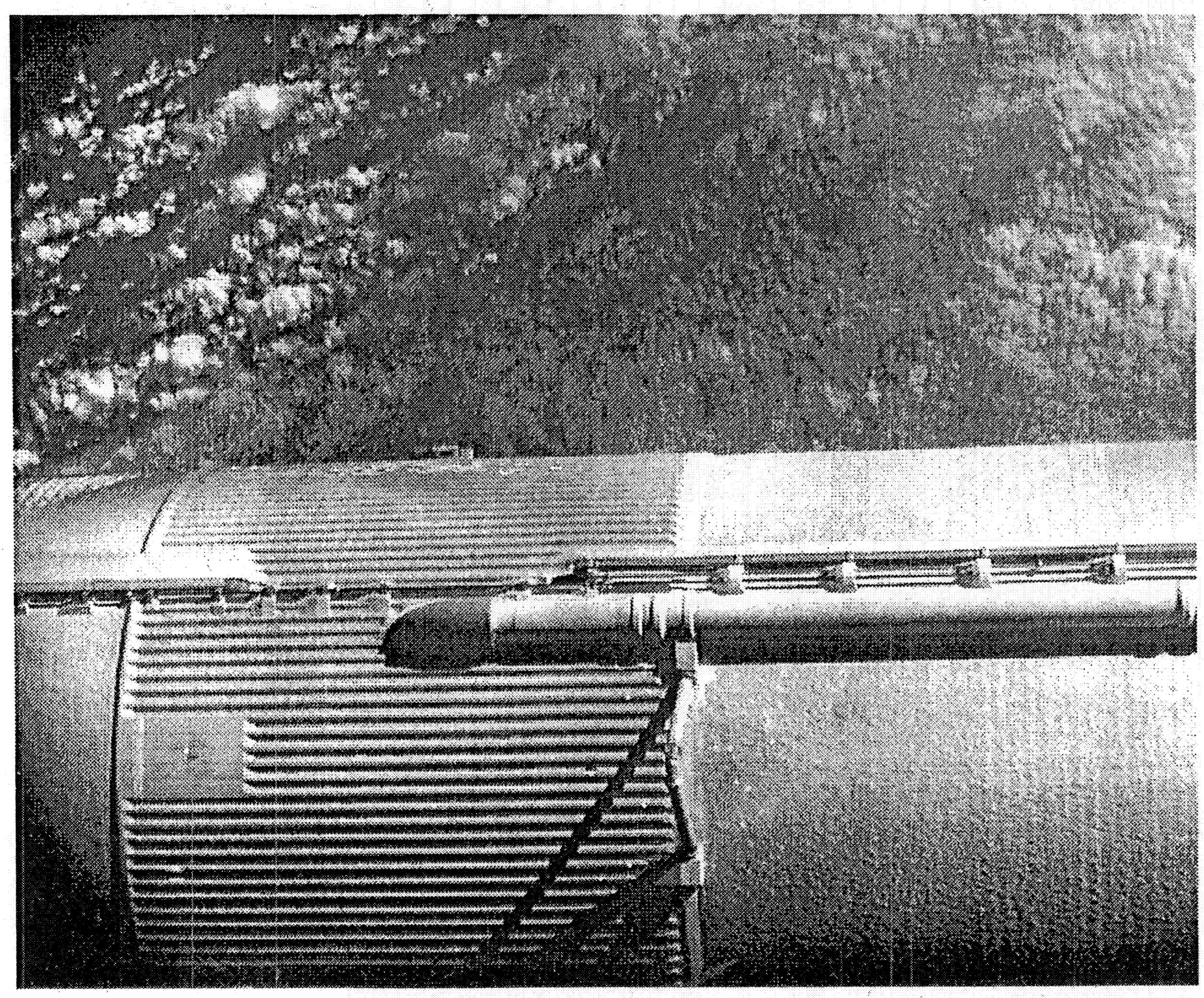


Figure 1: STS-87 Divots in Thrust Panel Region

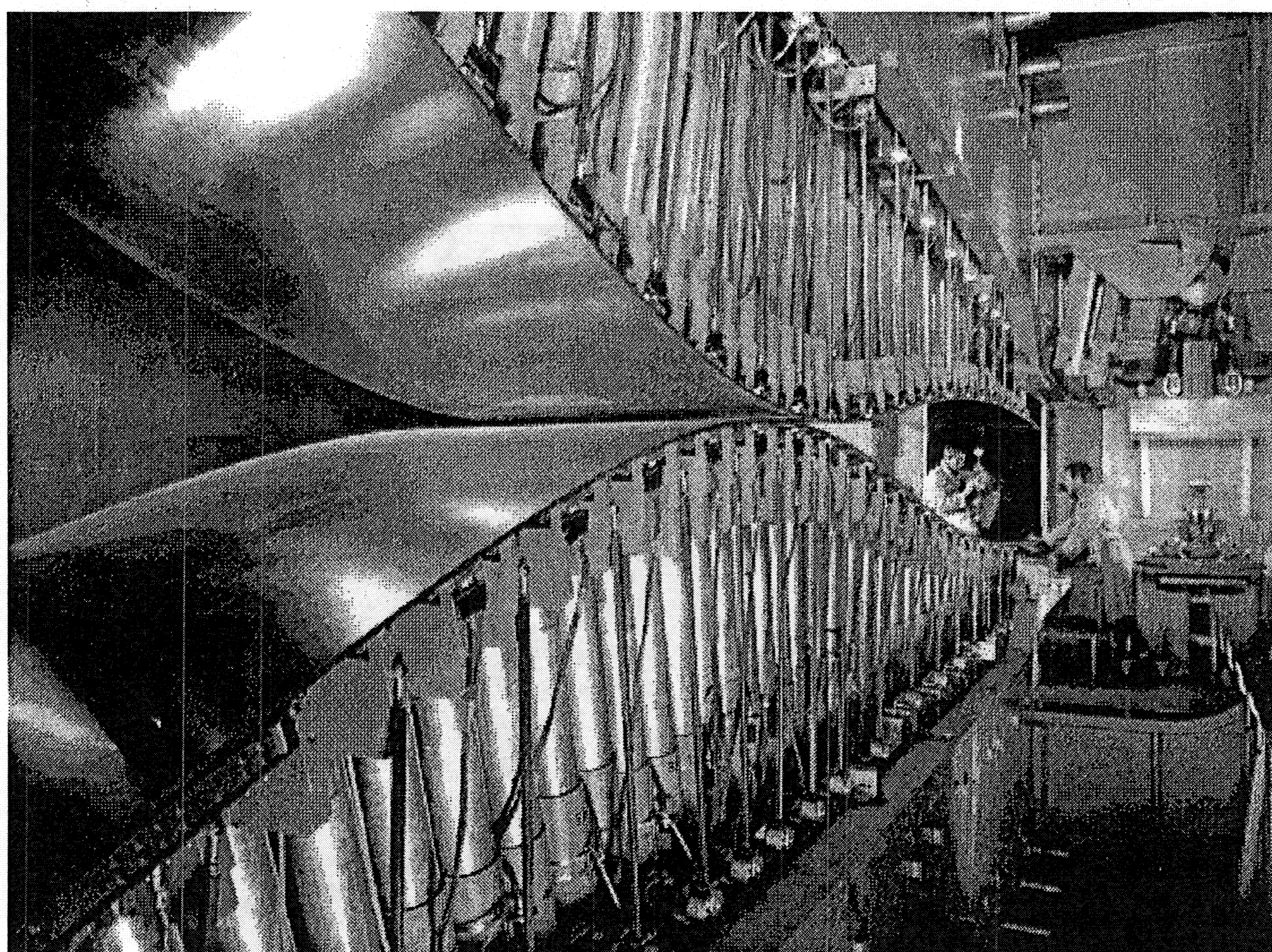


Figure 2: Tunnel A, Side-Wall Removed

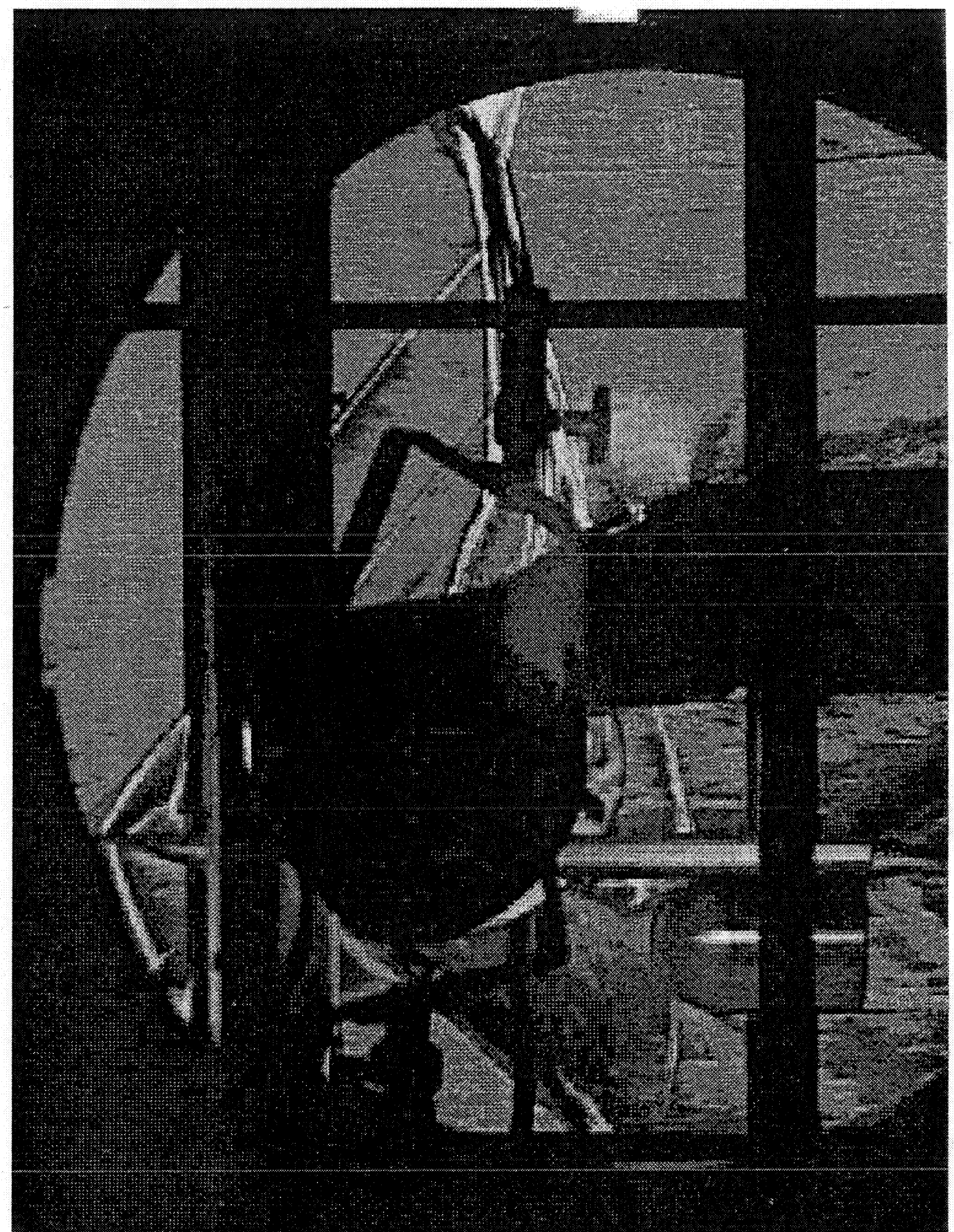


Figure 3: Typical Shadowgraph/Schlieren Data

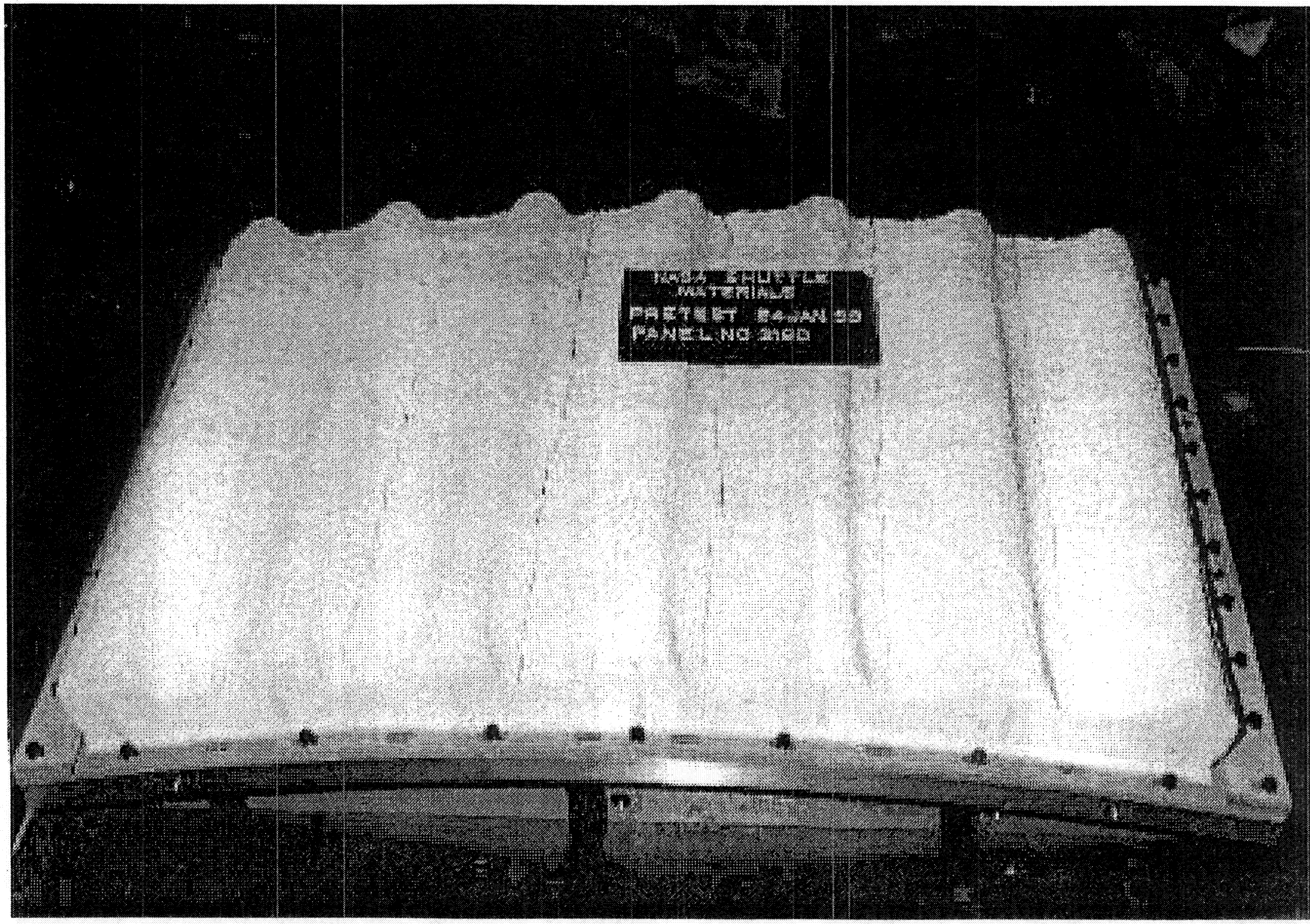


Figure 4: 77” Radius Panel

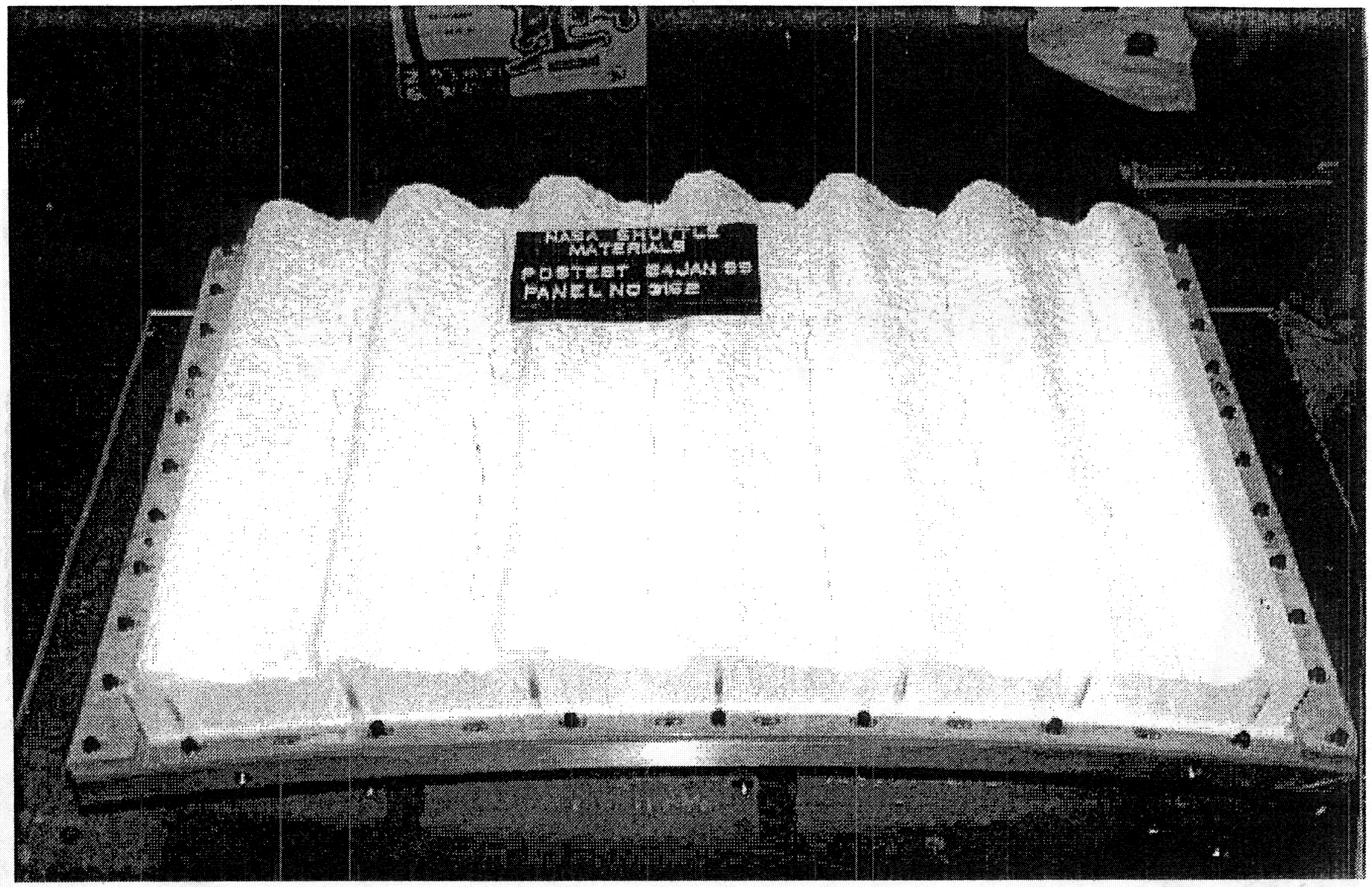


Figure 5: 99" Radius Panel

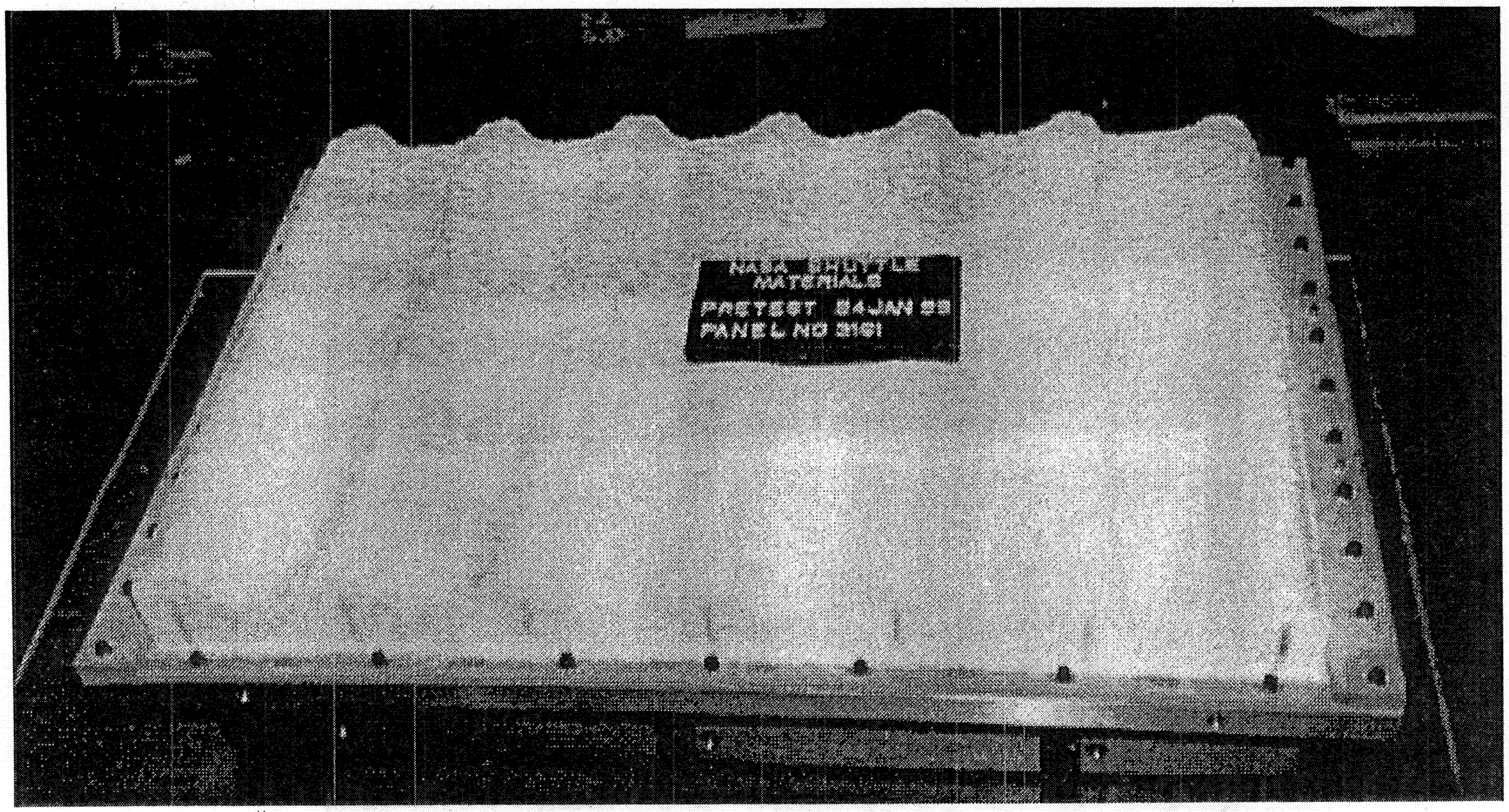


