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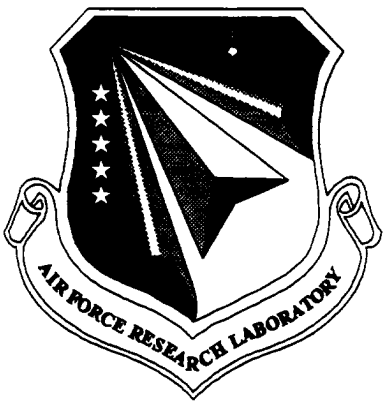

ANALYSIS OF LIMIT CYCLE OSCILLATION/TRANSONIC HIGH ALPHA FLOW VISUALIZATION

Part 3: Oscillating Model Data

Atlee M. Cunningham, Jr.
Lockheed Martin Tactical Aircraft Systems
Fort Worth TX

and

Evert G. M. Geurts
National Aerospace Laboratory (NLR)
Amsterdam, The Netherlands

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L. J. HUTTSELL
Project Engineer
Vibration & Aeroelasticity Branch

MIKE ZEIGLER
Core Area Leader
Structural Integrity of Aging Aircraft

BRADLEY J. BUXTON, CAPT, USAF
Acting Chief, Vibration & Aeroelasticity Branch
Structures Division

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ATLEE M. CUNNINGHAM, JR., EVERT G. M. GEURTS

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National Aerospace Laboratory (NLR), Amsterdam, The Netherlands

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A flow visualization test was conducted with the simple straked wing in August, 1996 (at the National Aerospace Laboratory [NLR], The Netherlands), for the purpose of obtaining flow visualization data to complement the pressure and force data base generated in earlier tests of the same configuration. This test was conducted in two parts to examine the flow field characteristics (1) at high alpha conditions that involve vortices, shocks, and separated flows, and (2) at low alpha conditions typical of transonic LCO flows with and without tip stores. Laser light sheet/water vapor techniques were used to illuminate the flows, and video recording was used to obtain the data. Both low and high speed video cameras were used to examine spanwise and streamwise laser sheet positions. In addition, under NLR funding, some preliminary particle image velocimetry (PIV) data were obtained at M= 0.225 and 0.6, as well as some pulsed laser flow visualization (9 nano-sec pulse) at M=0.9. Correlation was performed between the flow visualization data from this test and the pressure/force data obtained in 1992 on the same configuration. This report contains the flow visualization results for the oscillating model.

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FOREWORD

This report summarizes the results of an investigation into transonic unsteady aerodynamics. Transonic wind tunnel tests were conducted for a semispan straked delta wing model with and without tip stores. Laser light sheet and water vapor were used to obtain flow visualization data to complement force and pressure data obtained in a previous test with the same model.

This test was conducted under a cooperative program of research between the Lockheed Martin Tactical Aircraft Systems (LMTAS), Fort Worth, Texas, USA and the National Aerospace Laboratory (NLR), Amsterdam, The Netherlands. The test was conducted in August, 1996 at NLR. The model and support system were designed and fabricated at NLR under an earlier subcontract during 1989 to 1993 from LMTAS (previously the Fort Worth Division of General Dynamics) that was funded under Air Force Contract F33657-84-C-0247 (CCP4551) for the Aeronautical Systems Center, Wright Patterson Air Force Base, Ohio. Additional funding was also provided for this earlier effort by NLR and the Dutch Ministry of Defense. The August, 1996 flow visualization test preparation, wind tunnel test, and reporting were performed at NLR under a follow-on subcontract from LMTAS. This work was conducted under Air Force Contract F49620-94-C-0093, Air Force Office of Scientific Research, Bolling Air Force Base, DC and administered by Dr. Leonidas Sakell, AFOSR/NA. Funding was provided by the Wright Laboratory Flight Dynamics Directorate, Wright Patterson Air Force Base, Ohio and administered by Mr. L. J. Huttsell (AFRL/VASV). Additional funding was provided by NLR. With funding provided by the Dutch Ministry of Defense, the test was extended with additional measurements on the tip launcher and tip missile configurations. This funding was monitored by Mr. C. Hoffman and Mr. E. Bos of The Netherlands Agency for Aerospace Programes (NIVR-Contract: 07501N).

The Program Manager was Dr. A. M. Cunningham, Jr. at LMTAS. The principal investigators were Dr. Cunningham at LMTAS, Mr. E. G. M. Geurts at NLR, and Mr. R. G. den Boer (during the early part of the program) also at NLR. Assistance was provided by the following NLR specialists, C.D.G. Dogger, A. J. Persoon, and R. J. Zwaan.

This test is documented in three parts. Part 1(AFRL-VA-WP-TR-1998-3003) presents background, test setup, and data base descriptions. A detailed discussion of results is also given with continuous references to the data presented in Parts 2 and 3, AFRL-VA-WP-TR-1998-3004 and AFRL-VA-WP-TR-1998-3005. Part 2 includes a large selection of flow visualization video frames and accompanying pressure data for the model stationary at varying Mach and incidence. This report (Part 3) is similar to Part 2, but is for the model oscillating in pitch at both small and large amplitudes also for varying Mach and incidence. The three parts are listed below:

1. "Analysis of Limit Cycle Oscillation/Transonic High Alpha Flow Visualization, Part 1: Discussion", AFRL-VA-WP-TR-1998-3003.
2. "Analysis of Limit Cycle Oscillation/Transonic High Alpha Flow Visualization, Part 2: Stationary Model Data", AFRL-VA-WP-TR-1998-3004.
3. "Analysis of Limit Cycle Oscillation/Transonic High Alpha Flow Visualization, Part 3: Oscillating Model Data", AFRL-VA-WP-TR-1998-3005.

1.0 HIGH SPEED VIDEO FLOW VISUALIZATION AND PRESSURE DATA FOR THE CLEAN WING AT M = 0.6, OSCILLATING BETWEEN 9 DEG AND 35 DEG

Individual frames from the high speed video data base (243 frames per second) on tape are presented in this section for the spanwise sheet position 9 as shown in Figure 1, below. The flow visualization data were obtained at 64 frames per cycle with the model oscillating at 4.0 Hz in pitch between the angles of 9 deg and 35 deg and were recorded only on VHS tape. The corresponding pressure data (Reference 1) were obtained with the model performing single pulse (1- cos) motions between 7 deg and 37 deg and back to 7 deg. Both pressure and flow visualization data are shown in Figures 2.01 through 2.66 in a side-by-side format in order to permit direct correlation on the basis of motion phase angle and approximate correlation on the basis of angle.

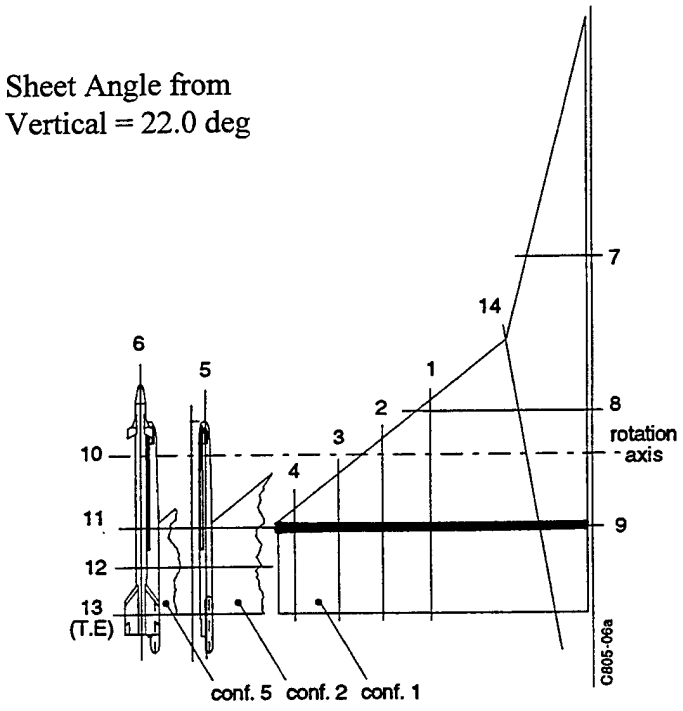


Figure 1 - Flow Visualization Sheet Location for Figures 2, Clean Wing, M = 0.6, Oscillating Between 9 deg and 35 deg

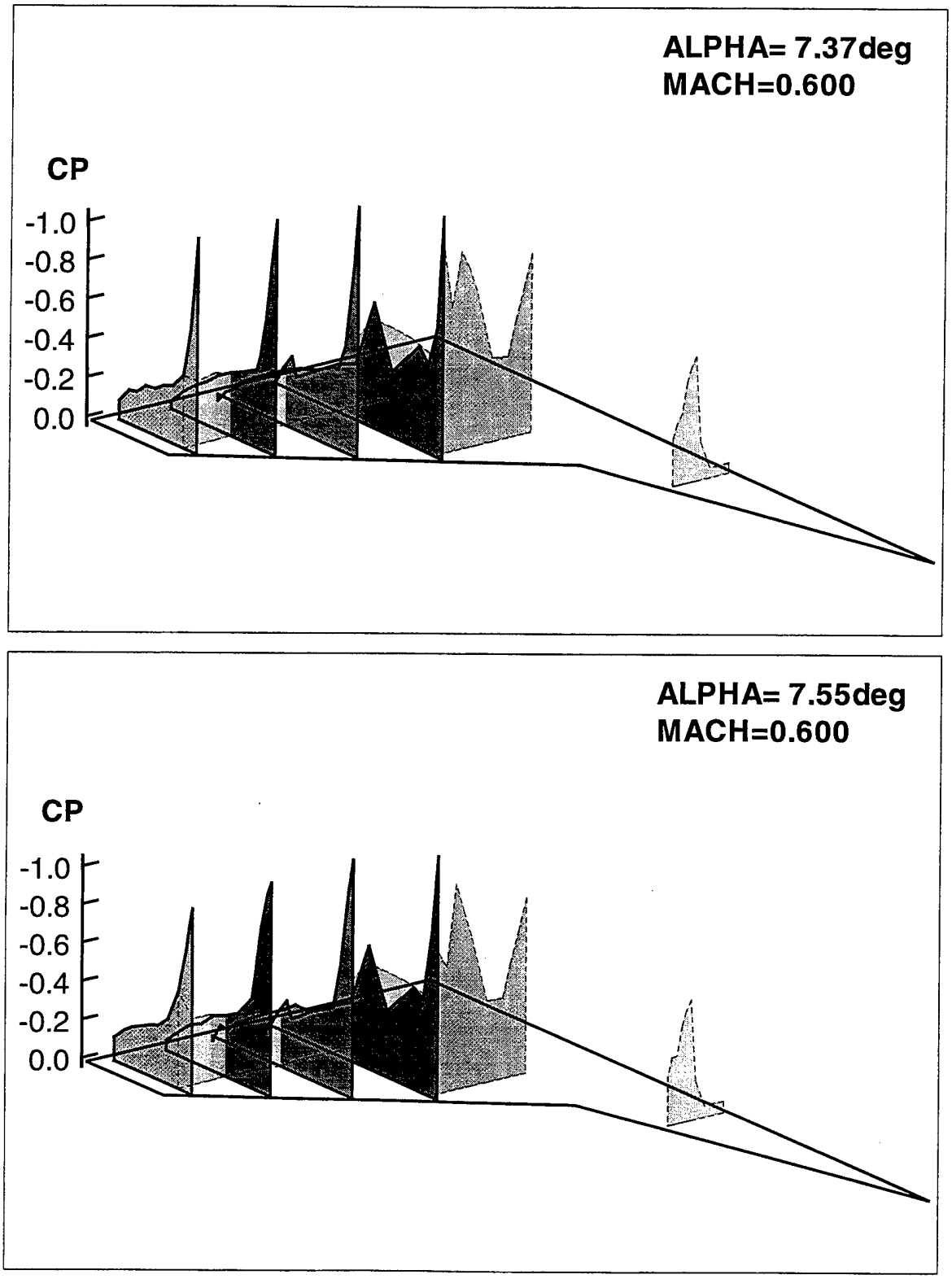
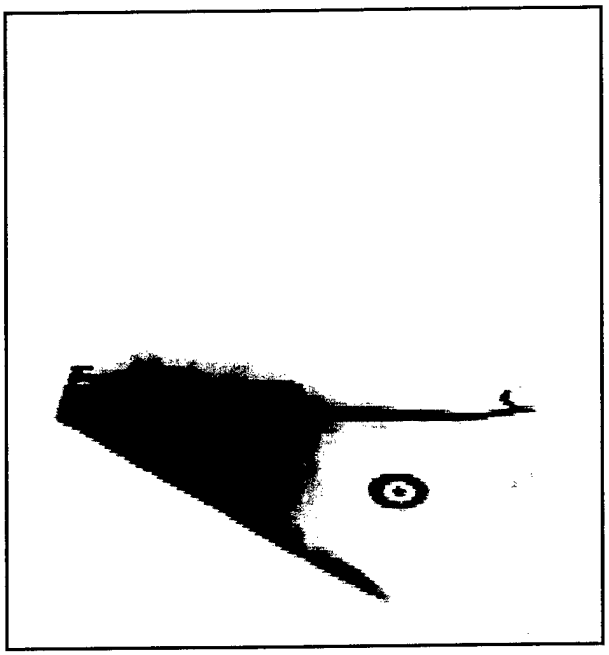
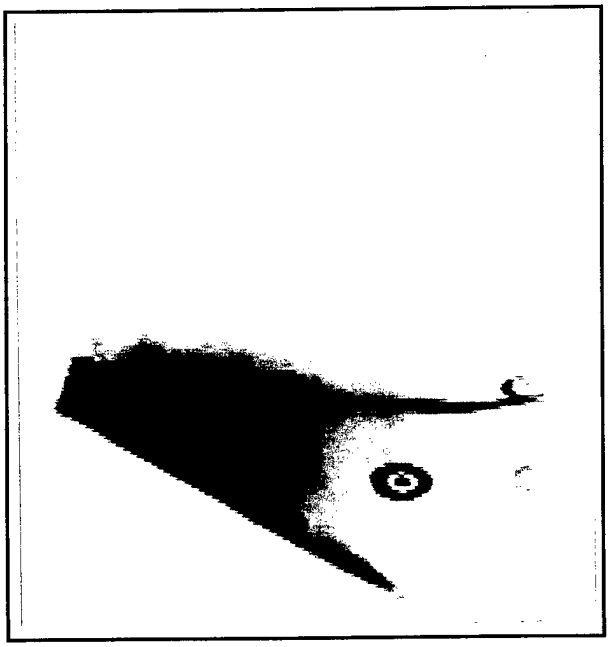


Figure 2.01 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 0.00 deg and 5.62 deg

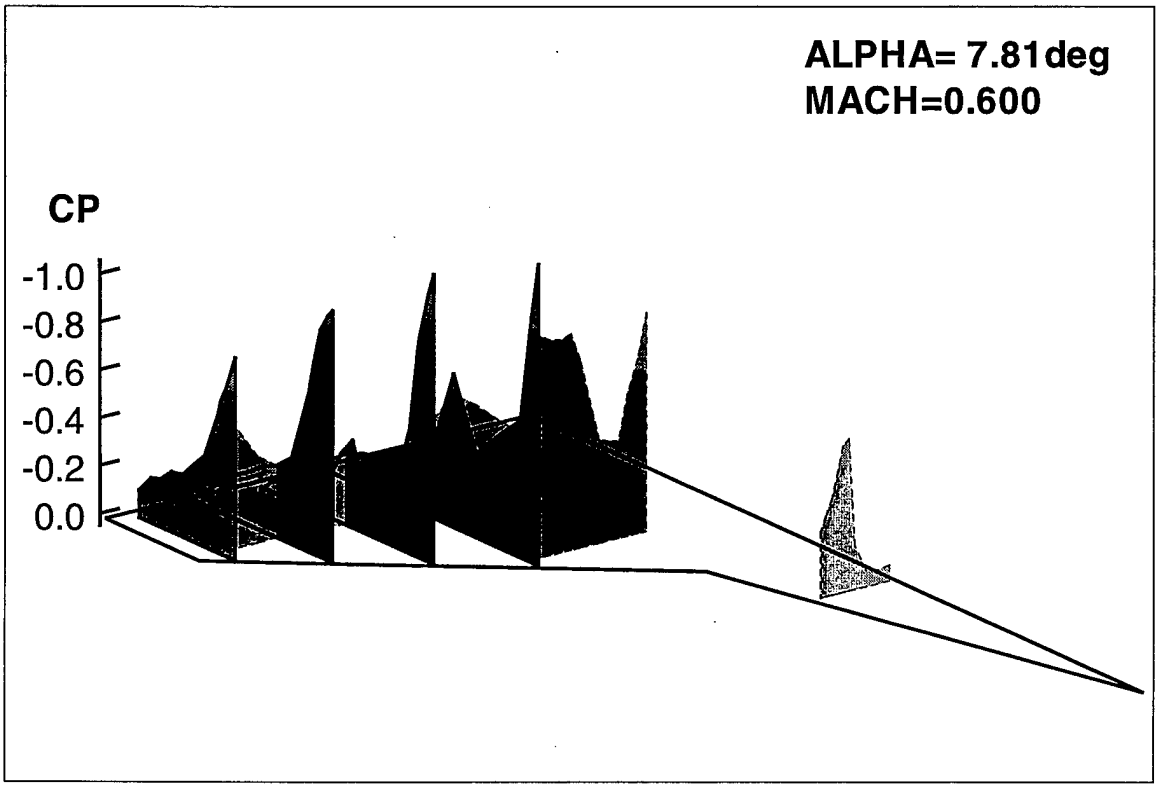


Sheet Position 9, Alpha = 9.01 deg
(Run ID = 77, Frame = 111)



Sheet Position 9, Alpha = 9.07 deg
(Run ID = 77, Frame = 112)

Figure 2.02 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 0.0 Deg and 5.63 Deg



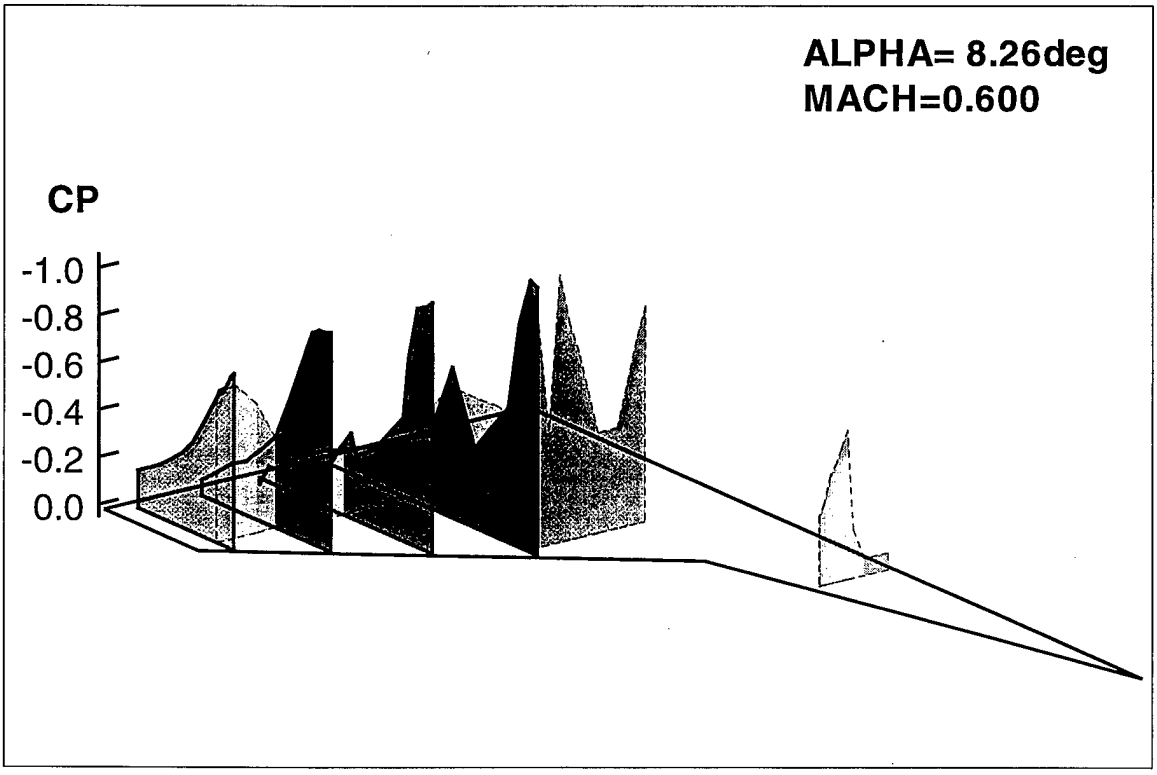
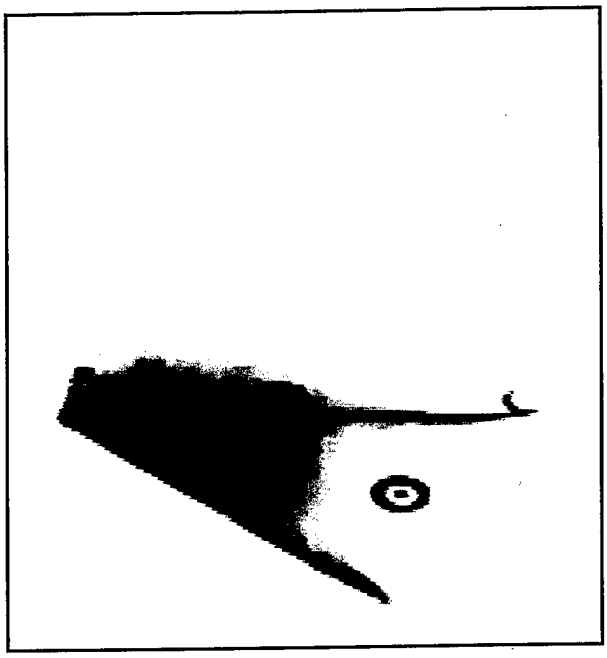


Figure 2.03 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 11.25 deg and 16.88 deg



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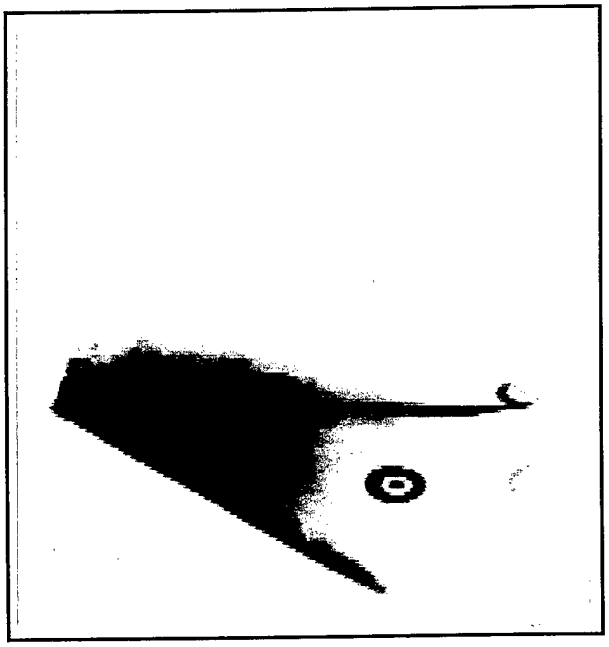
(Run ID = 77, Frame = 113)



Sheet Position 9, Alpha = 9.57 deg
(Run ID = 77, Frame = 114)

Figure 2.04 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 11.25 Deg and 16.88 Deg

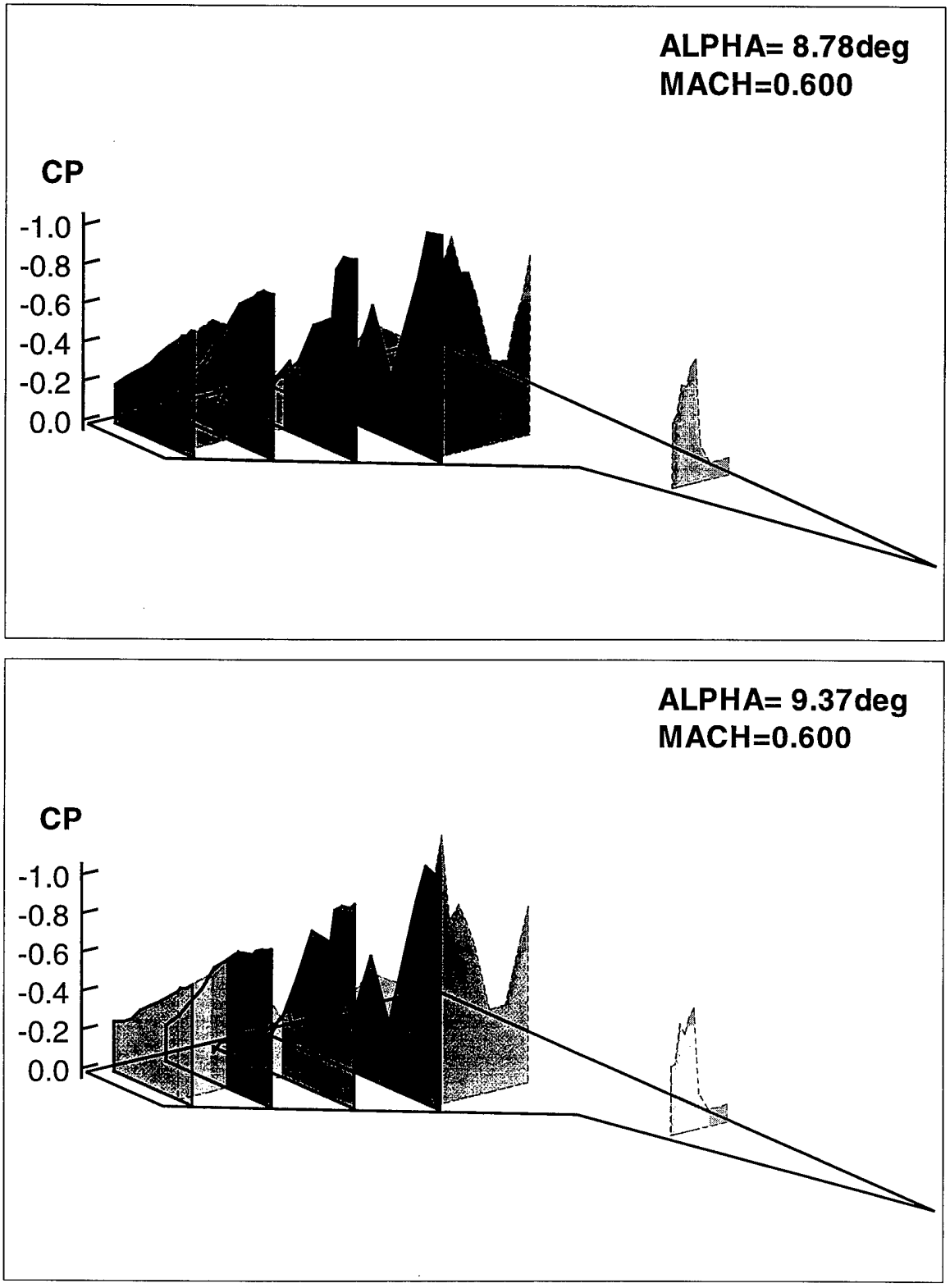
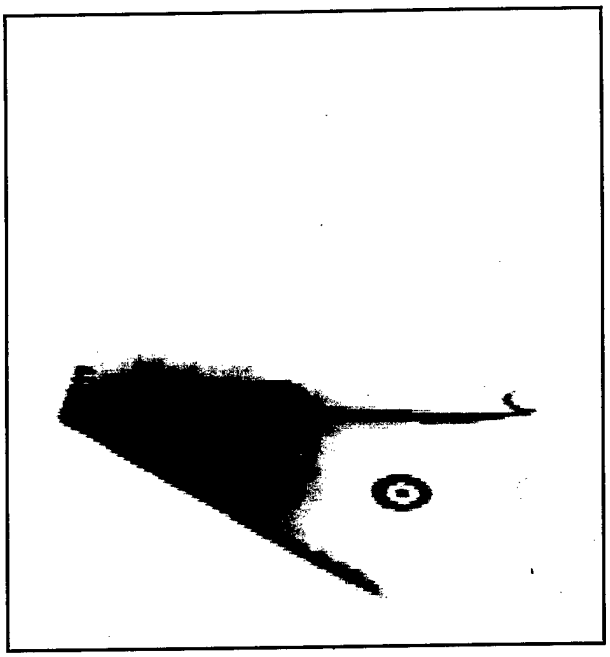


Figure 2.05 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 22.50 deg and 28.12 deg



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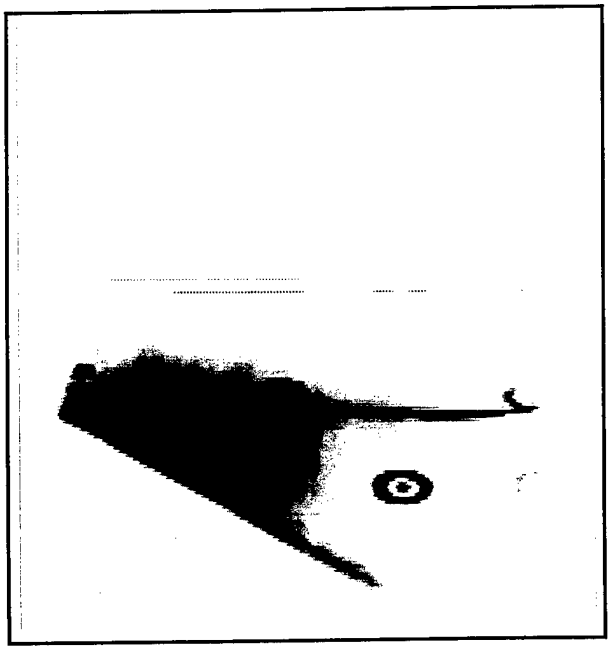


Sheet Position 9, Alpha = 10.54 deg
(Run ID = 77, Frame = 116)

Figure 2.06 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 22.50 Deg and 28.13 Deg

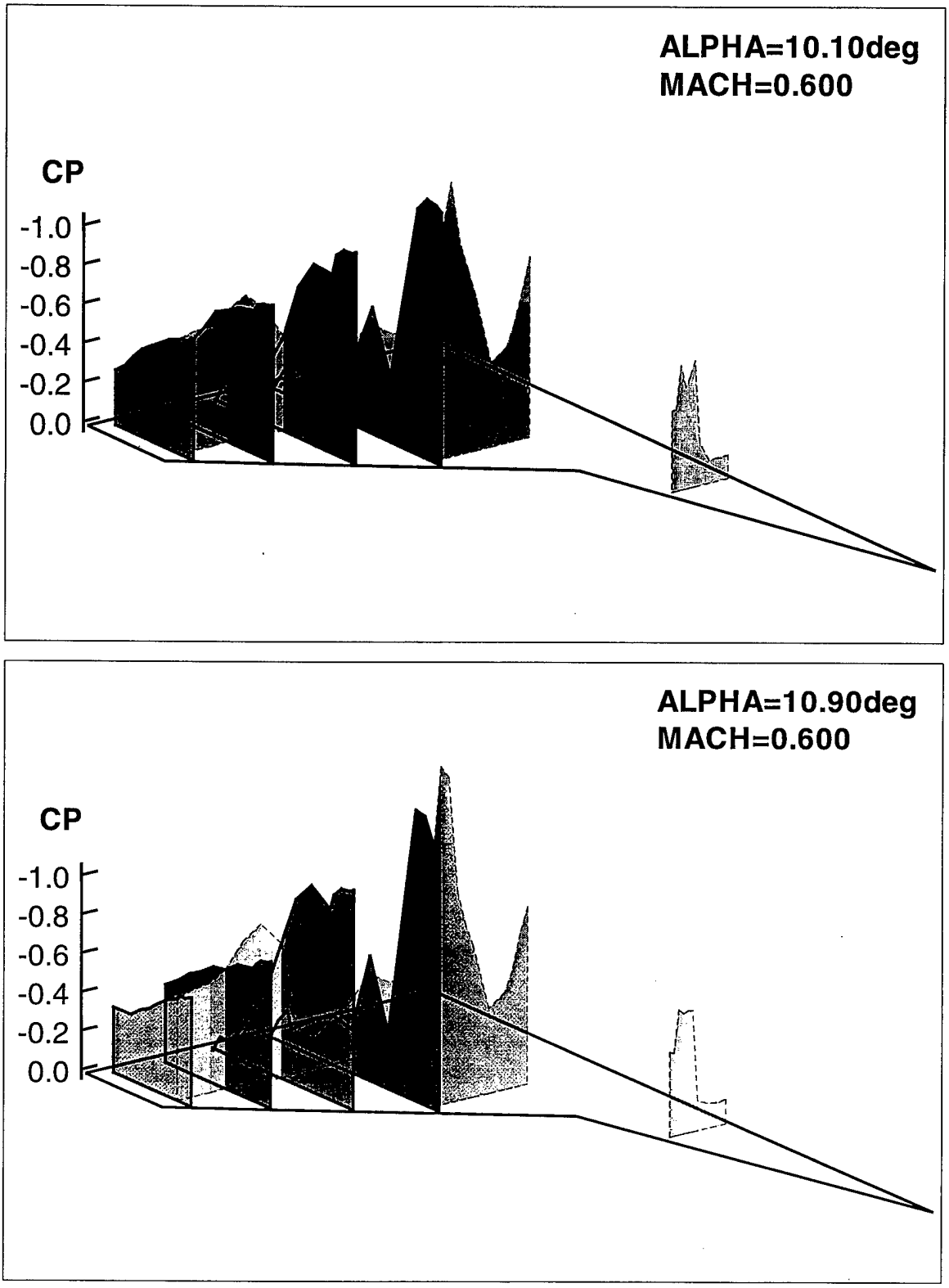
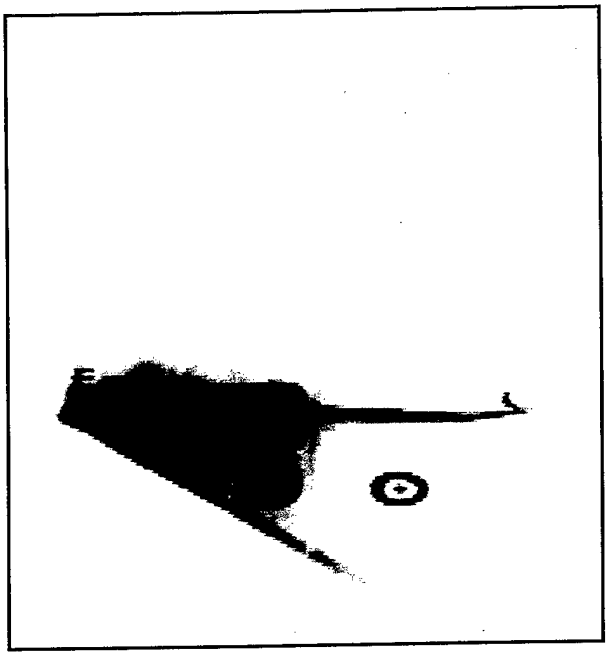


Figure 2.07 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 33.75 deg and 39.38 deg



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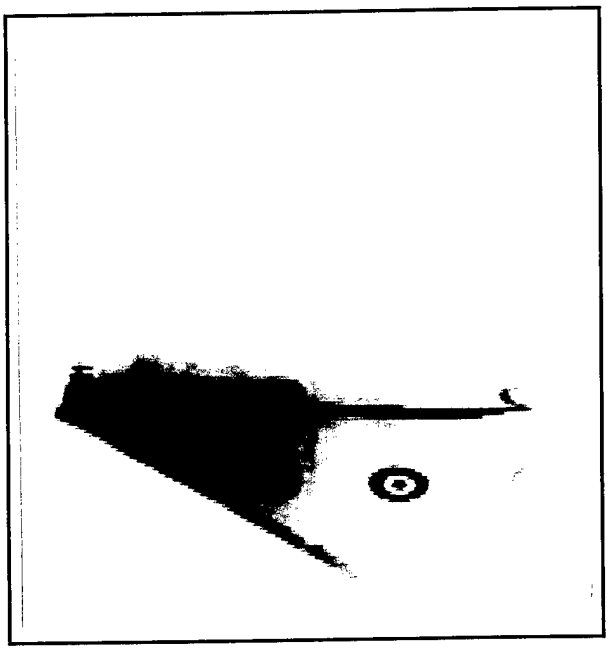


Sheet Position 9, Alpha = 11.96 deg
(Run ID = 77, Frame = 118)

Figure 2.08 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 33.75 Deg and 39.30 Deg

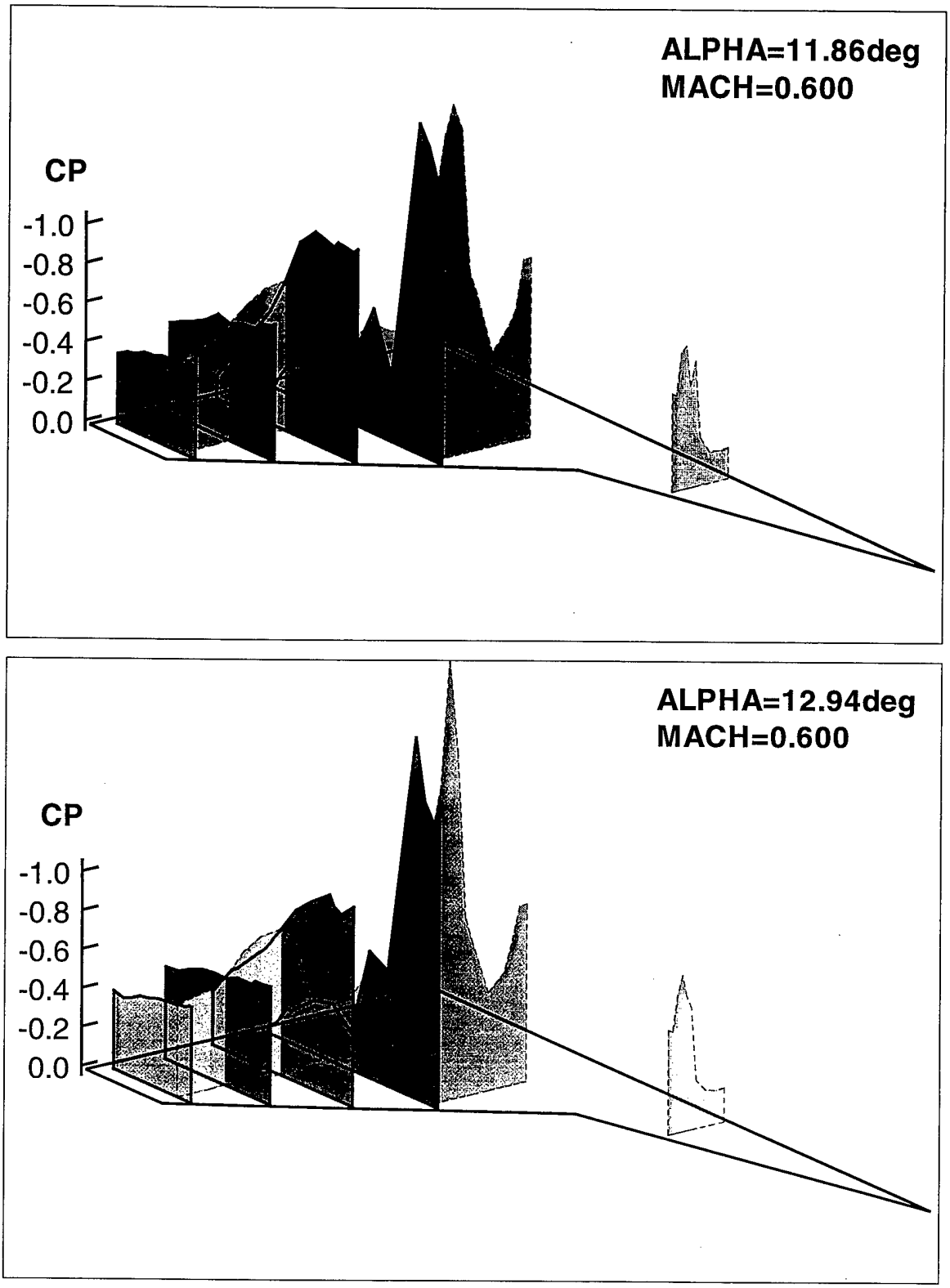
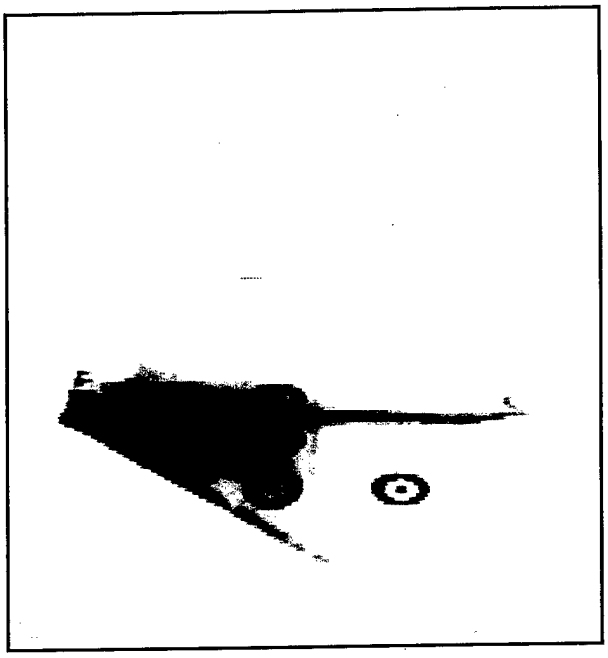


Figure 2.09 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 45.00 deg and 50.62 deg



Sheet Position 9, Alpha = 12.81 deg
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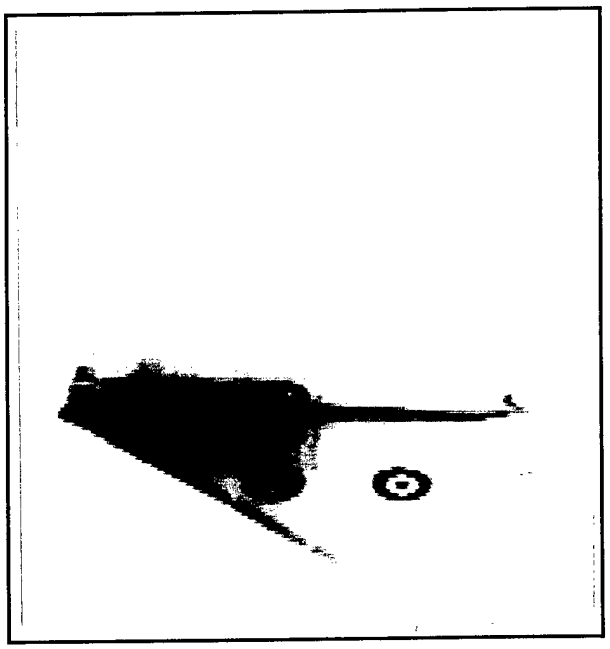


Sheet Position 9, Alpha = 13.76 deg
(Run ID = 77, Frame = 120)

Figure 2.10 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 45.00 Deg and 50.62 Deg

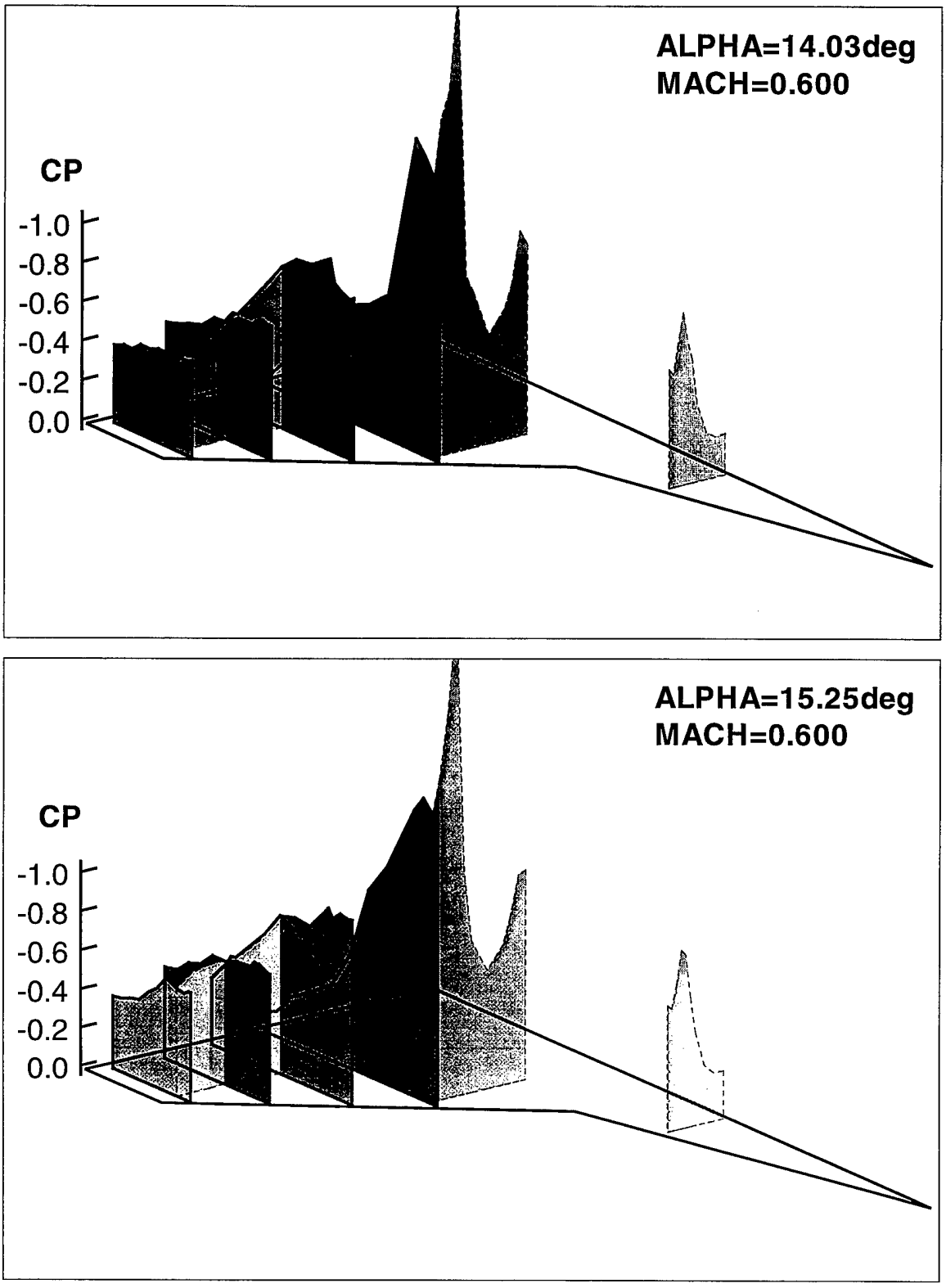
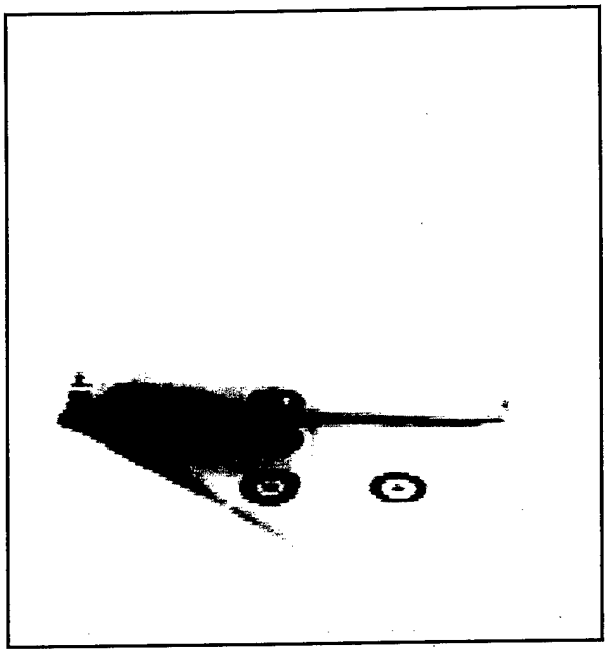
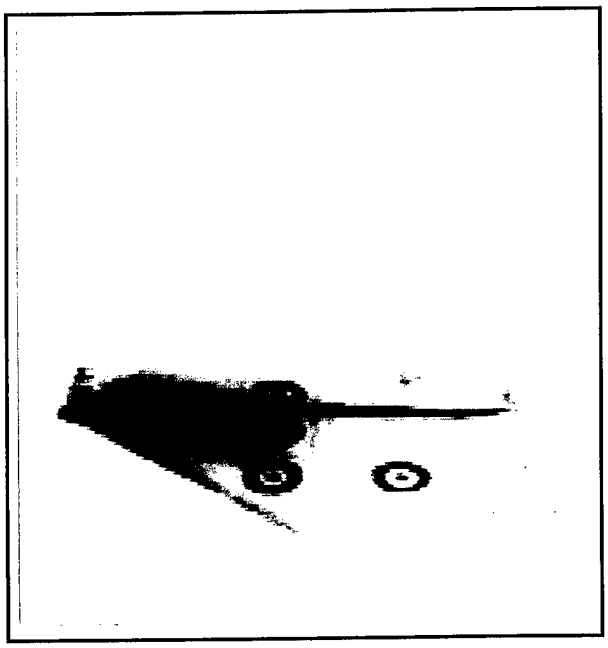


Figure 2.11 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 56.25 deg and 61.88 deg



Sheet Position 9, Alpha = 14.78 deg
(Run ID = 77, Frame =121)



Sheet Position 9, Alpha = 15.87 deg
(Run ID = 77, Frame = 122)

Figure 2.12 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 56.25 Deg and 61.88 Deg

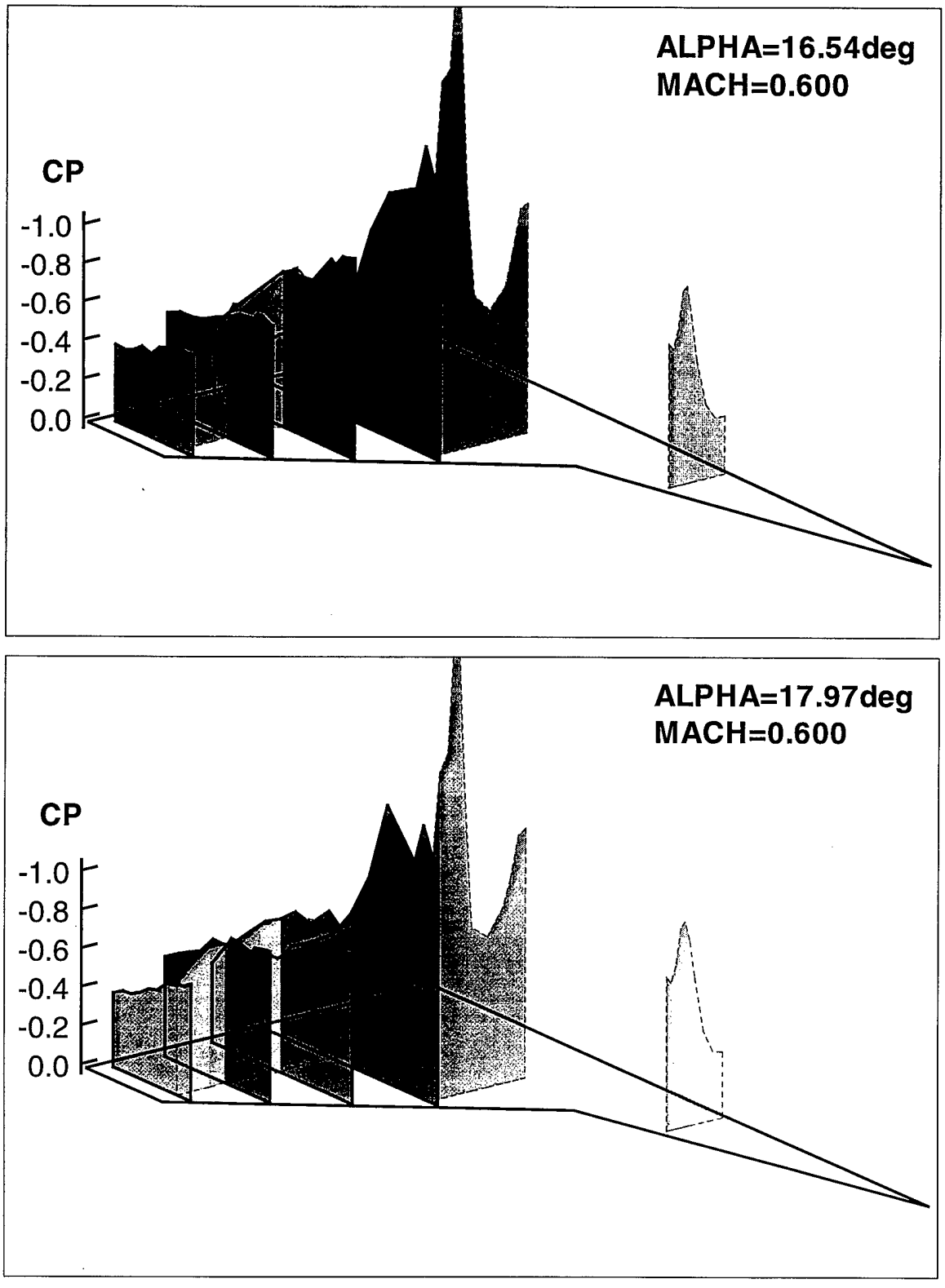
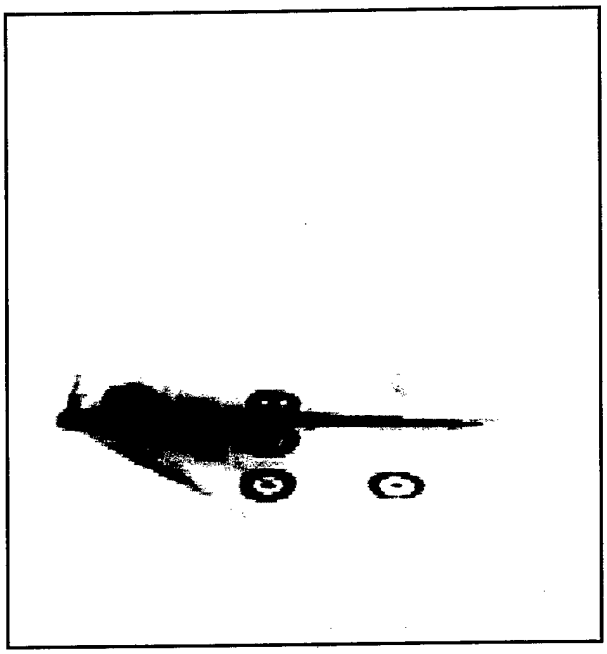


Figure 2.13 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 67.50 deg and 73.12 deg



Sheet Position 9, Alpha = 17.02 deg
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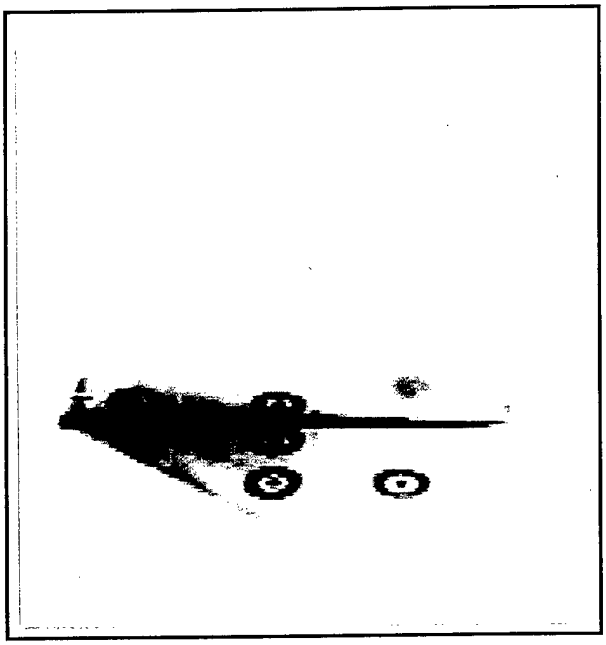


Sheet Position 9, Alpha = 18.22 deg
(Run ID = 77, Frame = 124)

Figure 2.14 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 67.50 Deg and 73.12 Deg

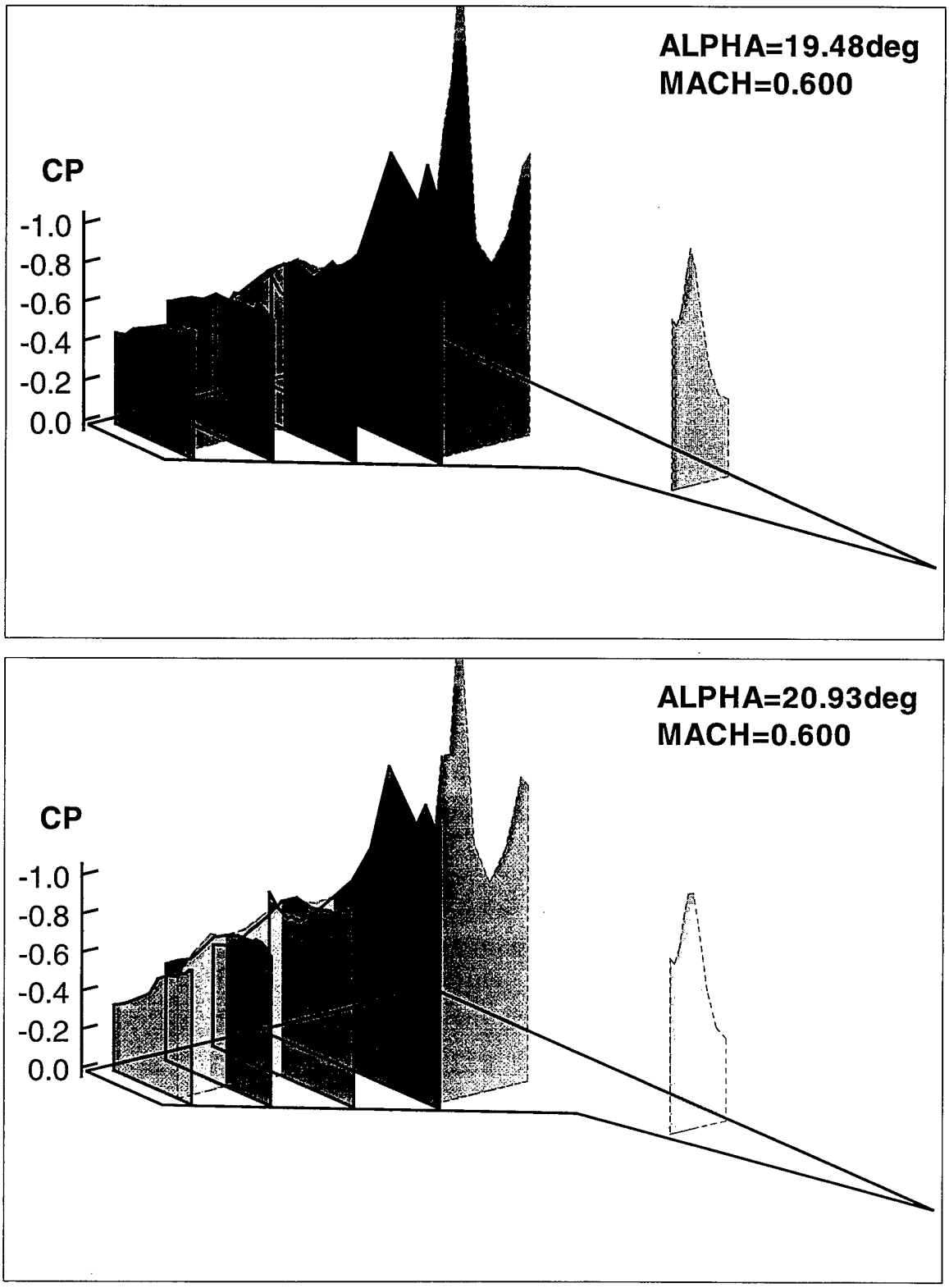
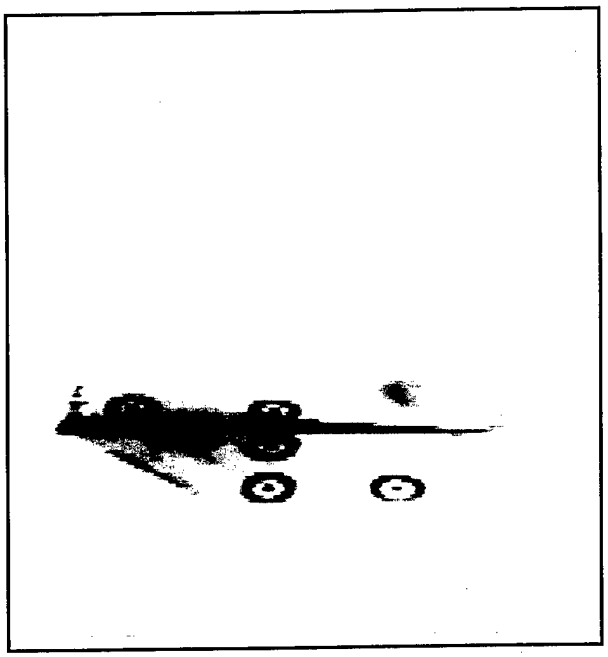
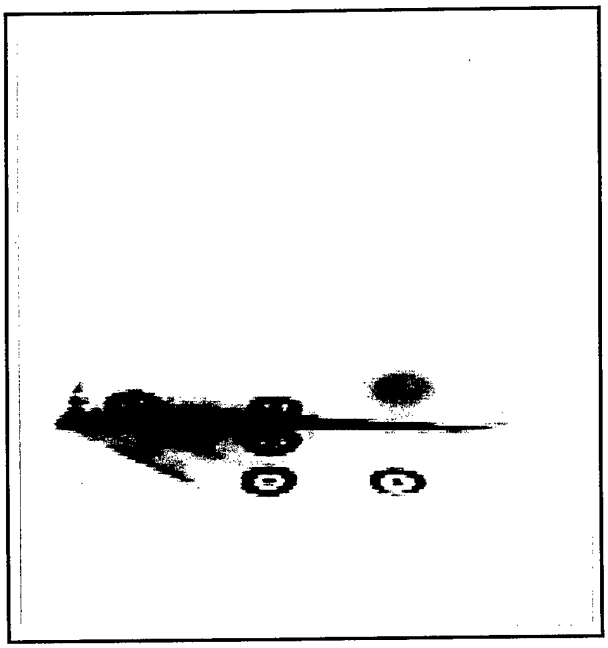


Figure 2.15 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 78.75 deg and 84.38 deg



Sheet Position 9, Alpha = 19.46 deg
(Run ID = 77, Frame = 125)



Sheet Position 9, Alpha = 20.72 deg
(Run ID = 77, Frame = 126)

Figure 2.16 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 78.75 Deg and 84.38 Deg

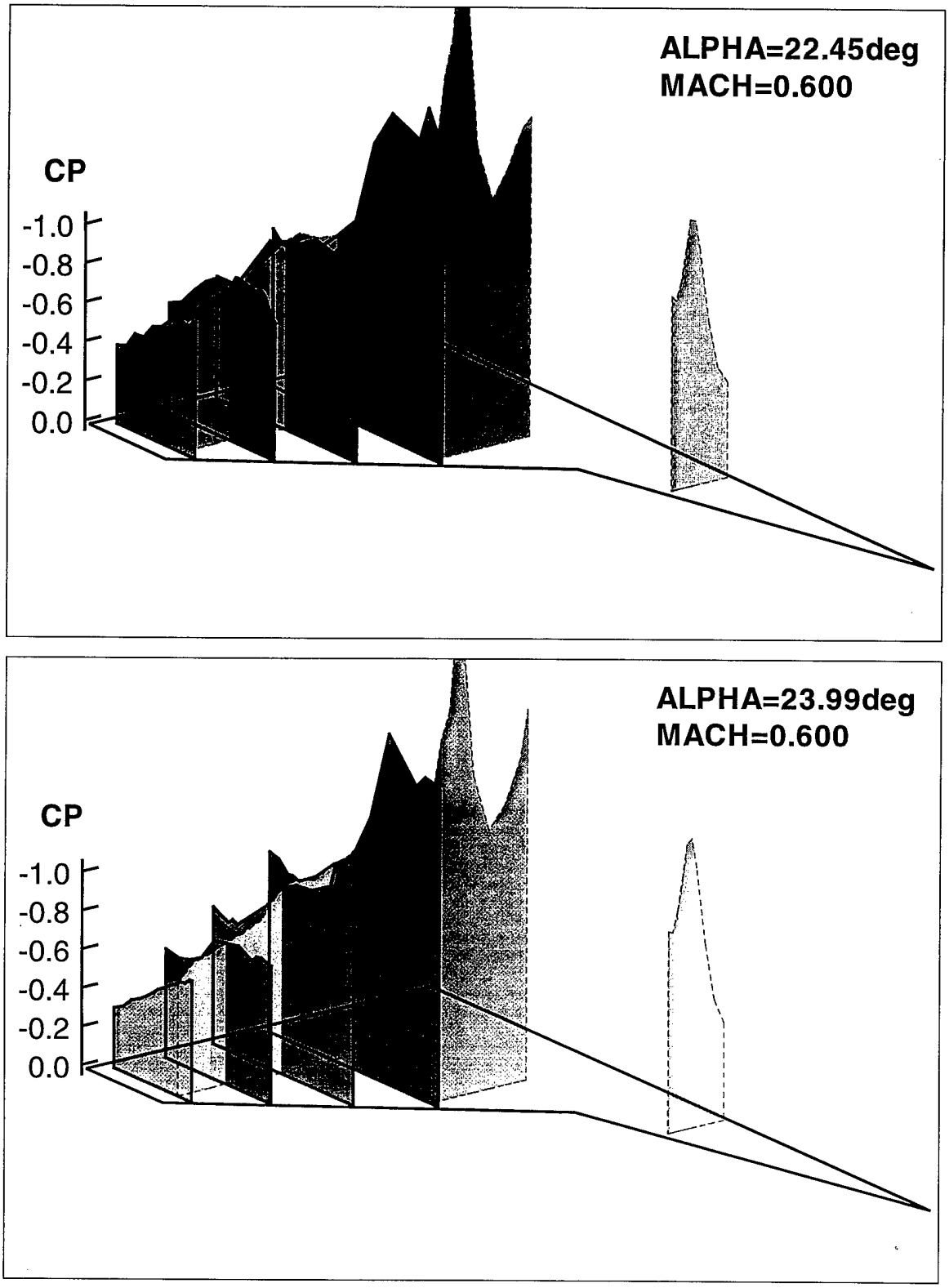
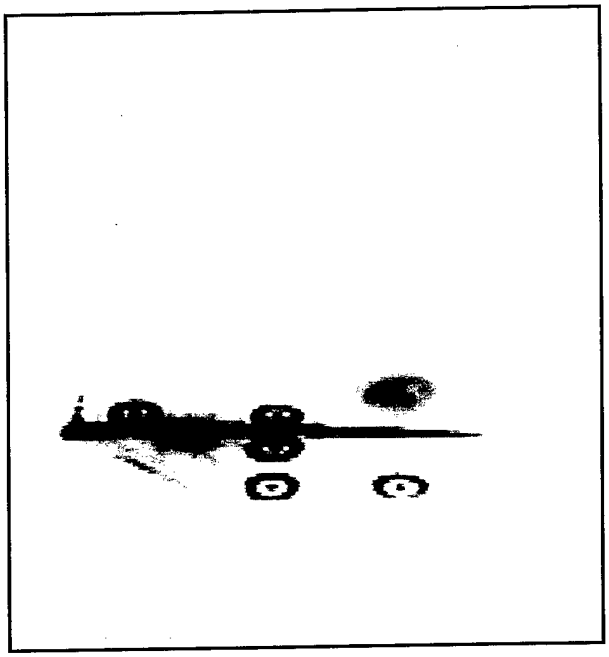
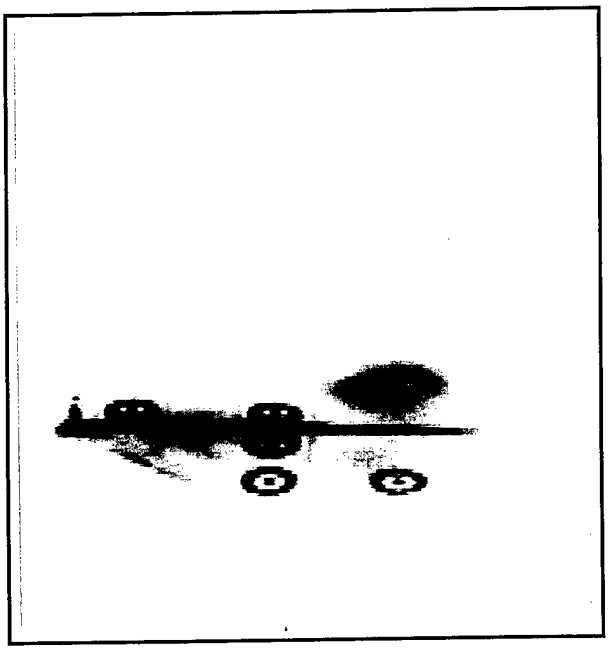


Figure 2.17 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 90.00 deg and 95.62 deg



Sheet Position 9, Alpha = 21.99 deg
(Run ID = 77, Frame = 127)



Sheet Position 9, Alpha = 23.26 deg
(Run ID = 77, Frame = 128)

Figure 2.18 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 90.00 Deg and 95.62 Deg