Figure 6: 337" Radius Panel

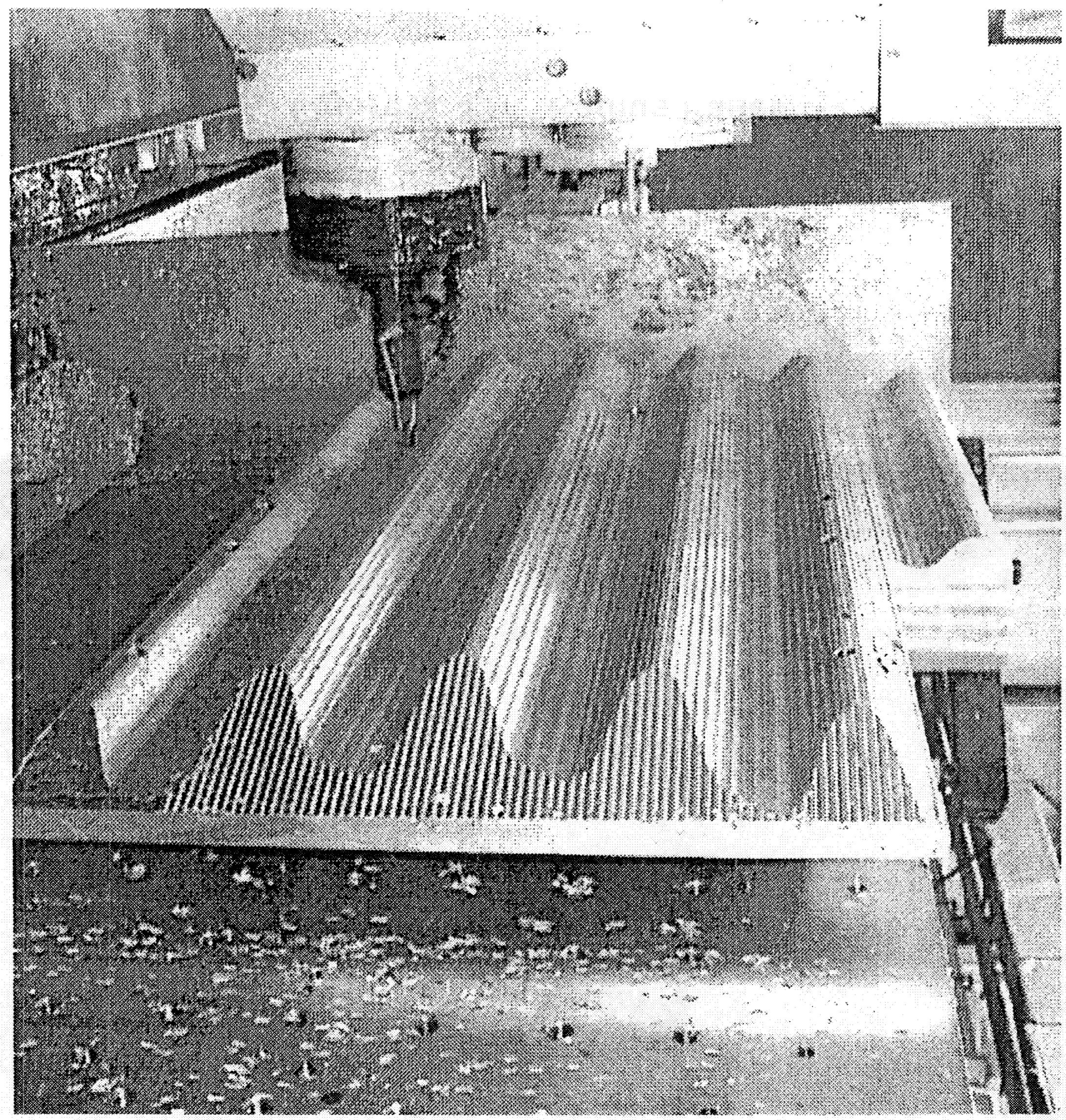


Figure 7: Calibration Panel

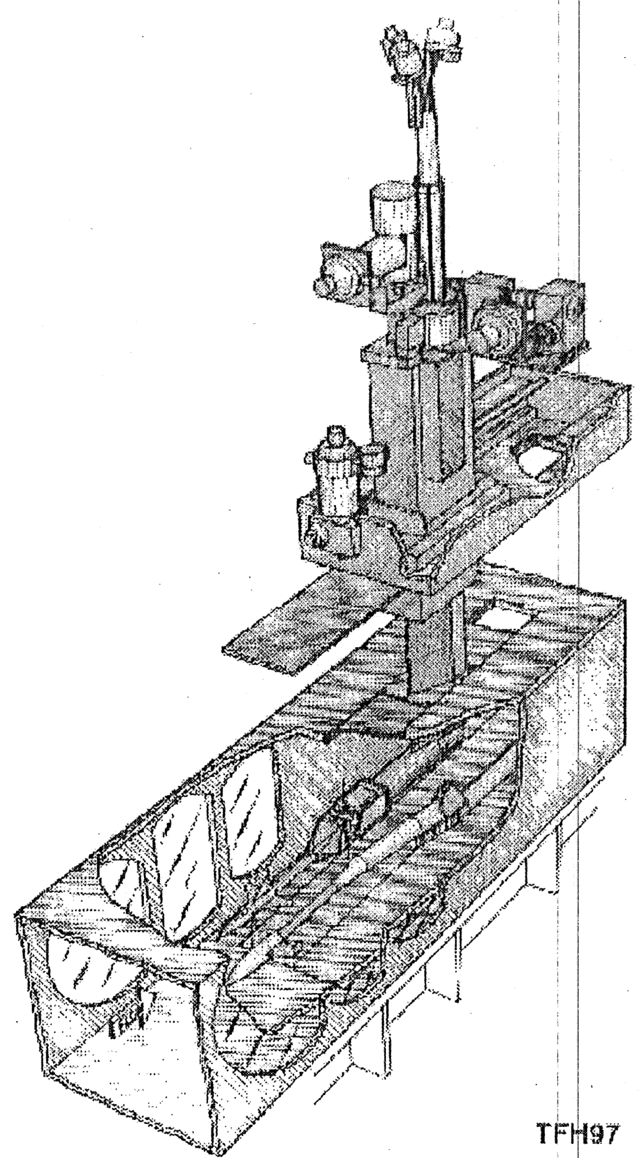


Figure 15: Captive Trajectory System (CTS)

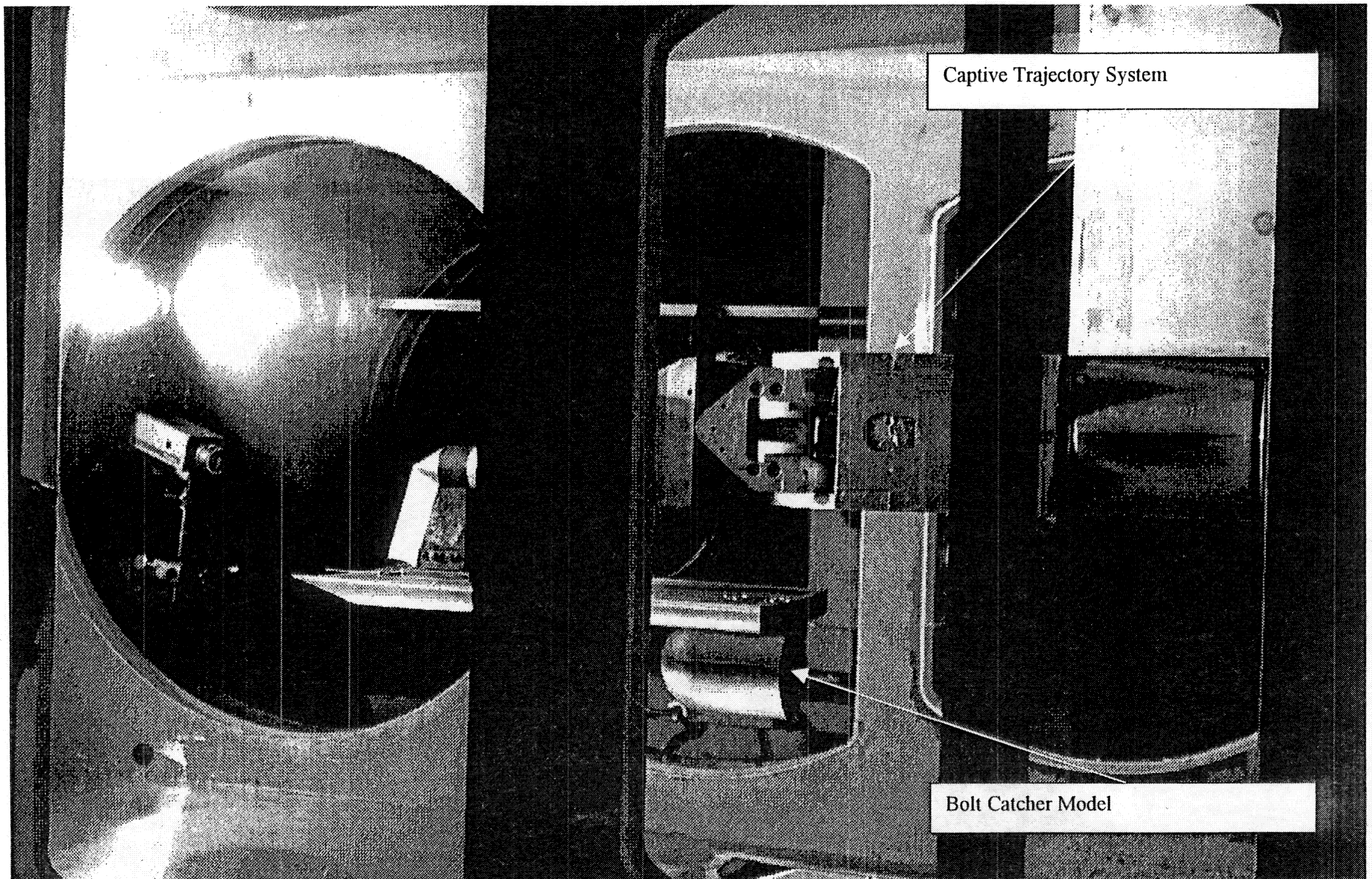


Figure 16: Bolt Catcher Simulation

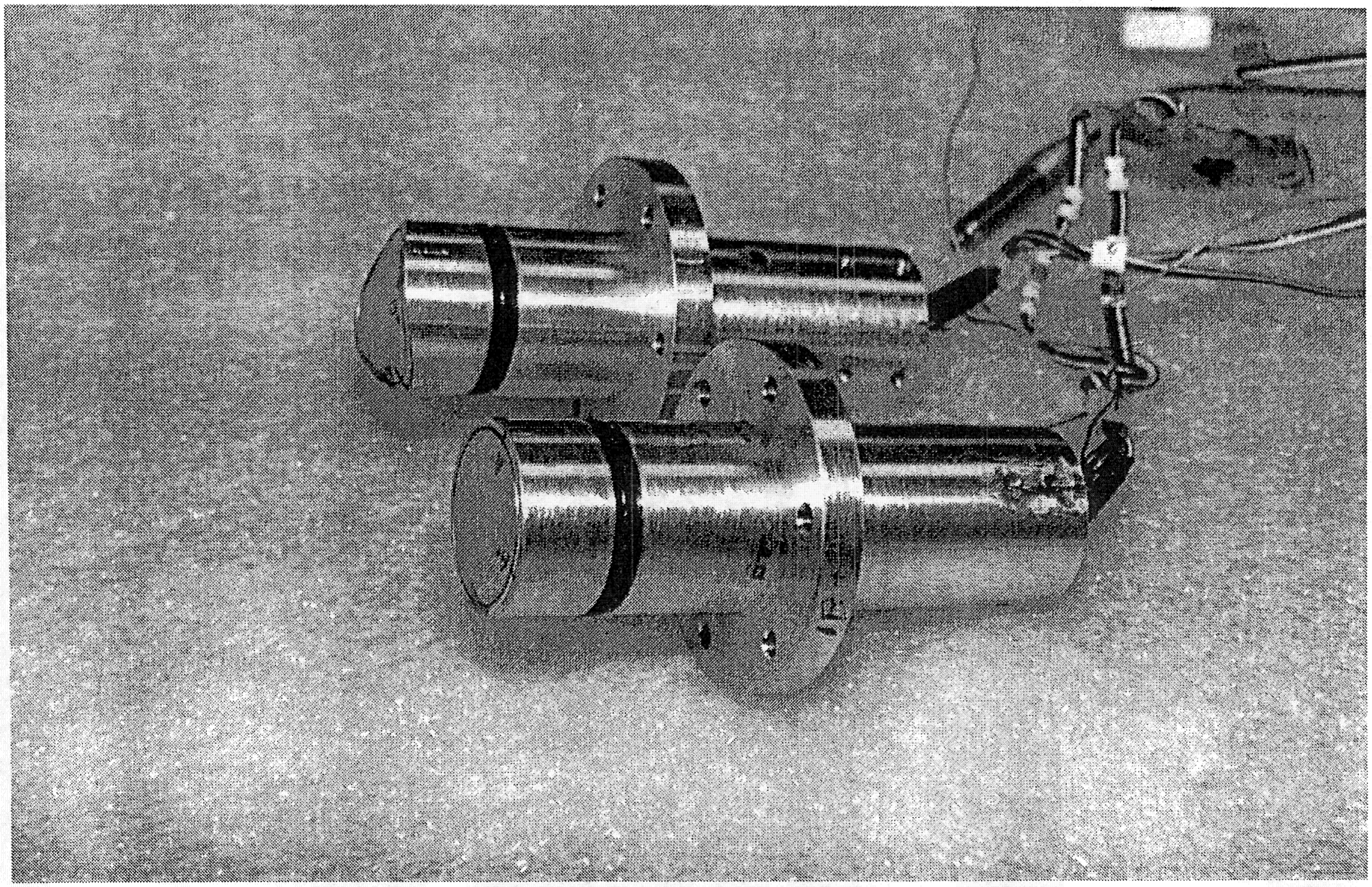


Figure 17: Skin Friction Gage

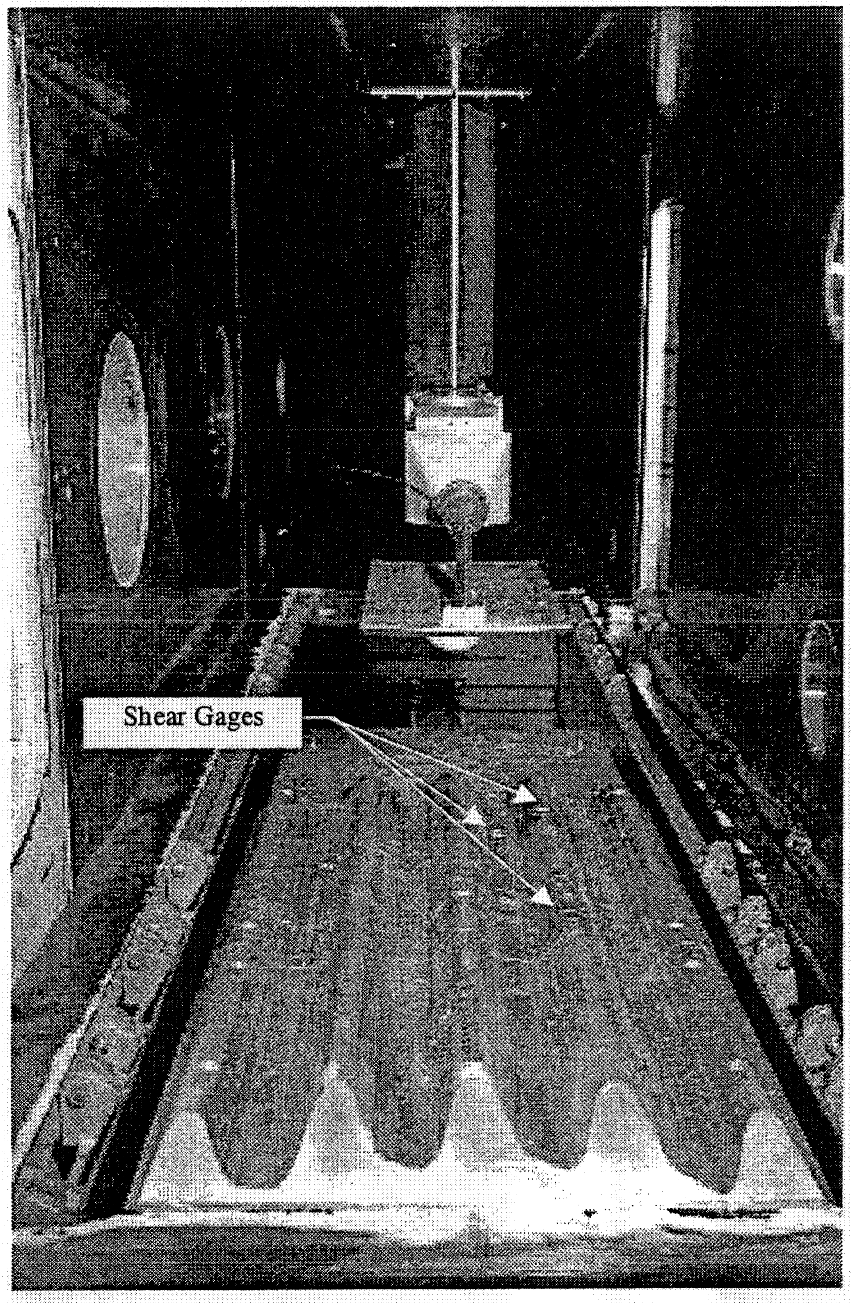
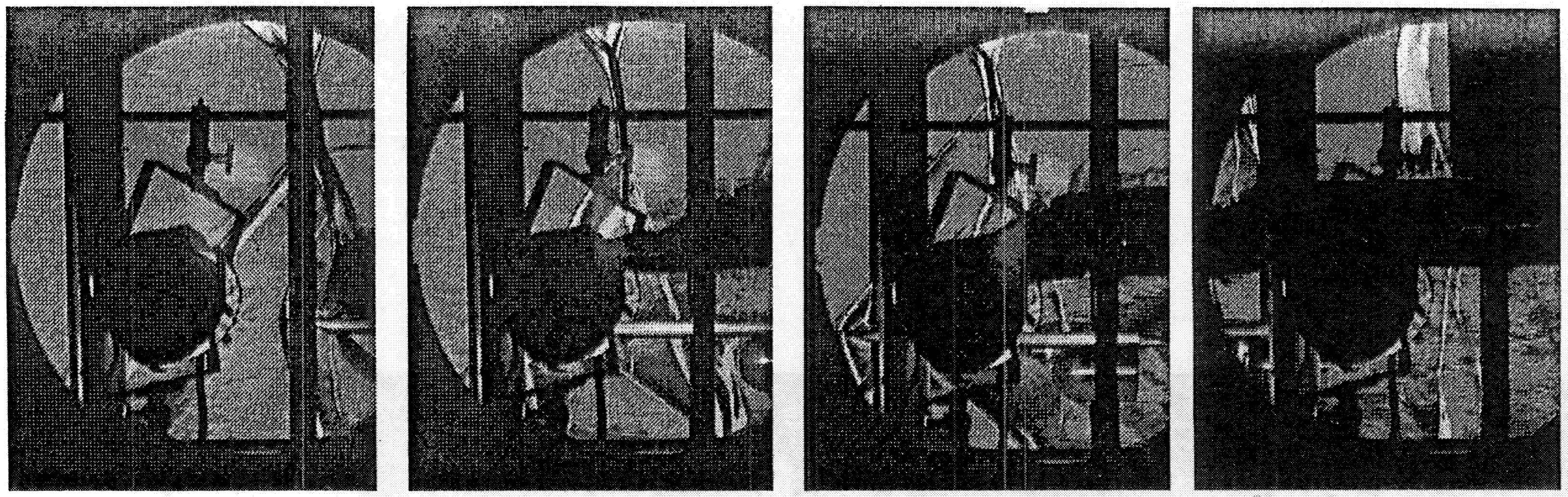
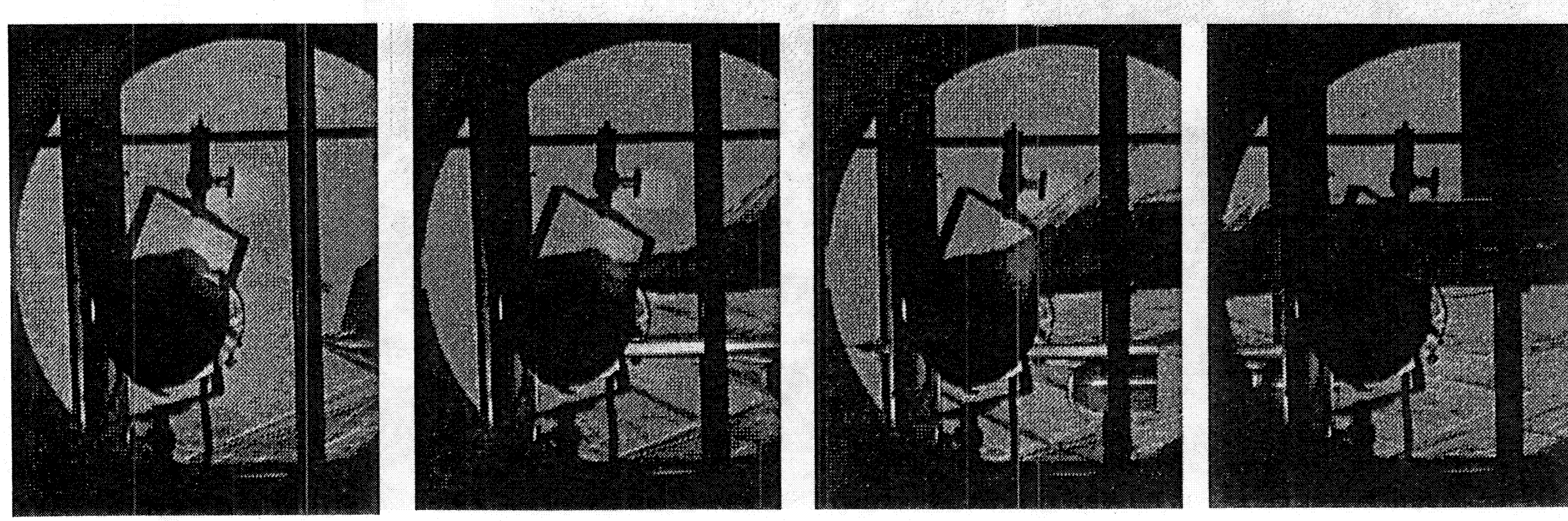