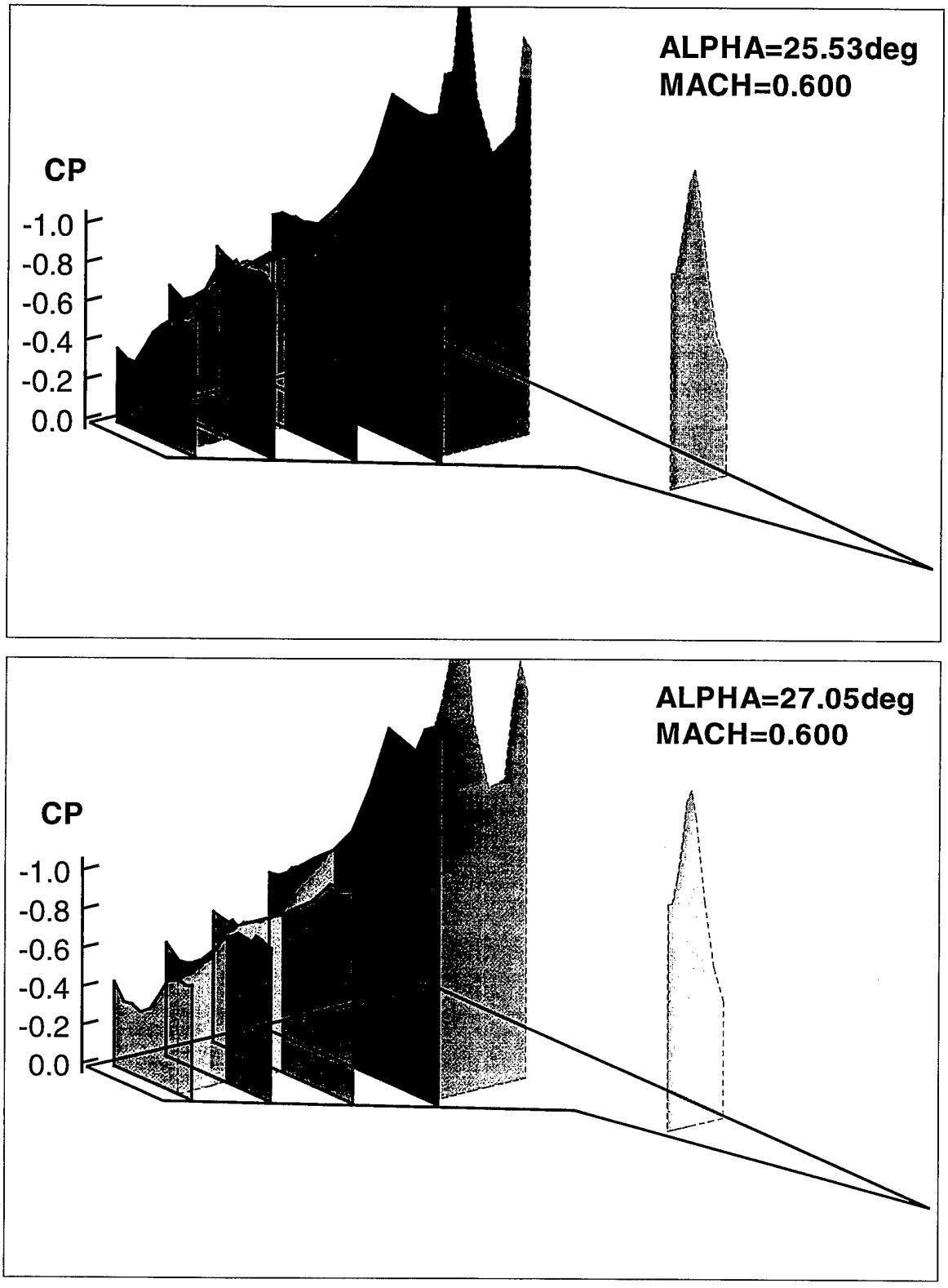
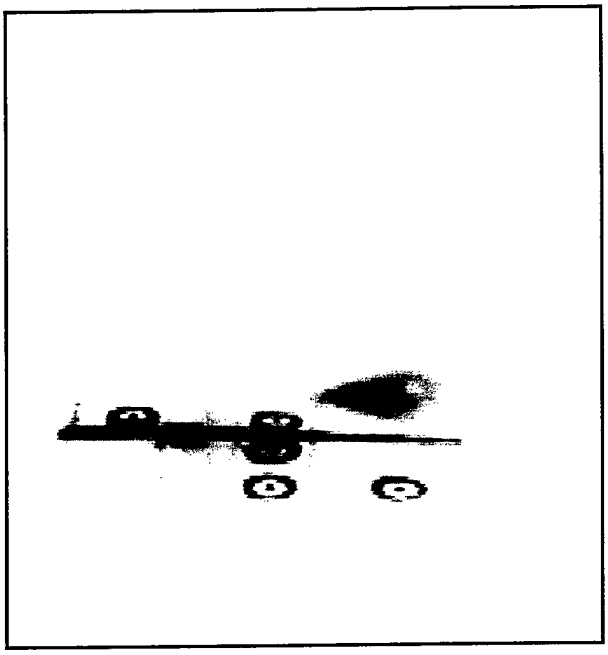
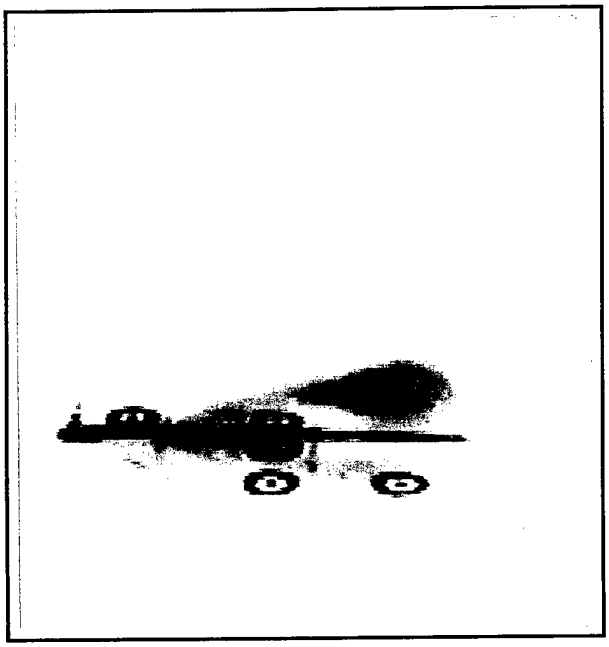


Figure 2.19 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 101.25 deg and 106.88 deg



Sheet Position 9, Alpha = 24.52 deg
(Run ID = 77, Frame = 129)



Sheet Position 9, Alpha = 25.67 deg
(Run ID = 77, Frame = 130)

Figure 2.20 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 101.25 Deg and 106.33 deg

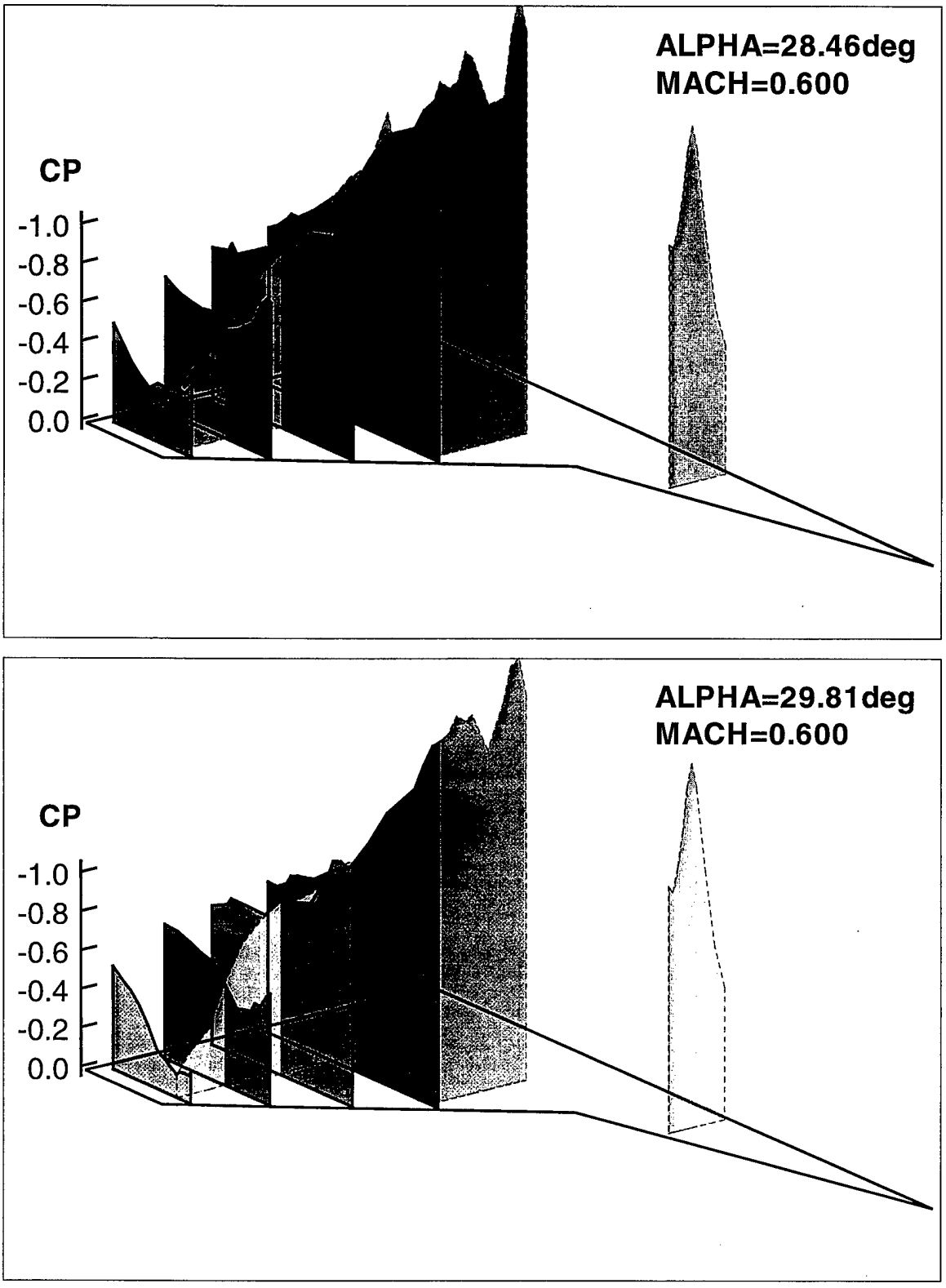
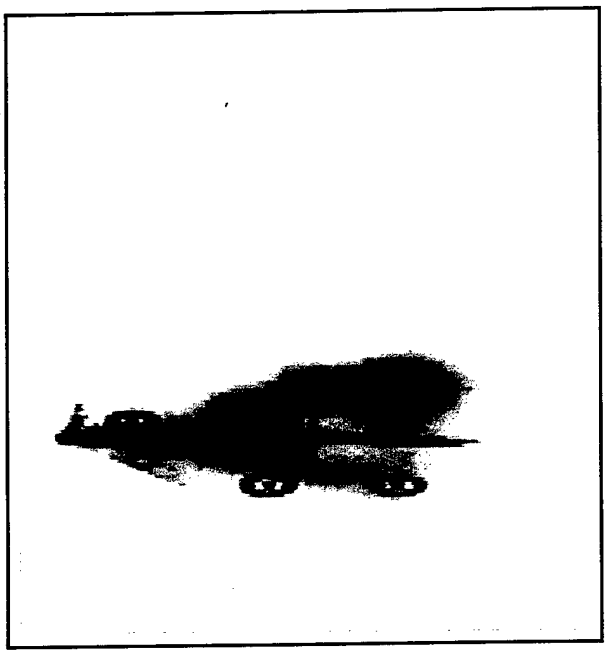
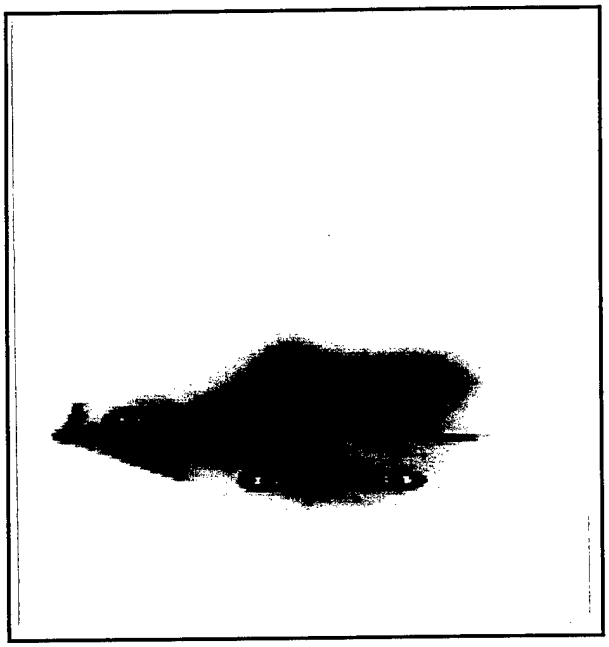


Figure 2.21 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 112.50 deg and 118.12 deg



Sheet Position 9, Alpha = 26.96 deg
(Run ID = 77, Frame = 131)



Sheet Position 9, Alpha = 28.11 deg
(Run ID = 77, Frame = 132)

Figure 2.22 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 112.50 Deg and 118.12 deg

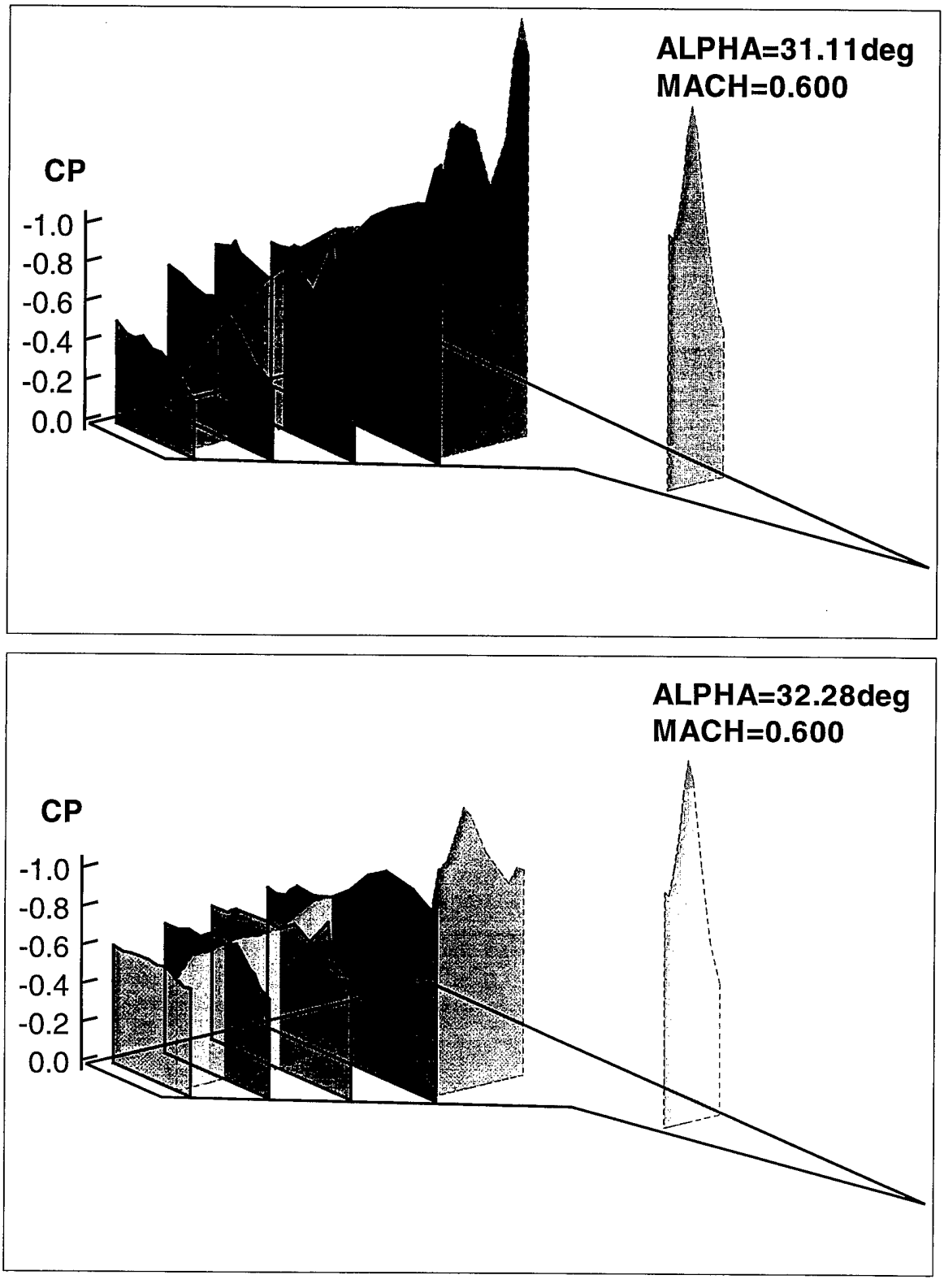
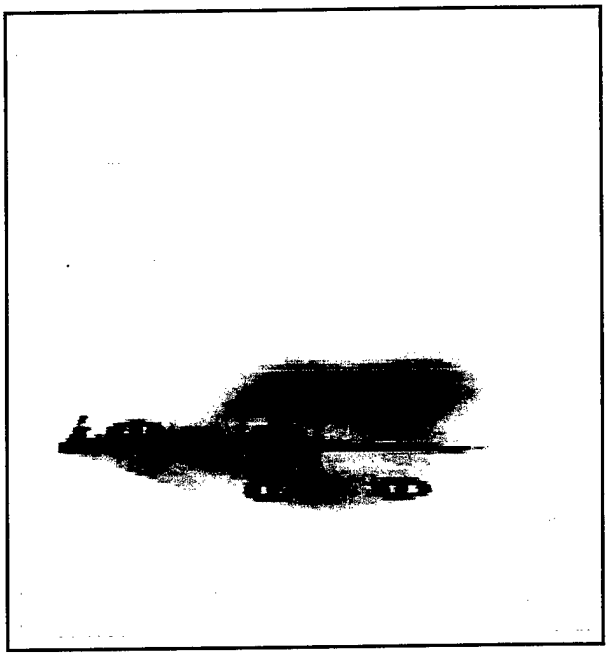
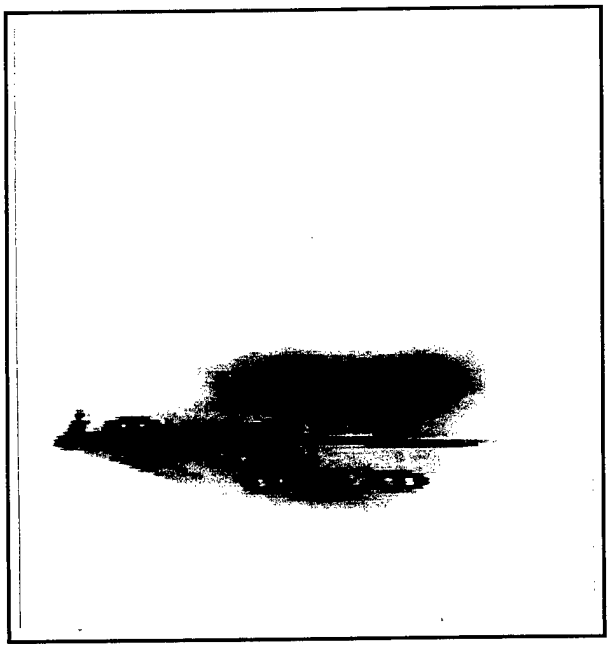


Figure 2.23 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 123.75 deg and 129.38 deg



Sheet Position 9, Alpha = 29.20 deg
(Run ID = 77, Frame = 133)



Sheet Position 9, Alpha = 30.22 deg
(Run ID = 77, Frame = 134)

Figure 2.24 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 123.75 Deg and 129.38 deg

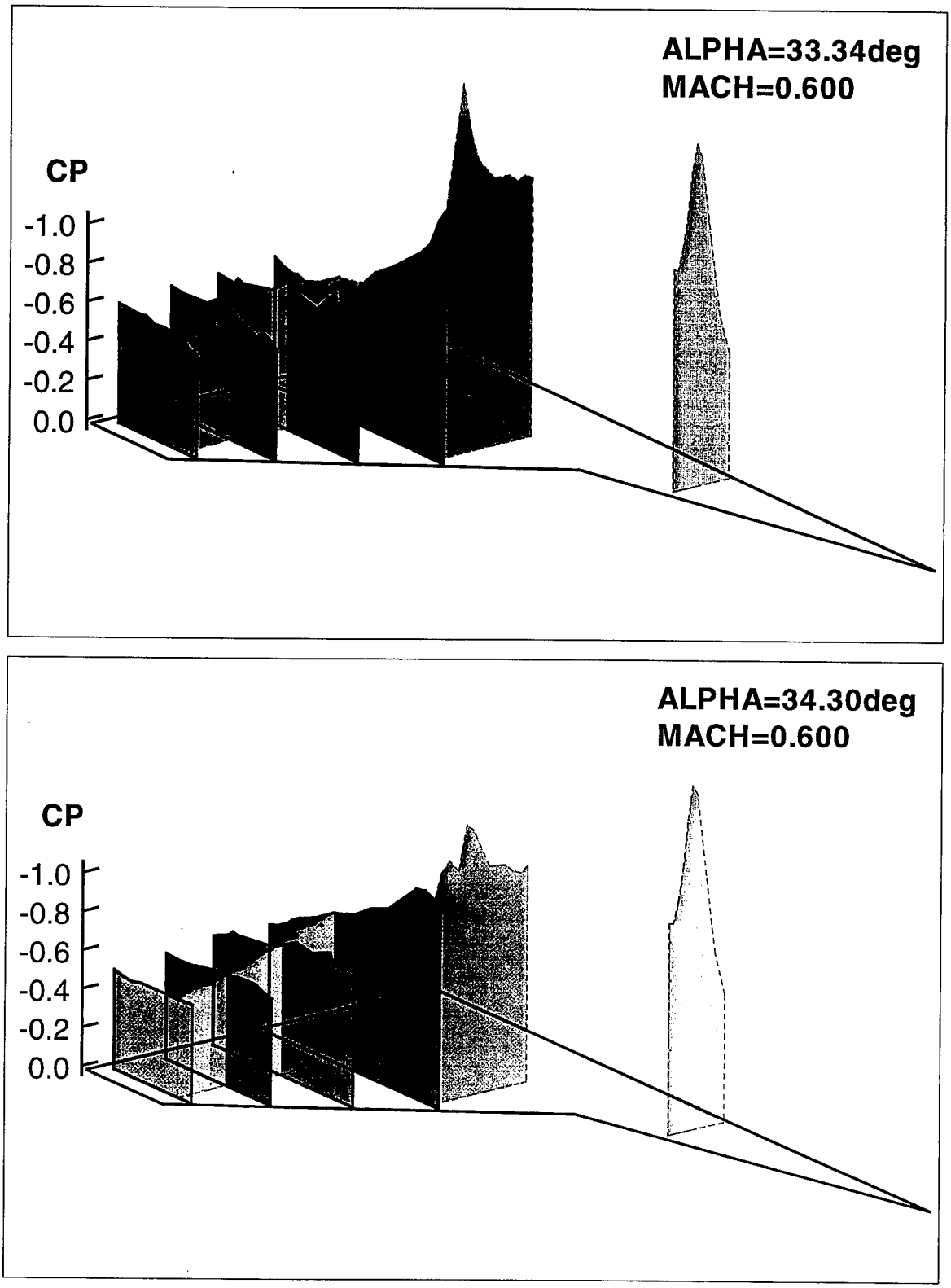
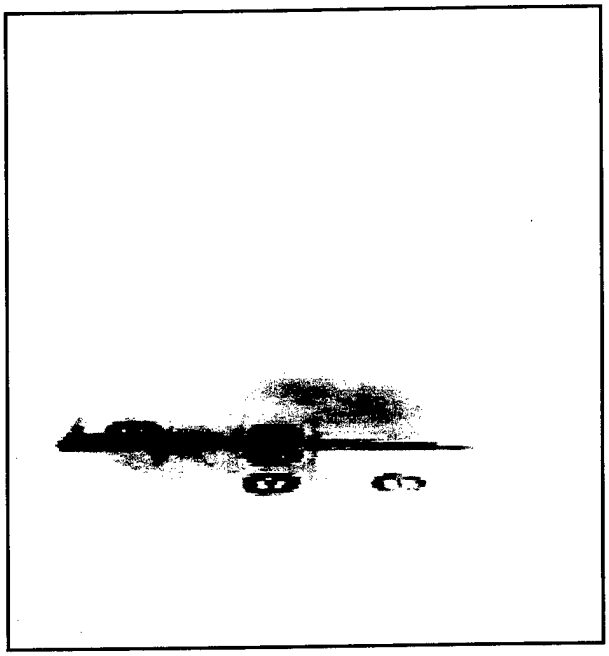
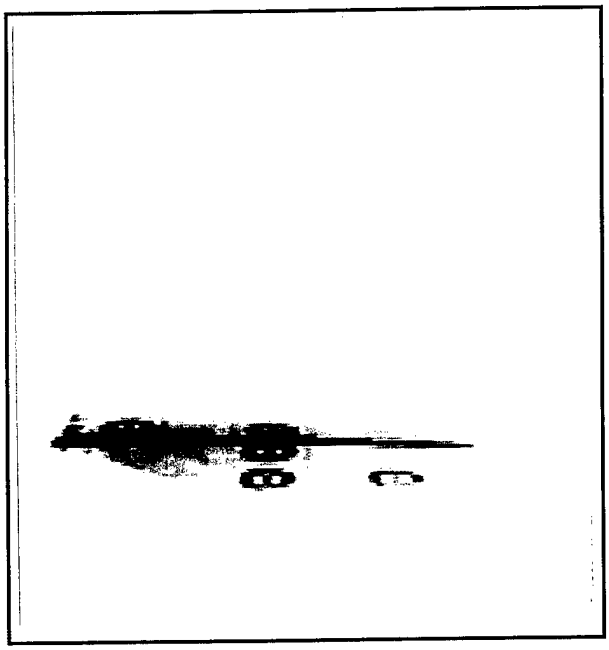


Figure 2.25 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 135.00 deg and 140.62 deg



Sheet Position 9, Alpha = 31.17 deg
(Run ID = 77, Frame = 135)



Sheet Position 9, Alpha = 32.02 deg
(Run ID = 77, Frame = 136)

Figure 2.26 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 135.00 Deg and 140.62 deg

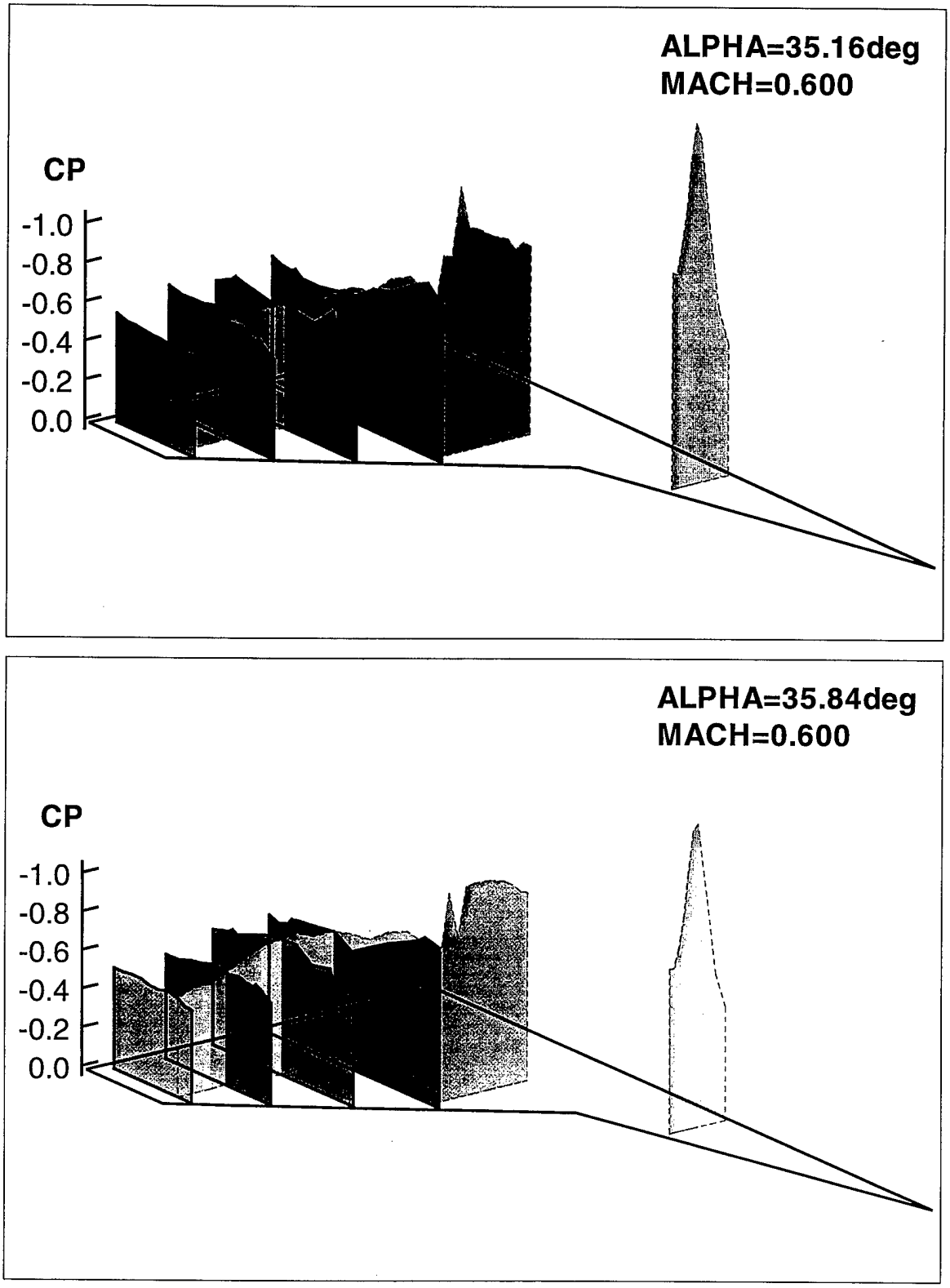
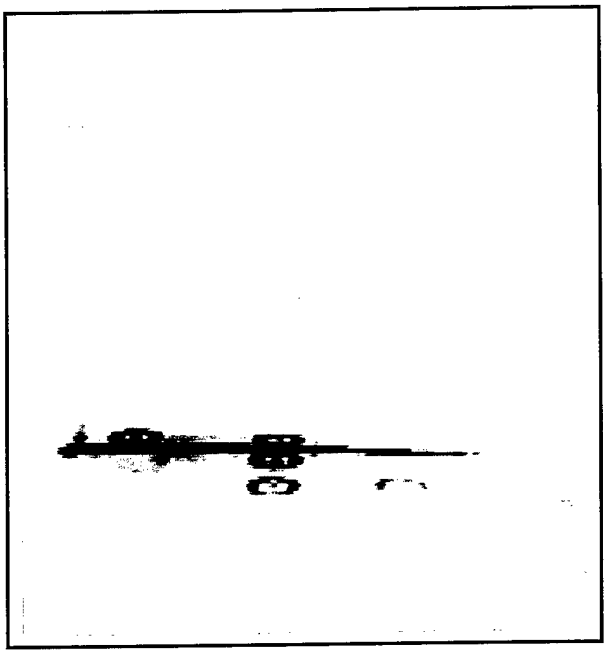
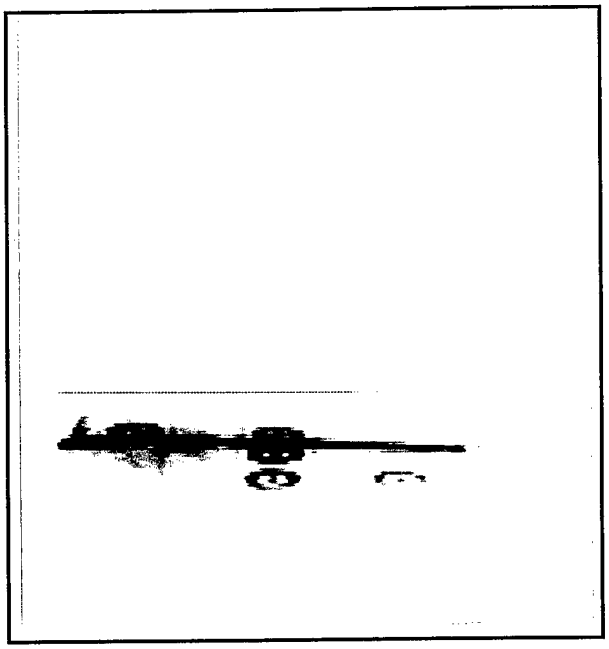


Figure 2.27 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 146.25 deg and 151.88 deg



Sheet Position 9, Alpha = 32.78 deg
(Run ID = 77, Frame = 137)



Sheet Position 9, Alpha = 33.44 deg
(Run ID = 77, Frame = 138)

Figure 2.28 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 146.25 Deg and 151.88 deg

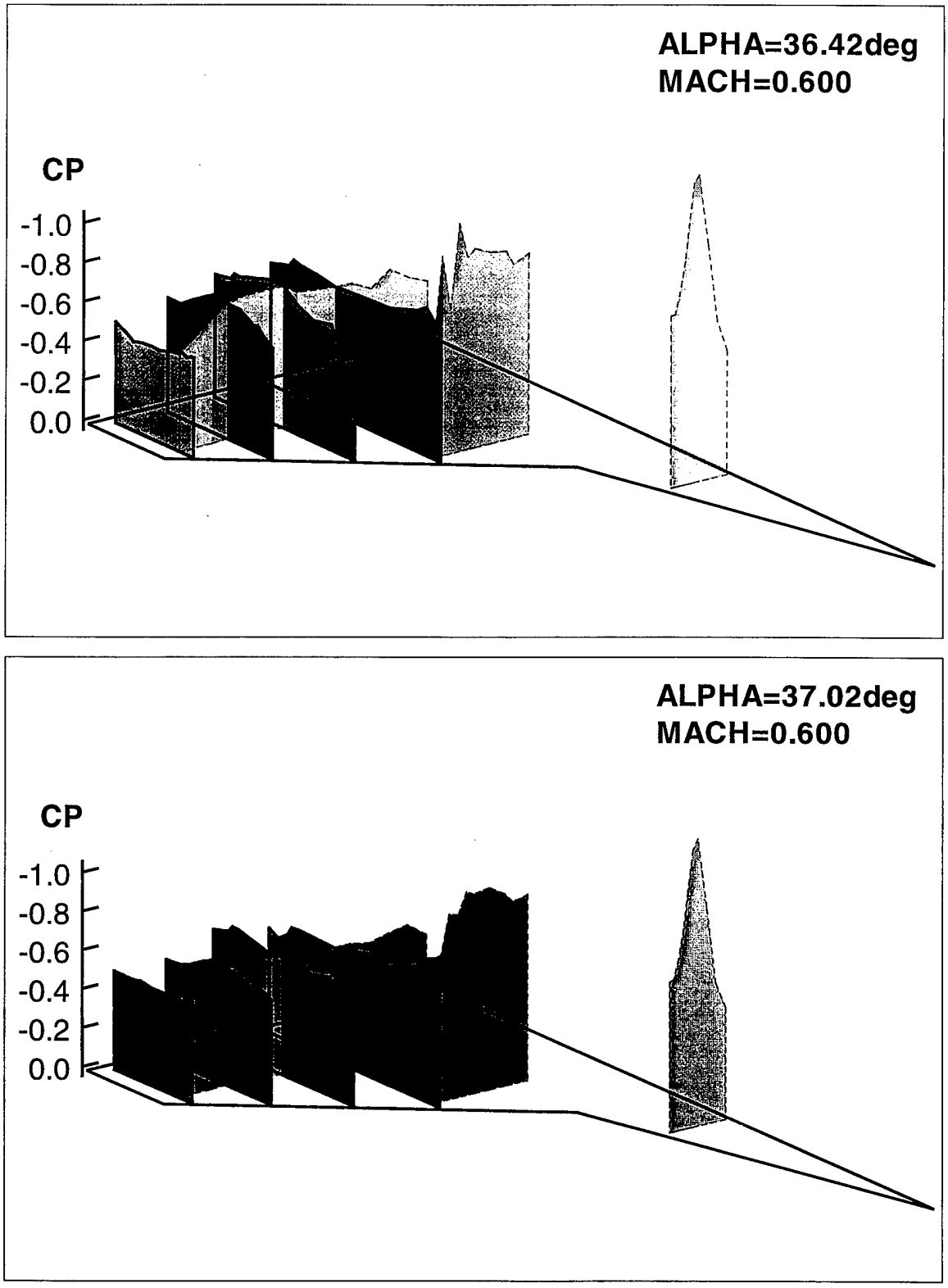
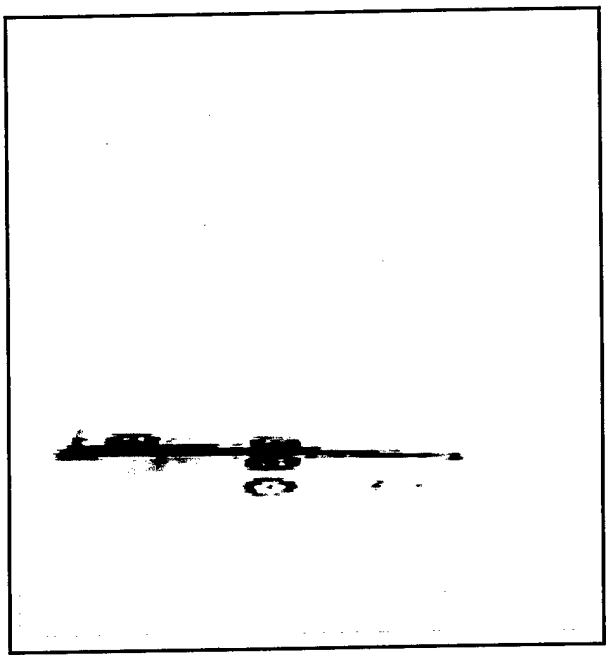
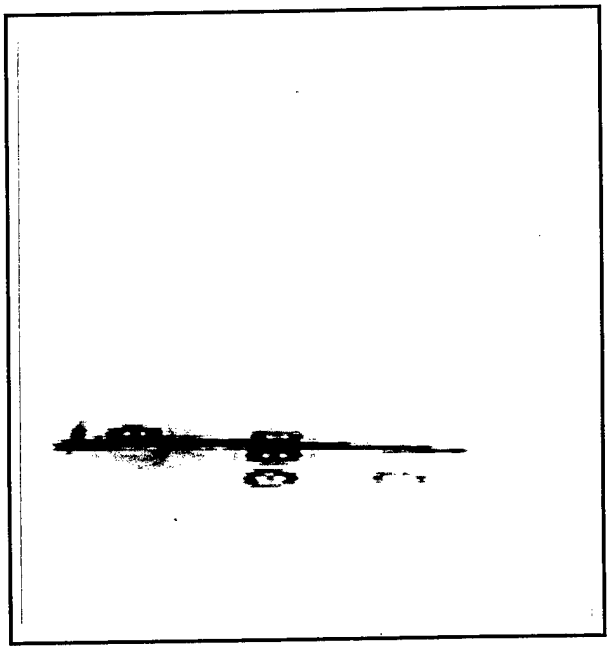


Figure 2.29 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 157.50 deg and 163.12 deg



Sheet Position 9, Alpha = 33.98 deg
(Run ID = 77, Frame = 139)



Sheet Position 9, Alpha = 34.41 deg
(Run ID = 77, Frame = 140)

Figure 2.30 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 157.50 Deg and 163.12 deg

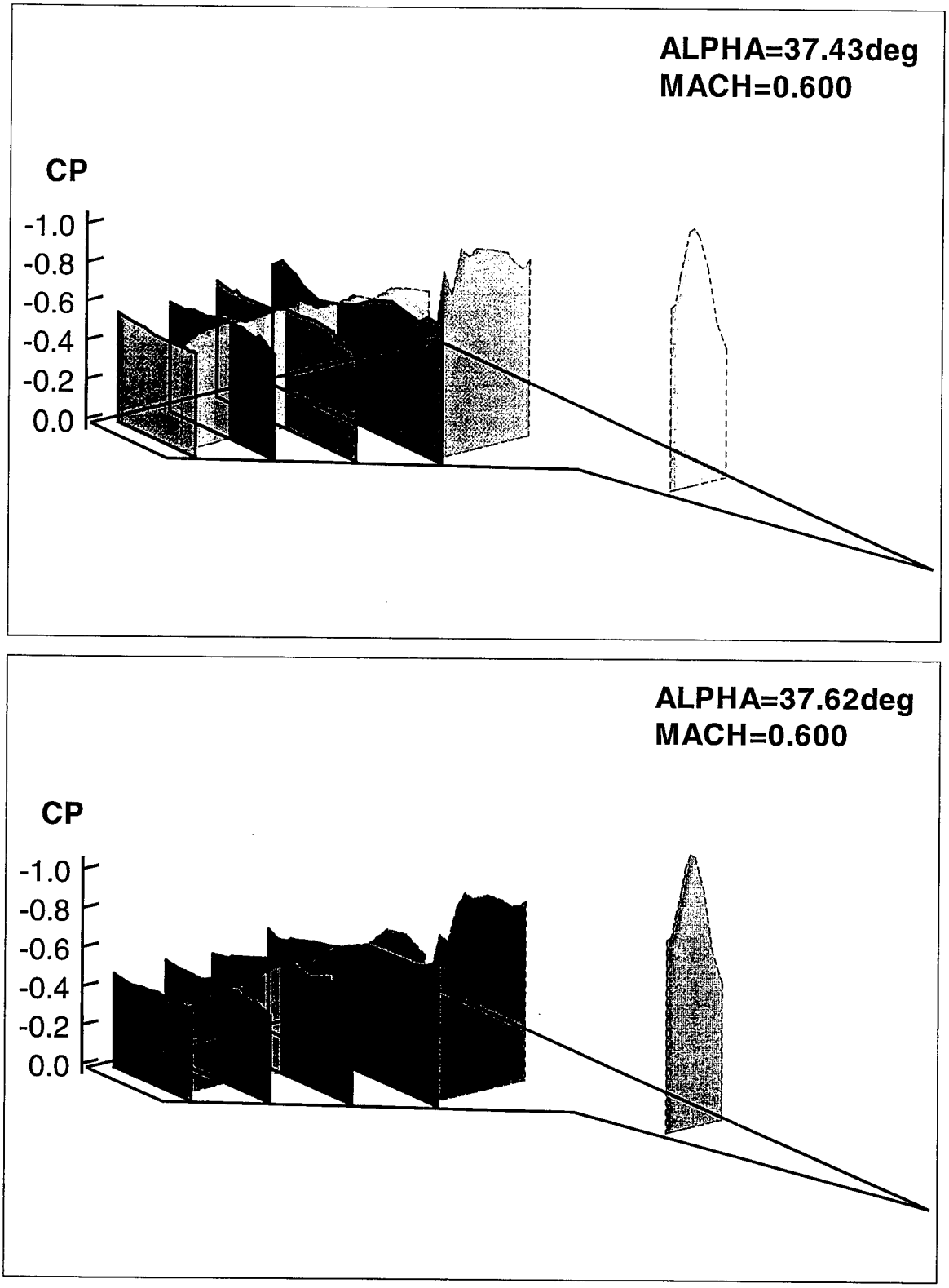
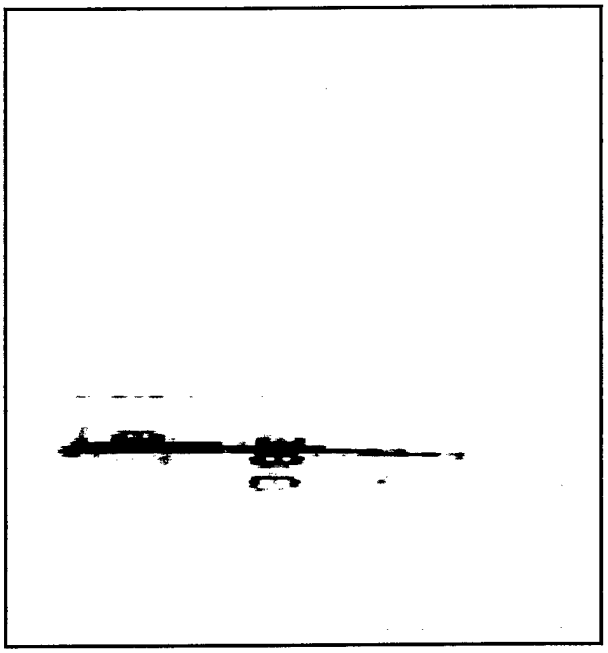
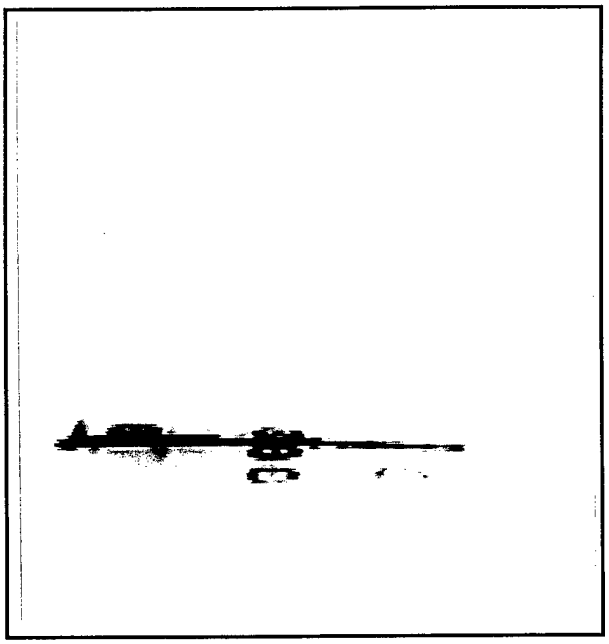


Figure 2.31 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 168.75 deg and 174.38 deg



Sheet Position 9, Alpha = 34.72 deg
(Run ID = 77, Frame = 141)



Sheet Position 9, Alpha = 34.91 deg
(Run ID = 77, Frame = 142)

Figure 2.32 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 168.75 Deg and 174.38 deg

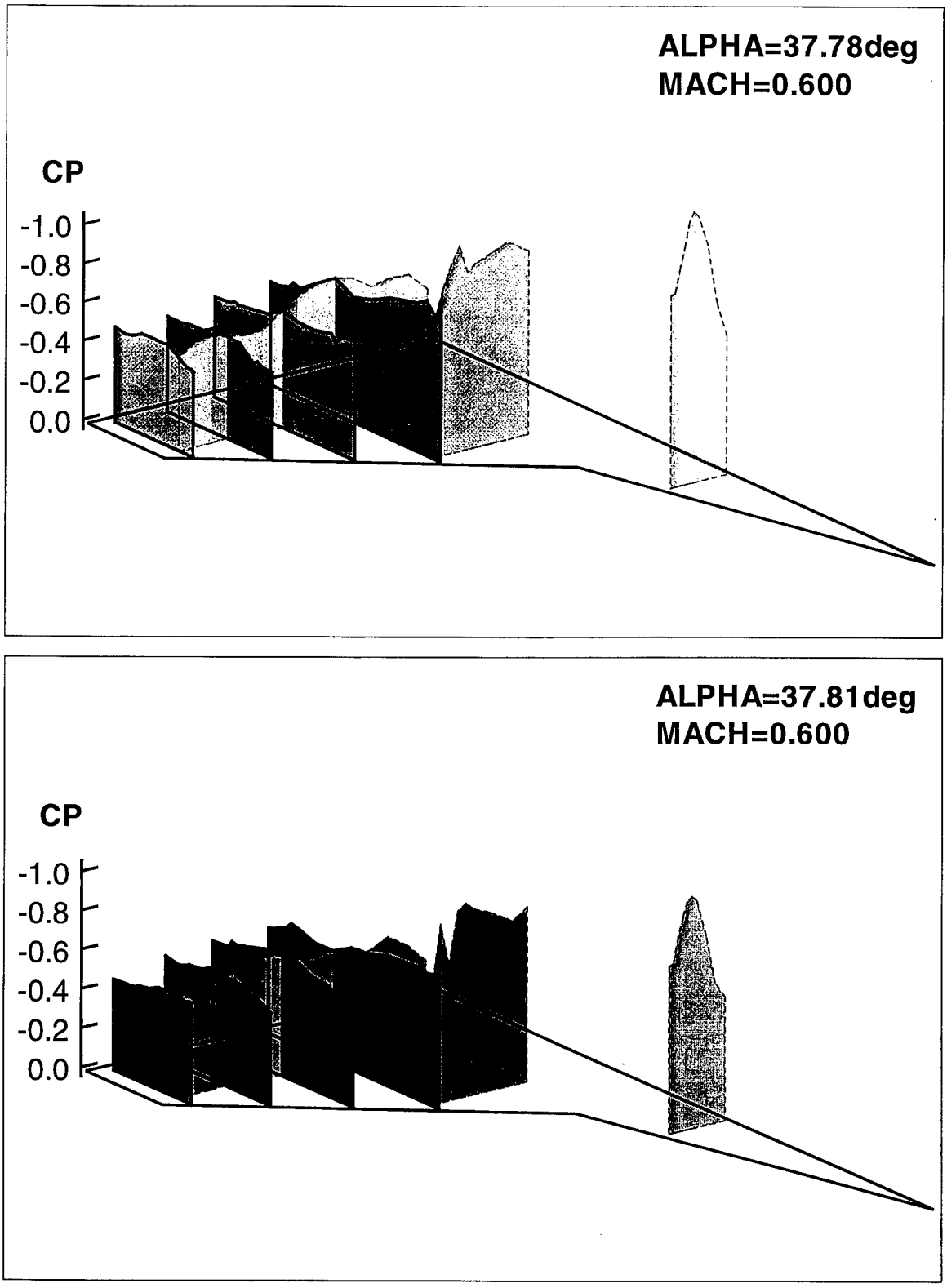
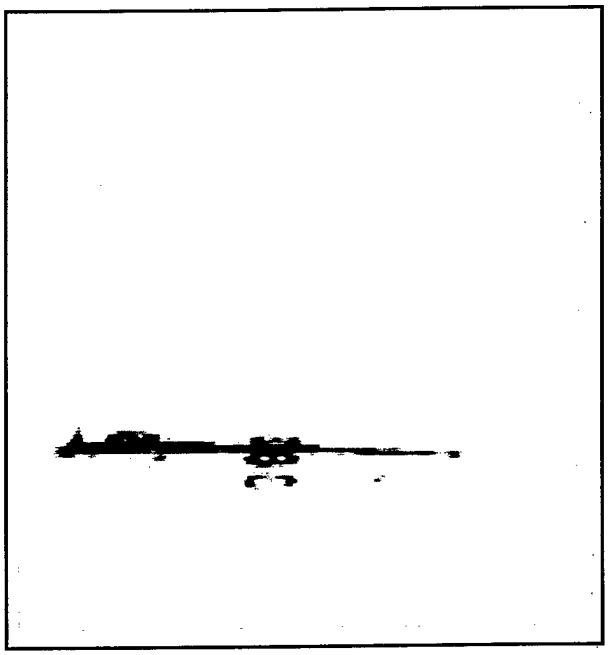
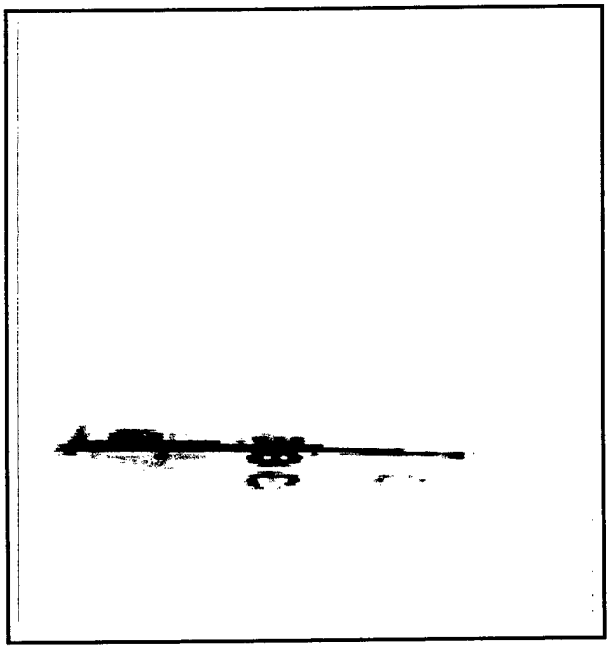


Figure 2.33 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 180.00 deg and 185.62 deg



Sheet Position 9, Alpha = 34.97 deg
(Run ID = 77, Frame = 143)



Sheet Position 9, Alpha = 34.91 deg
(Run ID = 77, Frame = 144)

Figure 2.34 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 180.00 Deg and 185.62 deg

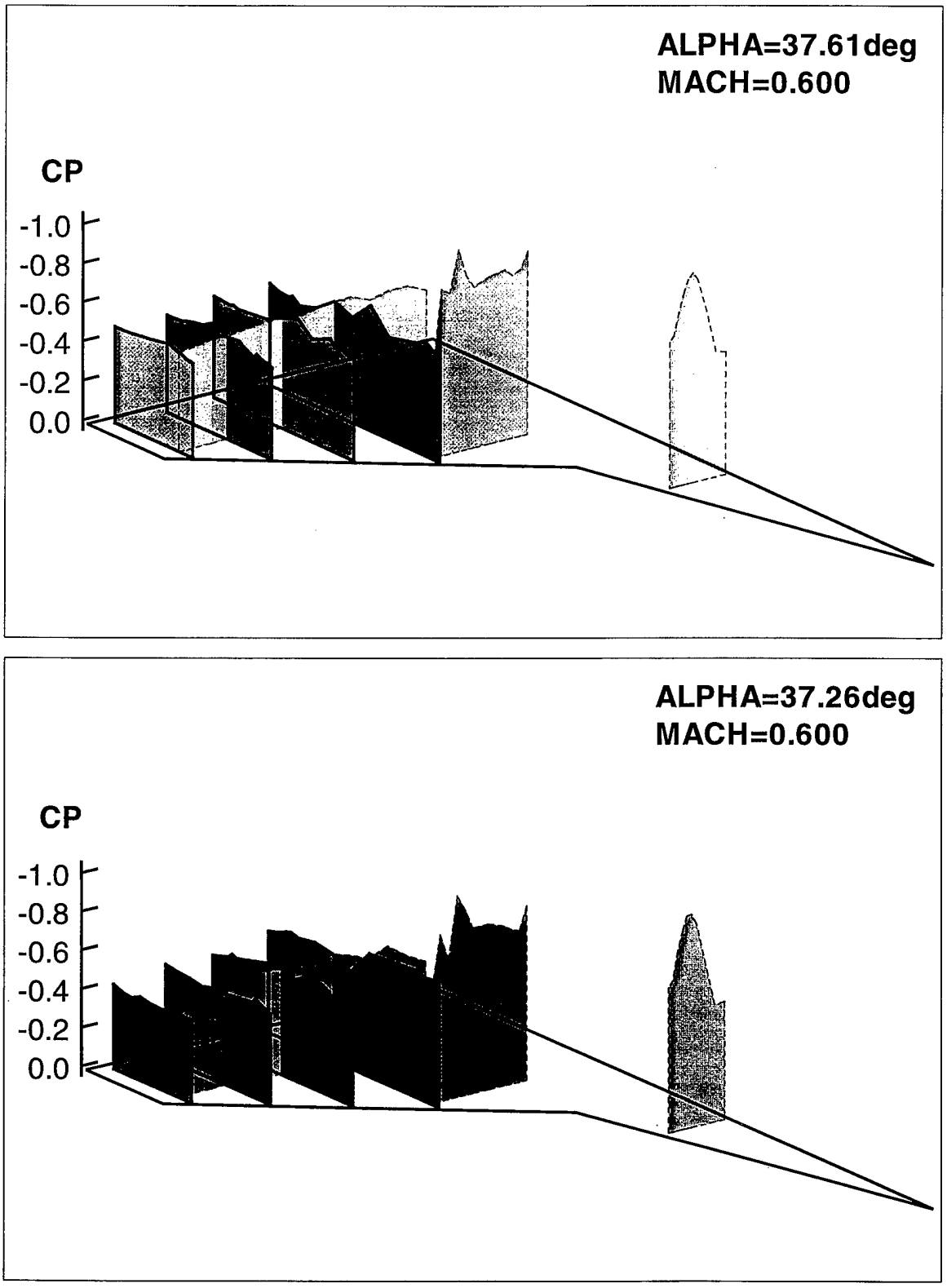
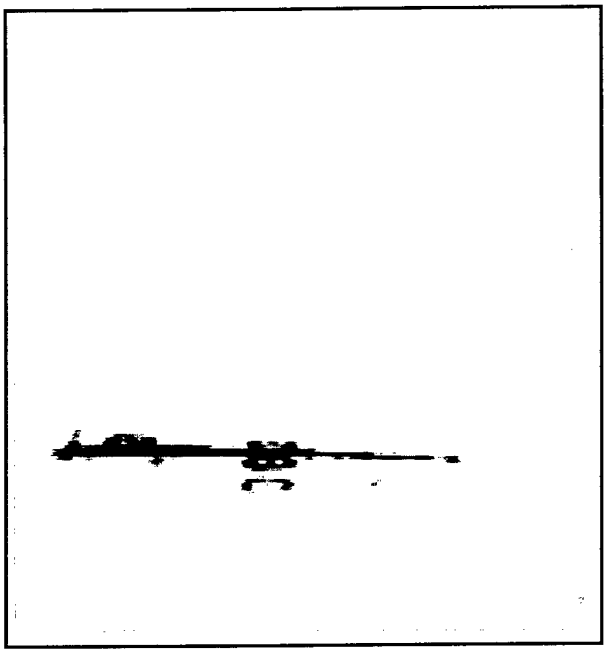
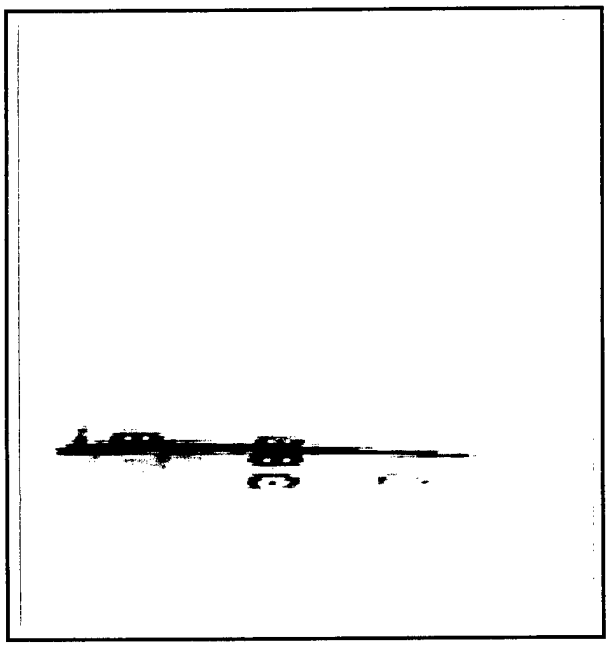


Figure 2.35 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 191.25 deg and 196.88 deg



Sheet Position 9, Alpha = 34.72 deg
(Run ID = 77, Frame = 145)



Sheet Position 9, Alpha = 34.41 deg
(Run ID = 77, Frame = 146)

Figure 2.36 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 191.25 Deg and 196.88 deg

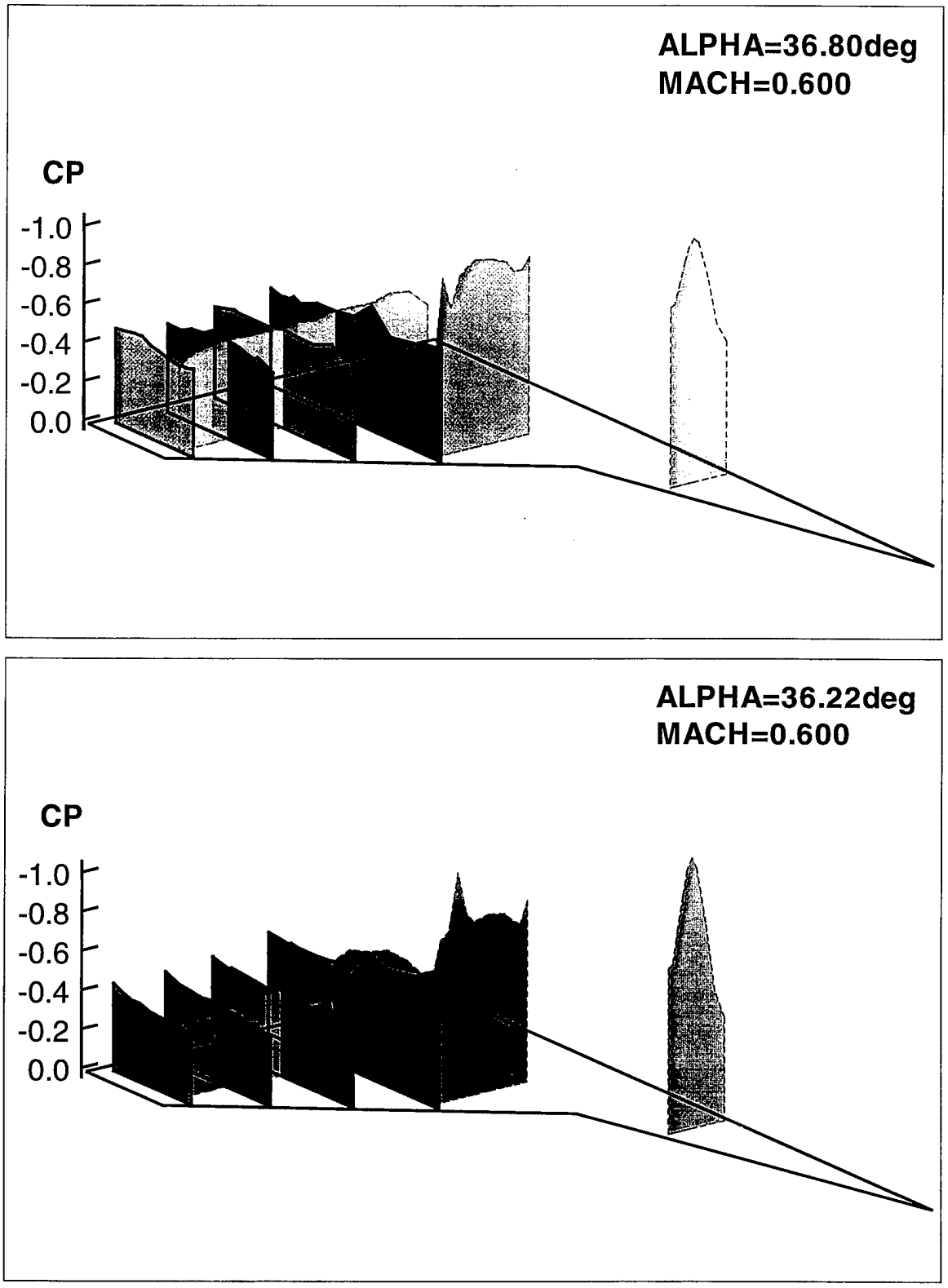
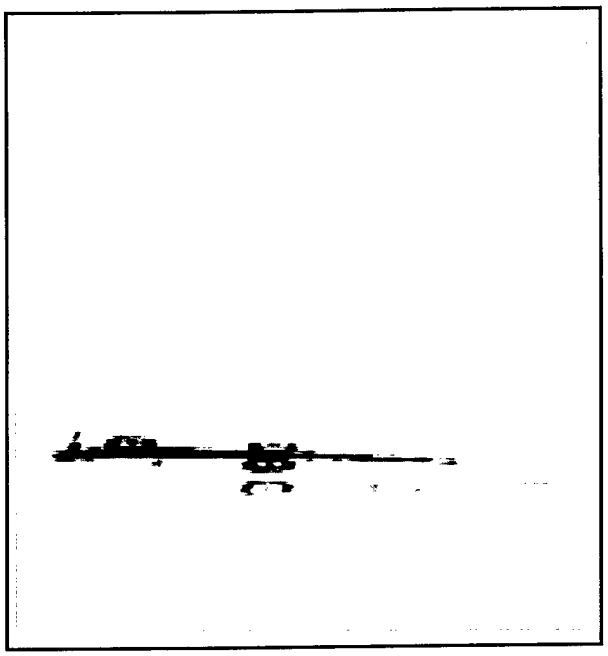
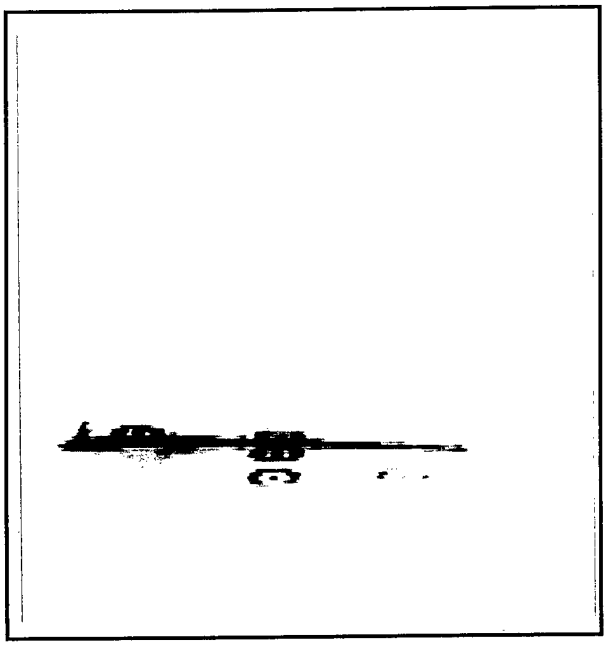


Figure 2.37 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 202.50 deg and 208.12 deg

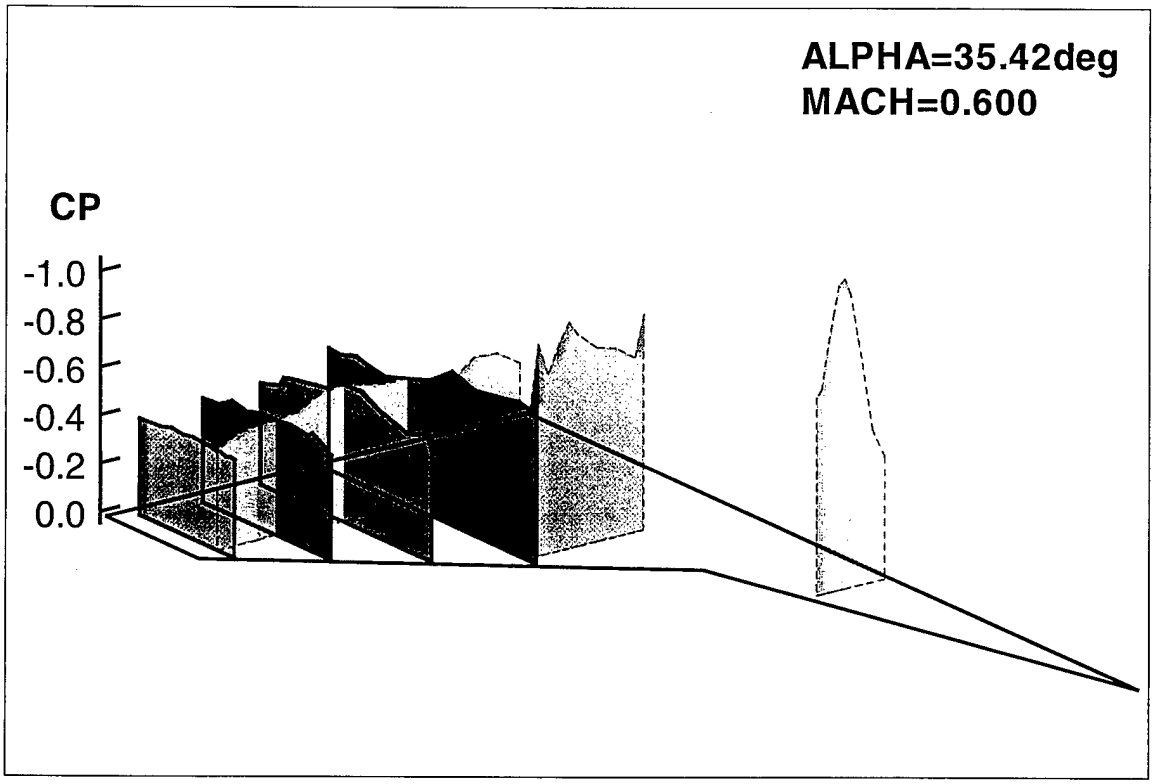


Sheet Position 9, Alpha = 33.98 deg
(Run ID = 77, Frame = 147)



Sheet Position 9, Alpha = 33.44 deg
(Run ID = 77, Frame = 148)

Figure 2.38 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 202.50 Deg and 208.12 deg