Figure 18: Skin Friction Gages on 0° Calibration Model



Mach 1.5 Shadowgraph of Panel 3155 Machined/Vented at 0° Orientation



Mach 4.0 Shadowgraph of Panel 3155 Machined/Vented at 0° Orientation

Figure 19: Shadowgraph/Schlieren at Mach 1.5 and 4.0

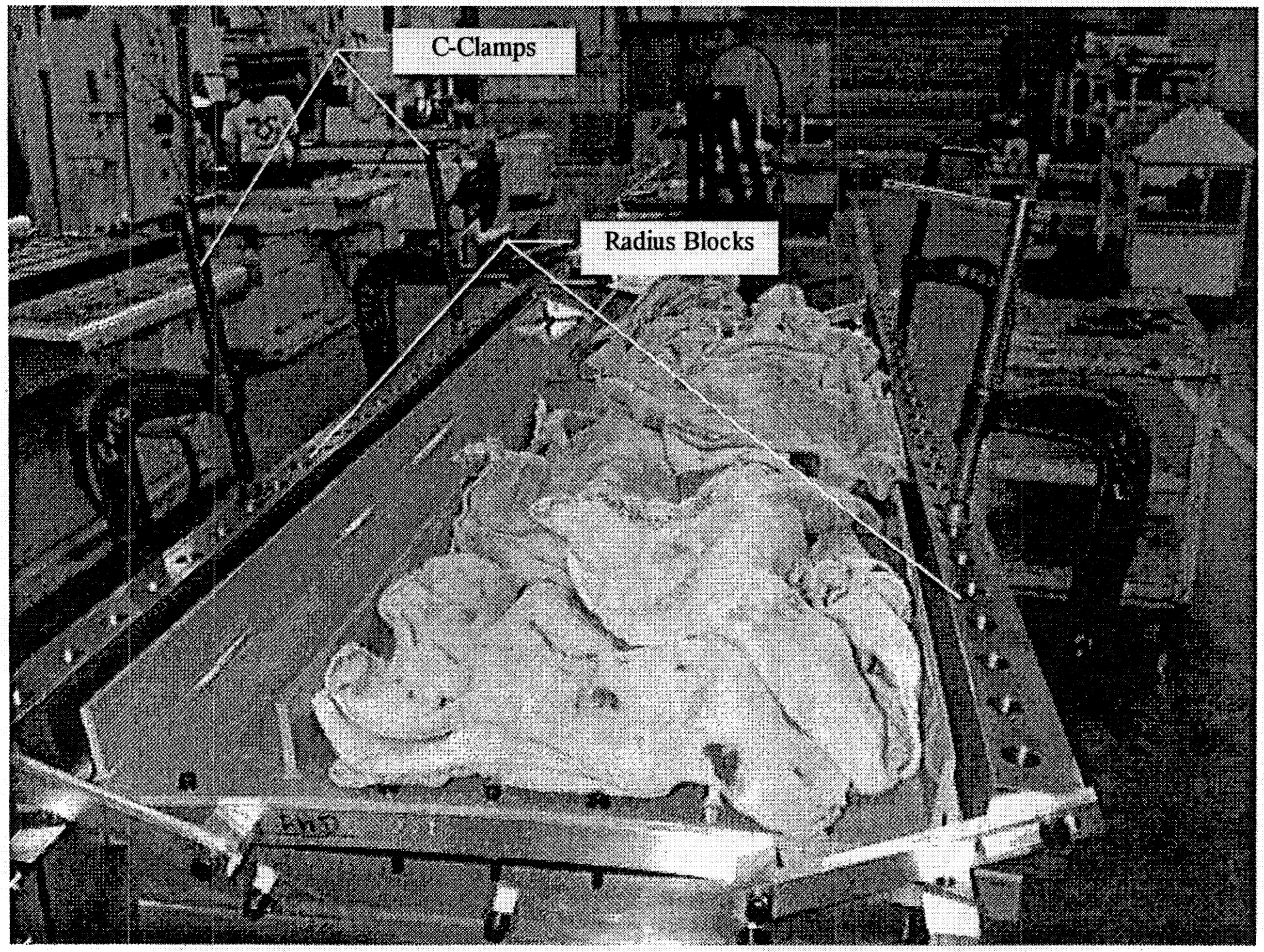


Figure 20: Radius Block Checkout on Substrate Test Article

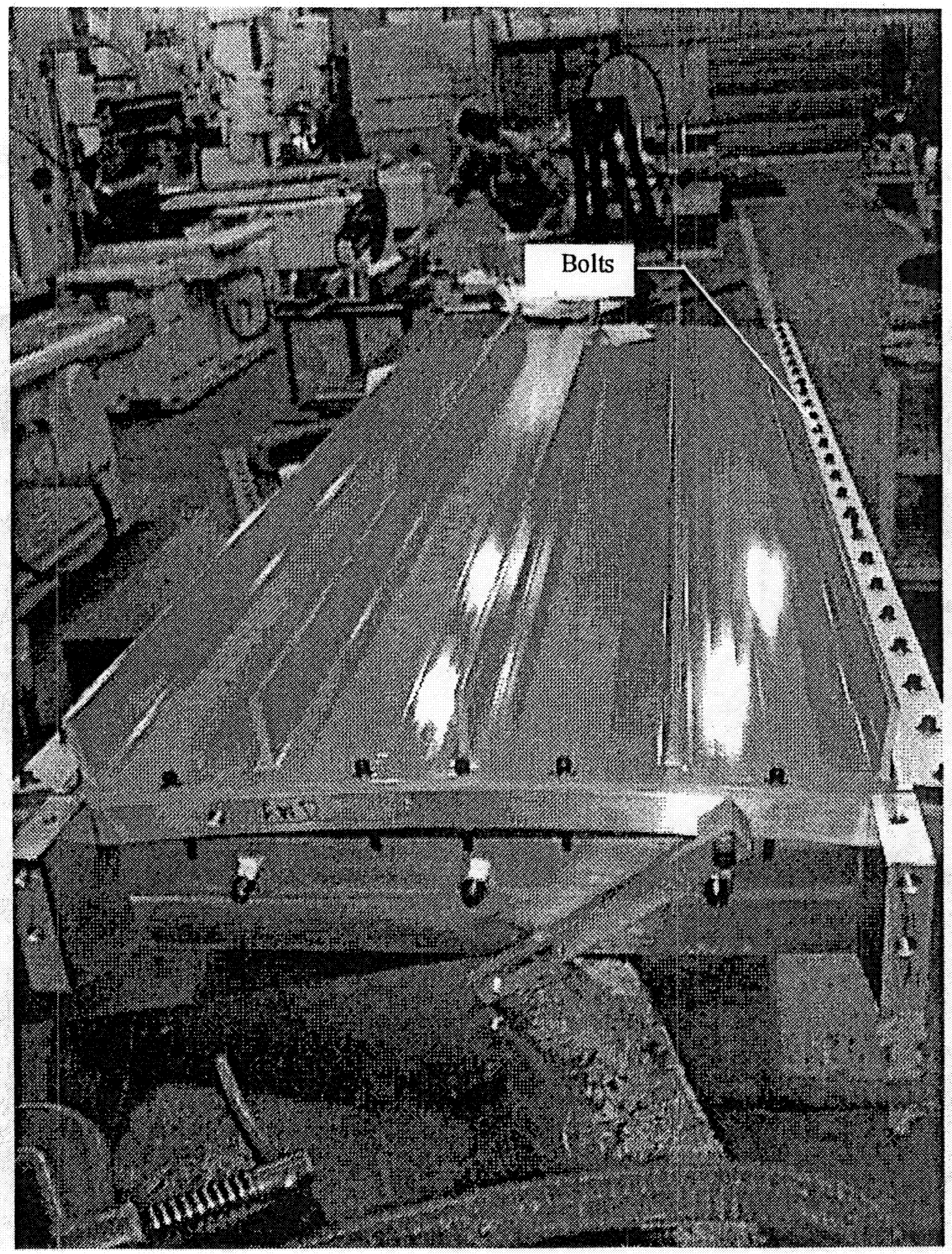


Figure 21: Radius Blocks Removed

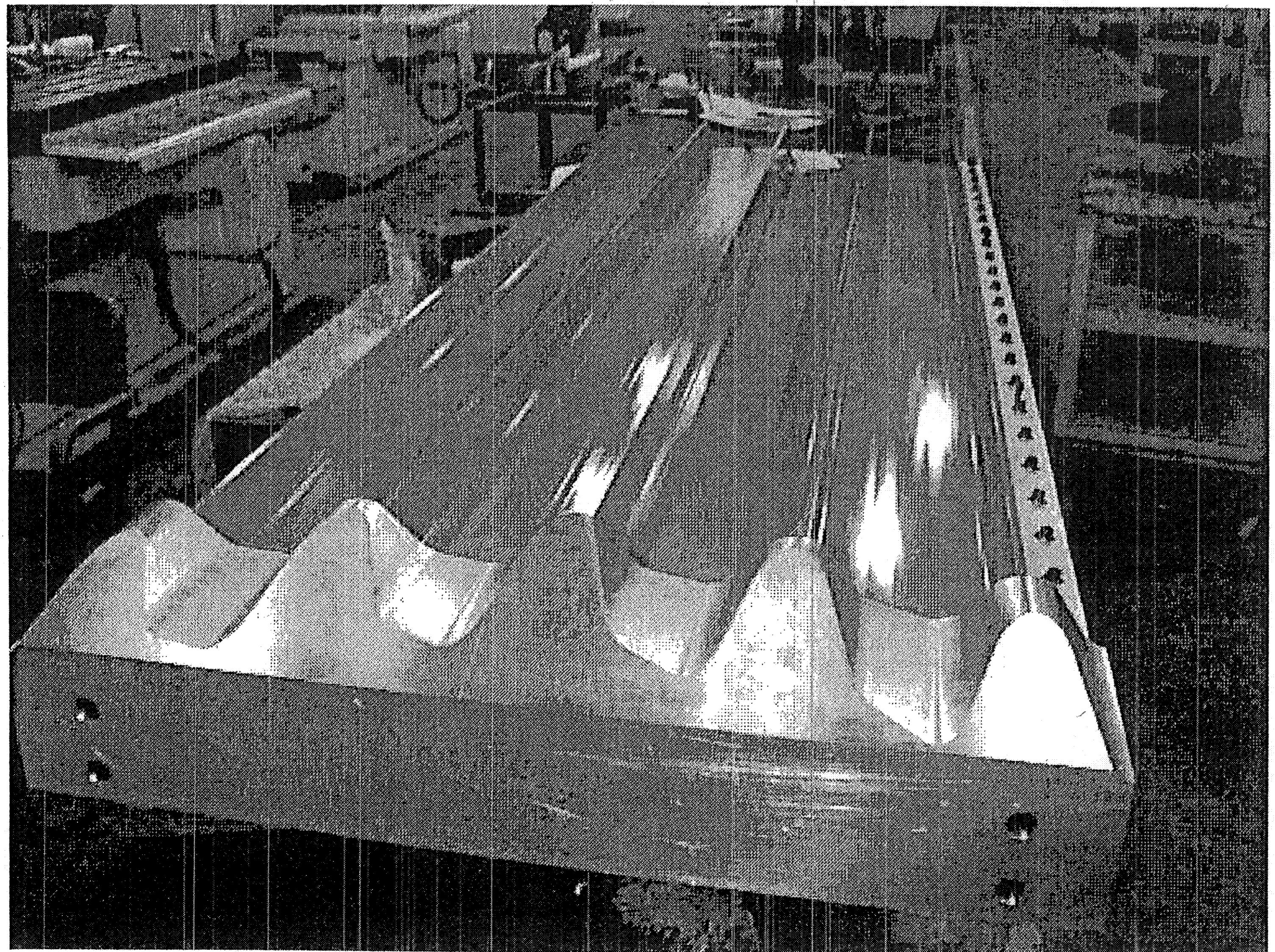
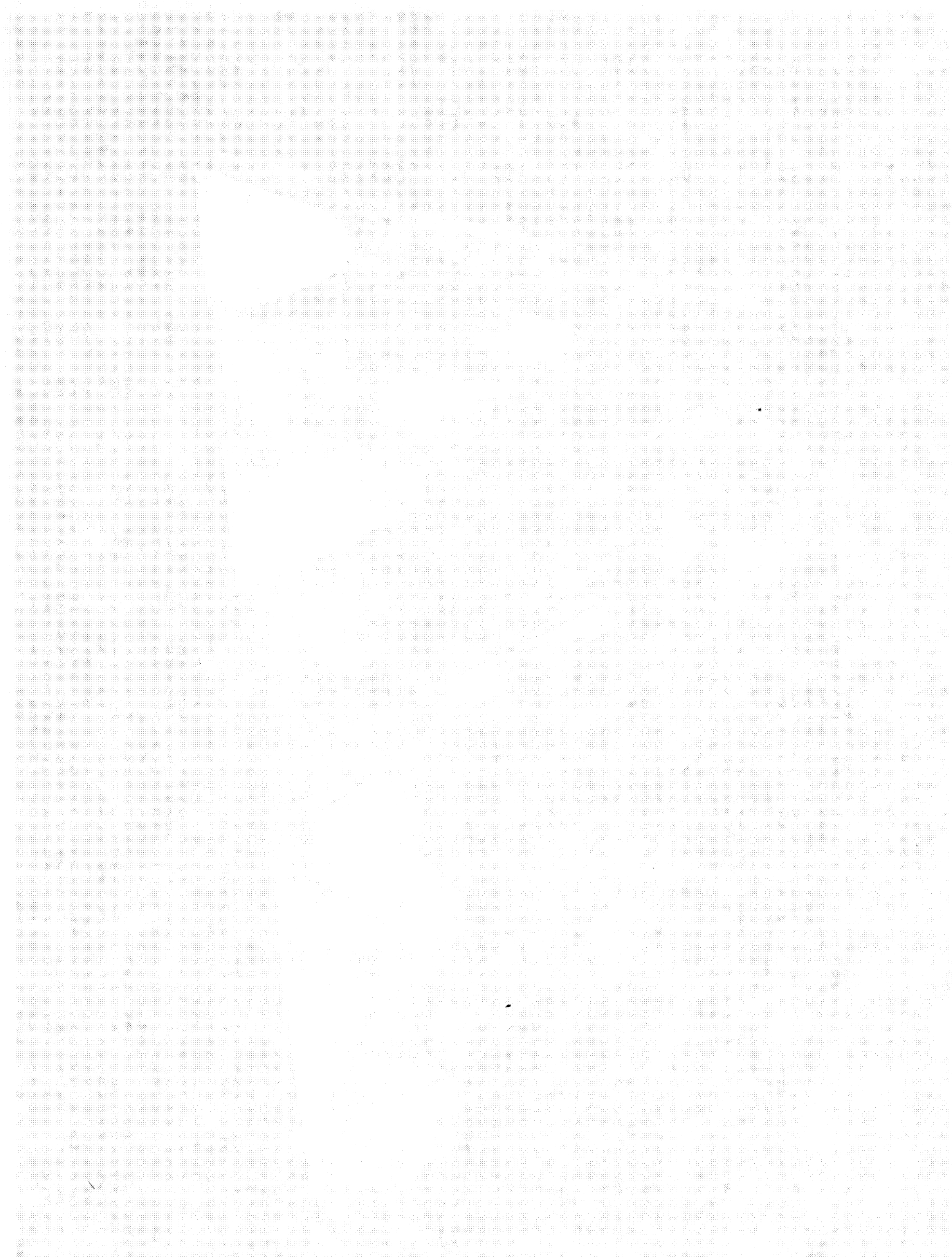