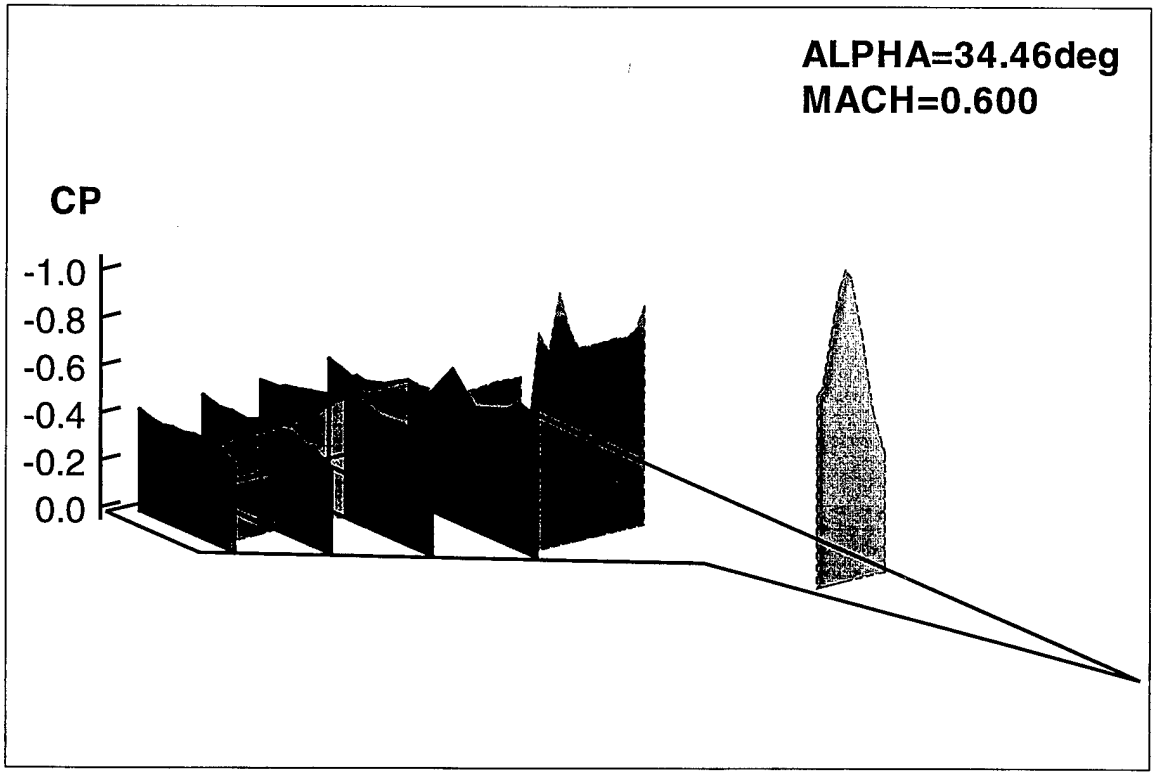
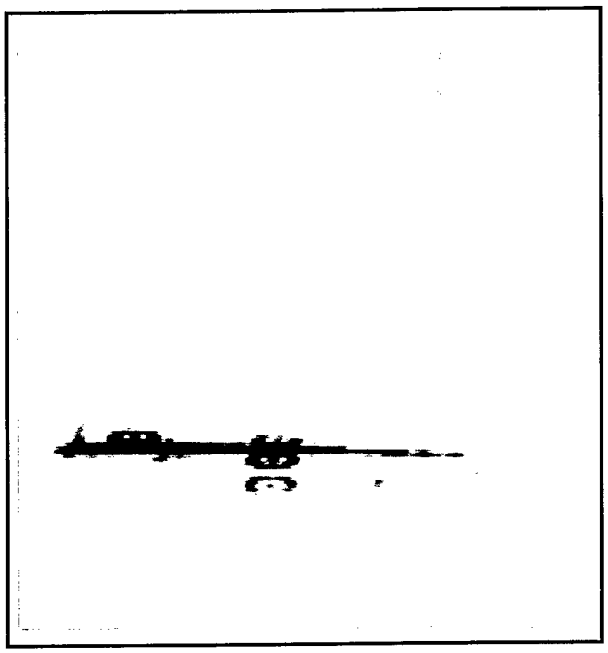
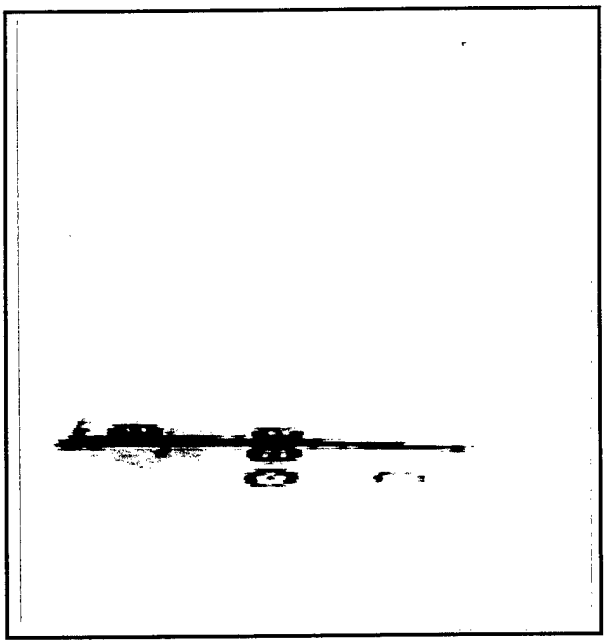


Figure 2.39 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 213.75 deg and 219.38 deg



Sheet Position 9, Alpha = 32.78 deg
(Run ID = 77, Frame = 149)



Sheet Position 9, Alpha = 32.02 deg
(Run ID = 77, Frame = 150)

Figure 2.40 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 213.75 Deg and 219.38 Deg

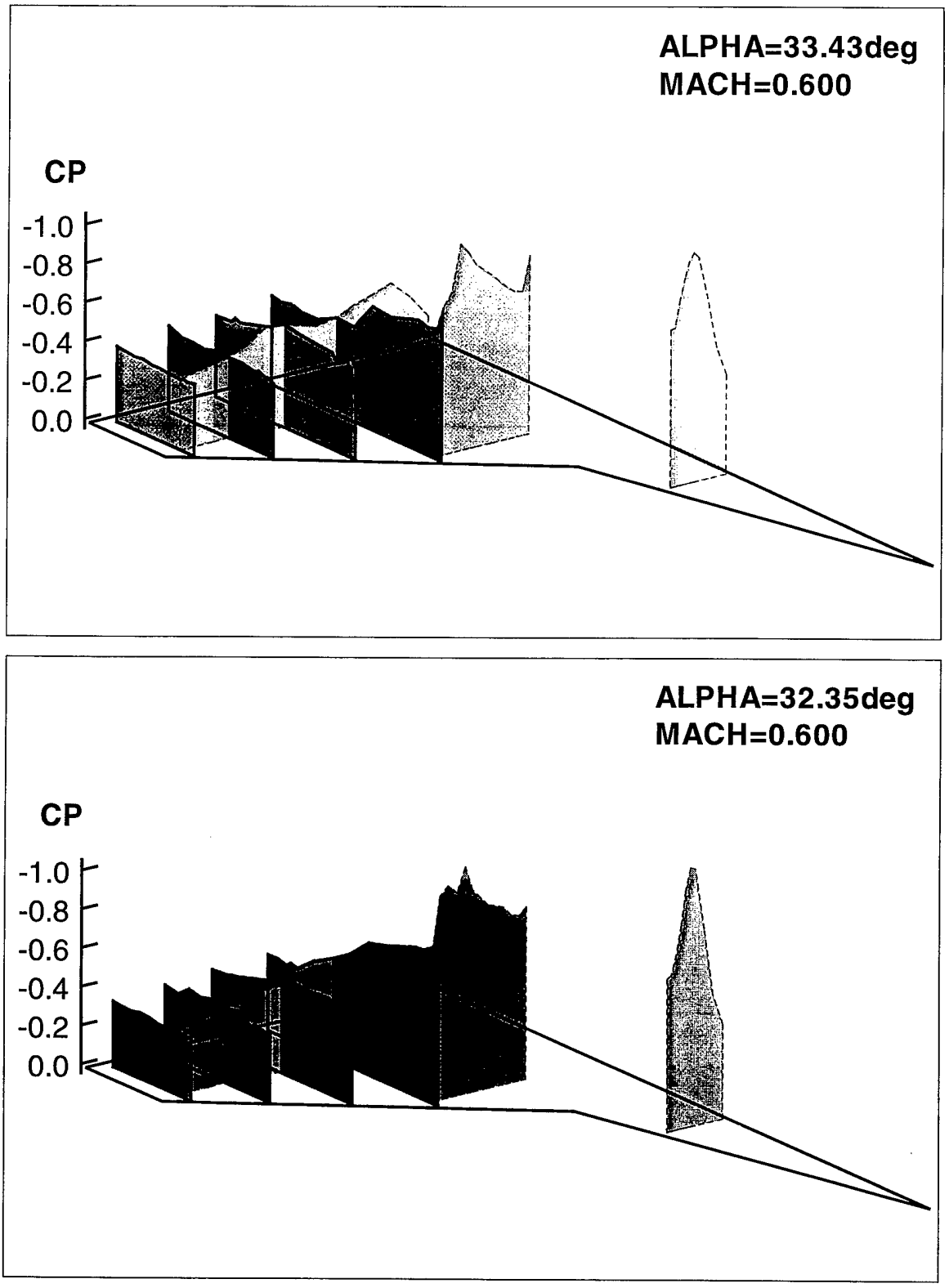
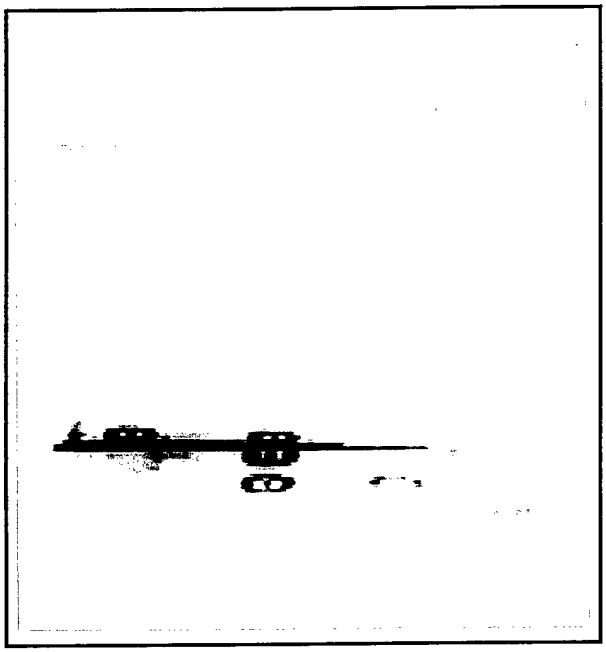
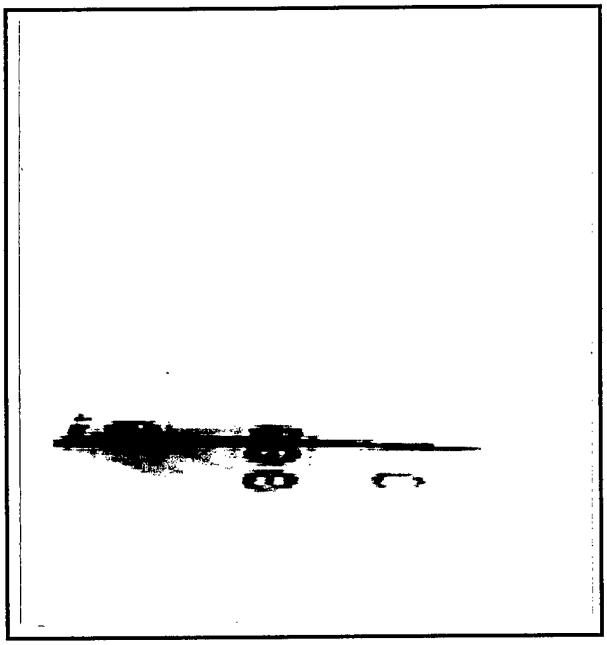


Figure 2.41 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 225.00 deg and 230.62 deg



Sheet Position 9, Alpha = 31.17 deg
(Run ID = 77, Frame = 151)



Sheet Position 9, Alpha = 30.22 deg
(Run ID = 77, Frame = 152)

Figure 2.42 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 225.00 Deg and 230.62 deg

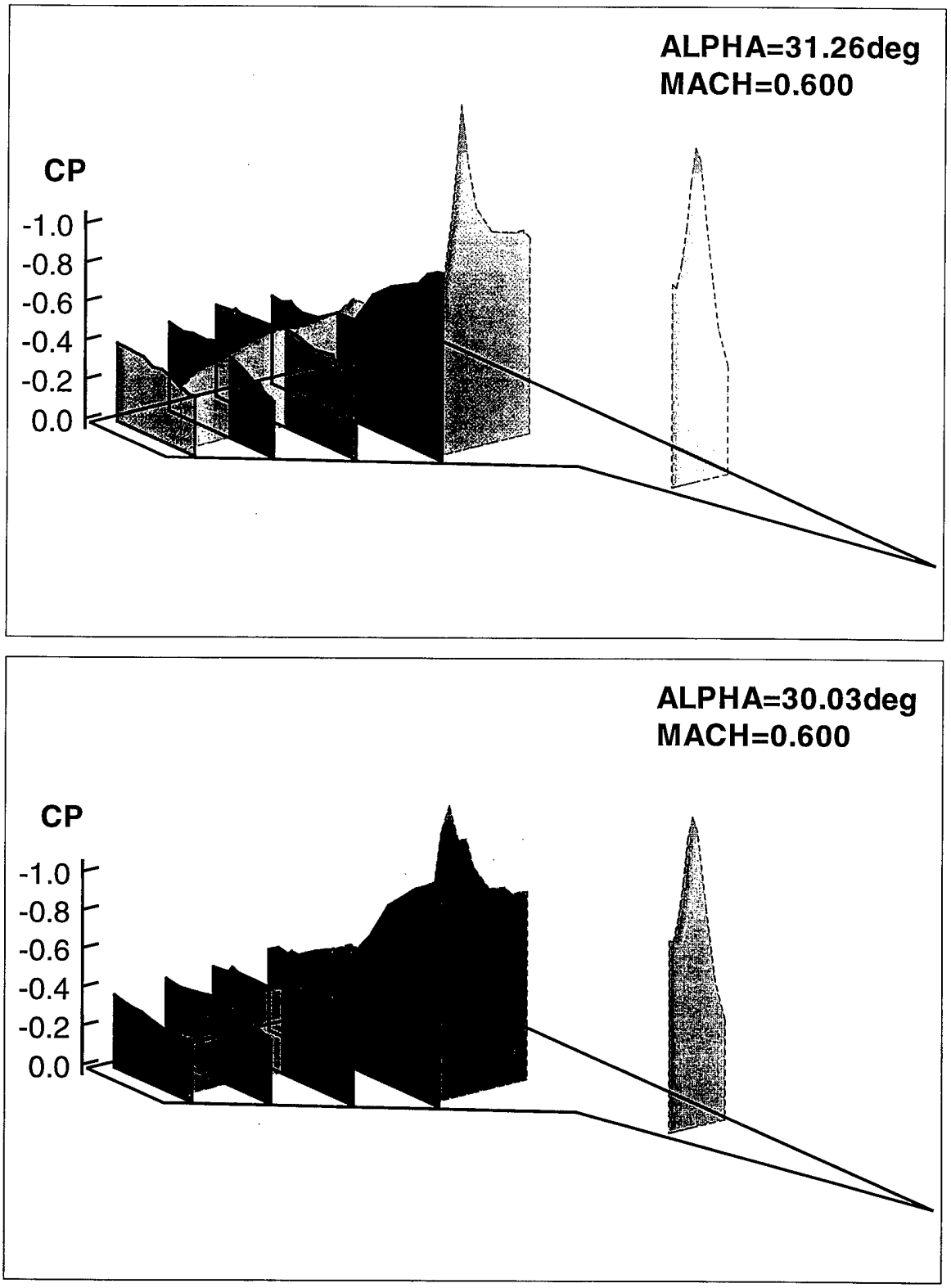
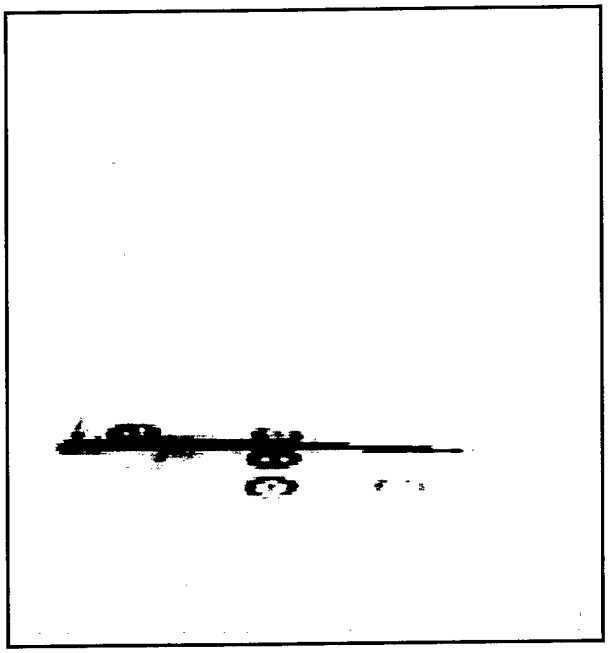
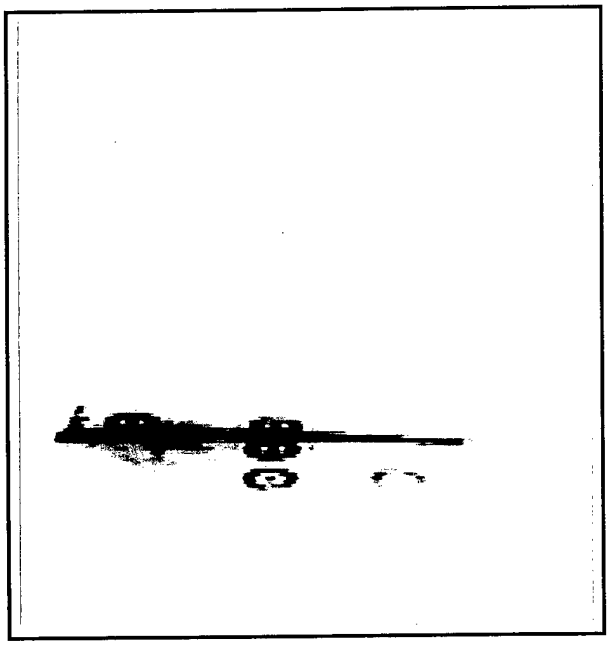


Figure 2.43 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 236.25 deg and 241.88 deg



Sheet Position 9, Alpha = 29.20 deg
(Run ID = 77, Frame = 153)



Sheet Position 9, Alpha = 28.11 deg
(Run ID = 77, Frame = 154)

Figure 2.44 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 236.25 Deg and 241.88 Deg

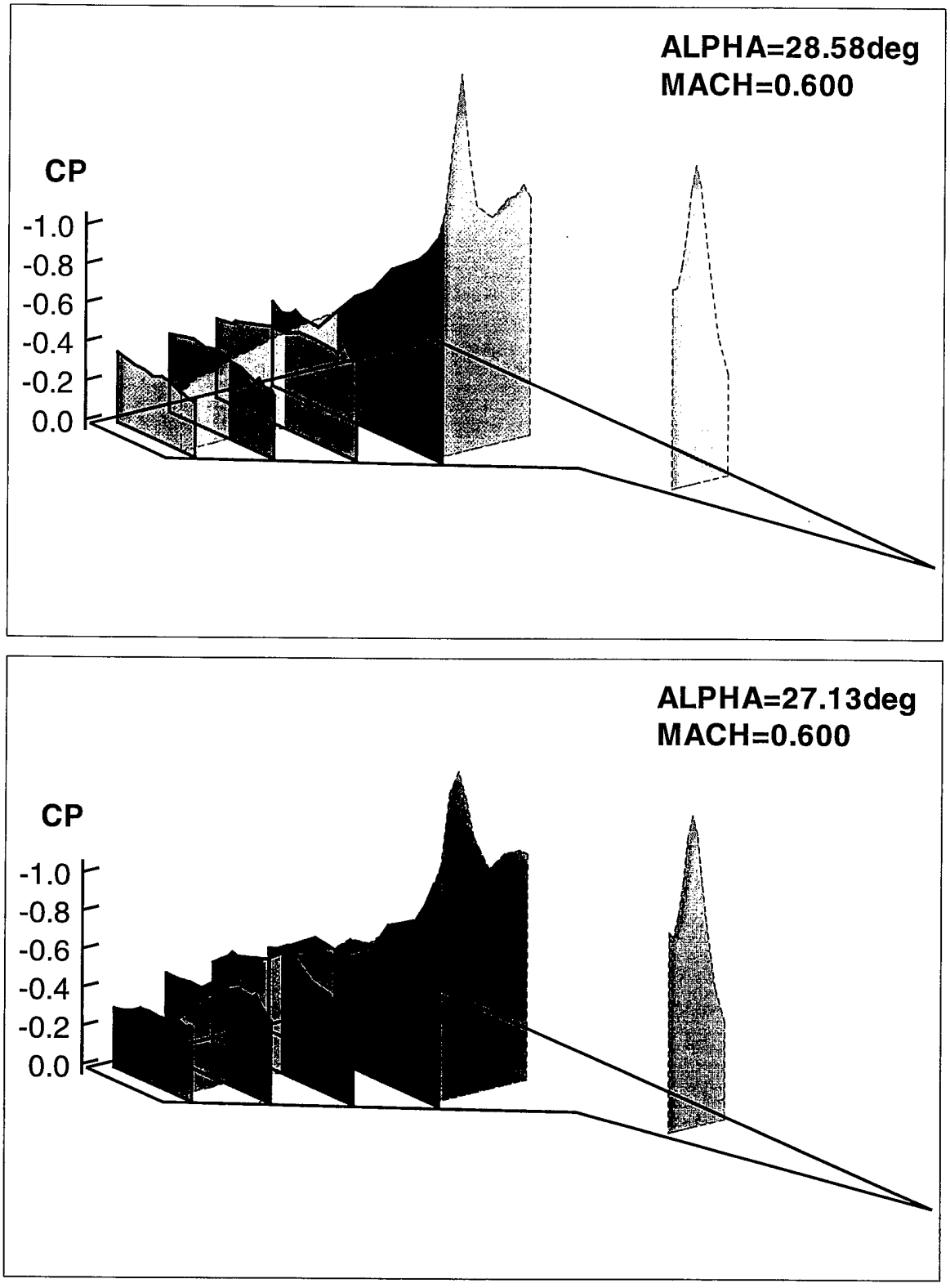
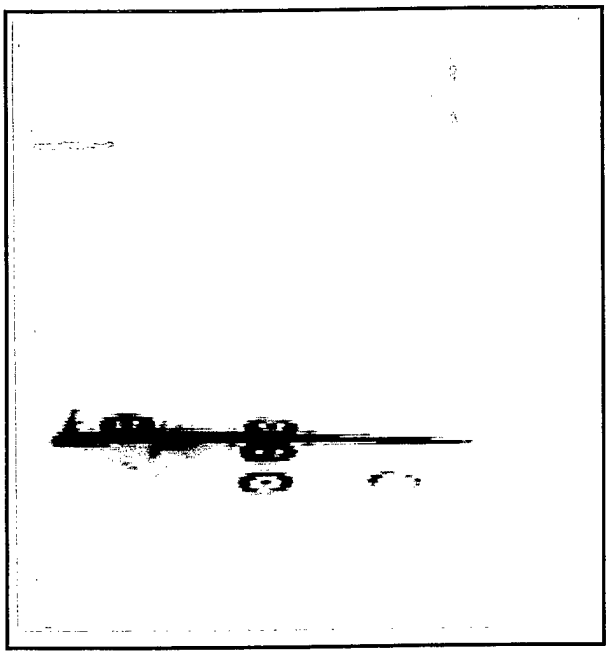
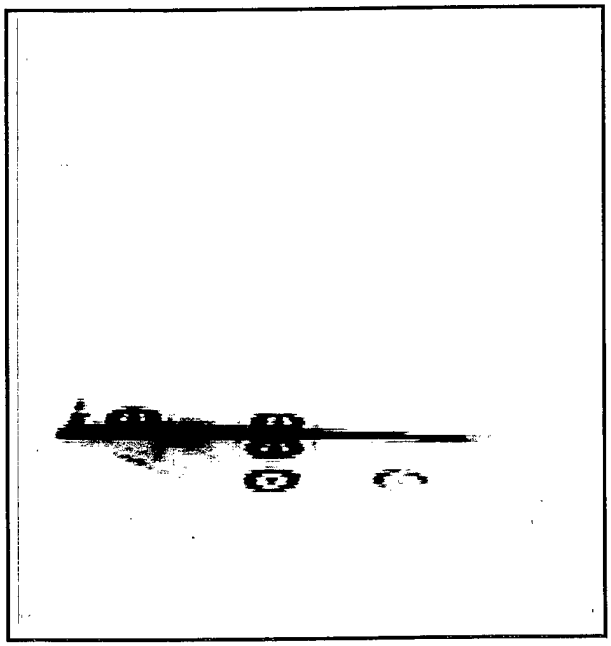


Figure 2.45 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 247.50 deg and 253.12 deg



Sheet Position 9, Alpha = 26.96 deg
(Run ID = 77, Frame = 155)



Sheet Position 9, Alpha = 25.76 deg
(Run ID = 77, Frame = 156)

Figure 2.46 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 247.50 Deg and 253.12 Deg

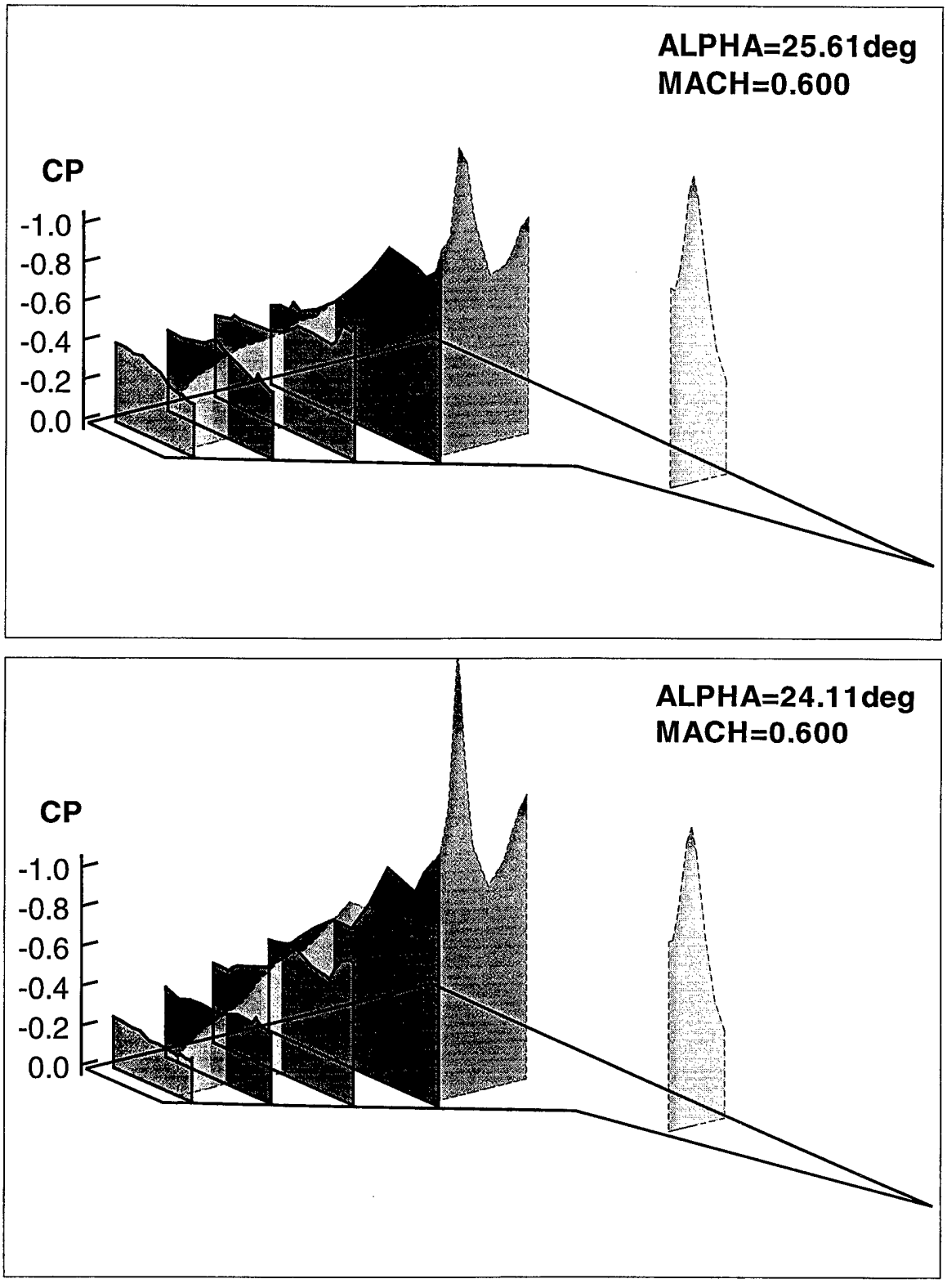
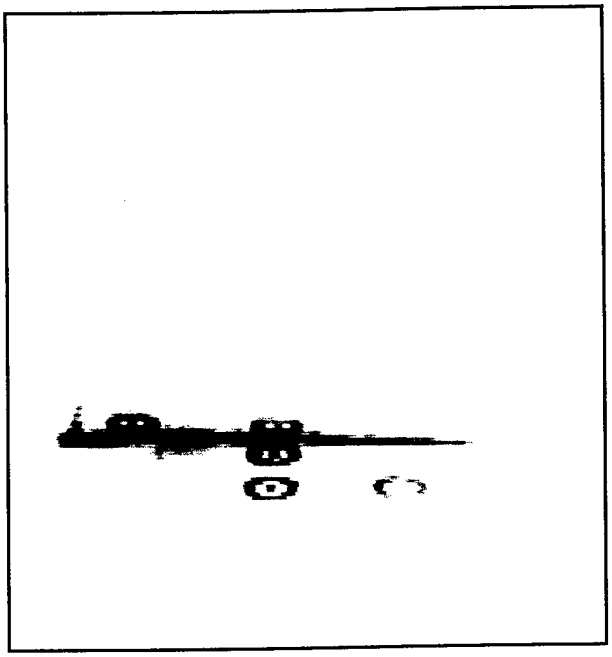
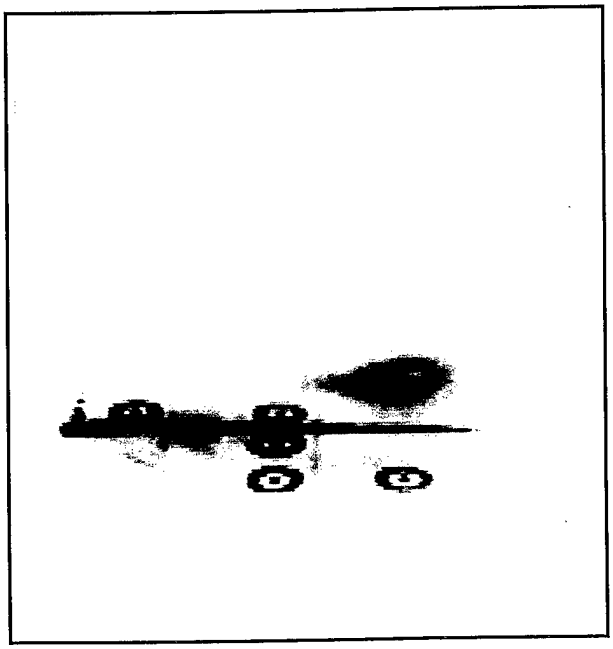


Figure 2.47 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 258.75 deg and 264.38 deg



Sheet Position 9, Alpha = 24.52 deg
(Run ID = 77, Frame = 157)



Sheet Position 9, Alpha = 23.26 deg
(Run ID = 77, Frame = 158)

Figure 2.48 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 258.75 Deg and 264.38 Deg

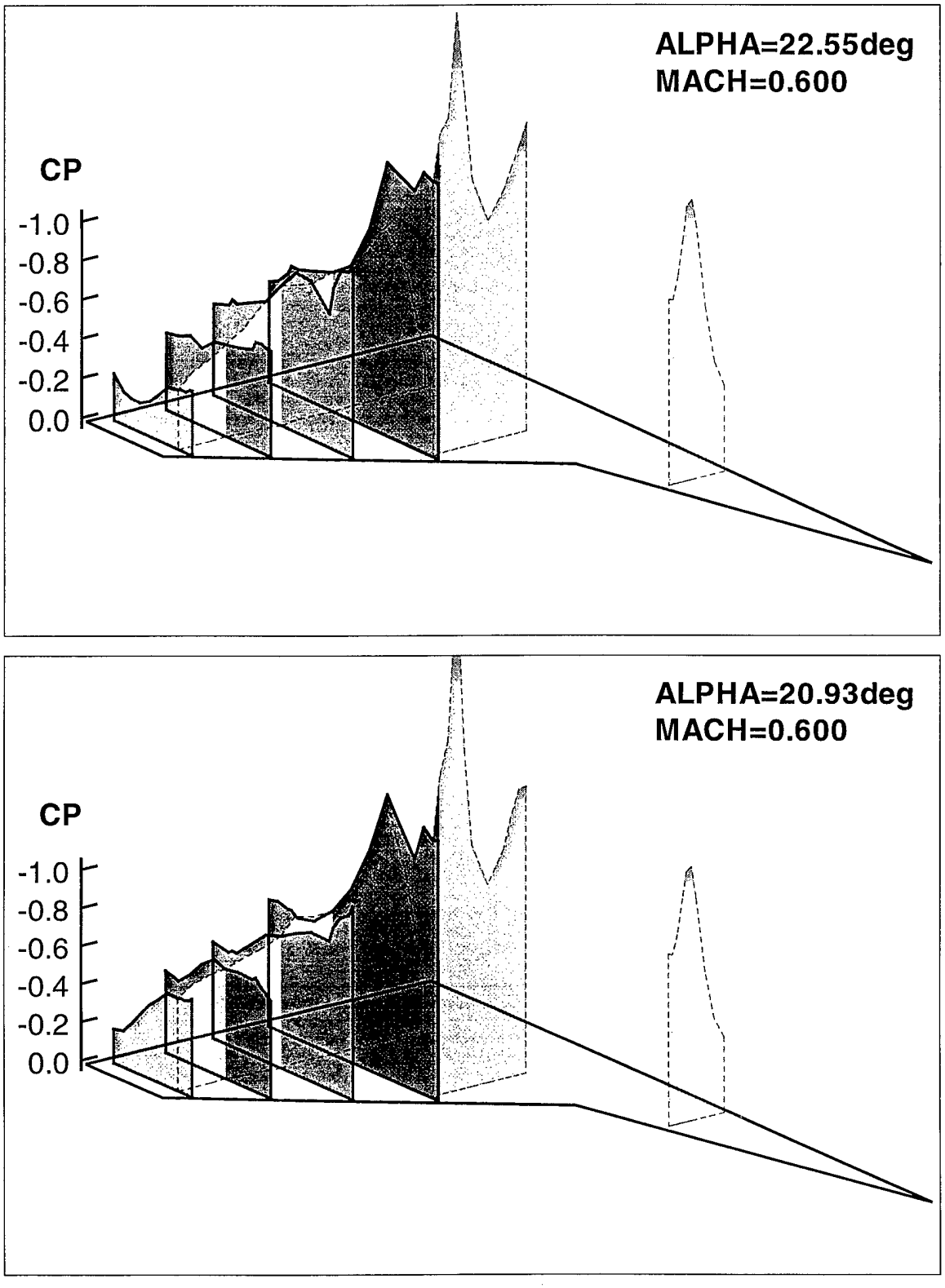
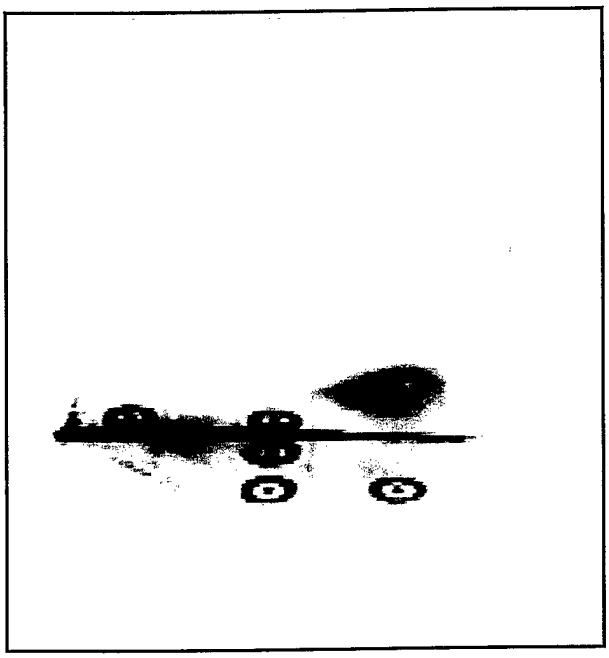
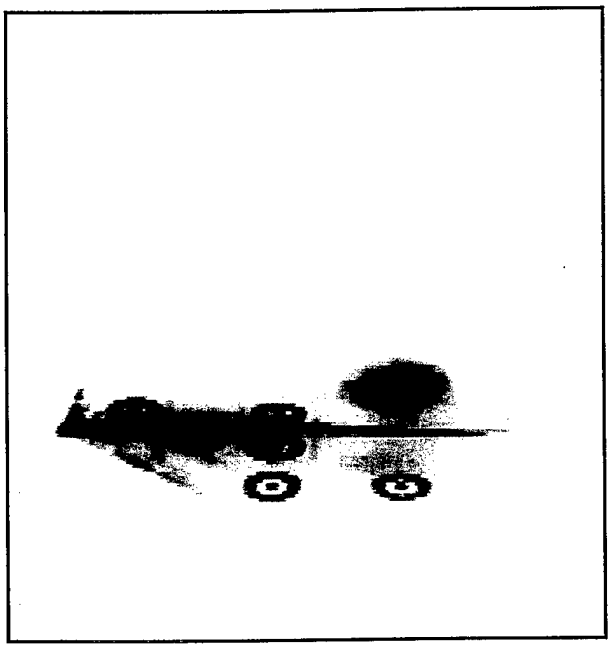


Figure 2.49 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 270.00 deg and 275.62 deg



Sheet Position 9, Alpha = 21.99 deg
(Run ID = 77, Frame = 159)



Sheet Position 9, Alpha = 20.72 deg
(Run ID = 77, Frame = 160)

Figure 2.50 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 270.00 Deg and 275.62 Deg

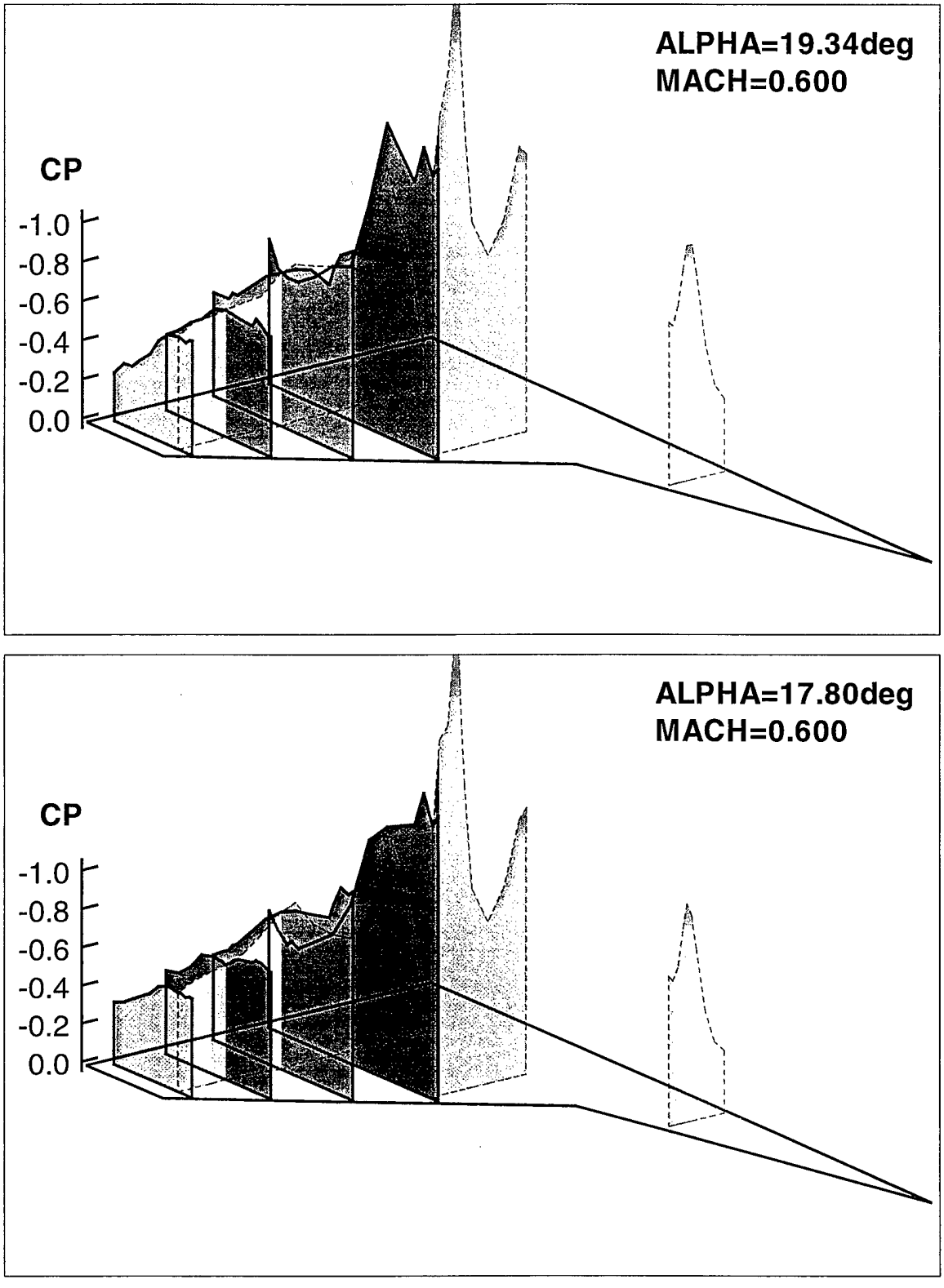
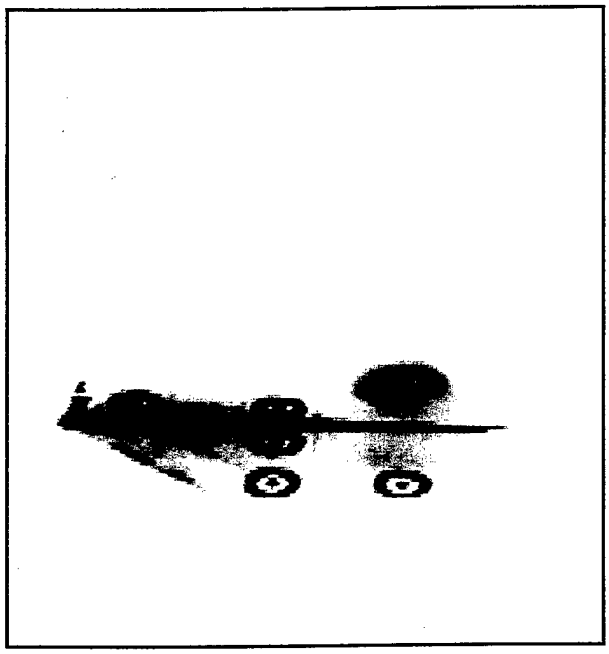
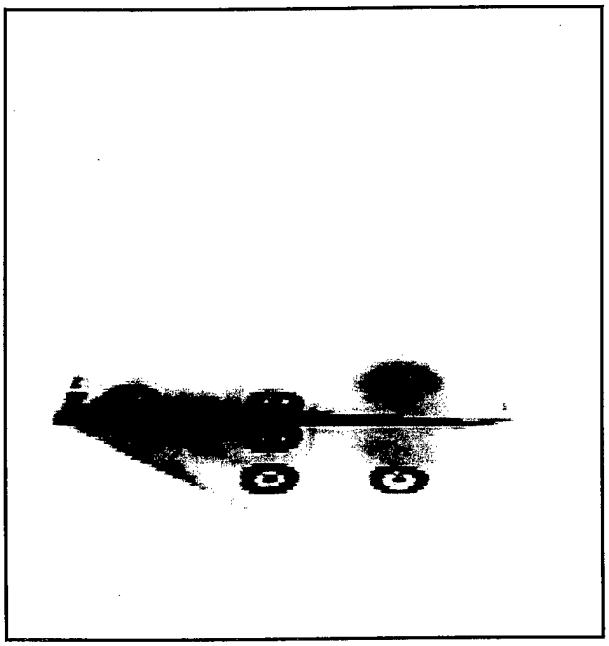


Figure 2.51 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 281.25 deg and 286.88 deg



Sheet Position 9, Alpha = 19.46 deg
(Run ID = 77, Frame = 161)



Sheet Position 9, Alpha = 18.22 deg
(Run ID = 77, Frame = 162)

Figure 2.52 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 281.25 Deg and 286.88 Deg

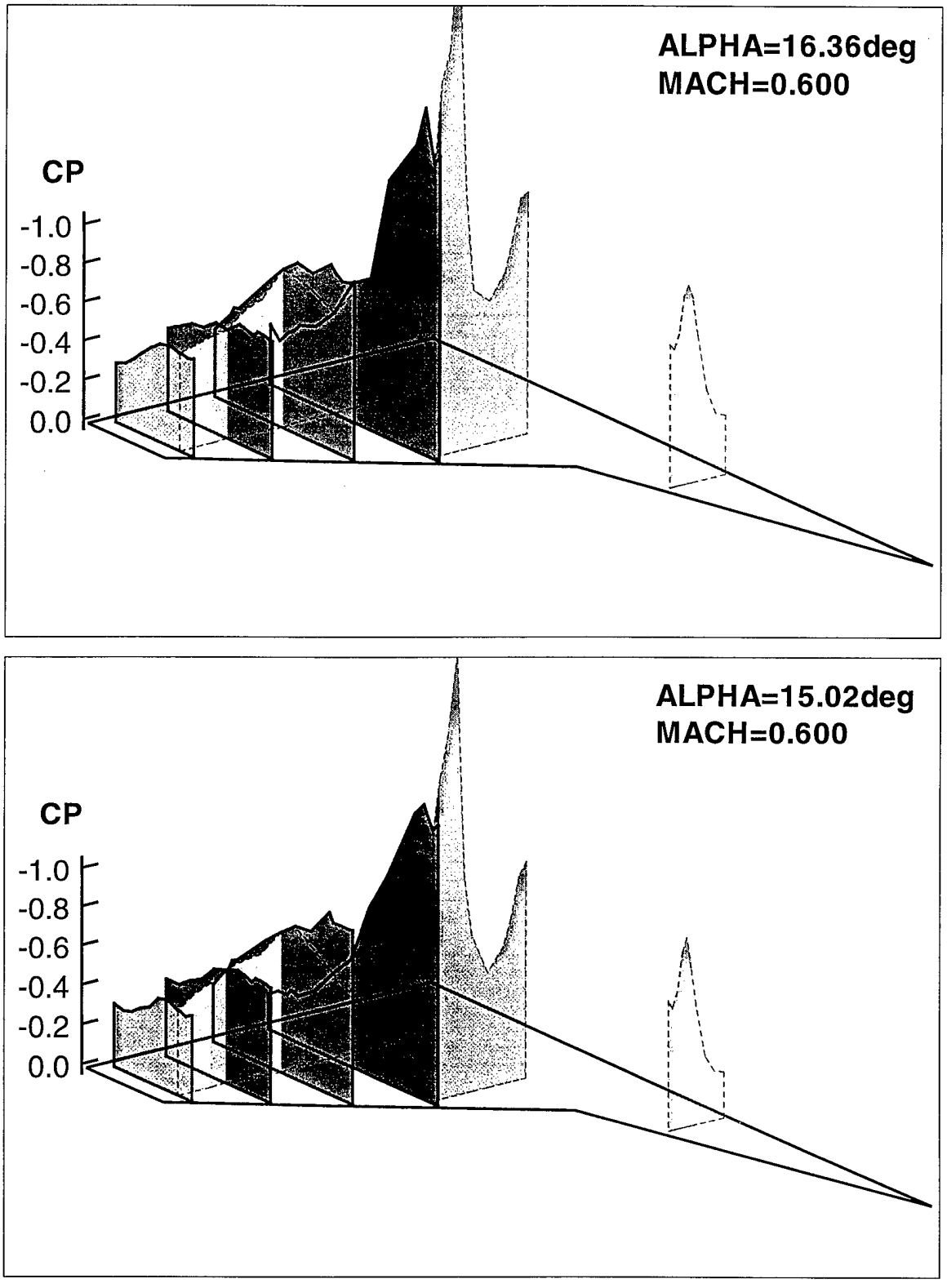
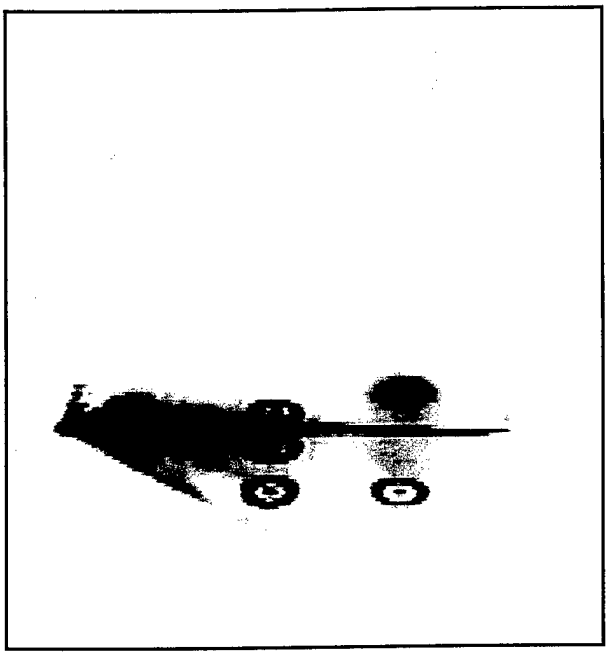
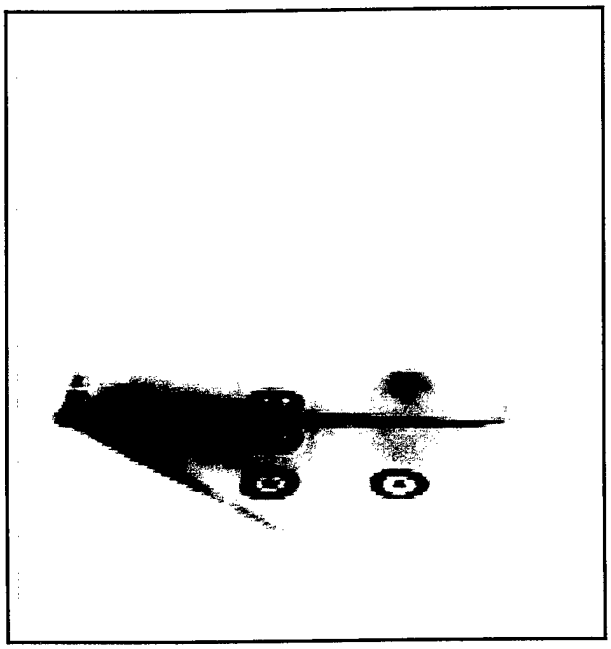


Figure 2.53 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 292.50 deg and 298.12 deg



Sheet Position 9, Alpha = 17.02 deg
(Run ID = 77, Frame = 163)



Sheet Position 9, Alpha = 15.87 deg
(Run ID = 77, Frame = 164)

Figure 2.54 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 292.50 Deg and 298.12 Deg

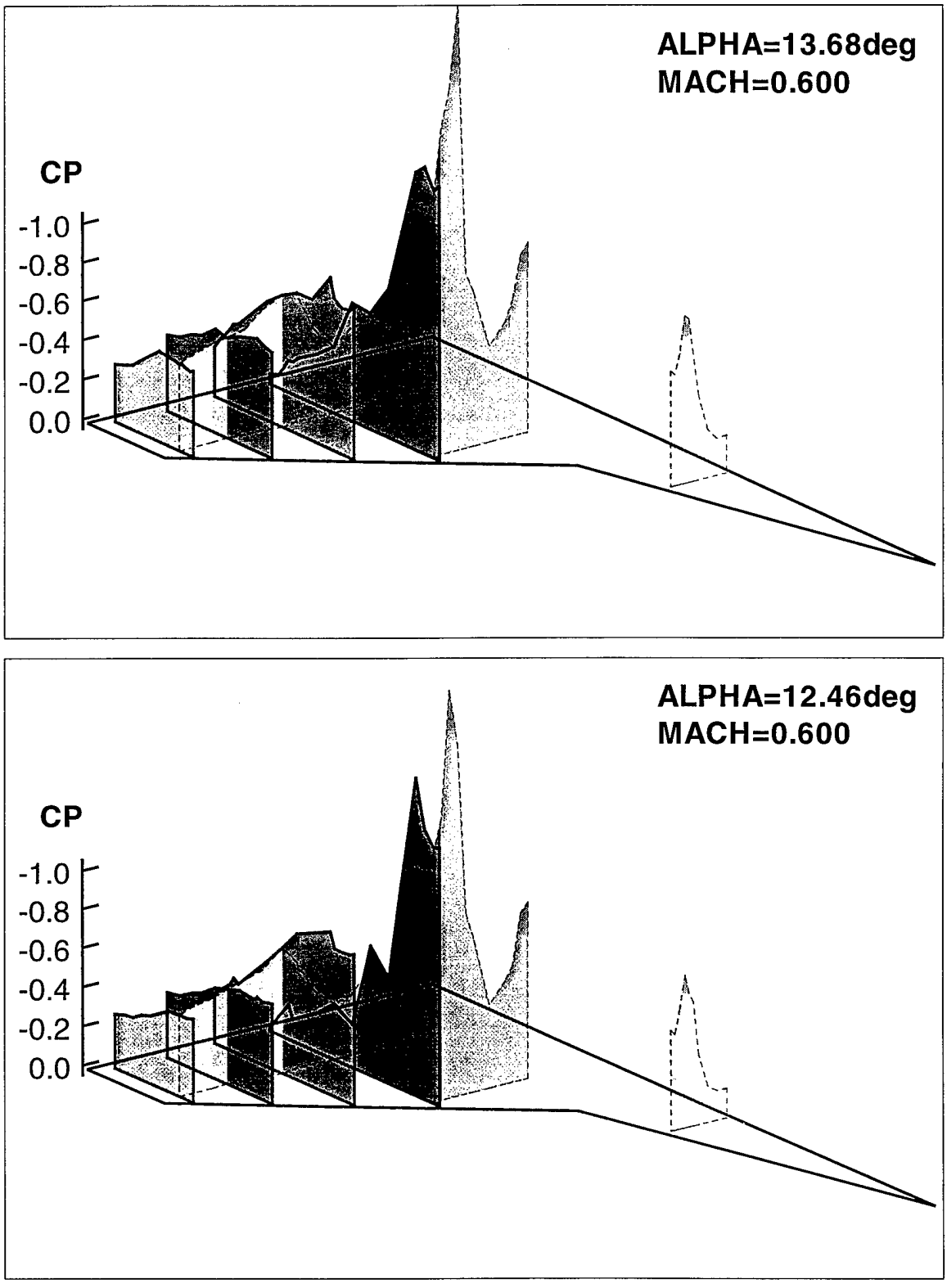
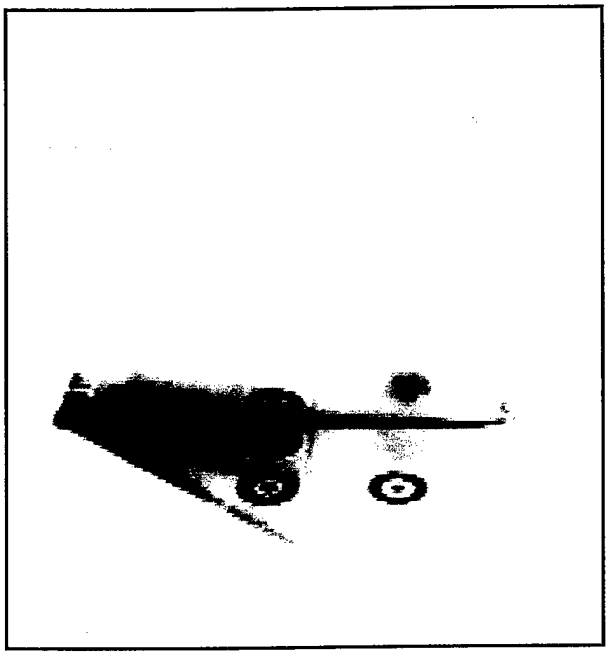
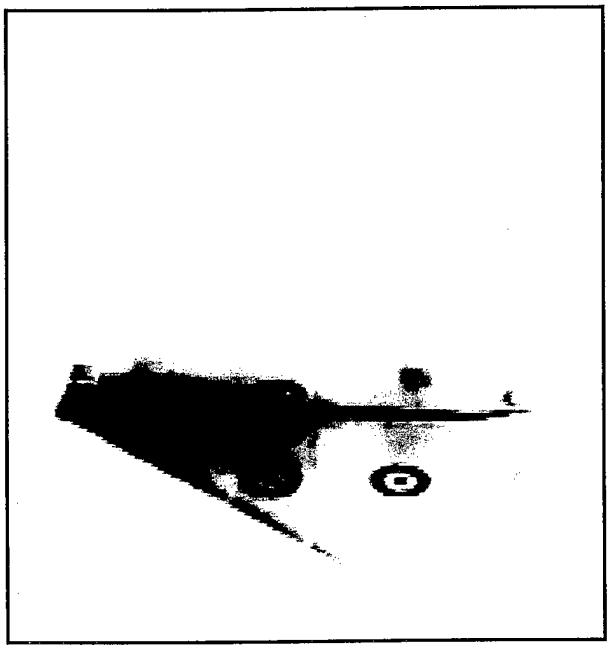


Figure 2.55 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 303.75 deg and 309.38 deg



Sheet Position 9, Alpha = 14.78 deg
(Run ID = 77, Frame = 165)



Sheet Position 9, Alpha = 13.76 deg
(Run ID = 77, Frame = 166)

Figure 2.56 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 303.75 Deg and 309.38 Deg

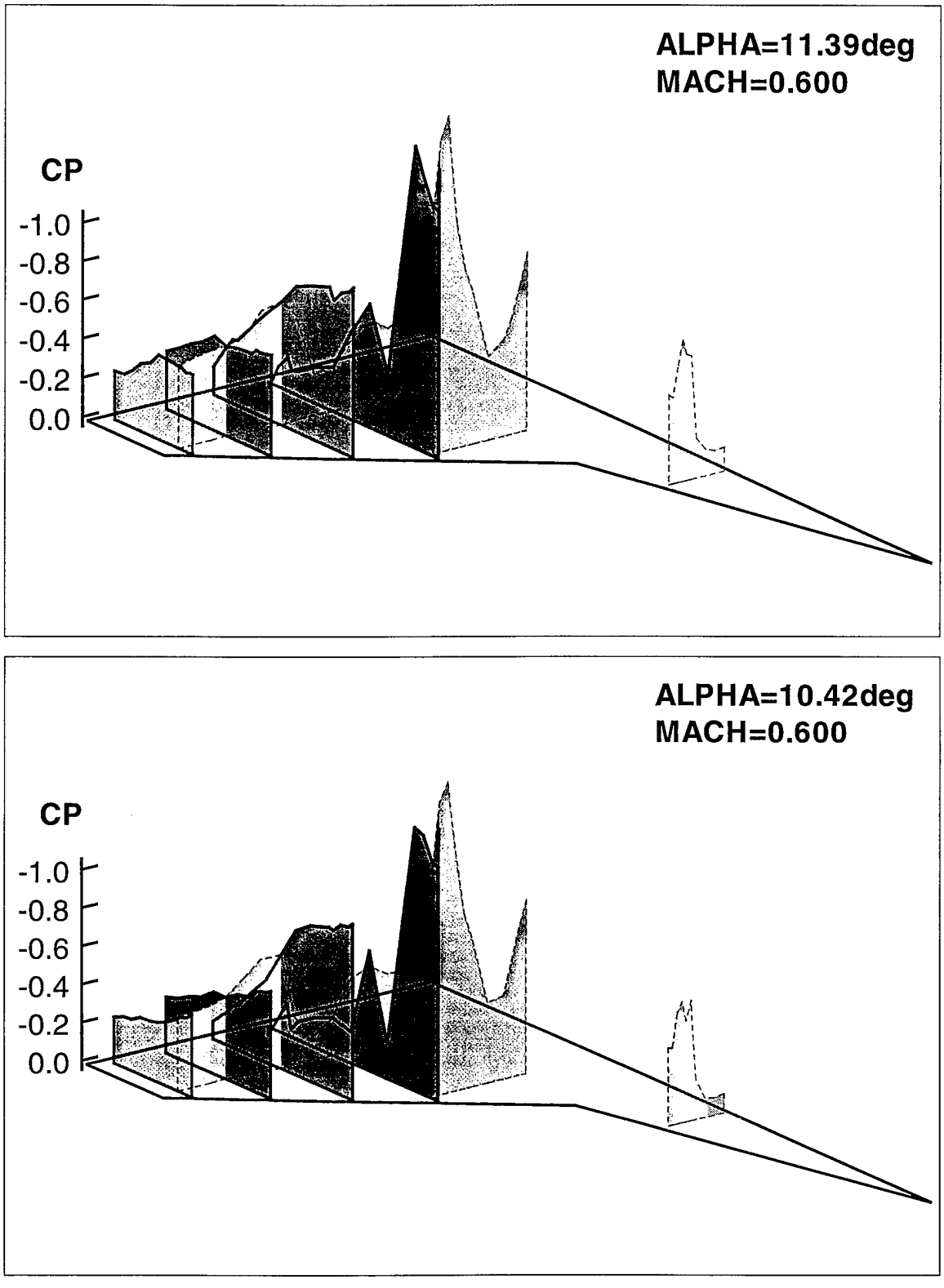
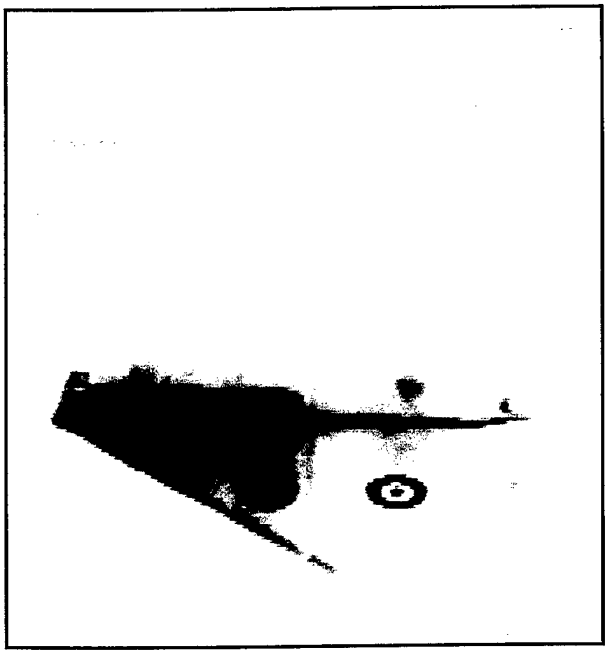
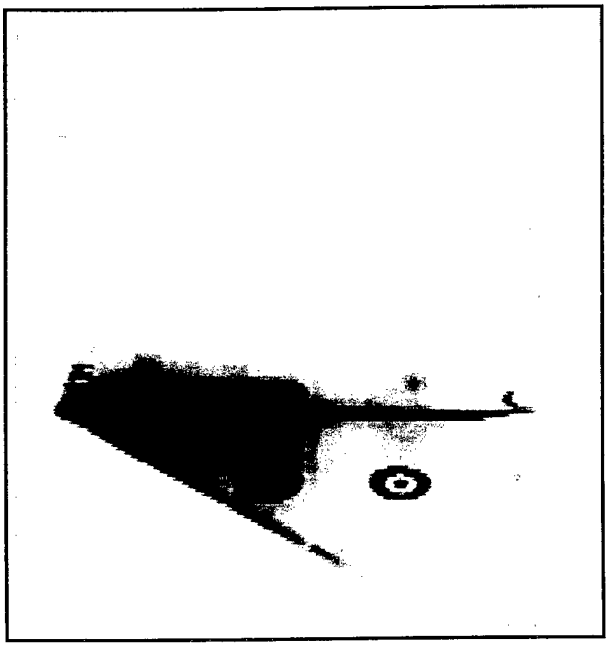


Figure 2.57 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 315.00 deg and 320.62 deg



Sheet Position 9, Alpha = 12.81 deg
(Run ID = 77, Frame = 167)



Sheet Position 9, Alpha = 11.96 deg
(Run ID = 77, Frame = 168)

Figure 2.58 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 315.00 Deg and 320.62 Deg

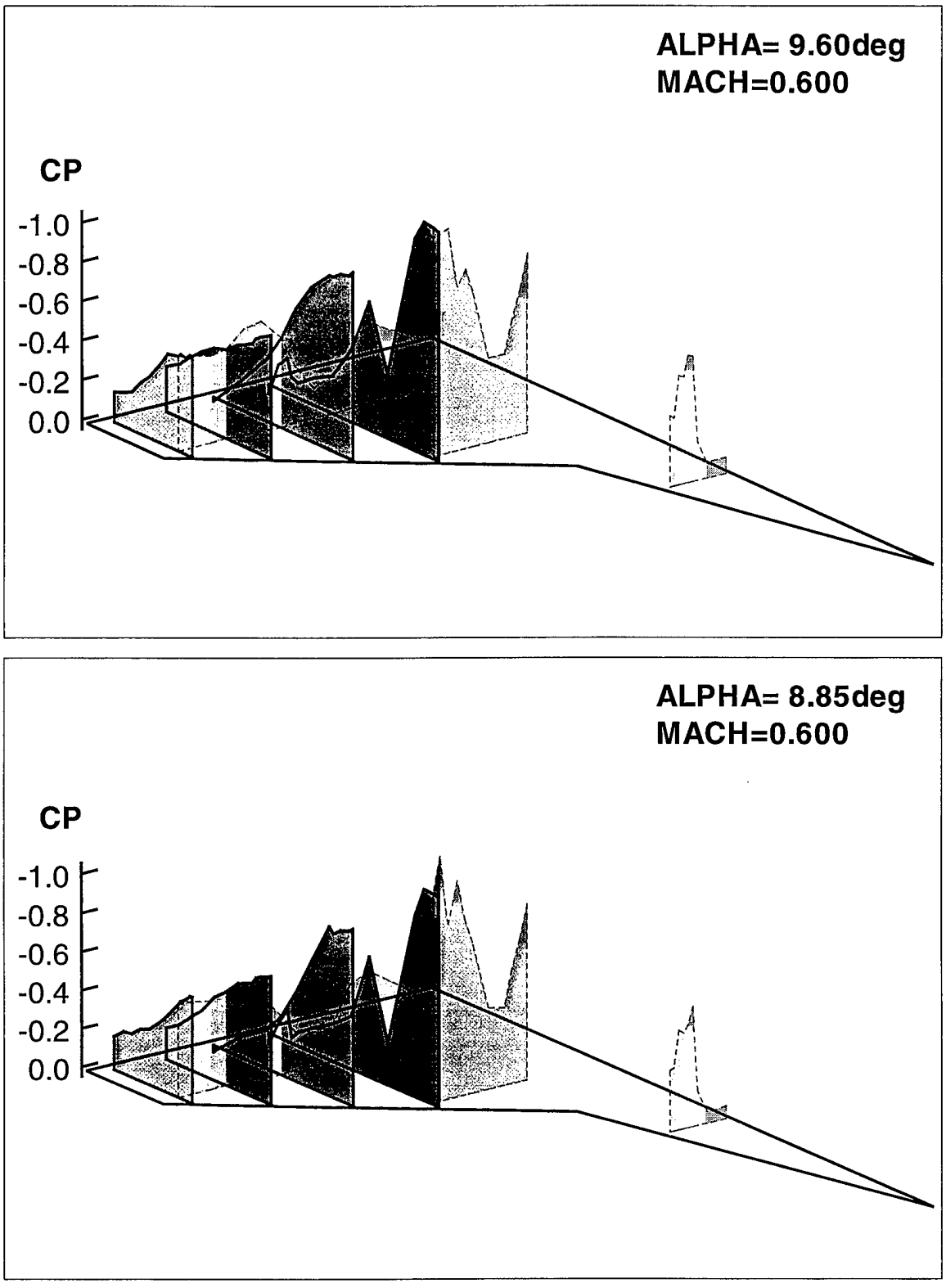
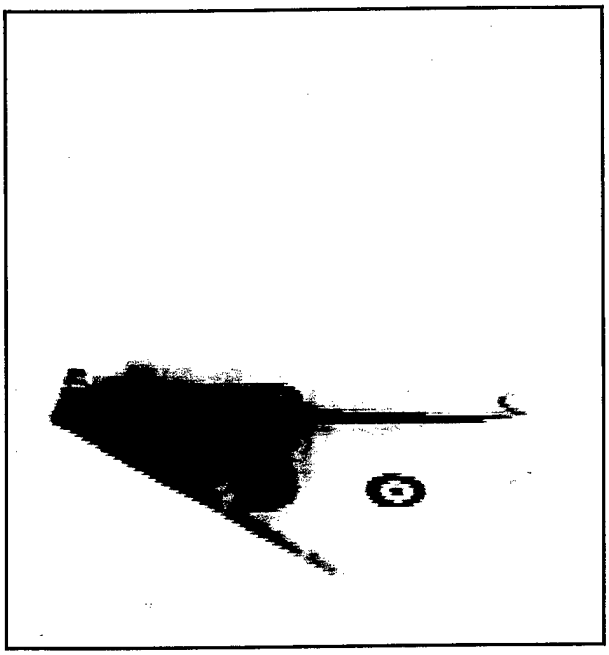
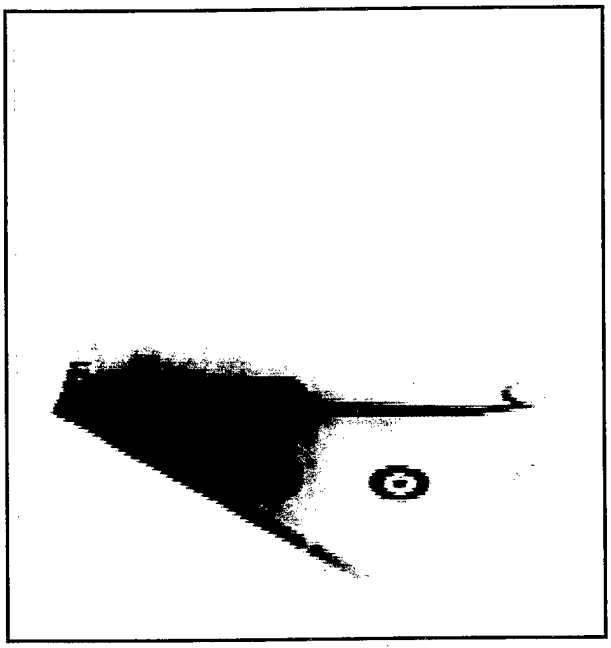


Figure 2.59 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 326.25 deg and 331.88 deg



Sheet Position 9, Alpha = 11.20 deg
(Run ID = 77, Frame = 169)



Sheet Position 9, Alpha = 10.54 deg
(Run ID = 77, Frame = 170)

Figure 2.60 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 326.25 Deg and 331.88 Deg