Figure 22: Machined Air-Dam Fit Check



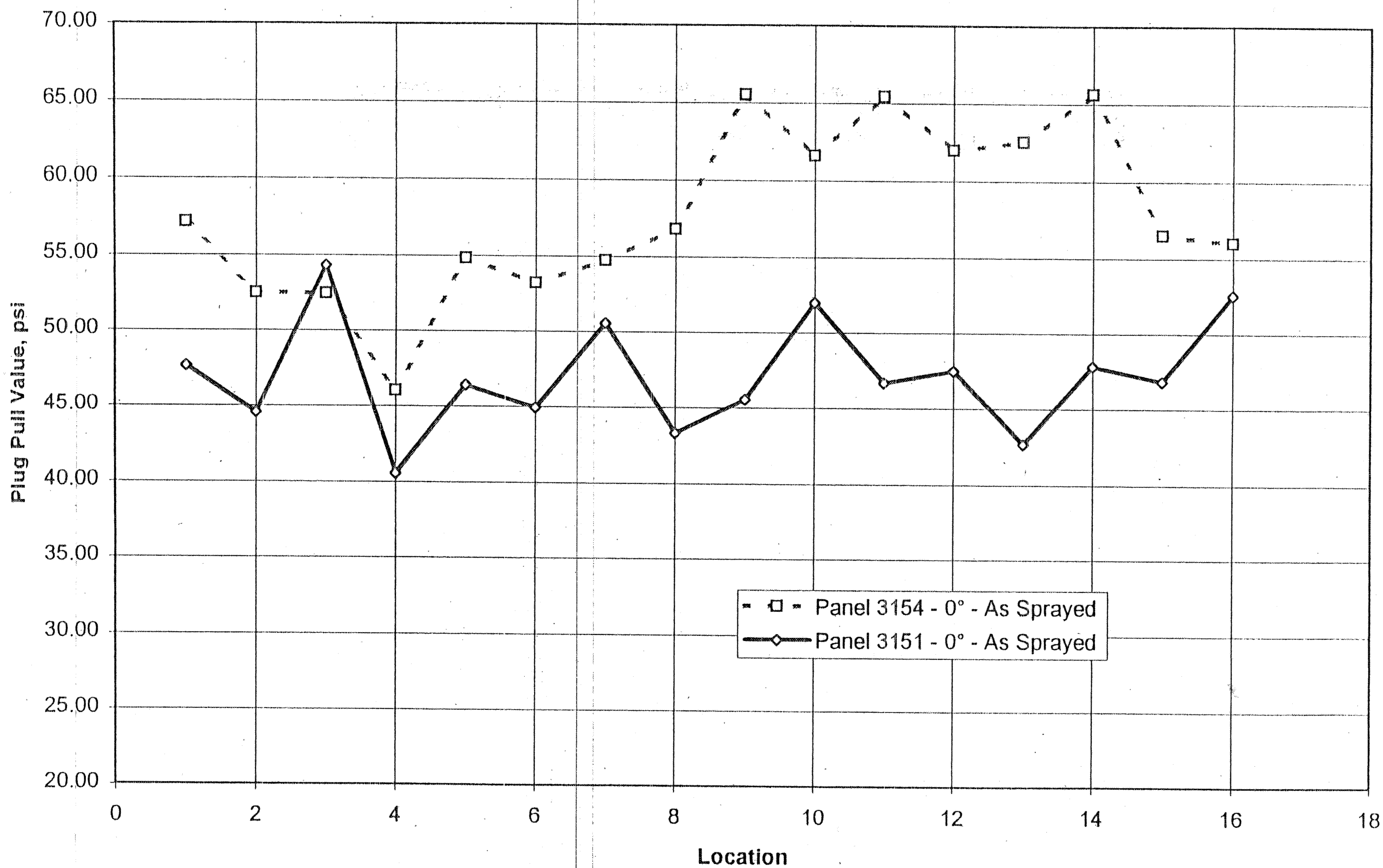


Figure 25: Plug Pull Values on Net Sprayed 0° Oriented Panels

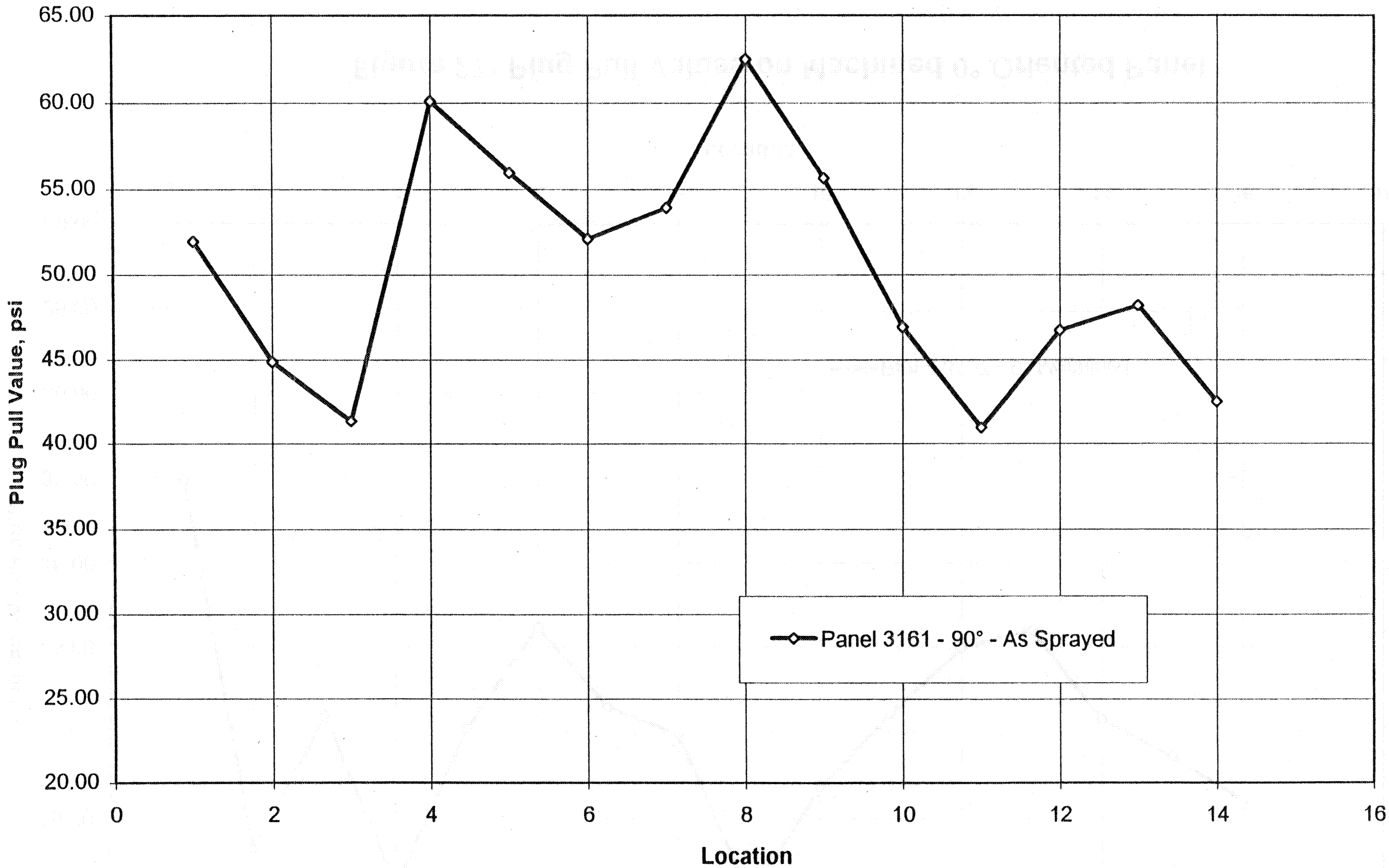


Figure 26: Plug Pull Values on Net Sprayed 90° Oriented Panel

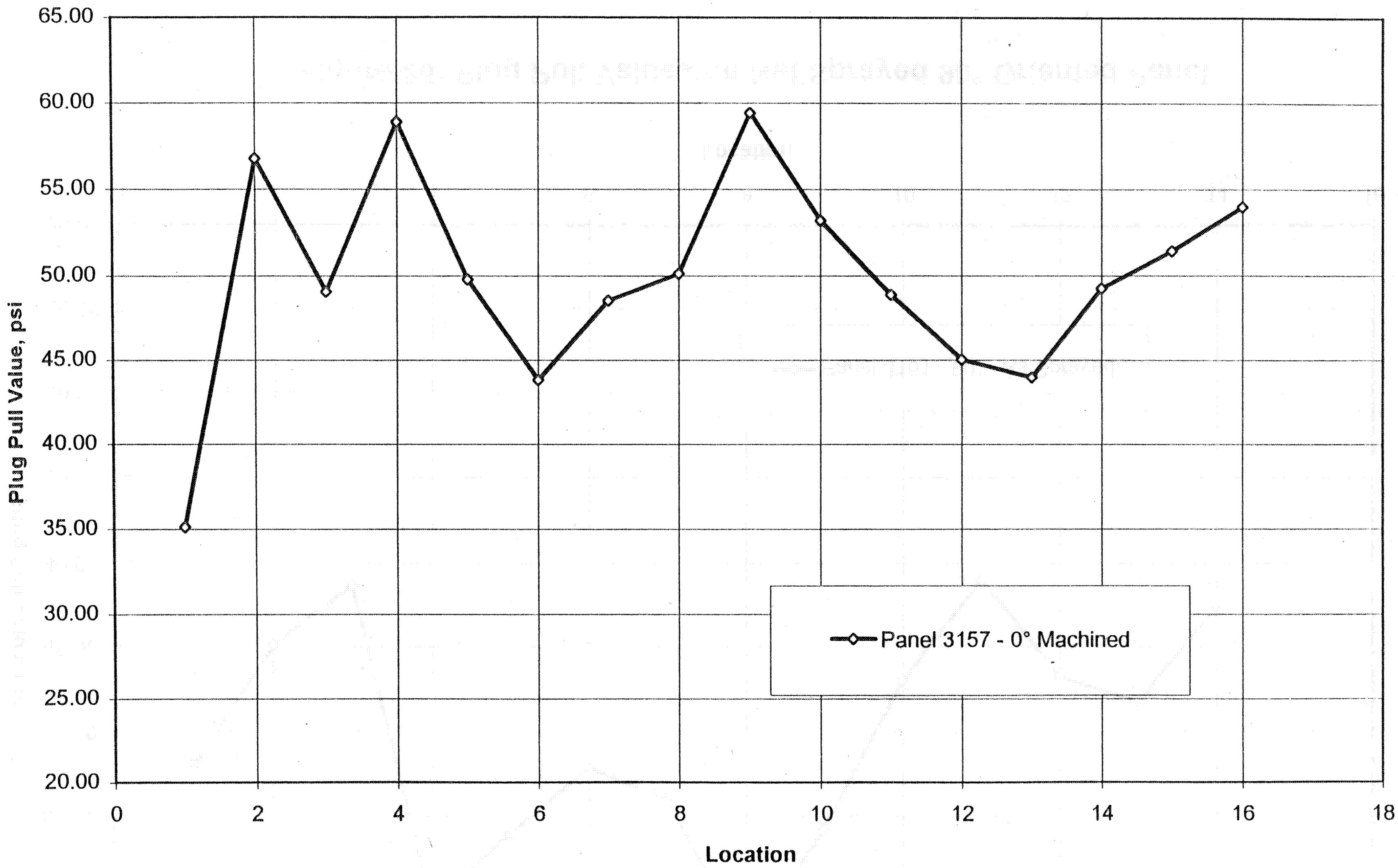


Figure 27: Plug Pull Values on Machined 0° Oriented Panel

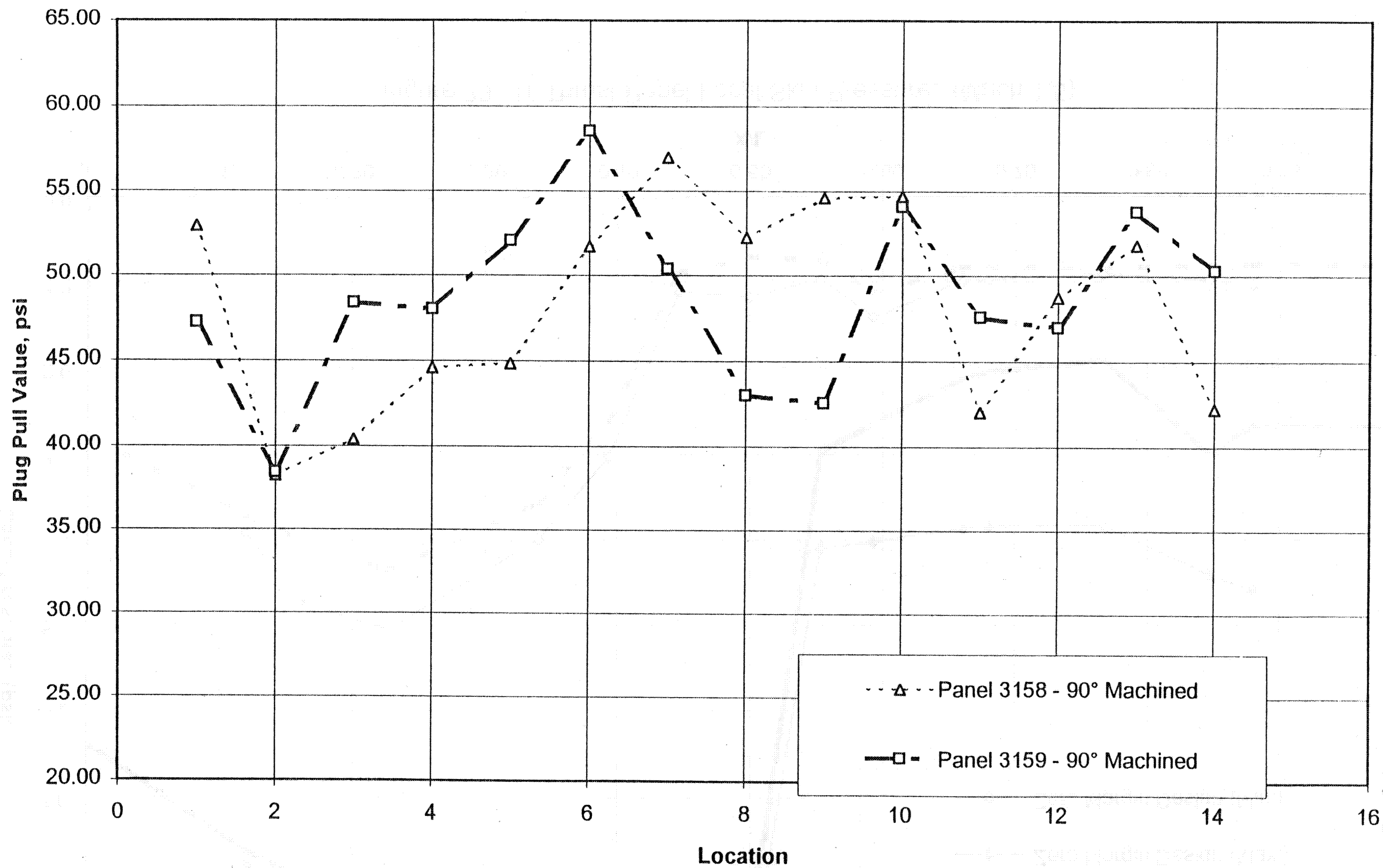


Figure 28: Plug Pull values on Machined Vented 90° Oriented Panels

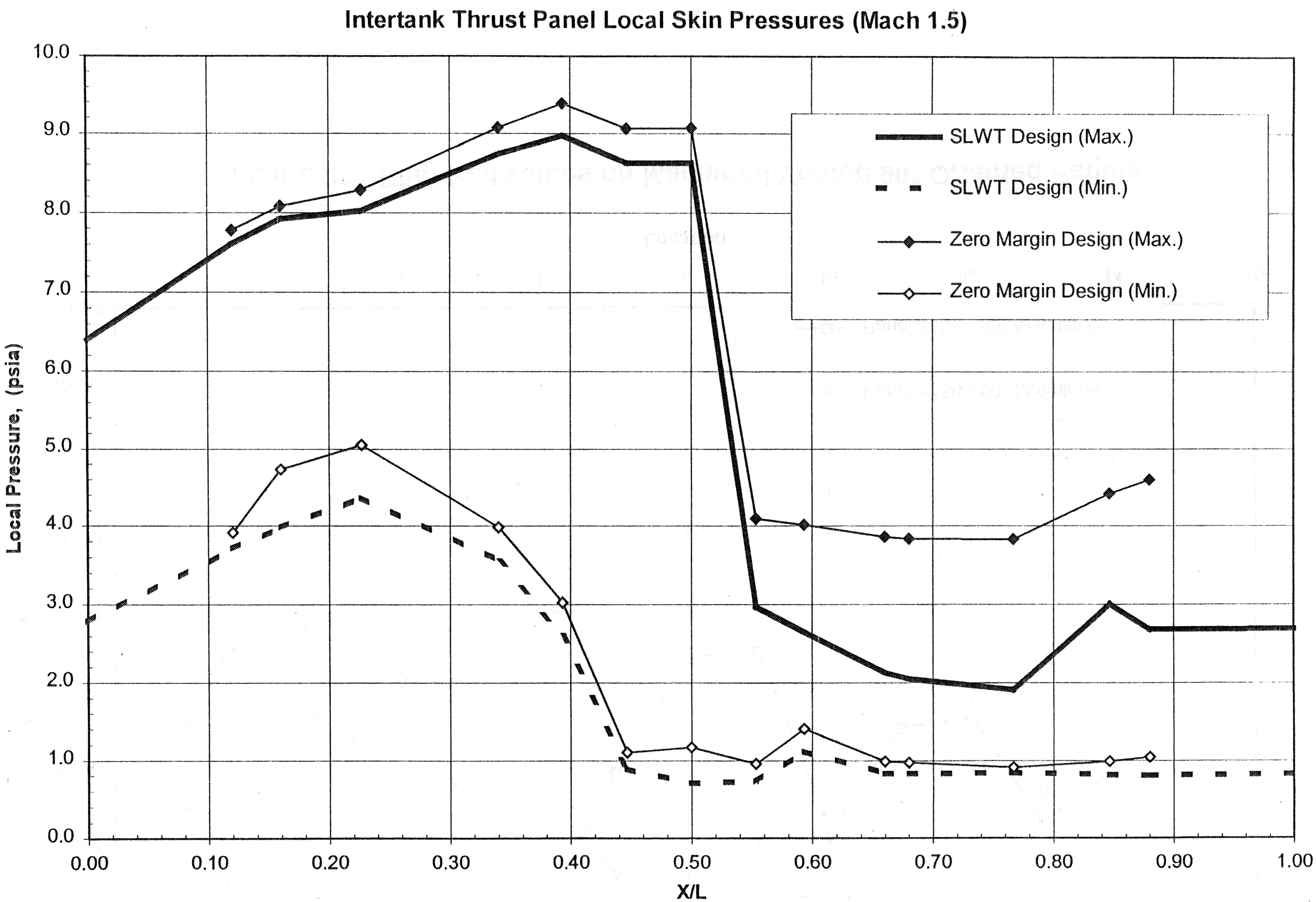


Figure 29: IT Thrust Panel Local Skin Pressures (Mach 1.5)

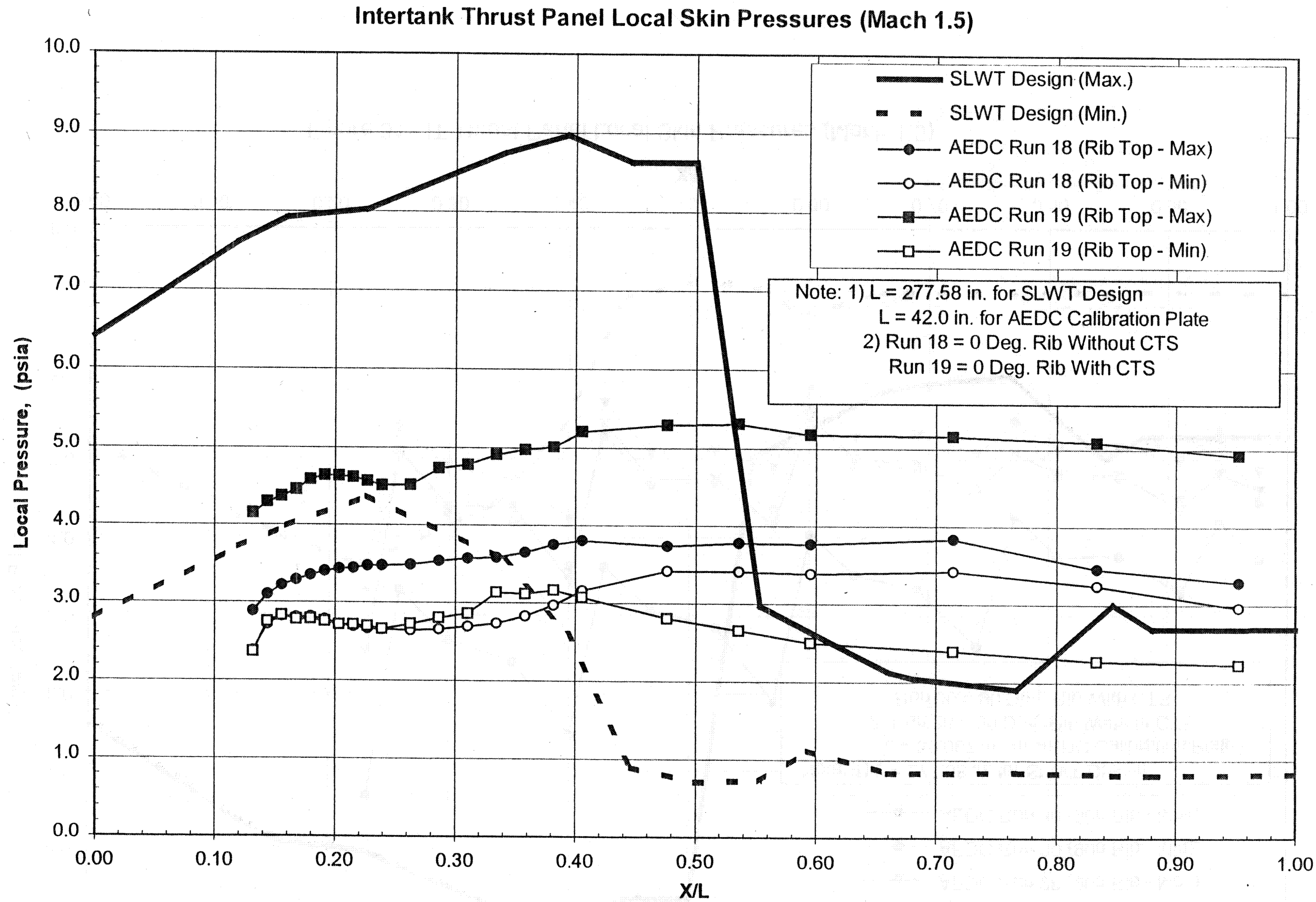


Figure 30: IT Thrust Panel Local Skin Pressures (Mach 1.5)

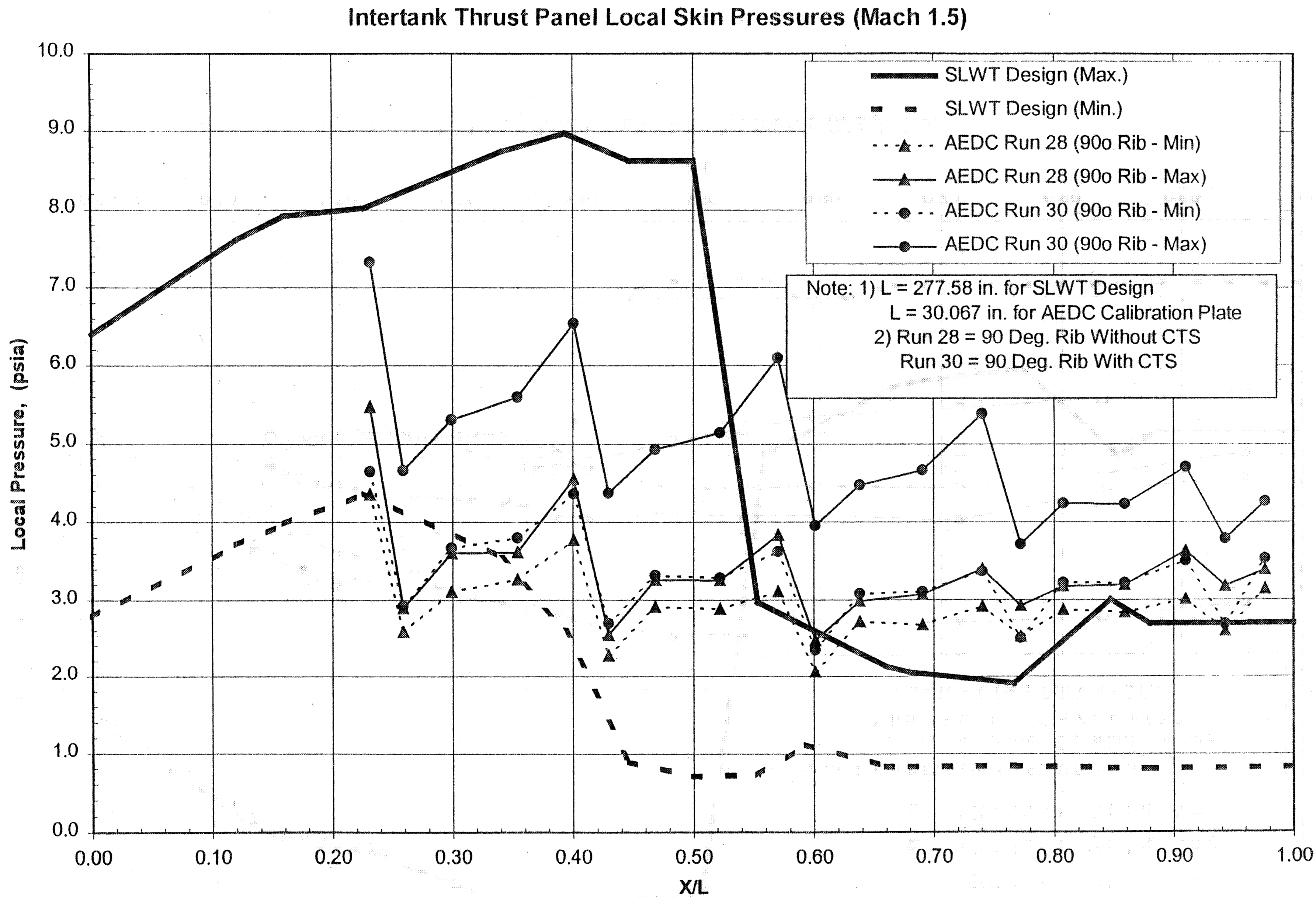


Figure 31: IT Thrust Panel Local Skin Pressures (Mach 1.5)

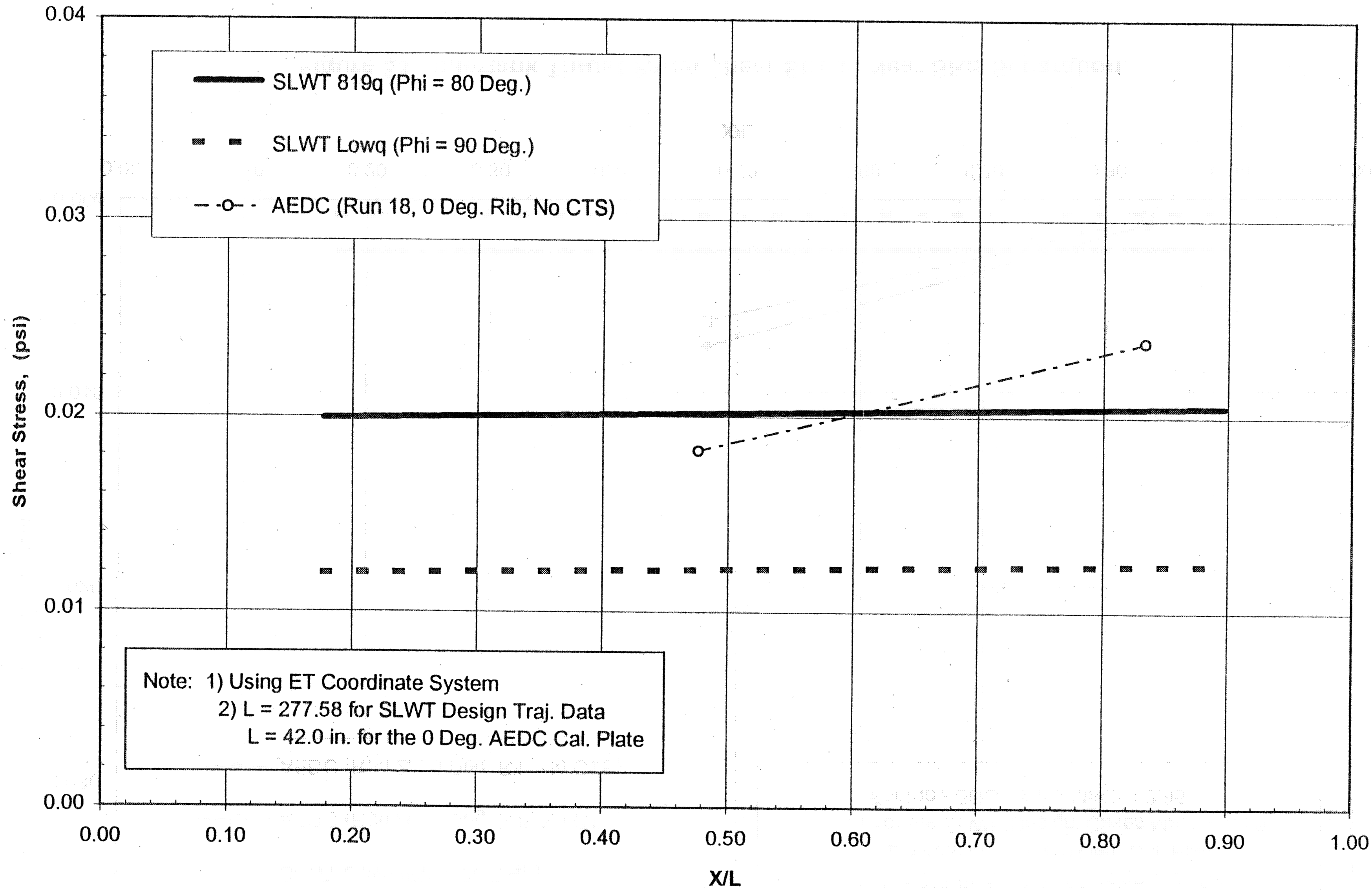


Figure 32: SLWT 'Design' vs. AEDC Derived Intertank Thrust Panel Shear Stress @Mach 1.5