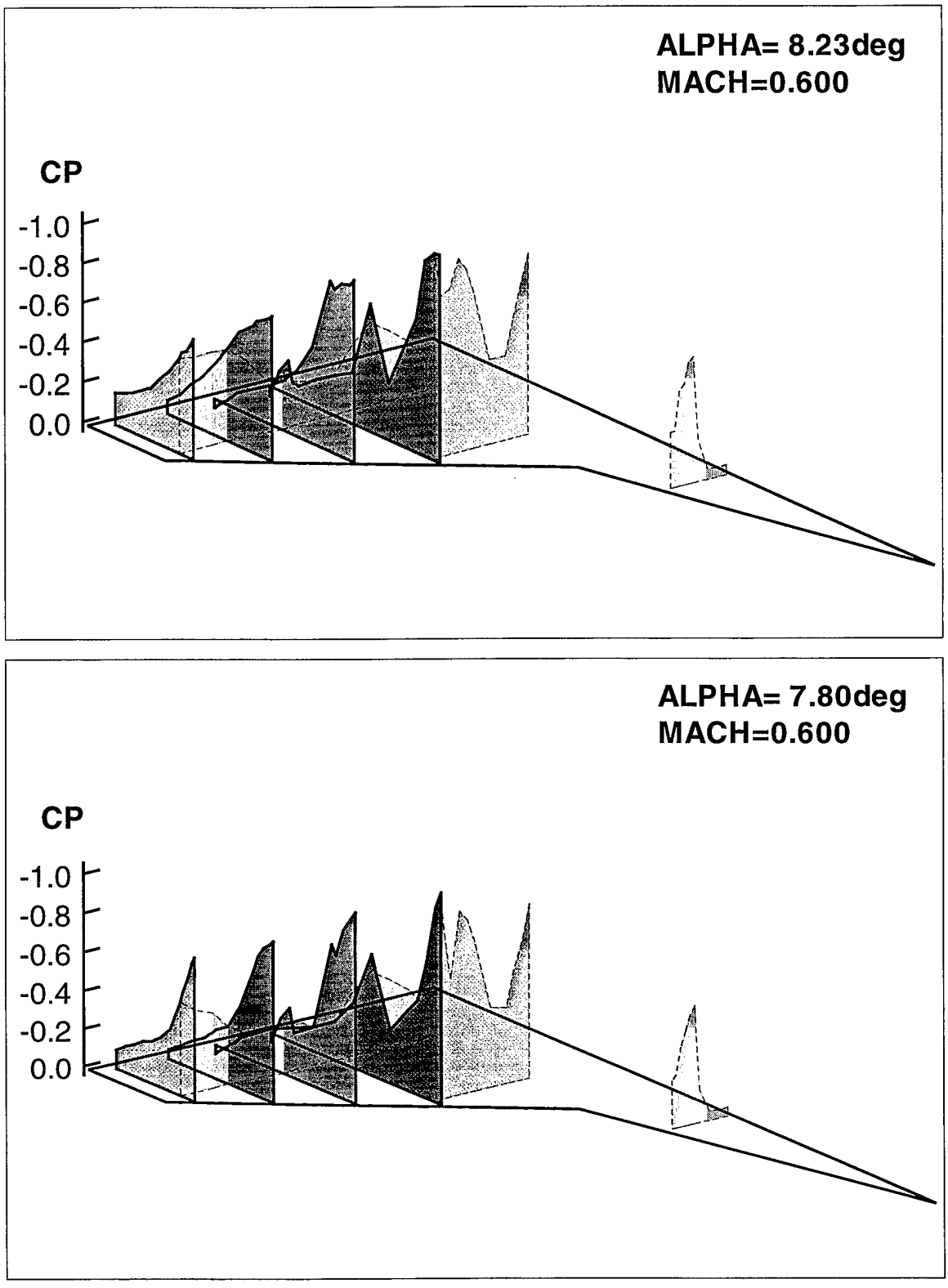
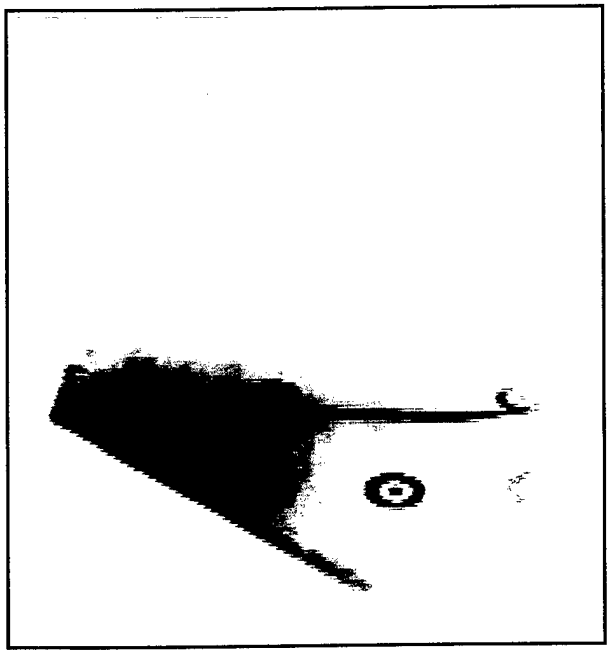
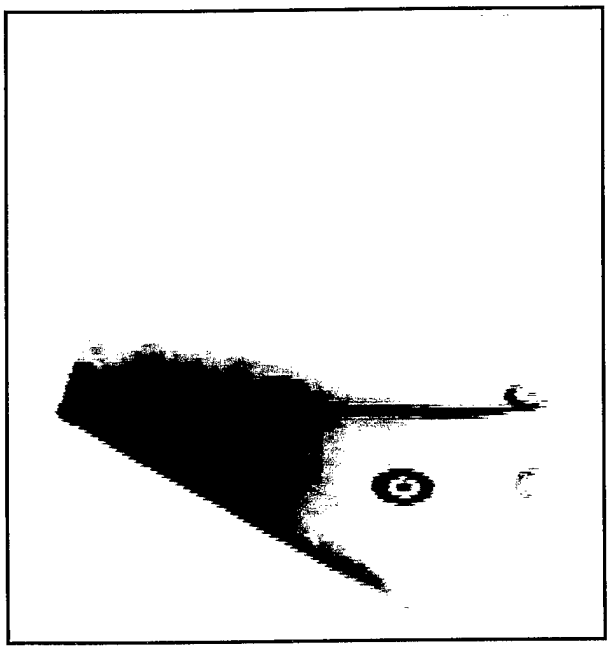


Figure 2.61 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 337.50 deg and 343.12 deg



Sheet Position 9, Alpha = 10.06 deg
(Run ID = 77, Frame = 171)



Sheet Position 9, Alpha = 9.57 deg
(Run ID = 77, Frame = 172)

Figure 2.62 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 337.50 Deg and 343.12 Deg

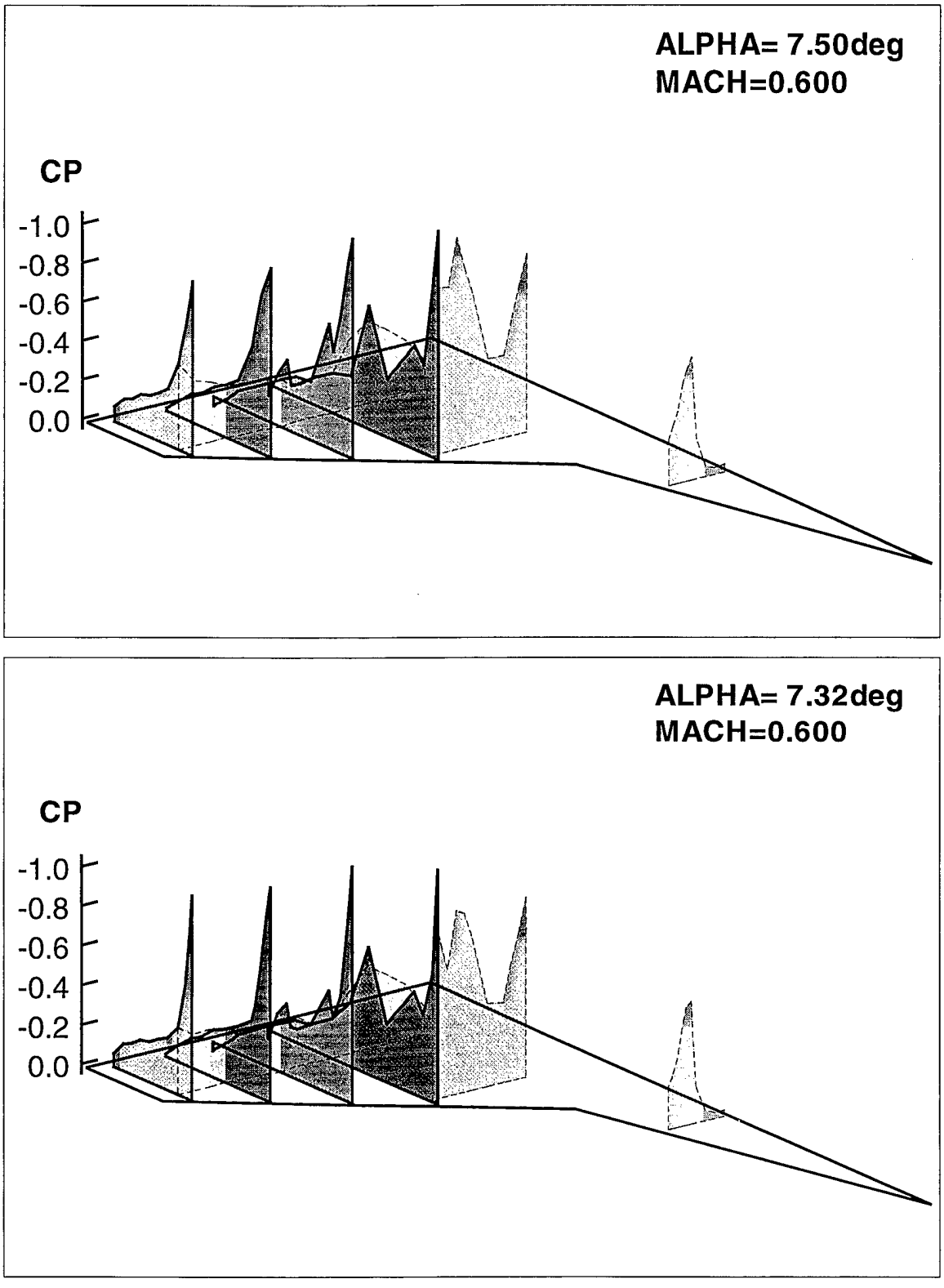
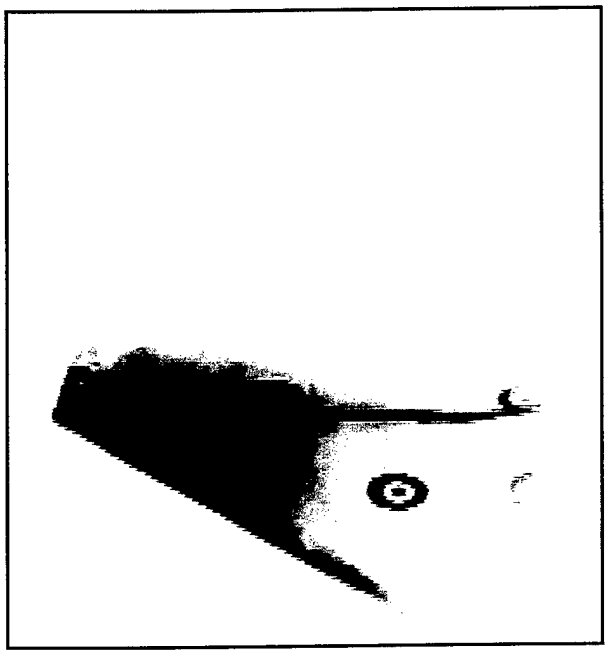
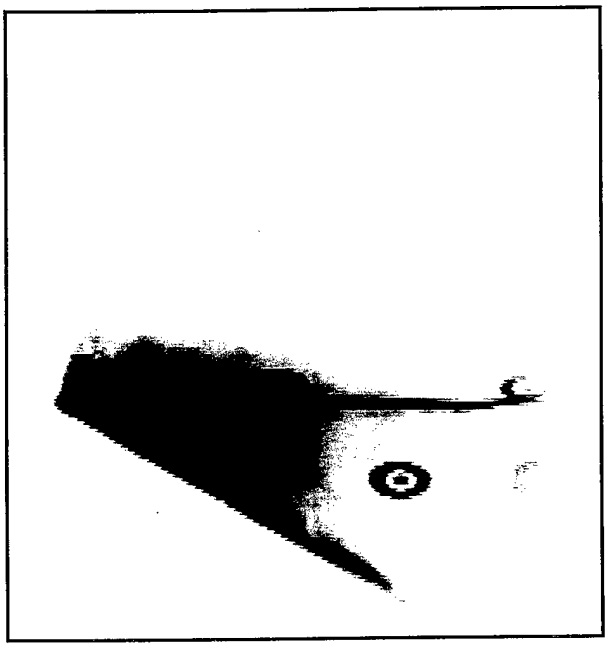


Figure 2.63 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 348.75 deg and 354.38 deg



Sheet Position 9, Alpha = 9.26 deg
(Run ID = 77, Frame = 173)



Sheet Position 9, Alpha = 9.07deg
(Run ID = 77, Frame = 174)

Figure 2.64 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 348.75 Deg and 354.38 Deg

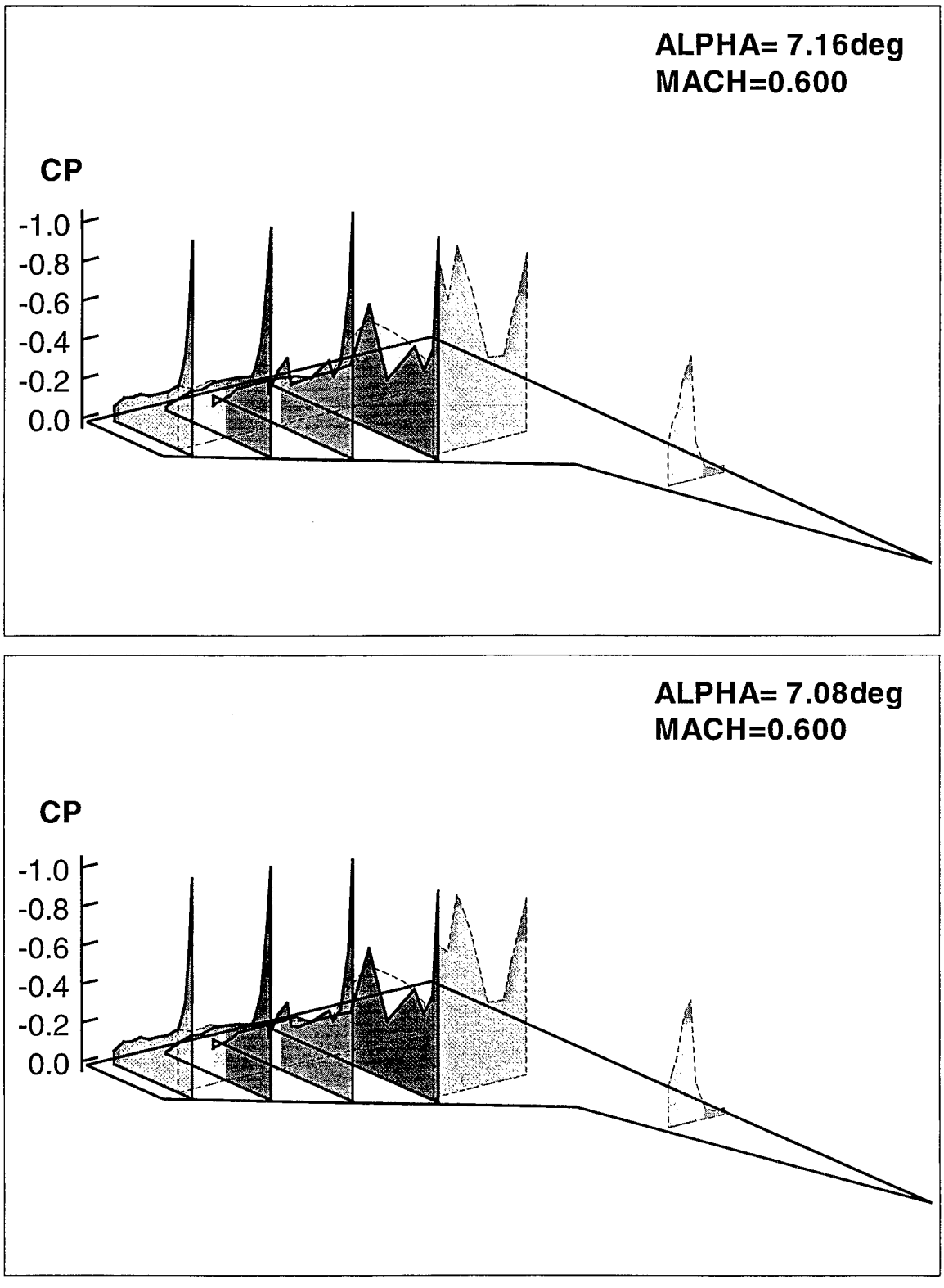
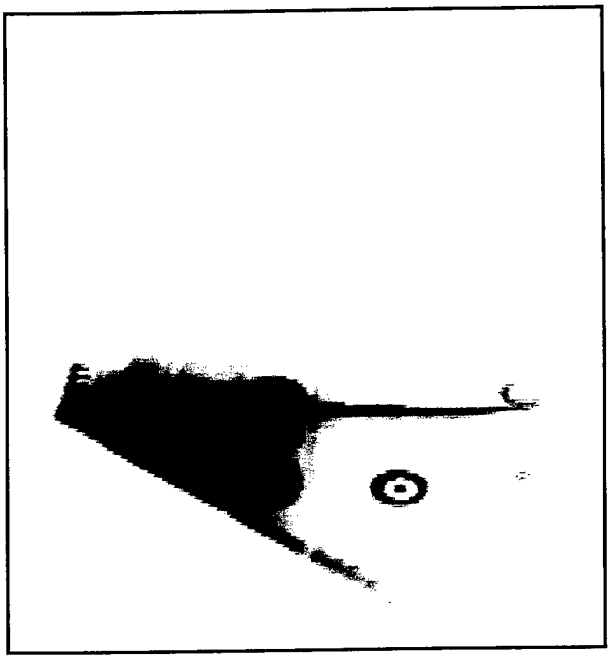
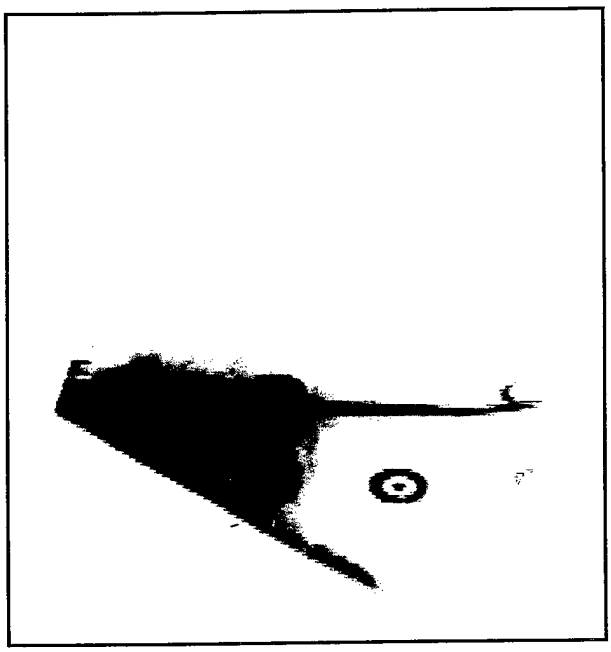


Figure 2.65 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 360.00 deg and 365.62 deg



Sheet Position 9, Alpha = 9.01 deg
(Run ID = 77, Frame = 109)



Sheet Position 9, Alpha = 9.07 deg
(Run ID = 77, Frame = 110)

Figure 2.66 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.6 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 360.00 Deg and 365.62 Deg

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2.0 HIGH SPEED VIDEO FLOW VISUALIZATION AND PRESSURE DATA FOR THE CLEAN WING AT M = 0.9, OSCILLATING BETWEEN 9 DEG AND 35 DEG

Individual frames from the high speed video data base (243 frames per second) are presented in this section for two spanwise sheet positions, 8 and 9, as shown in Figure 3. With exception of the additional sheet position and higher Mach number, the data selection process and presentation format, as shown in the following Figures 4.01 through 4.66 are the same as were used in Section 1 at M = 0.6.

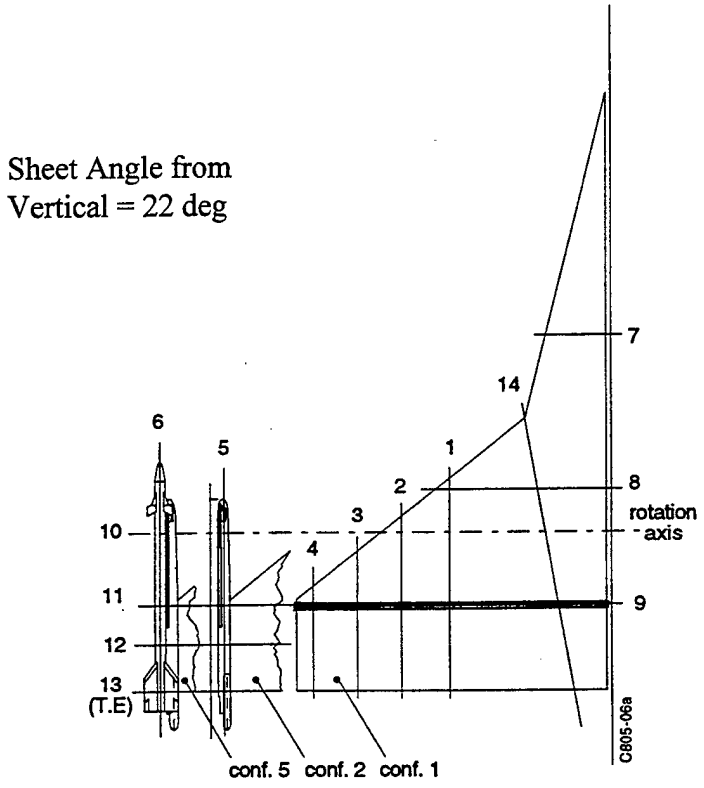


Figure 3 - Flow Visualization Sheet Locations for Figures 4, Clean Wing, M = 0.9, Oscillating Between 9 deg and 35 deg

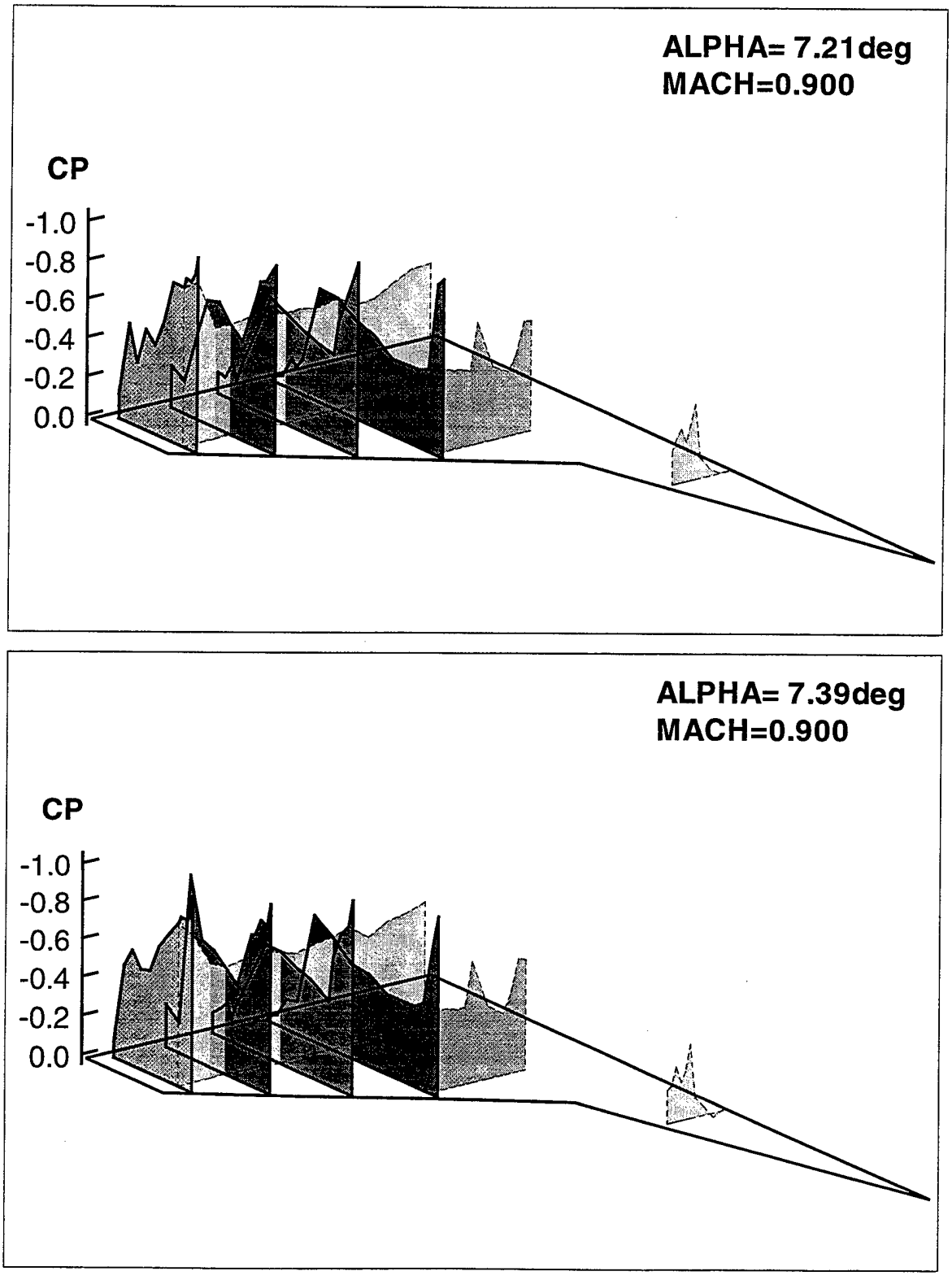
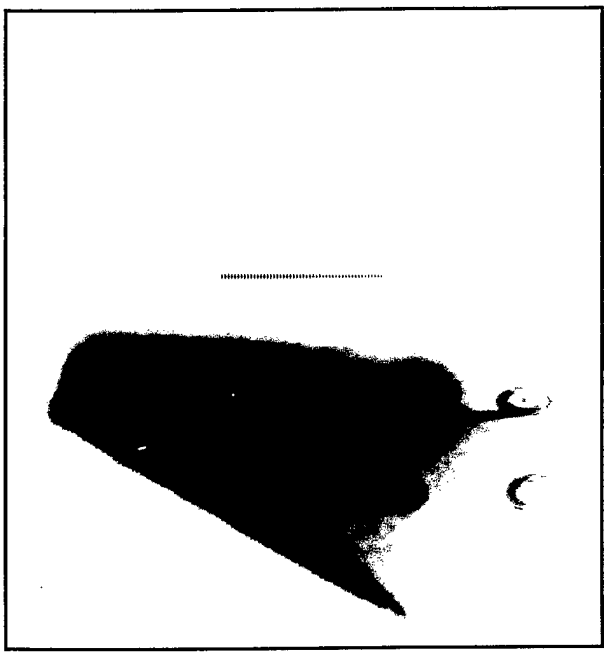
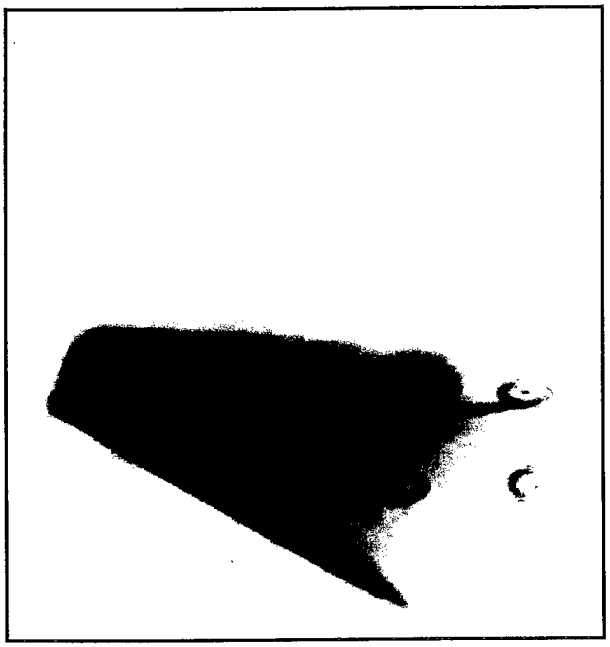


Figure 4.01 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 0.00 deg and 5.62 deg



Sheet Position 9, Alpha = 9.01 deg
(Run ID = 73, Frame = 99)



Sheet Position 9, Alpha = 9.07deg
(Run ID = 73, Frame = 100)

Figure 4.02 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 0.00 Deg and 5.62 Deg

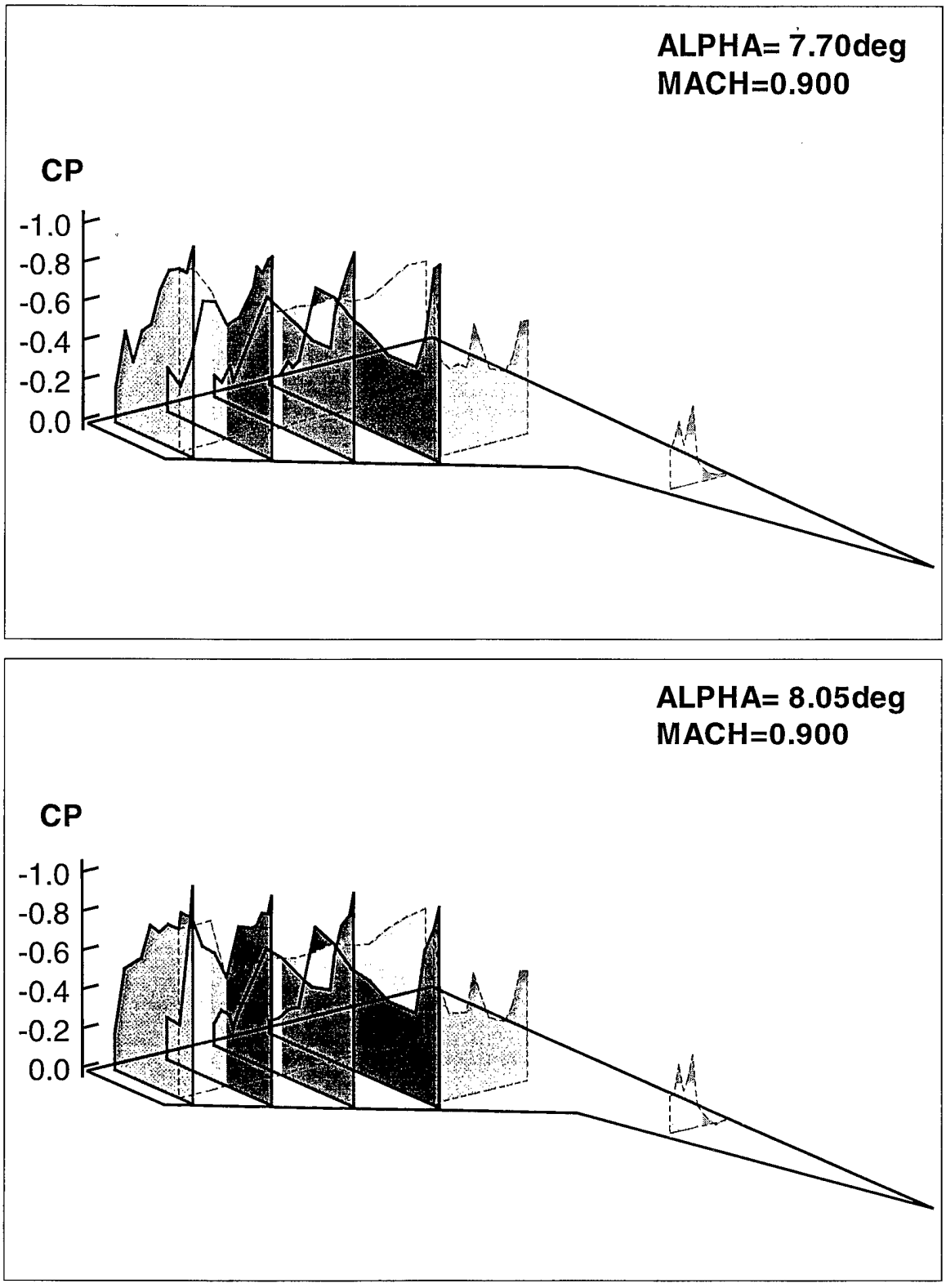
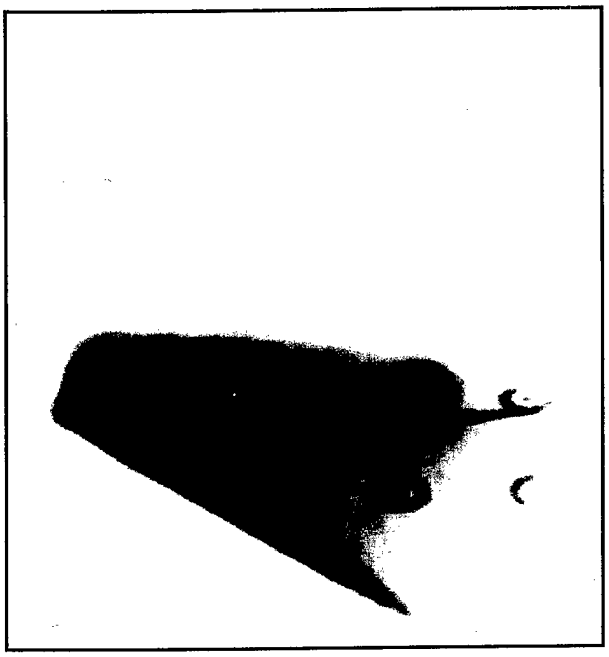
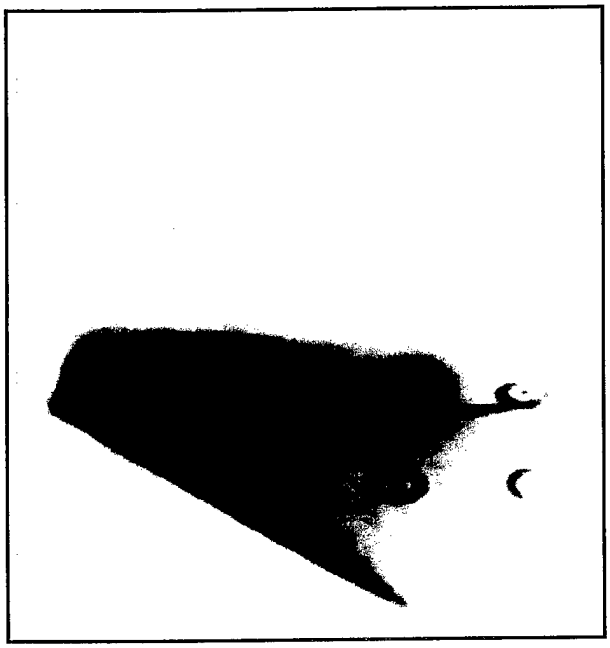


Figure 4.03 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 11.25 deg and 16.88 deg



Sheet Position 9, Alpha = 9.26 deg
(Run ID = 73, Frame = 101)



Sheet Position 9, Alpha = 9.59 deg
(Run ID = 73, Frame = 102)

Figure 4.04 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 11.25 Deg and 16.88 Deg