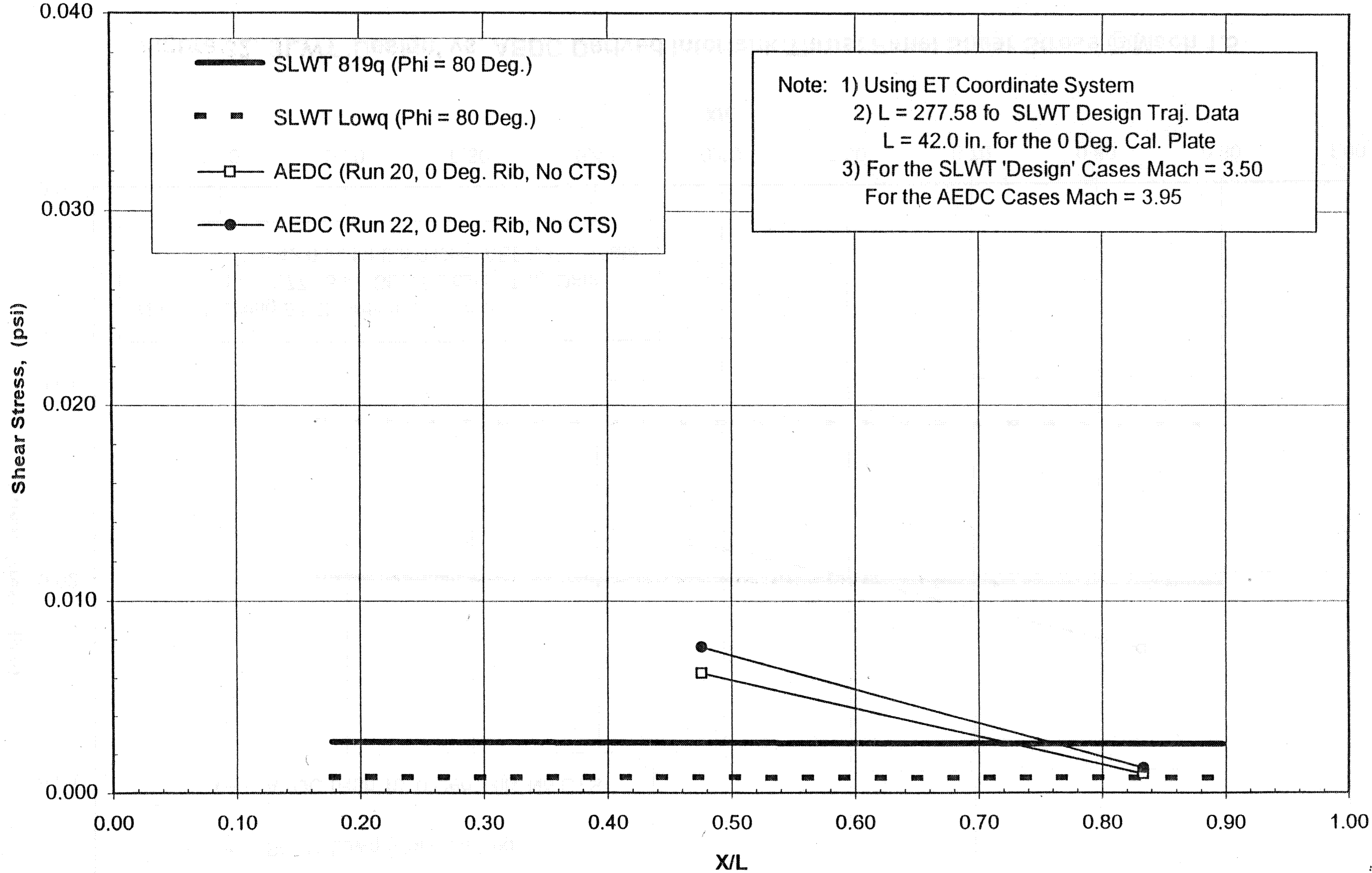


Figure 33: Intertank Thrust Panel Shear Stress Near SRB Separation.

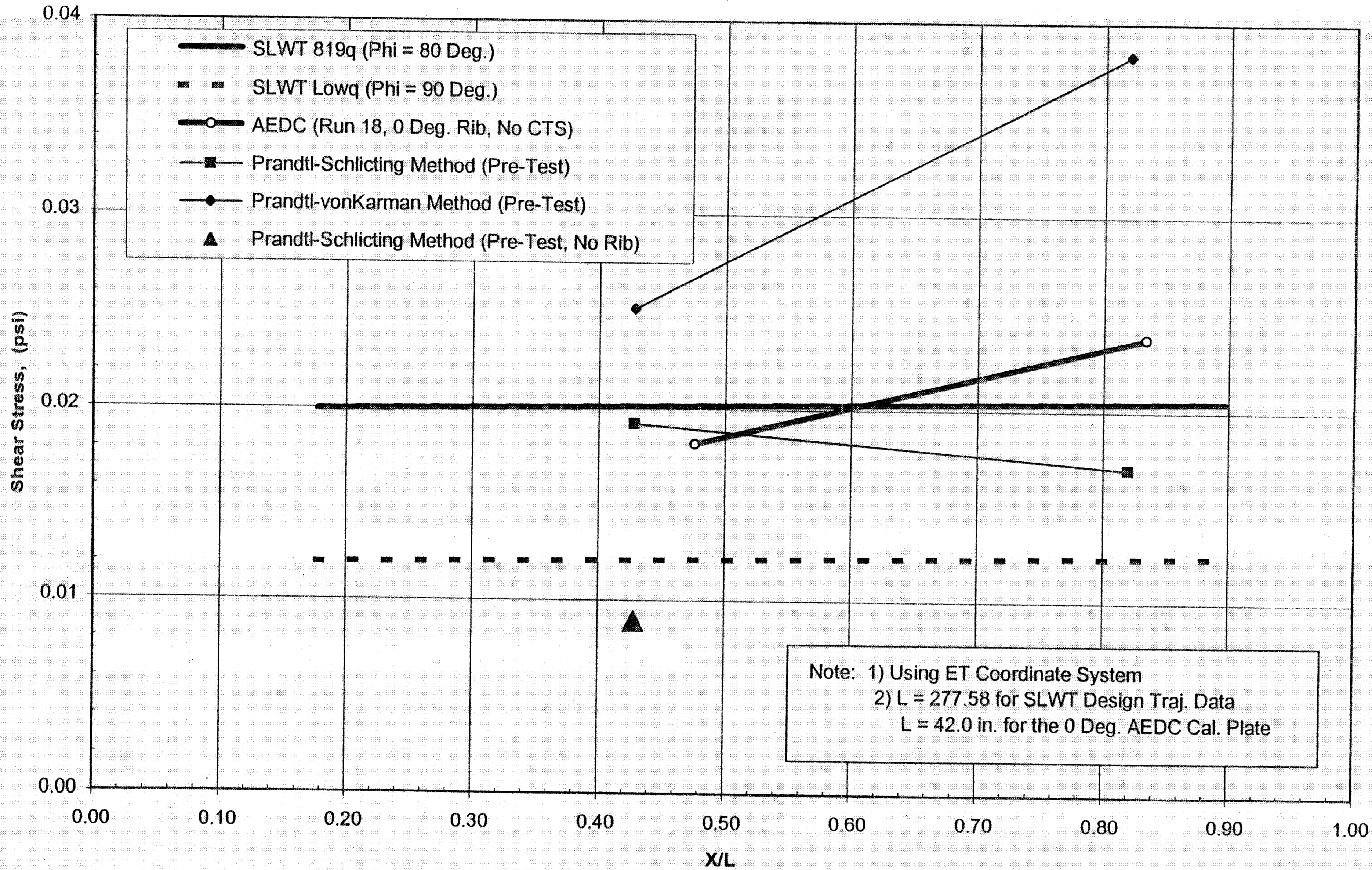


Figure 34: Intertank Thrust Panel Shear Stress Comparisons for Mach 1.5

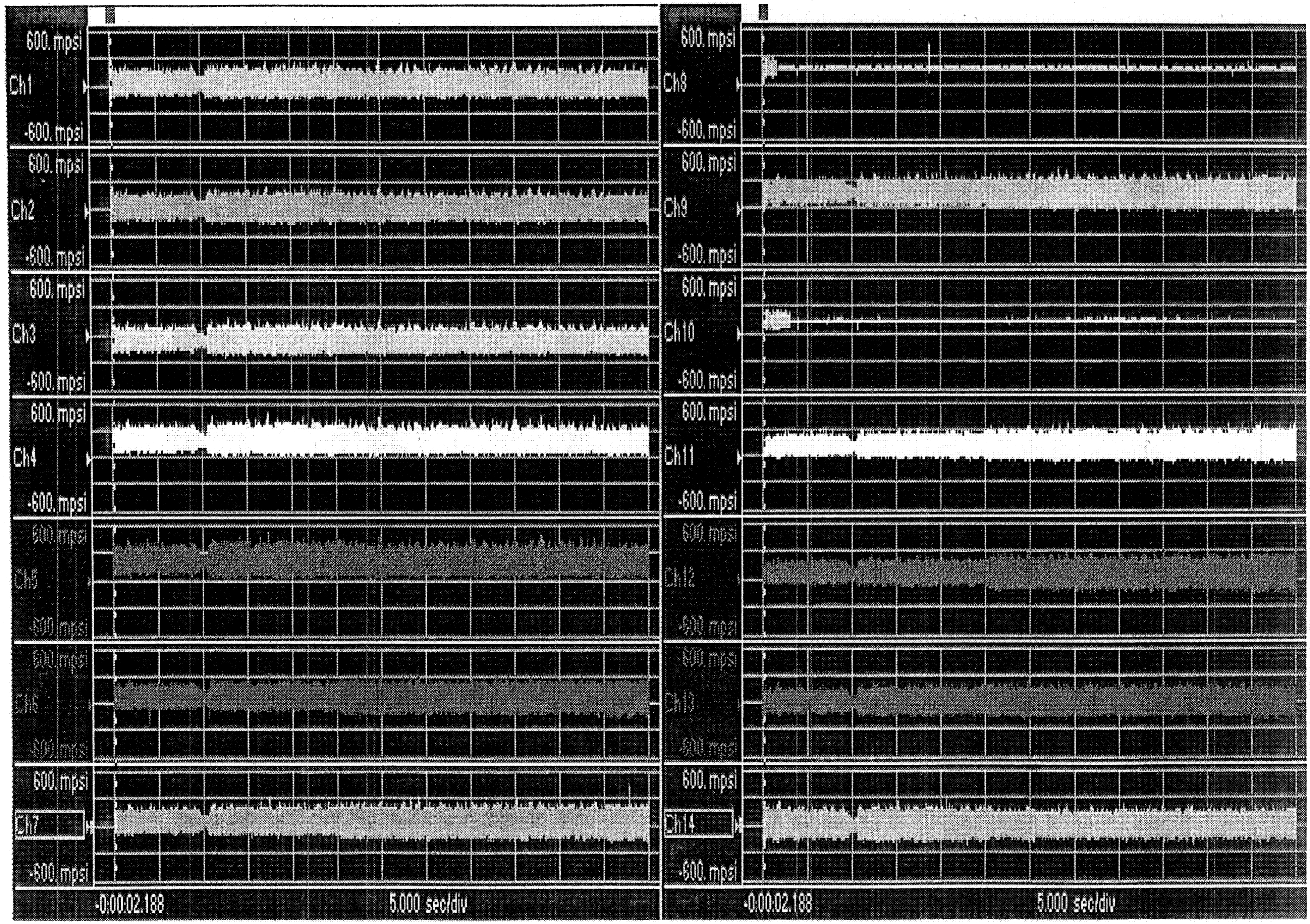


Figure 35: Recording 01 Time Records From Odyssey Screen Dump (Run #11)

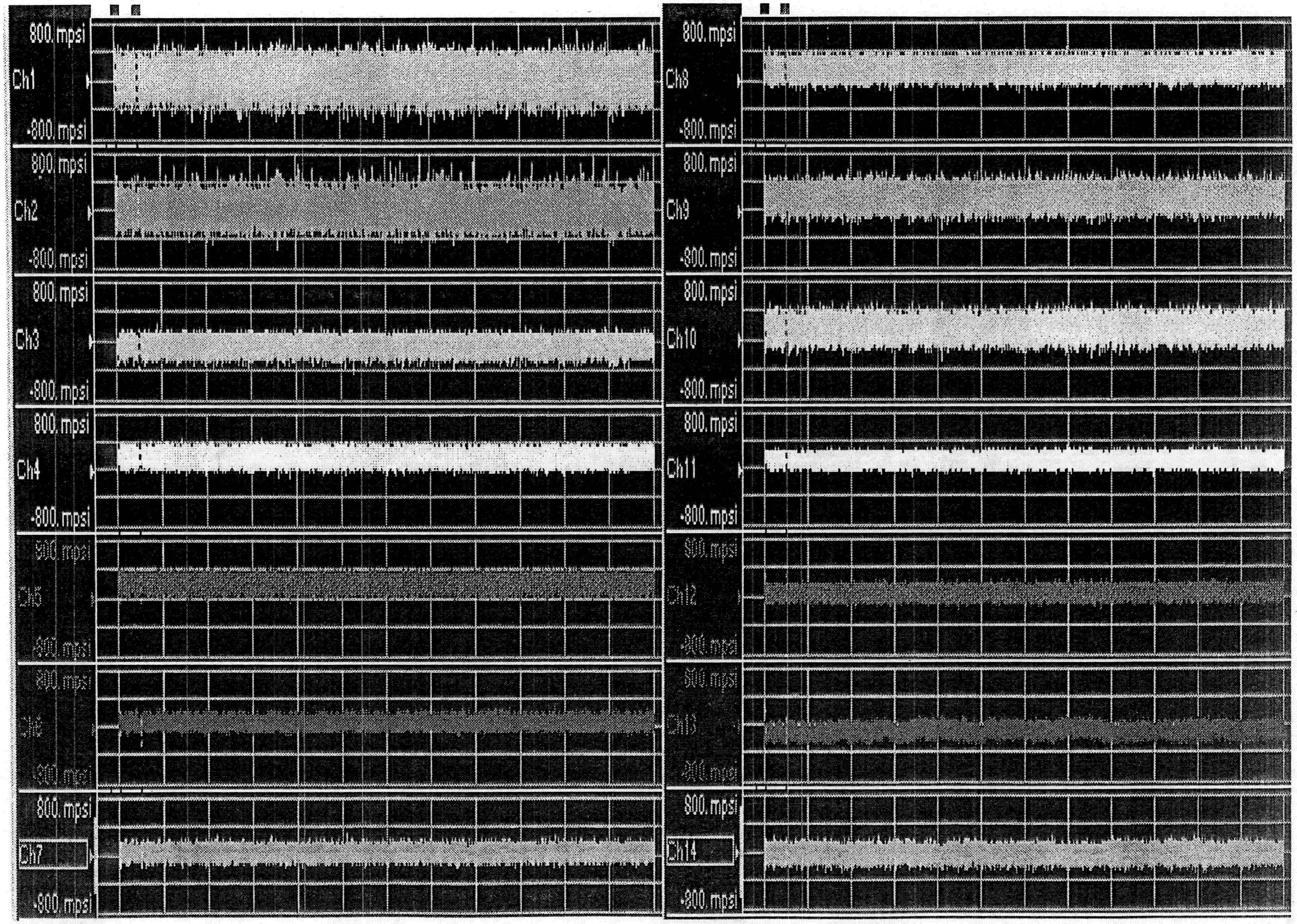


Figure 36: Recording 02 Time Records From Odyssey Screen Dump (Run #12)

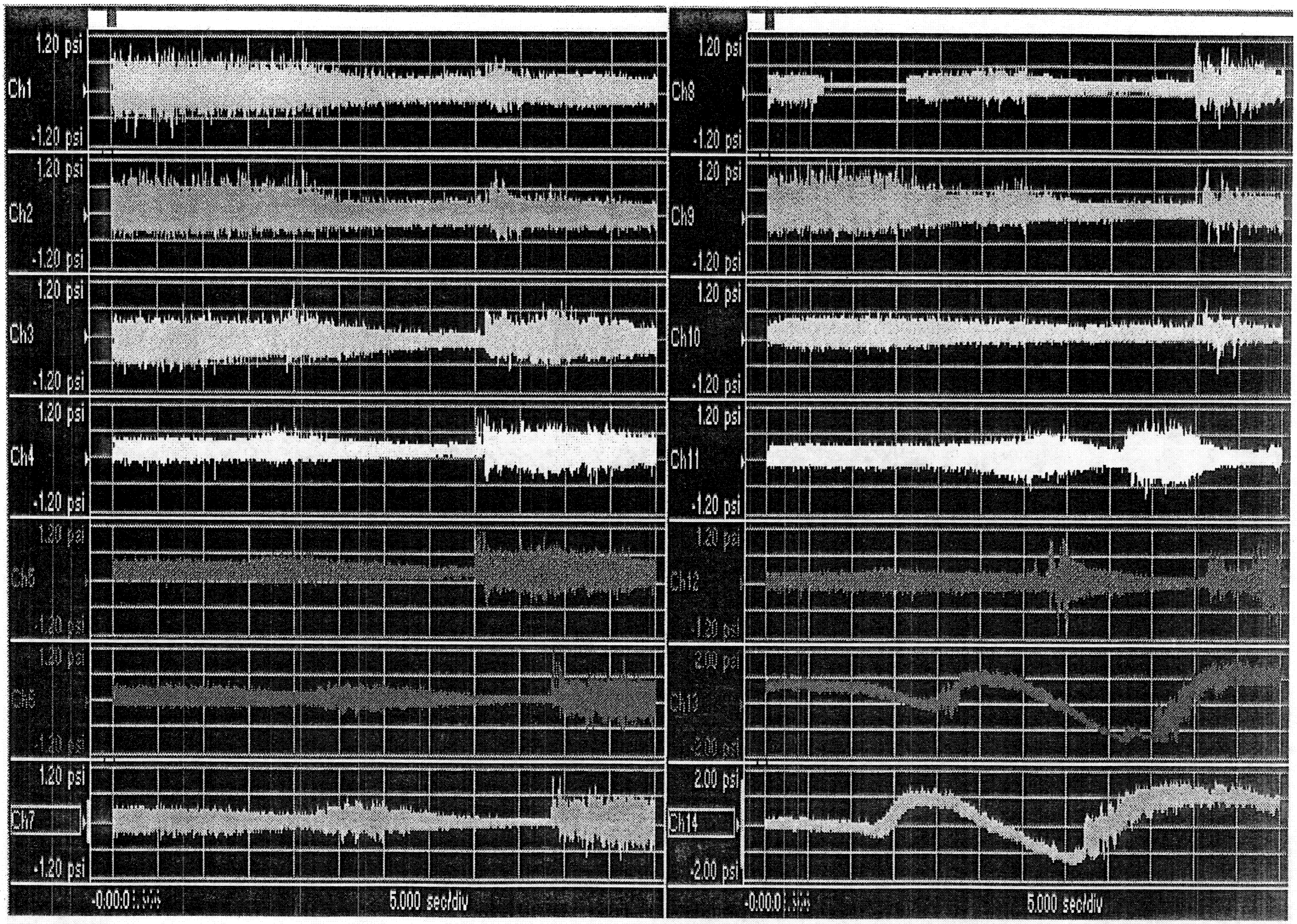


Figure 37: Recording 03 Time Records From Odyssey Screen Dump (Run #13)

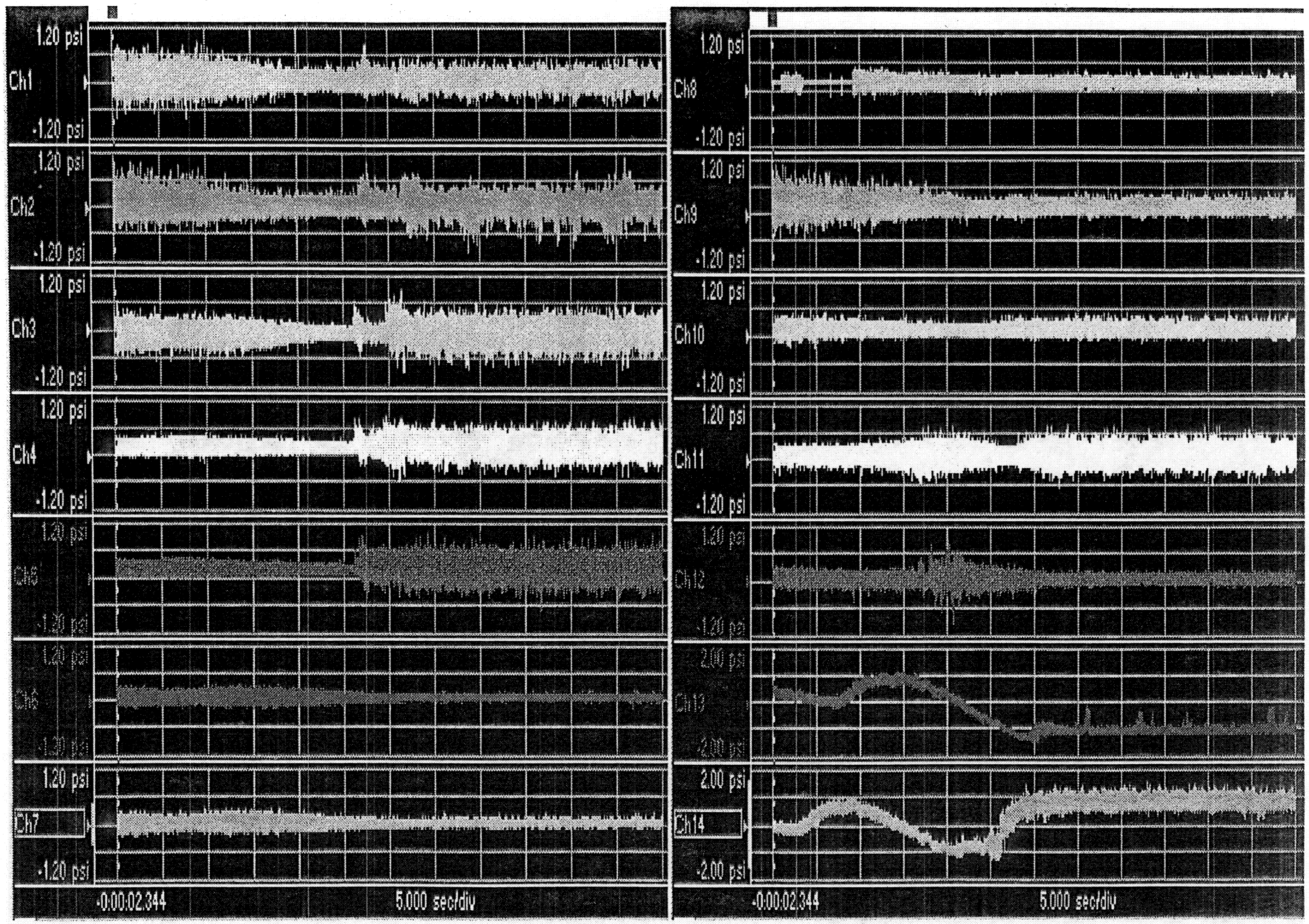


Figure 38: Recording 04 Time Records From Odyssey Screen Dump (Run #14)

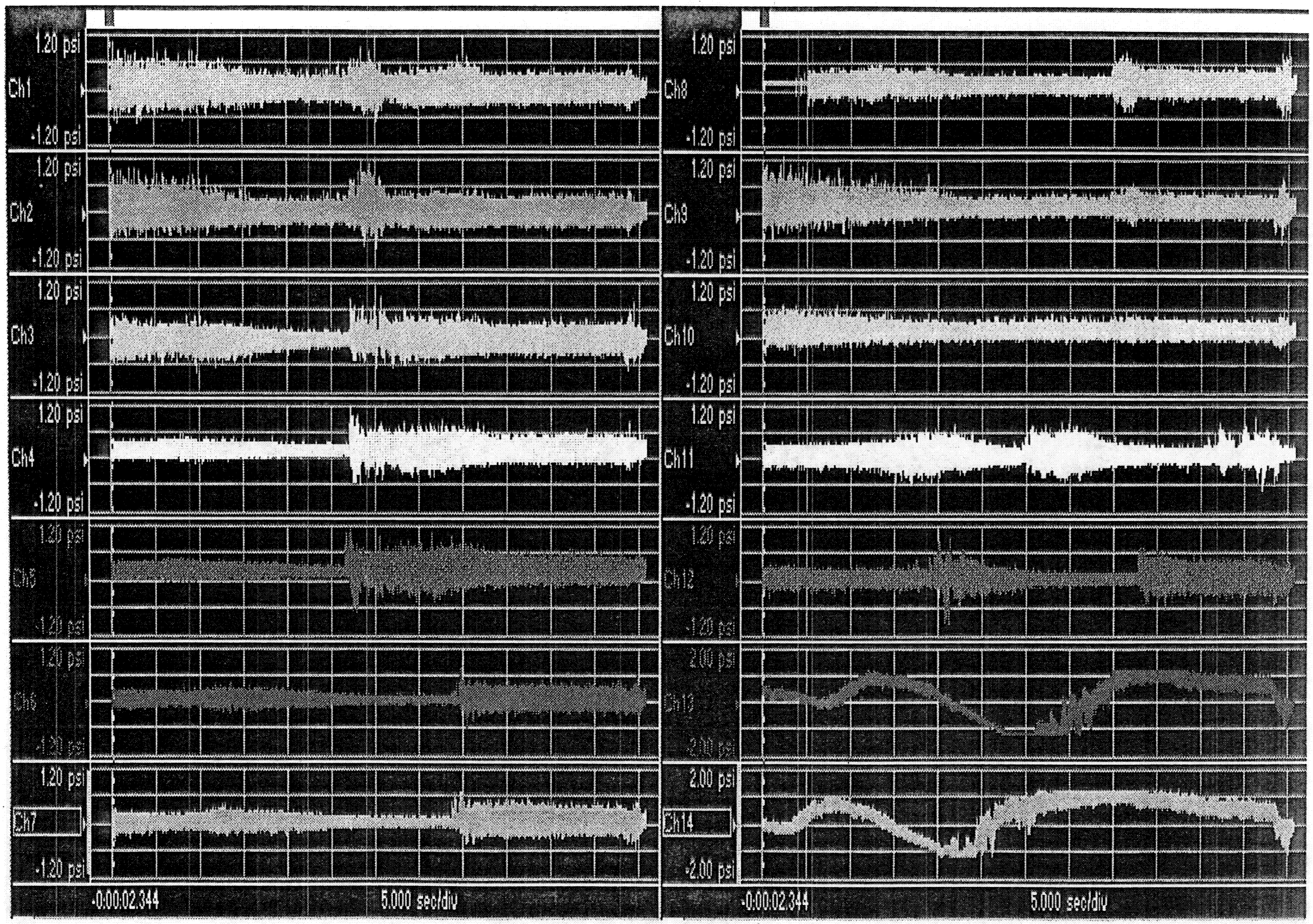


Figure 39: Recording 05 Time Records From Odyssey Screen Dump (Run #15)

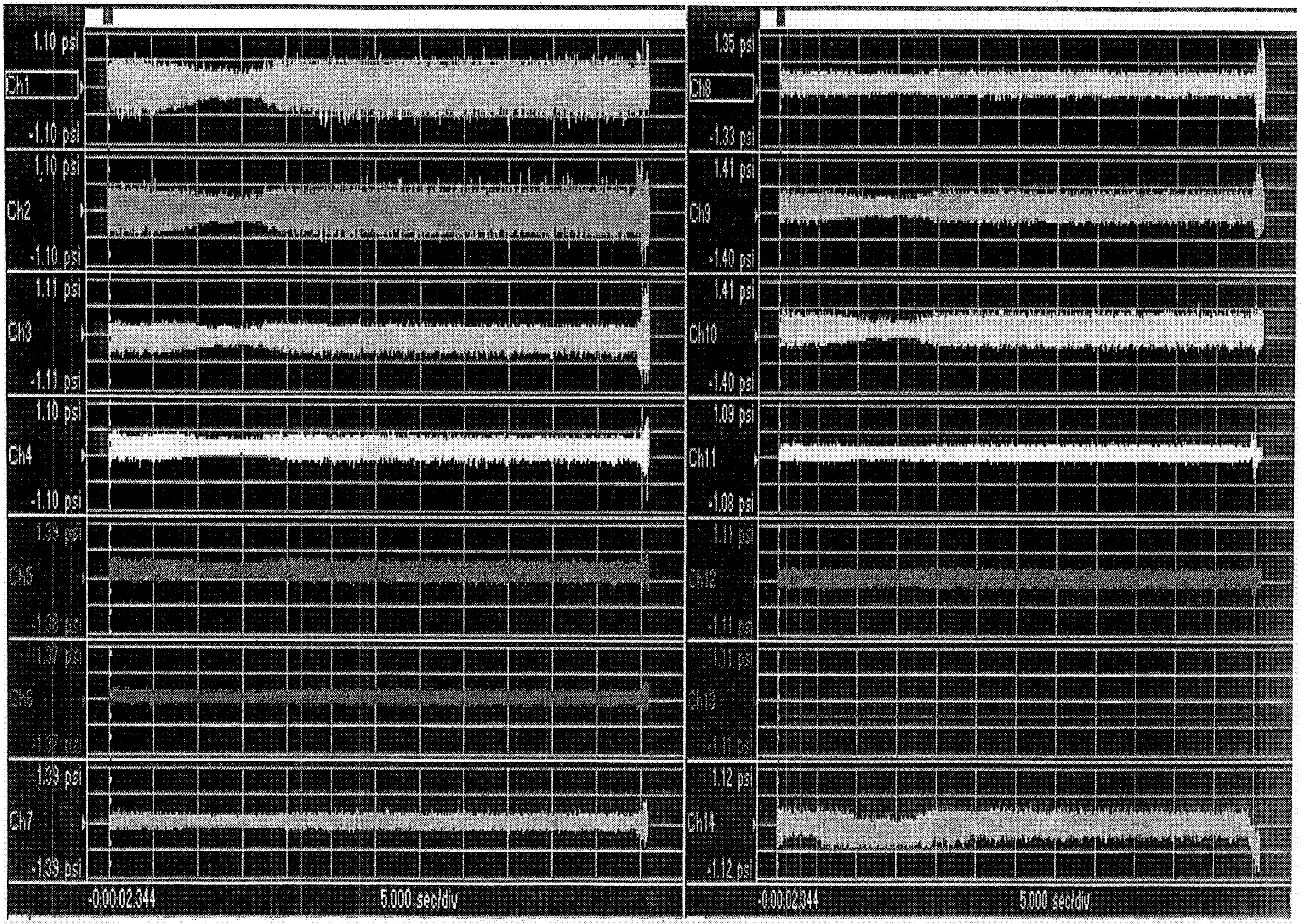


Figure 4D: Recording 06 Time Records From Odyssey Screen Dump (Run #16)

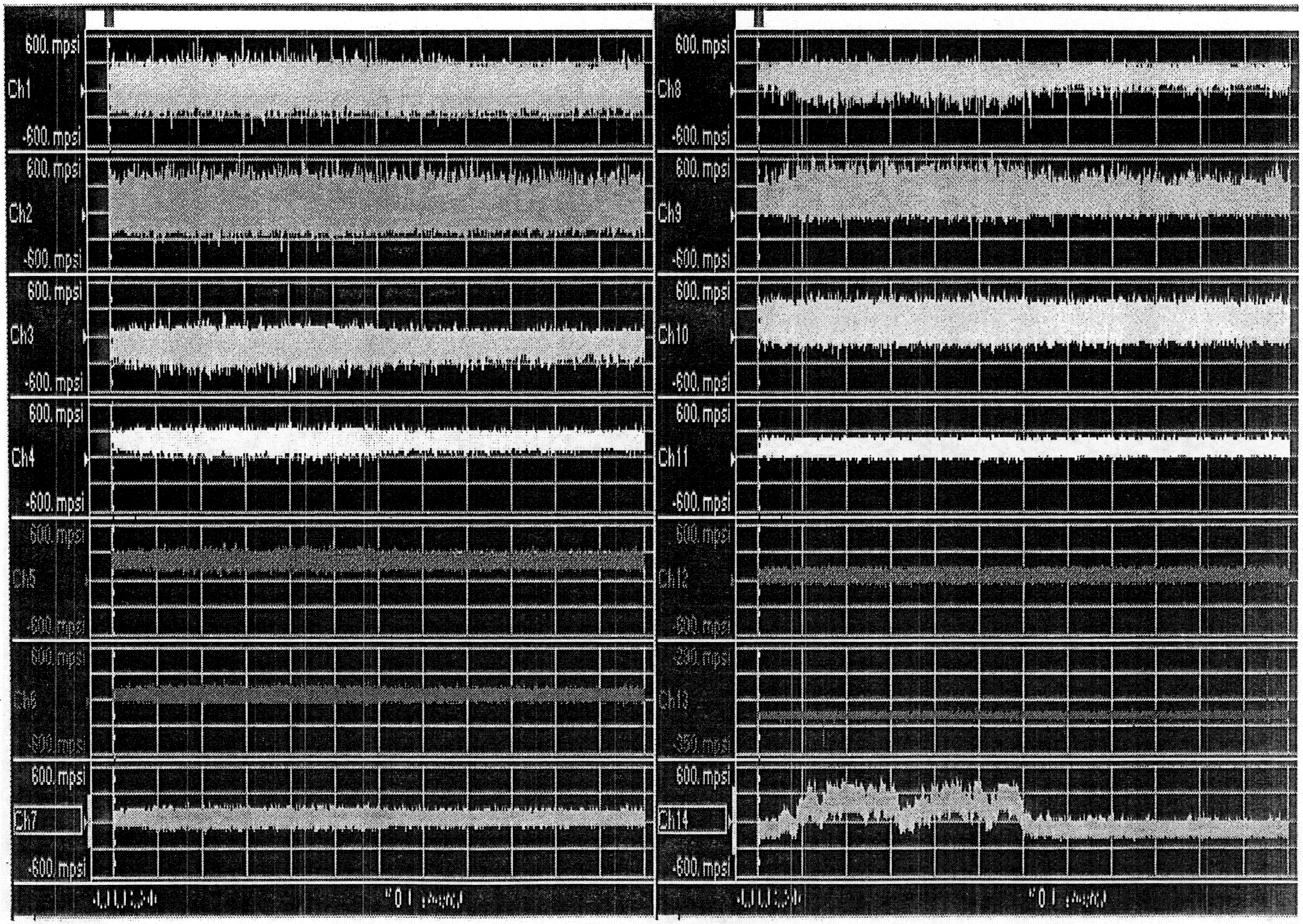


Figure 4l: Recording 07 Time Records From Odyssey Screen Dump (Run #17)

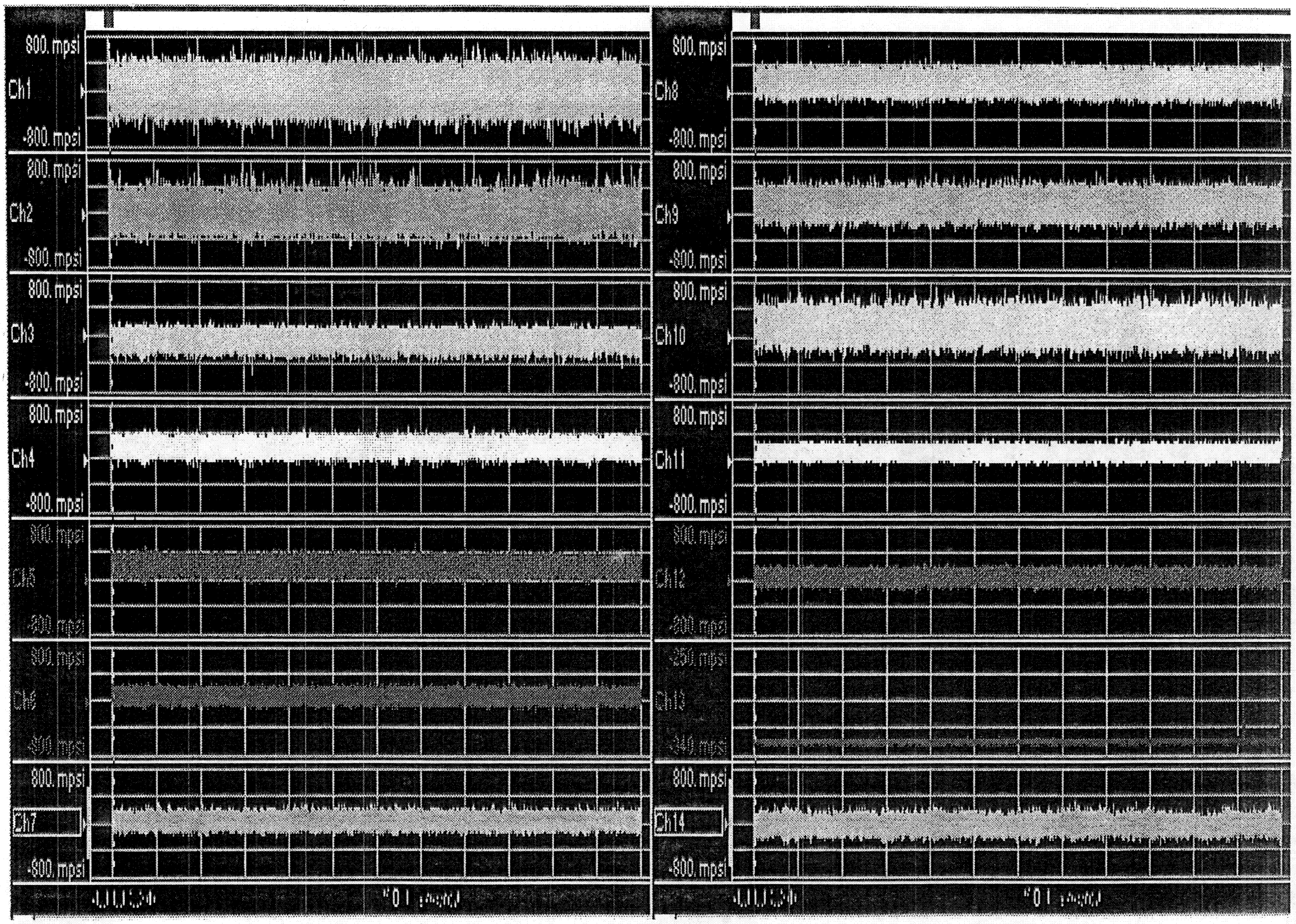


Figure 42: Recording 08 Time Records From Odyssey Screen Dump (Run #18)

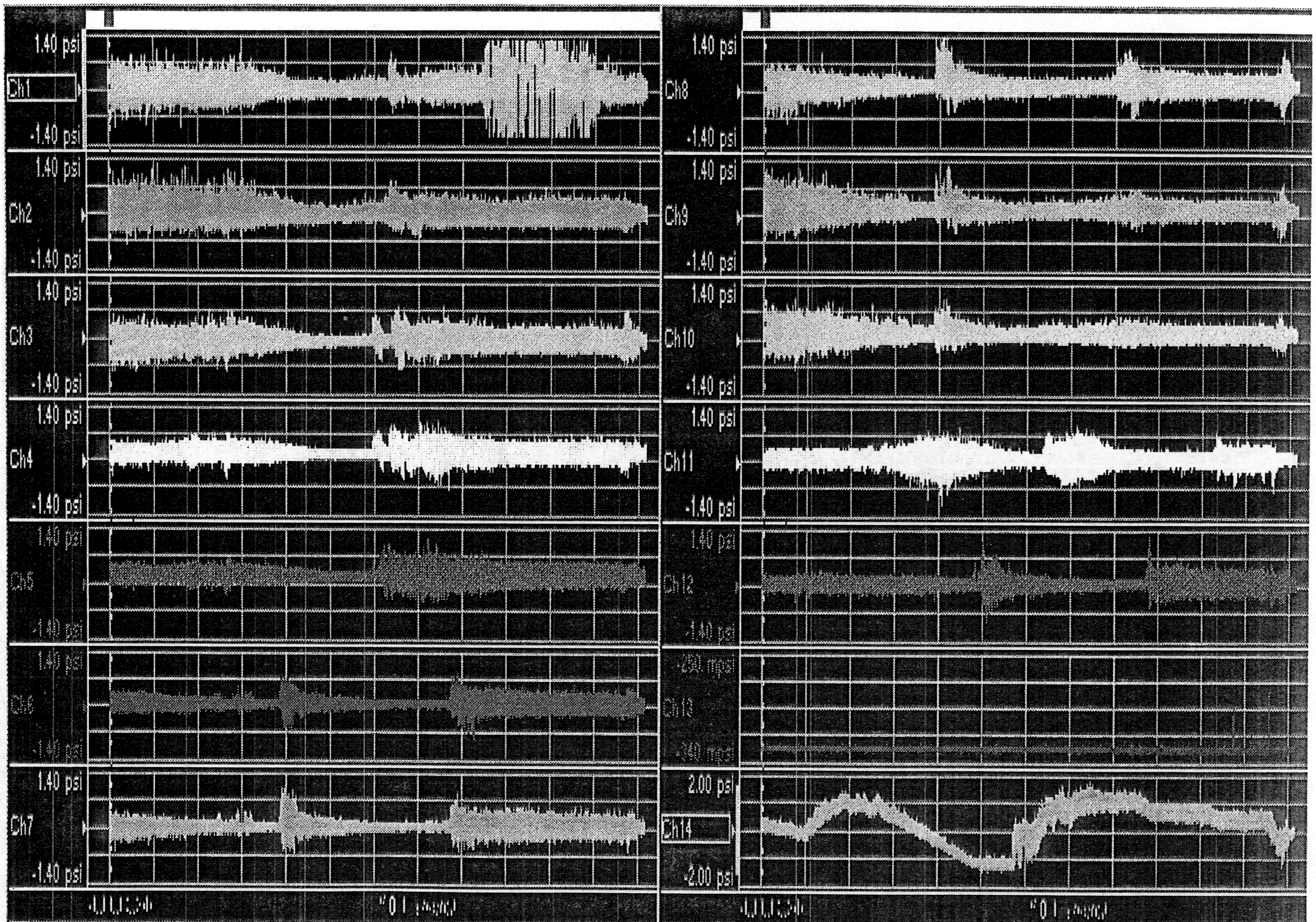


Figure 43: Recording 09 Time Records From Odyssey Screen Dump (Run #19)

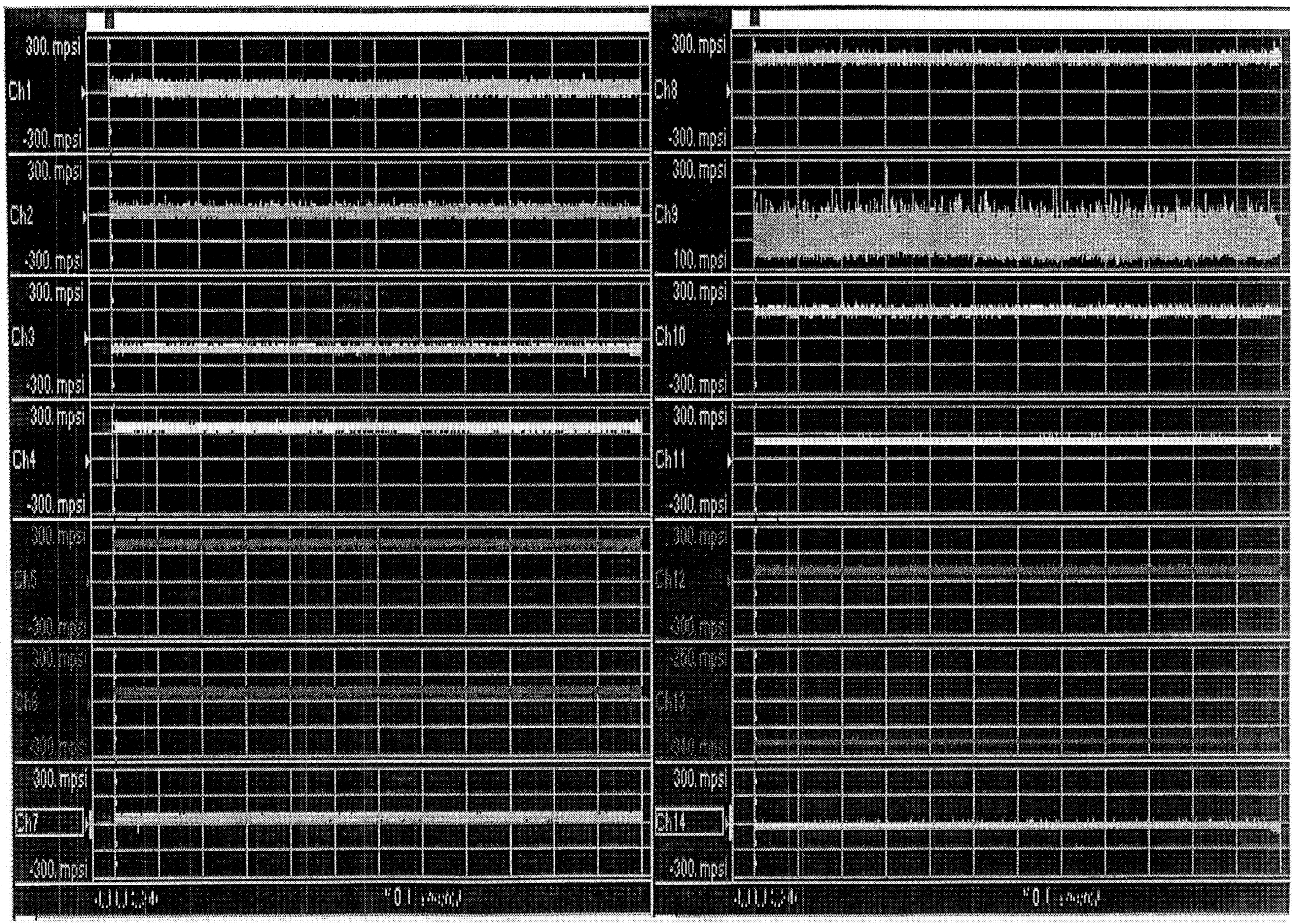


Figure 44: Recording 10 Time Records From Odyssey Screen Dump (Run #20)

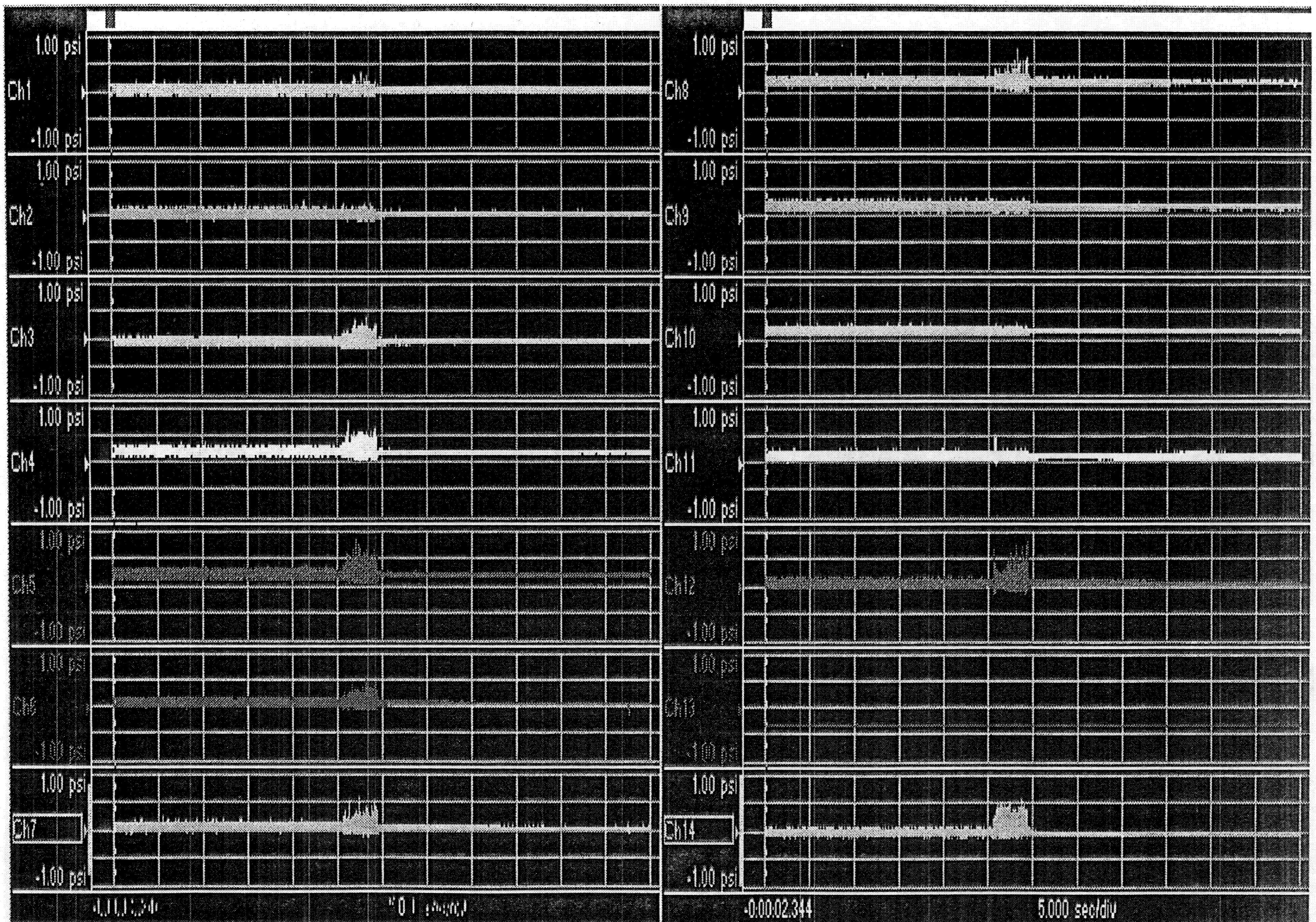


Figure 45: Recording 11 Time Records From Odyssey Screen Dump (Run #21)

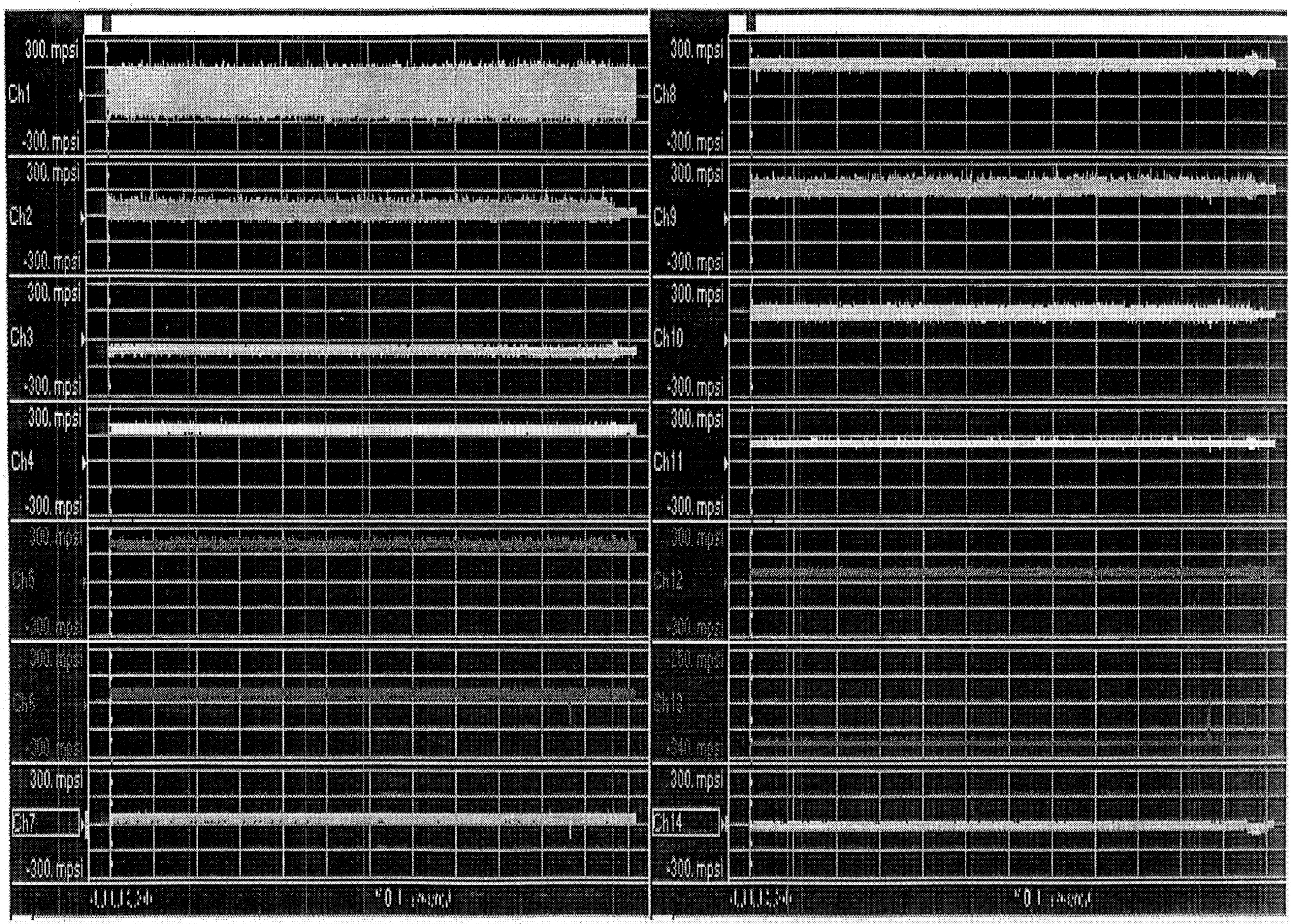


Figure 46: Recording 12 Time Records From Odyssey Screen Dump (Run #22)

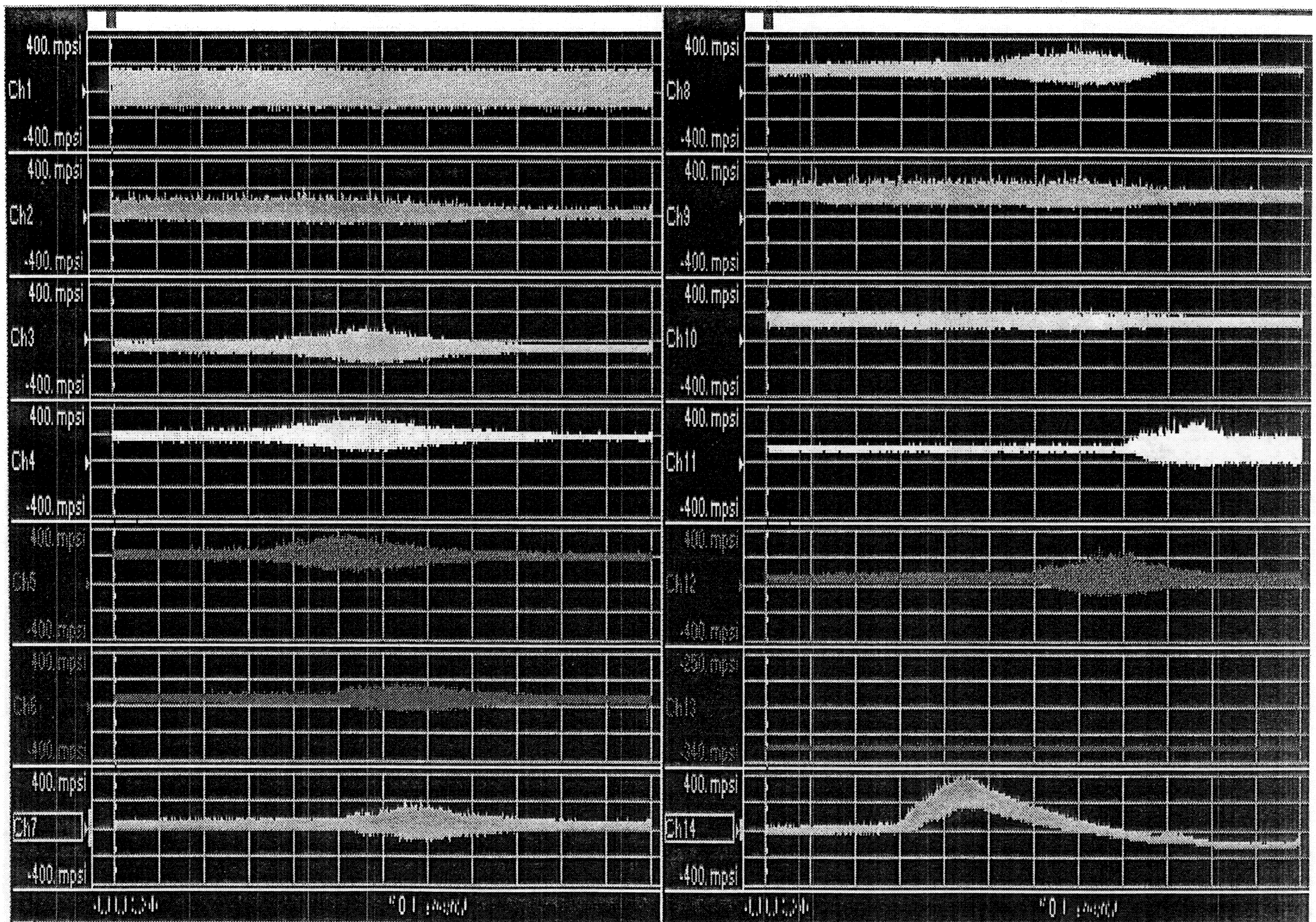


Figure 47: Recording 13 Time Records From Odyssey Screen Dump (Run #23)

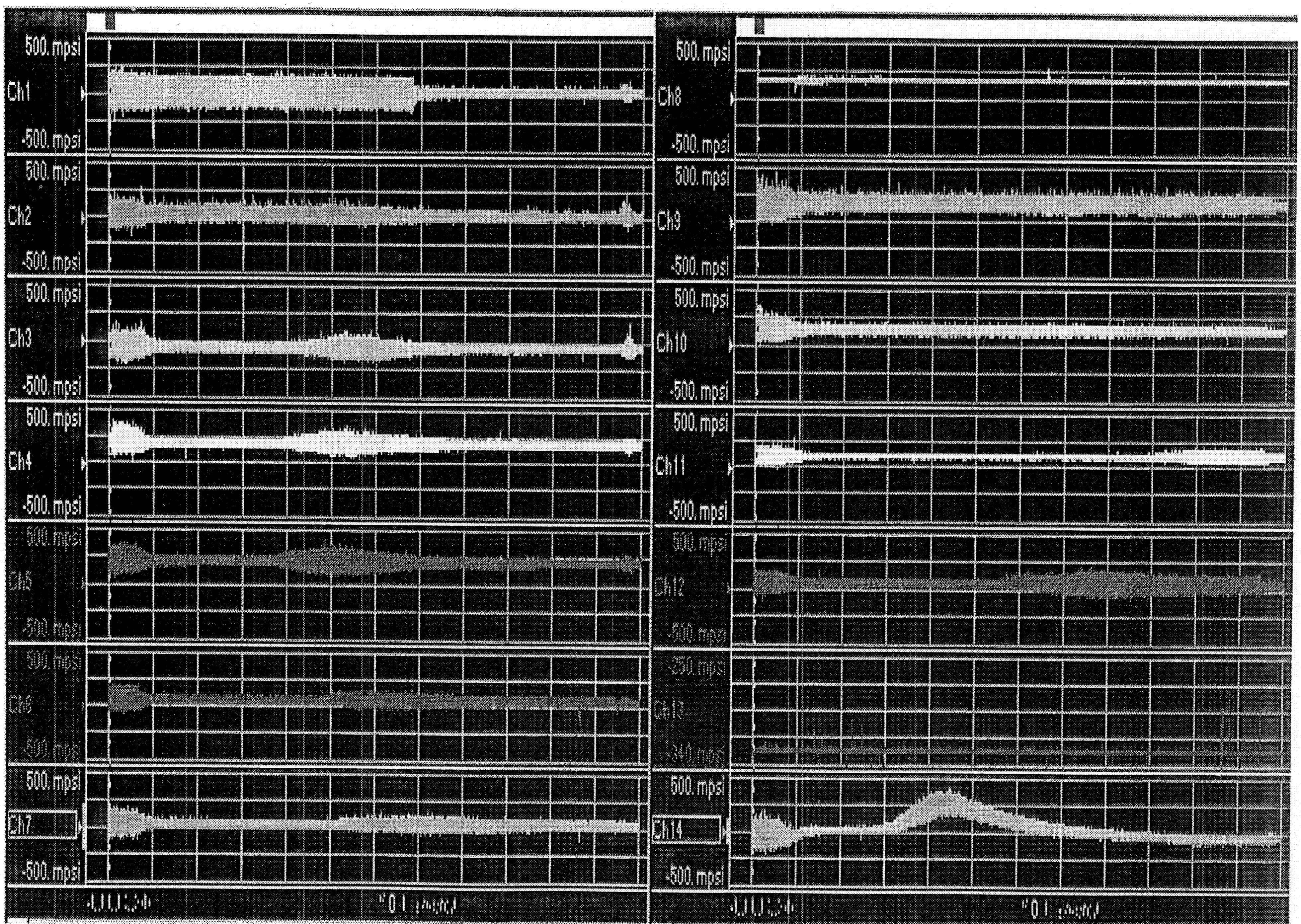


Figure 48: Recording 14 Time Records From Odyssey Screen Dump (Run #24)

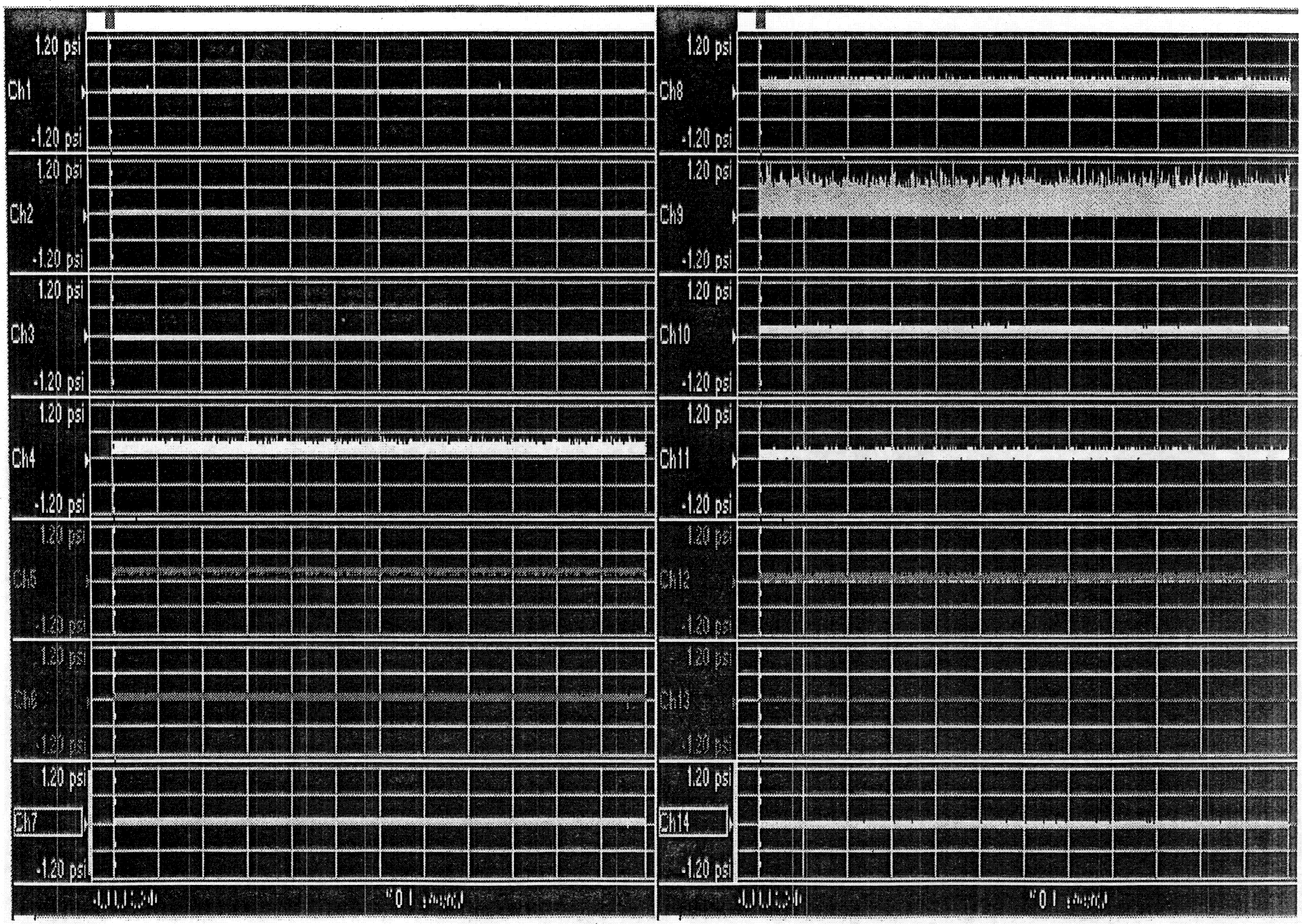


Figure 49: Recording 15 Time Records From Odyssey Screen Dump (Run #25)

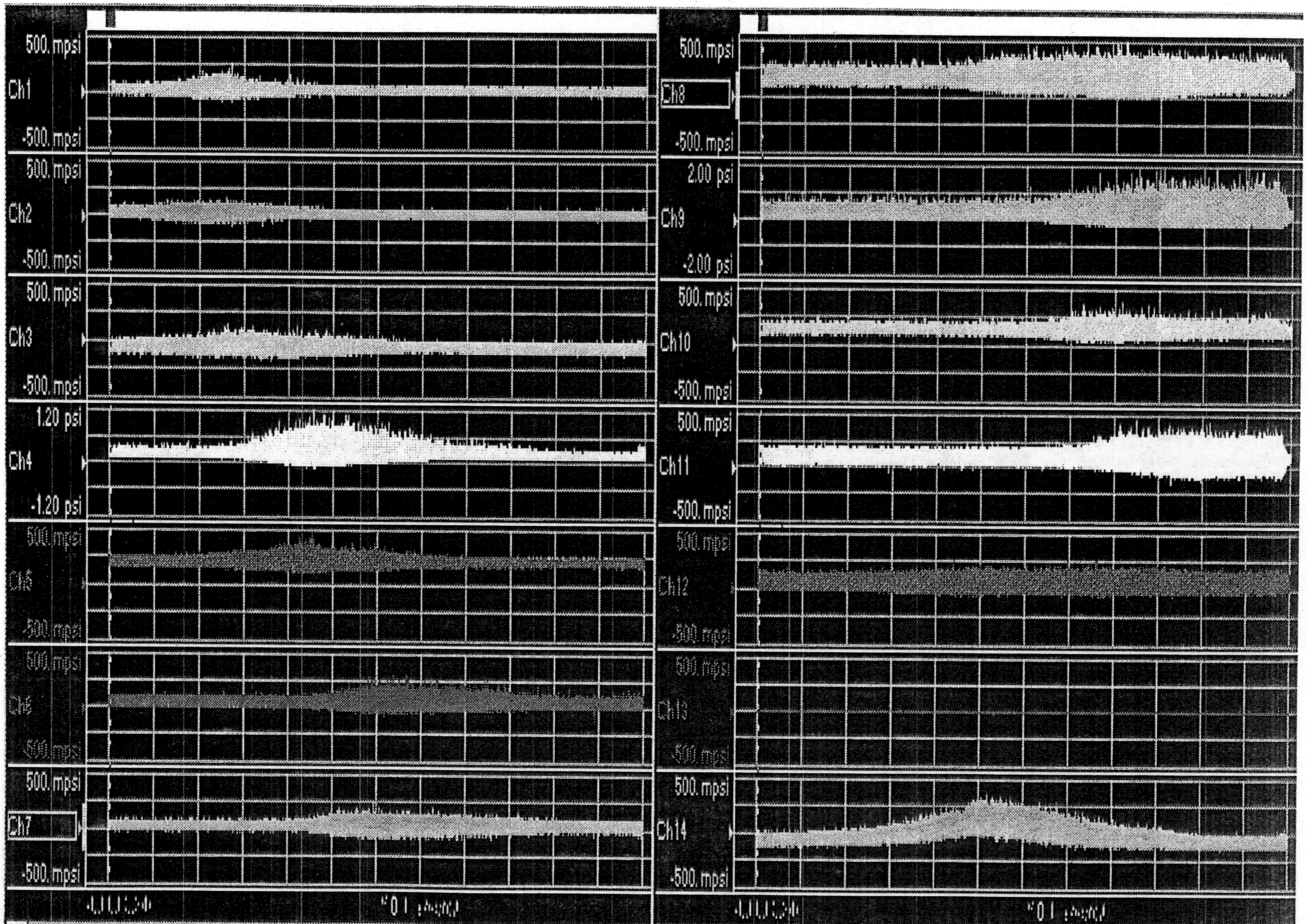


Figure 50: Recording 16 Time Records From Odyssey Screen Dump (Run #26)

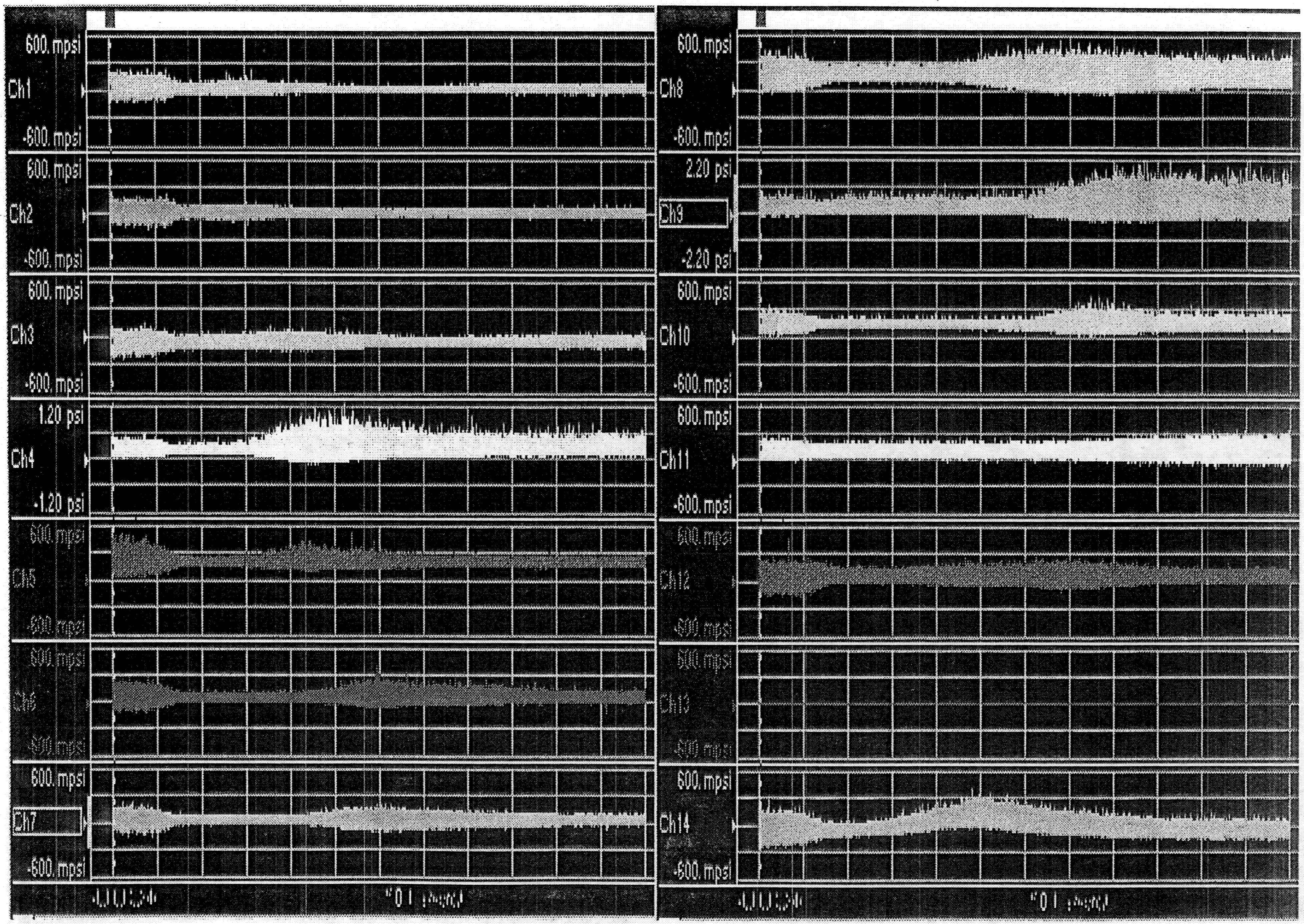


Figure 51: Recording 17 Time Records From Odyssey Screen Dump (Run #27)

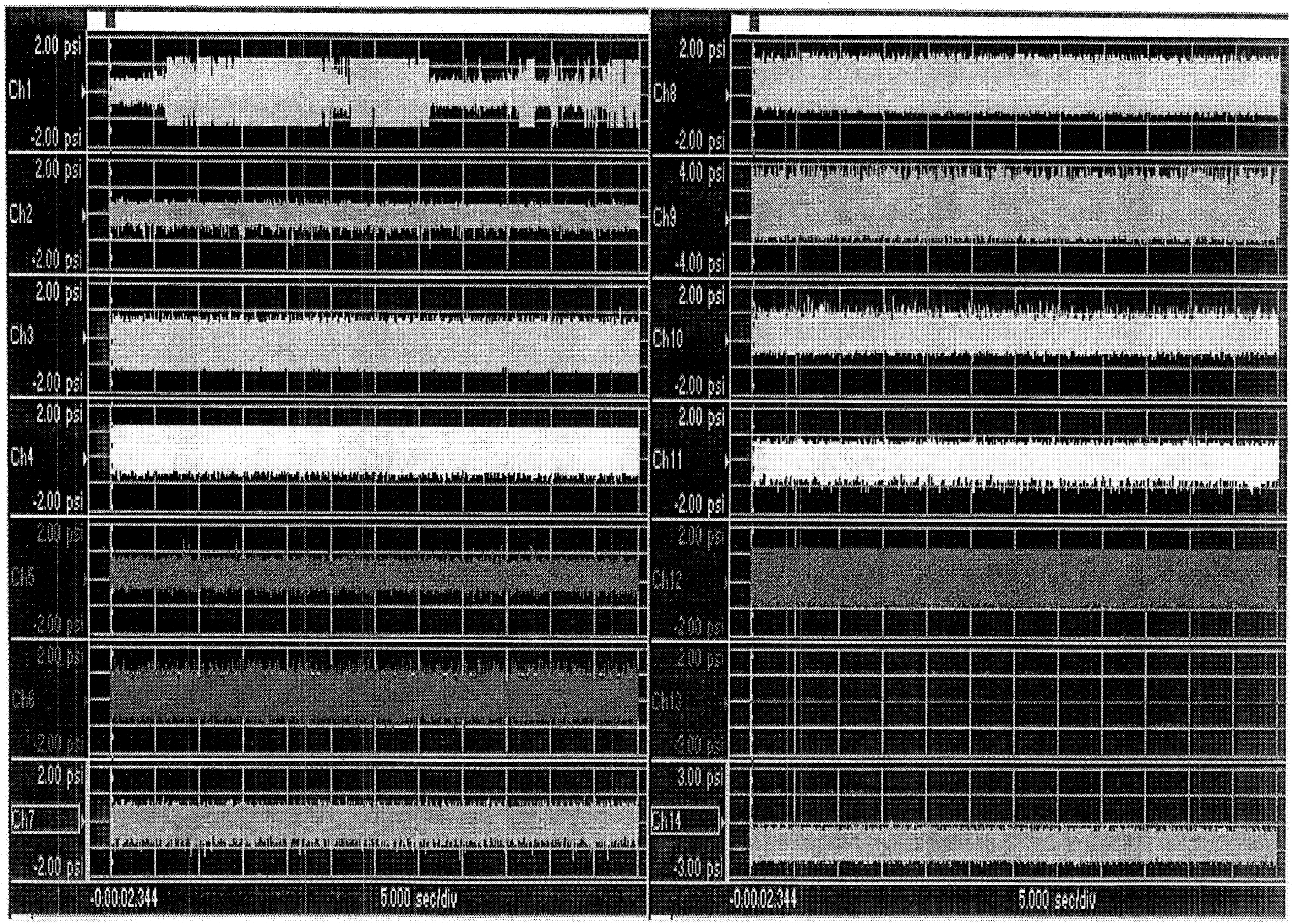


Figure 52: Recording 18 Time Records From Odyssey Screen Dump (Run #28)

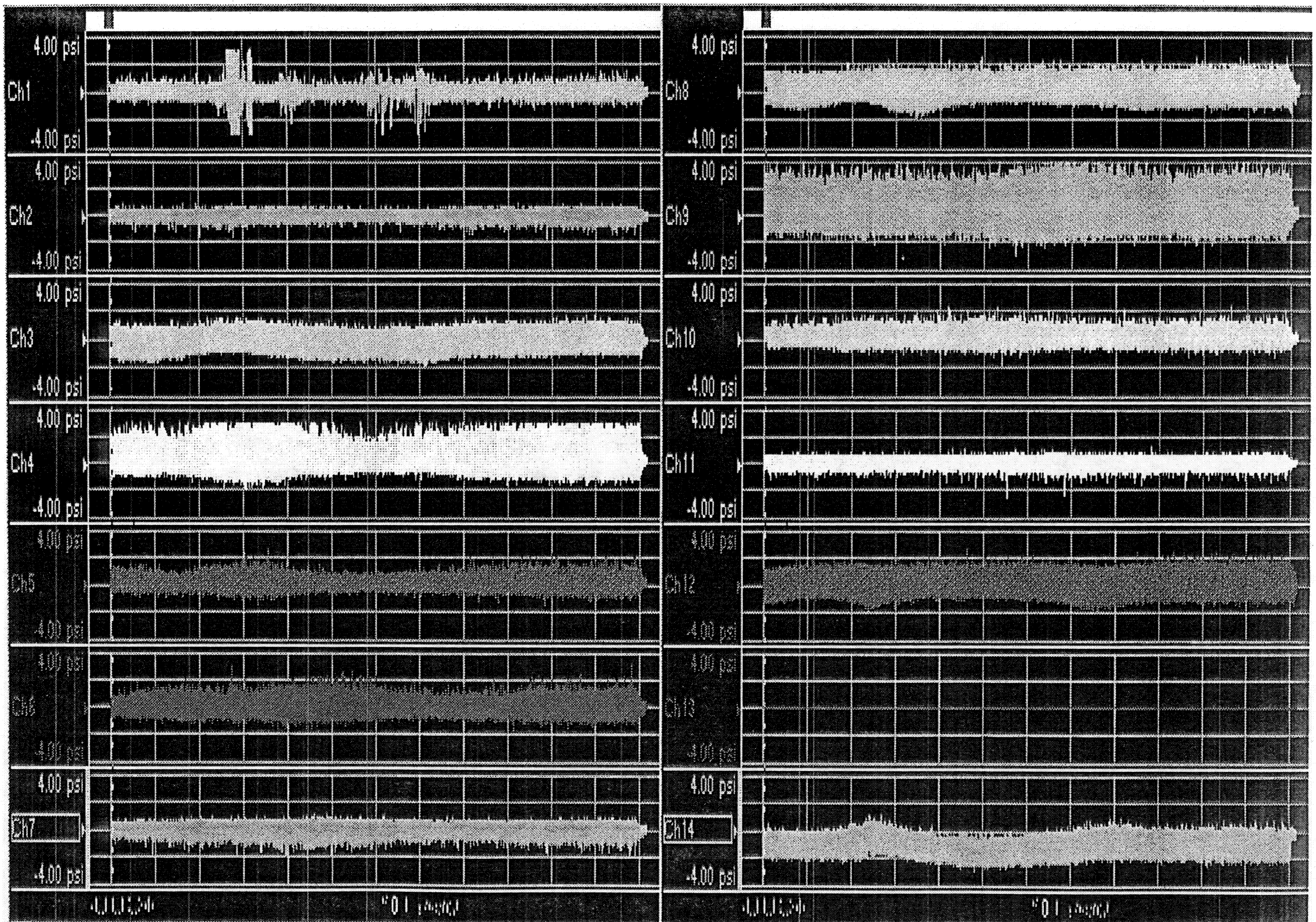


Figure 53: Recording 19 Time Records From Odyssey Screen Dump (Run #29)

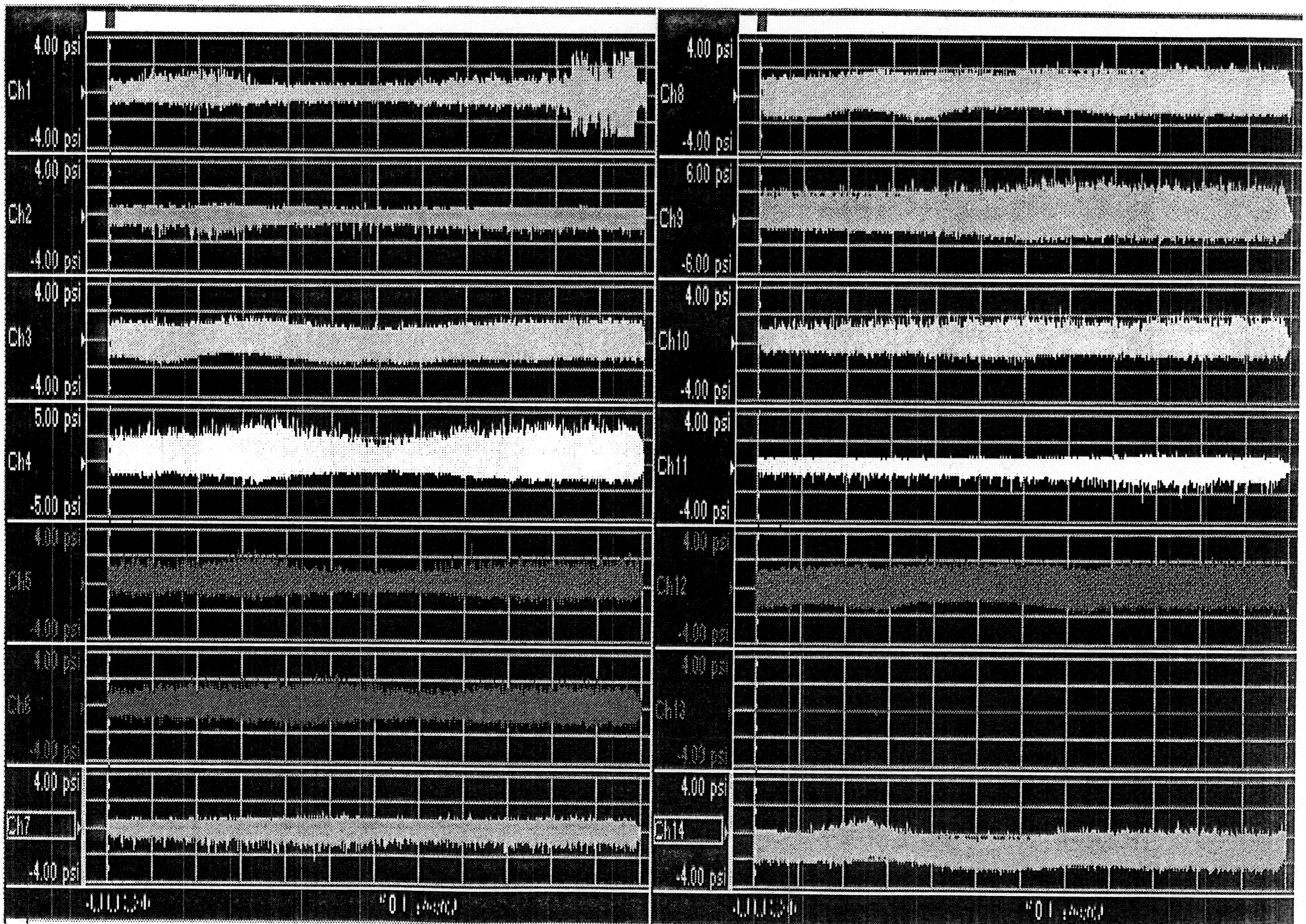


Figure 54: Recording 20 Time Records From Odyssey Screen Dump (Run #30)

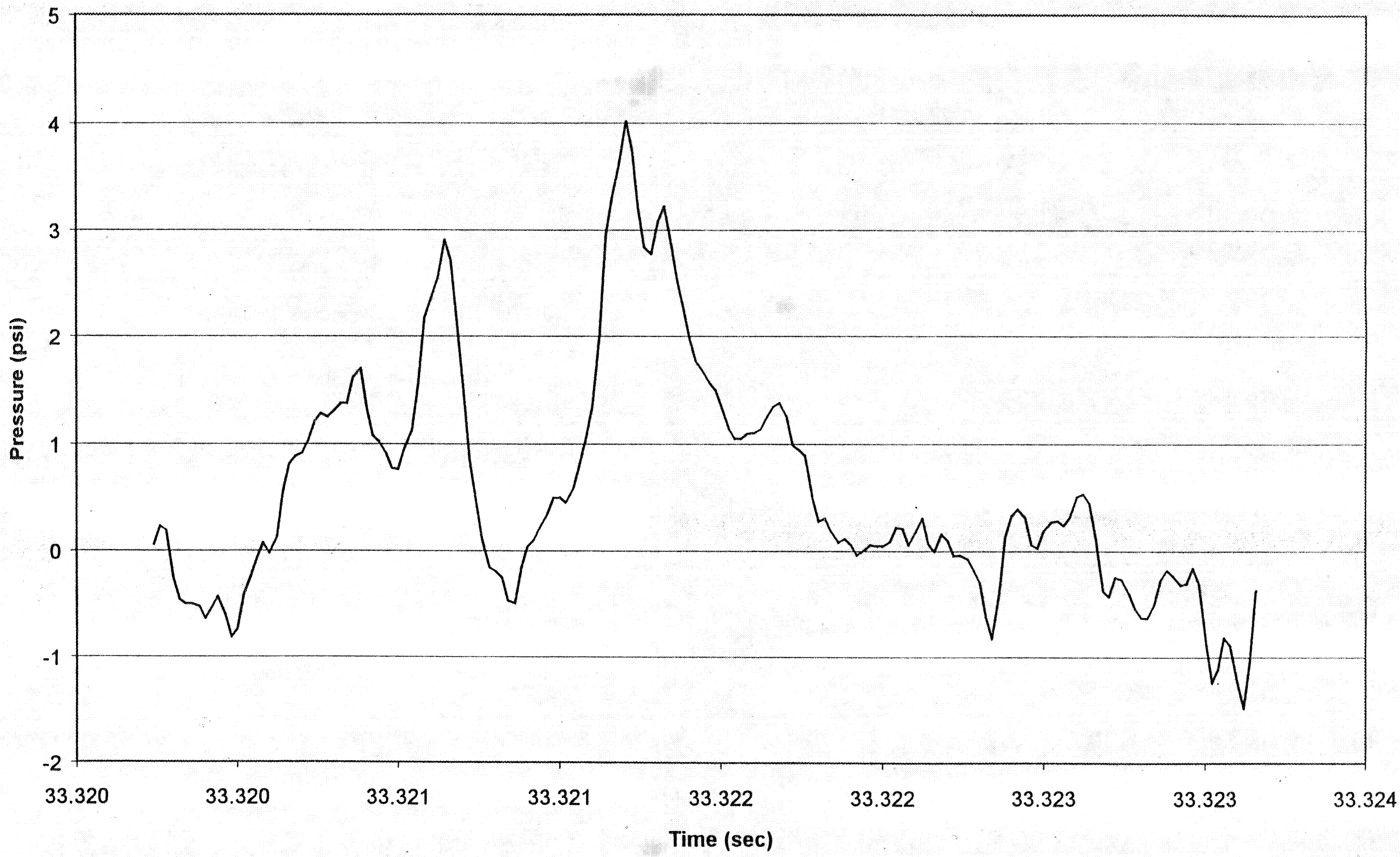


Figure 55: Expanded Time (Figure 54, Recording 20, Channel 9)