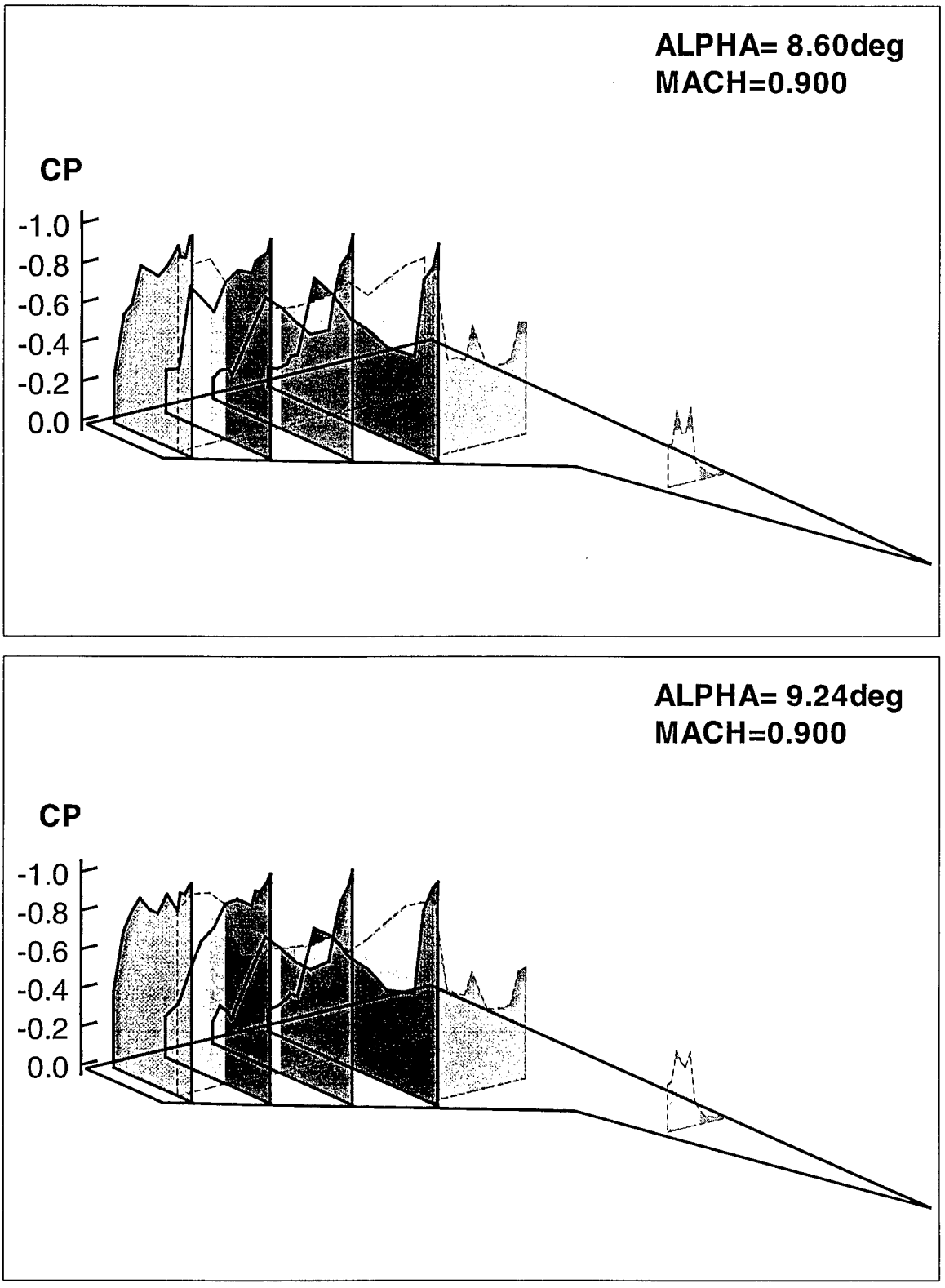
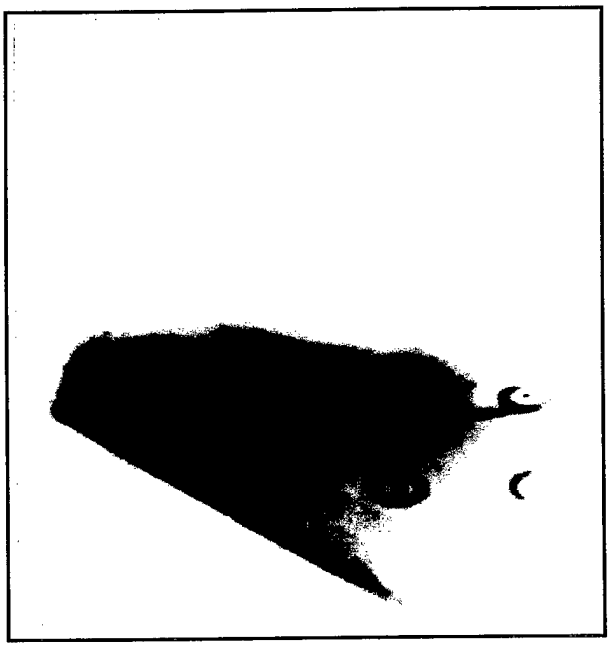


Figure 4.05 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 22.50 deg and 28.12 deg

Sheet Position 9, Alpha = 10.00 deg
(Run ID = 73, Frame = 103)



Sheet Position 9, Alpha = 10.54 deg
(Run ID = 73, Frame = 104)

Figure 4.06 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 22.50 Deg and 28.12 Deg

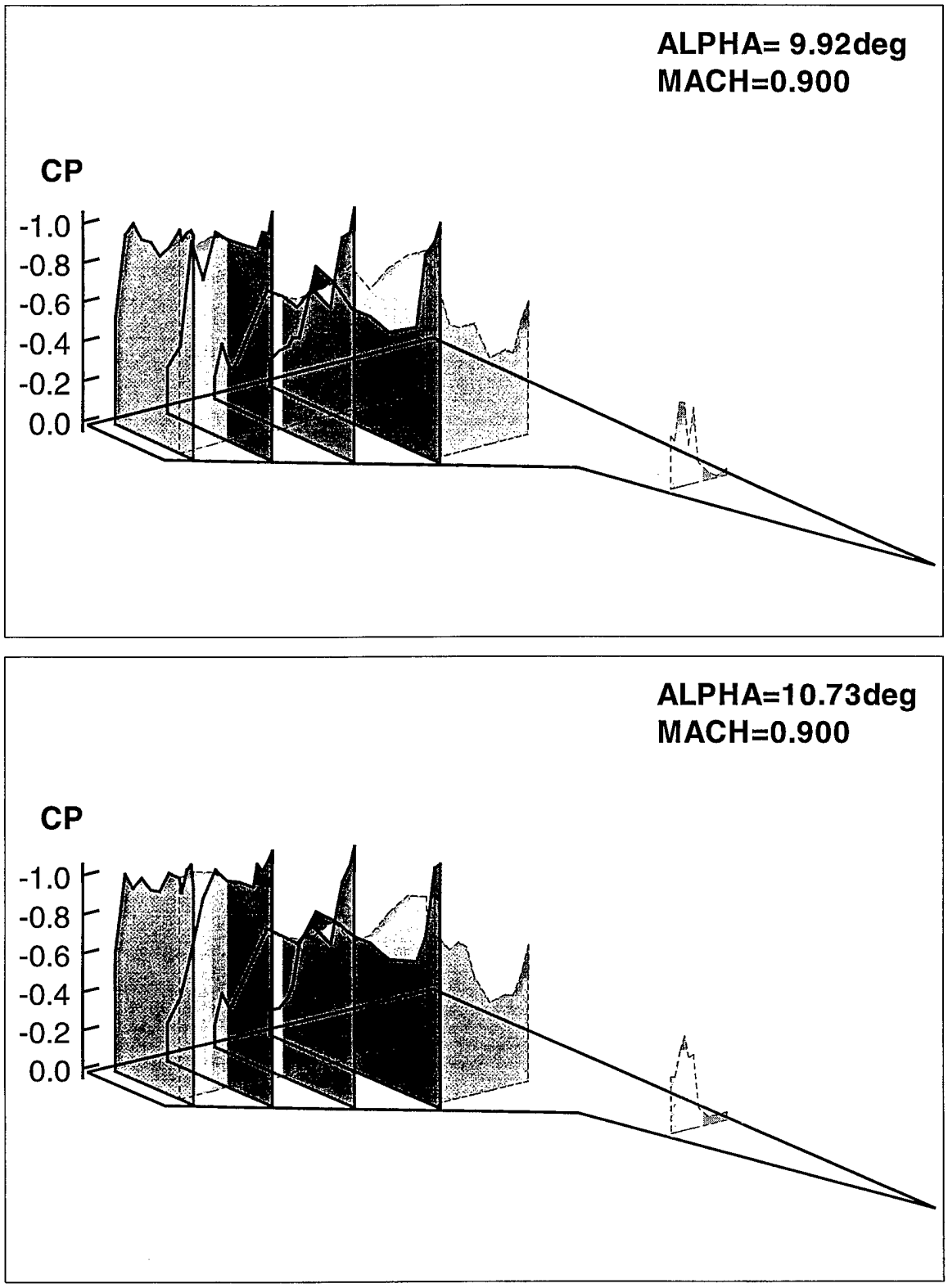
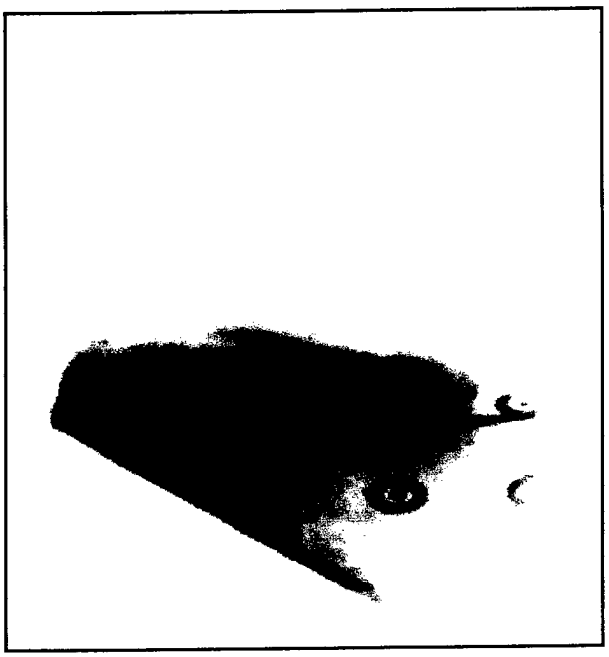
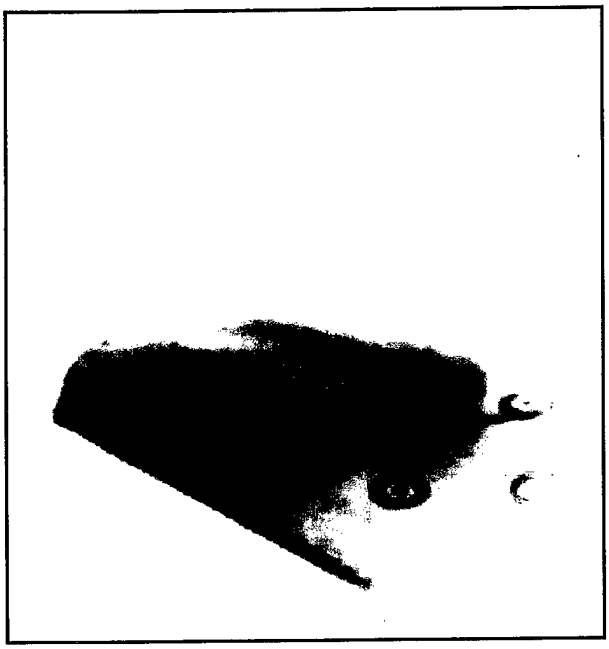


Figure 4.07 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 33.75 deg and 39.38 deg



Sheet Position 9, Alpha = 11.20 deg
(Run ID = 73, Frame = 105)



Sheet Position 9, Alpha = 11.96 deg
(Run ID = 73, Frame = 106)

Figure 4.08 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 33.75 Deg and 39.38 Deg

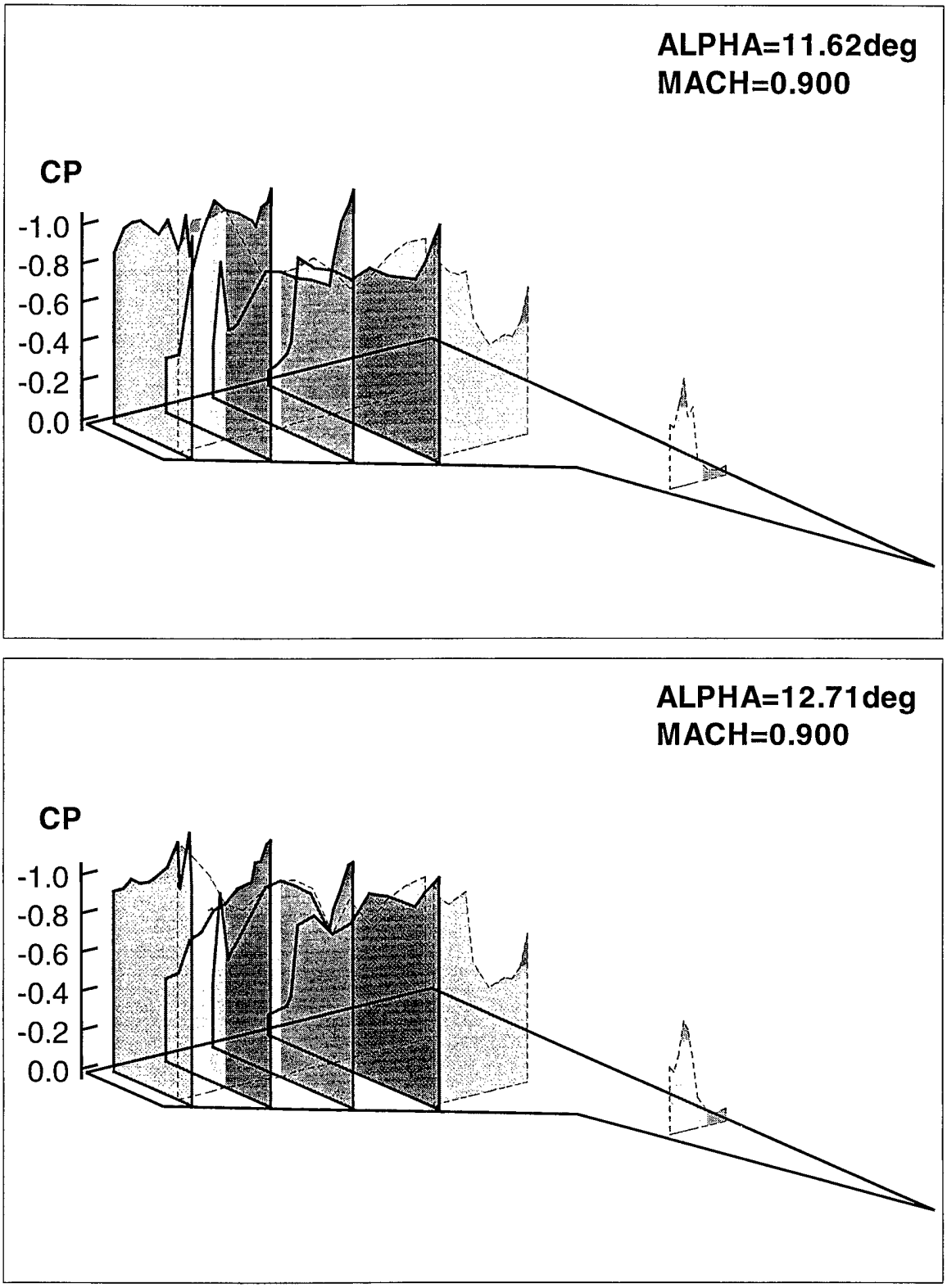
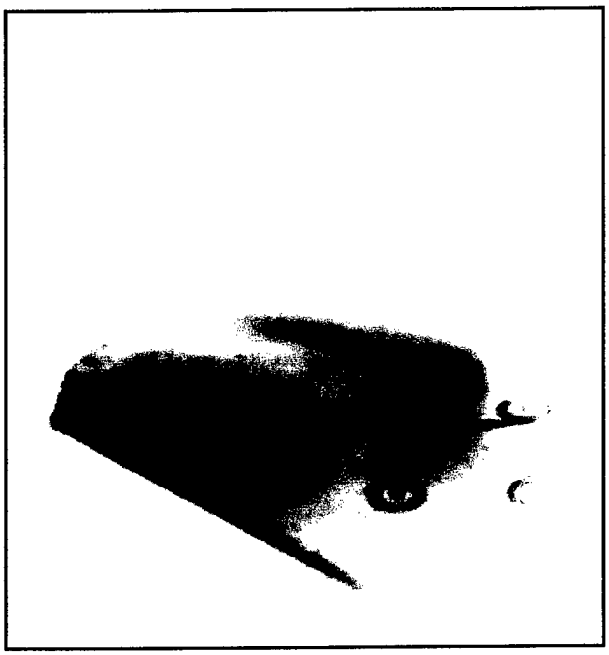
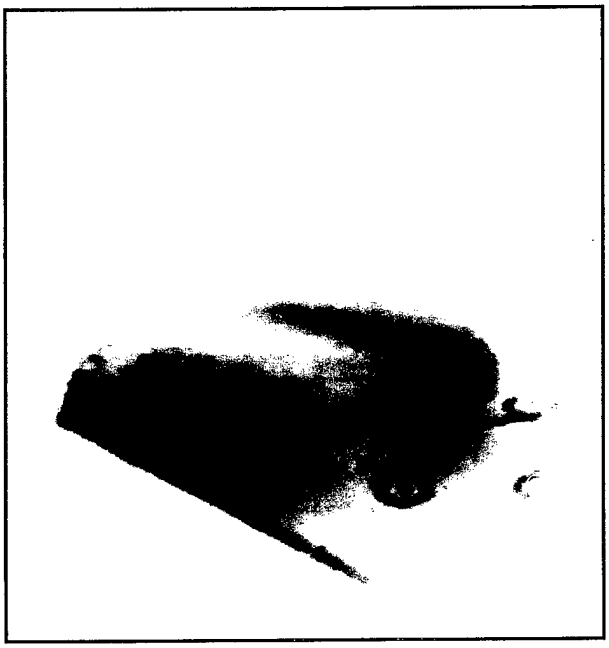


Figure 4.09 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 45.00 deg and 50.62 deg



Sheet Position 9, Alpha = 12.81 deg
(Run ID = 73, Frame = 107)



Sheet Position 9, Alpha = 13.76 deg
(Run ID = 73, Frame = 108)

Figure 4.10 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 45.00 Deg and 50.62 Deg

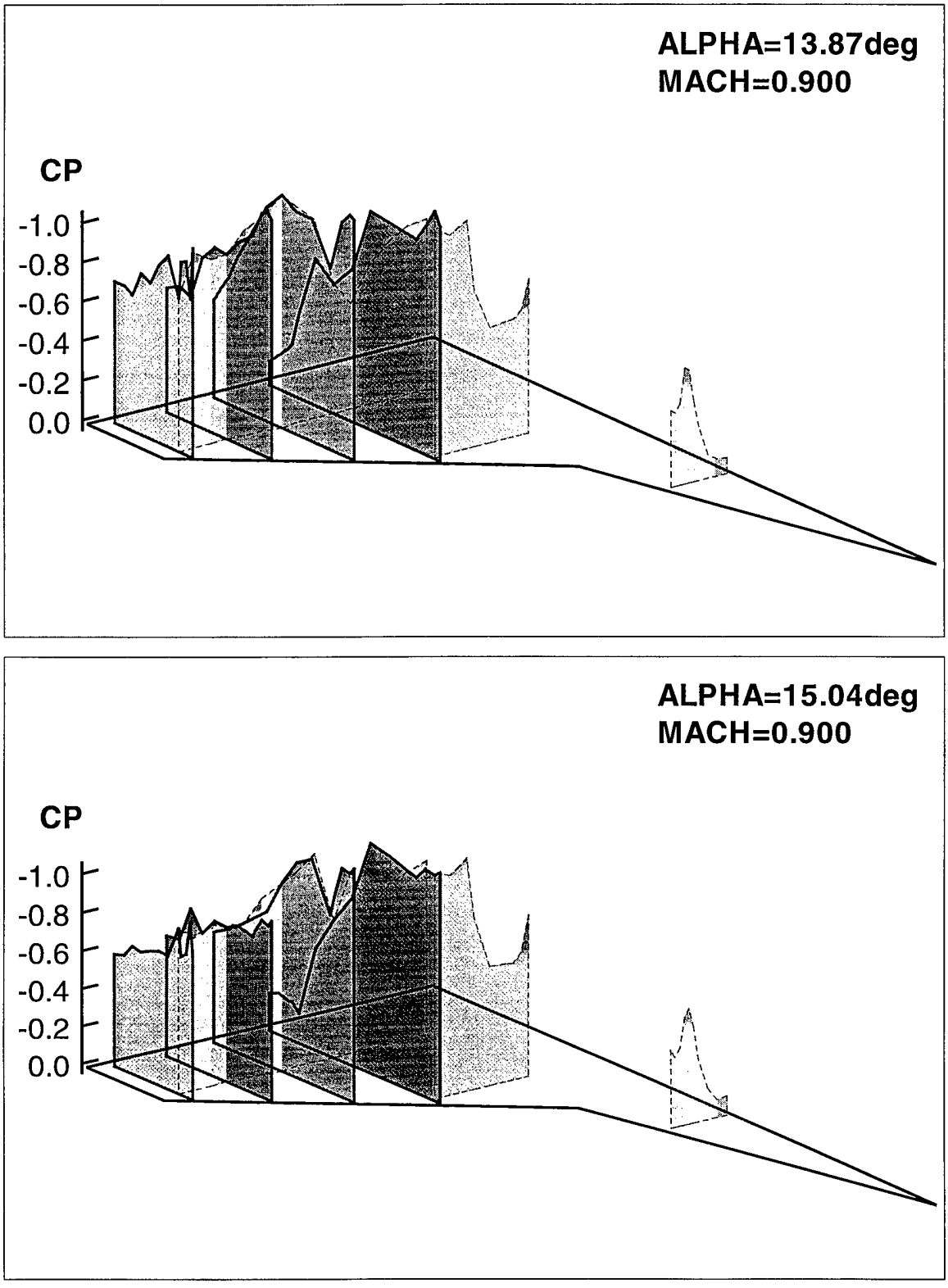
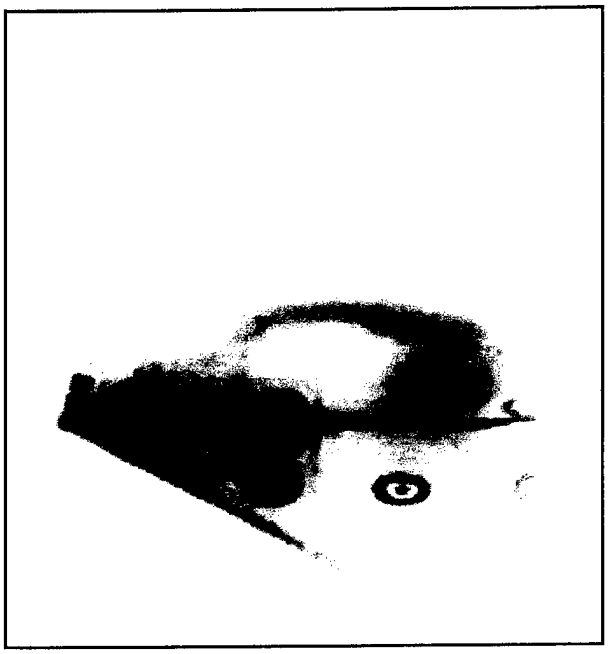
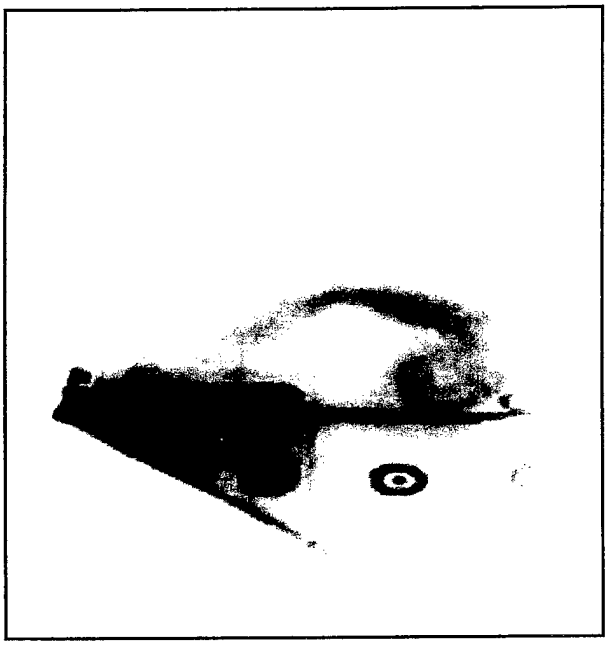


Figure 4.11 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 56.25 deg and 61.88 deg



Sheet Position 9, Alpha = 14.78 deg
(Run ID = 73, Frame = 109)



Sheet Position 9, Alpha = 15.87 deg
(Run ID = 73, Frame = 110)

Figure 4.12 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 56.25 Deg and 61.88 Deg

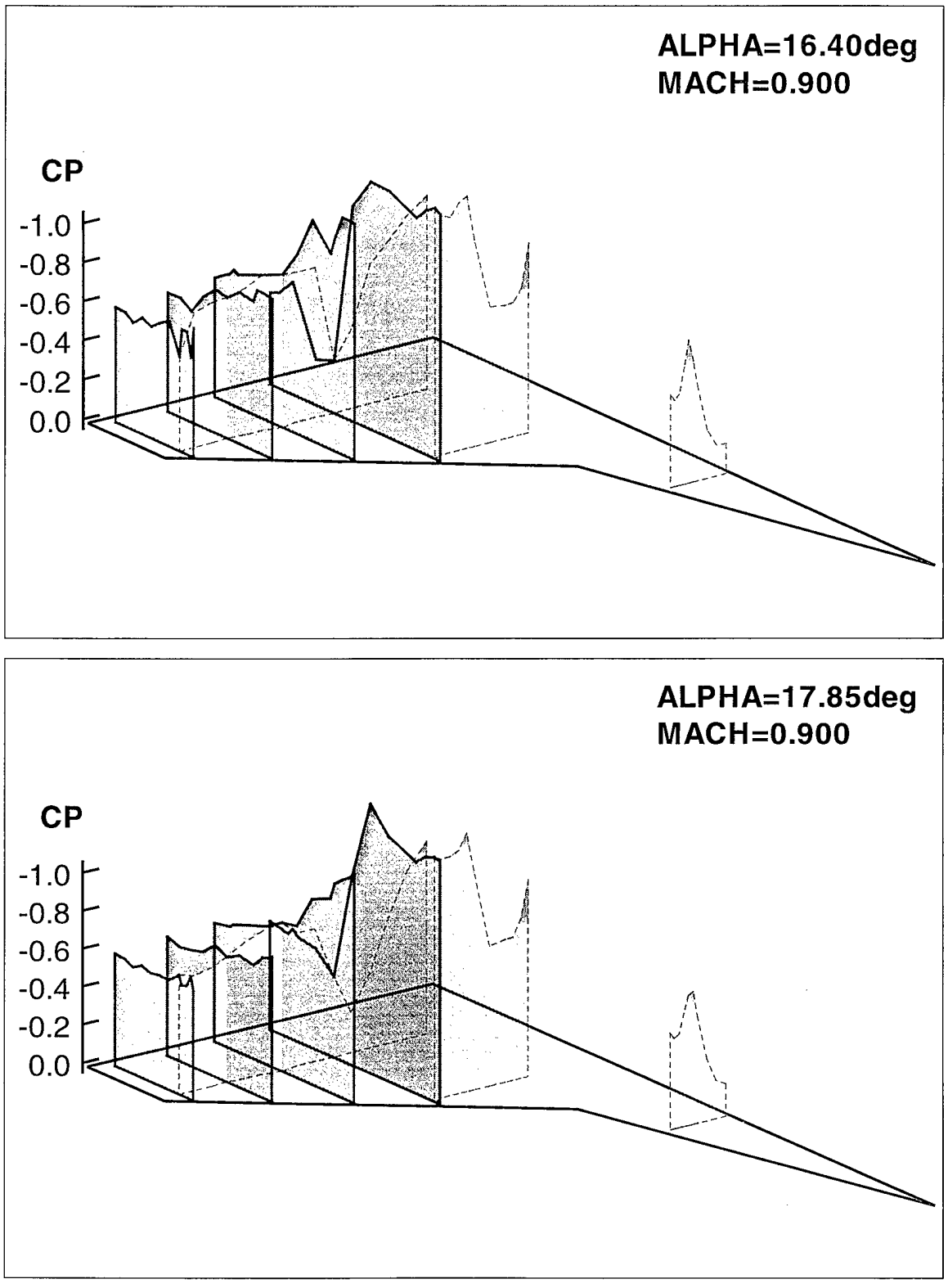
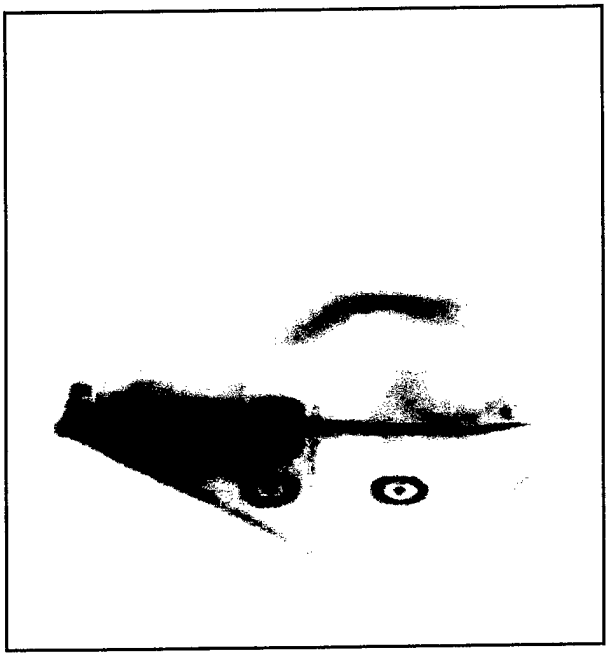
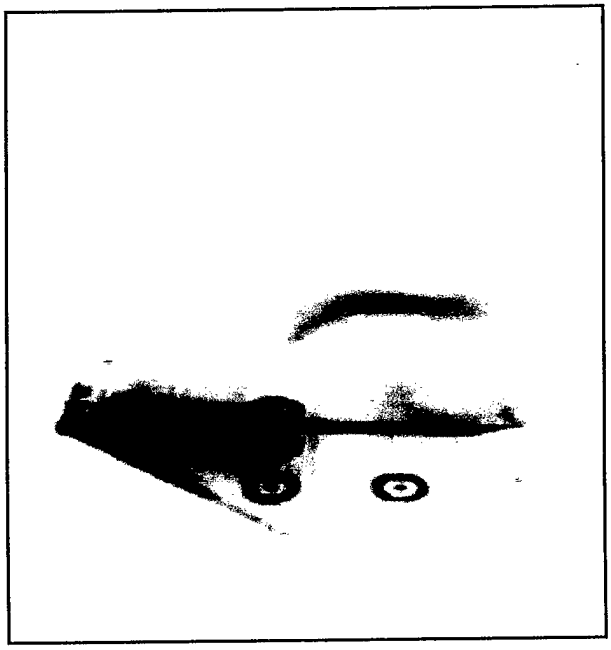


Figure 4.13 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 67.50 deg and 73.12 deg



Sheet Position 9, Alpha = 17.02 deg
(Run ID = 73, Frame = 111)



Sheet Position 9, Alpha = 18.22 deg
(Run ID = 73, Frame = 112)

Figure 4.14 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 67.50 Deg and 73.12 Deg

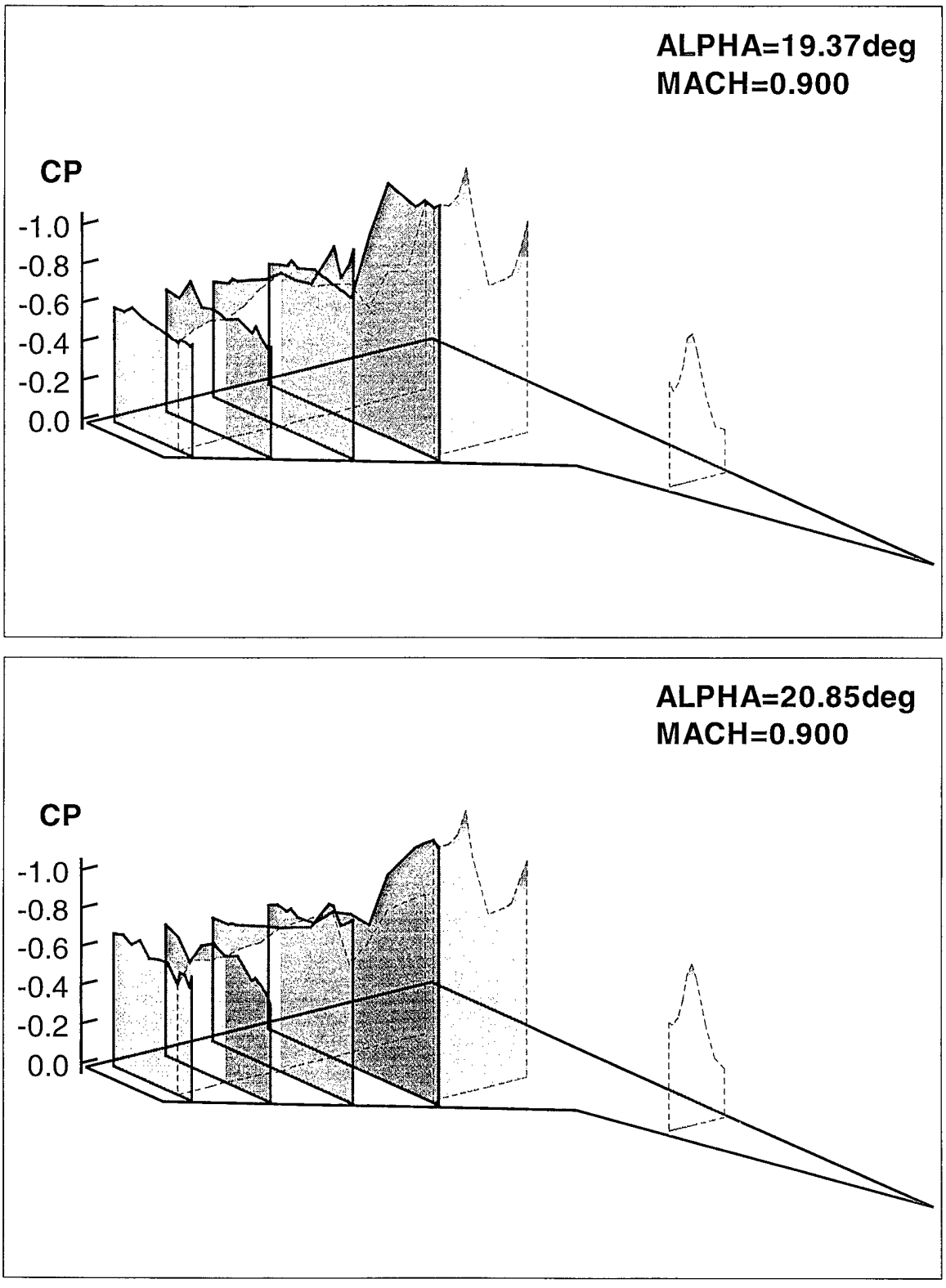
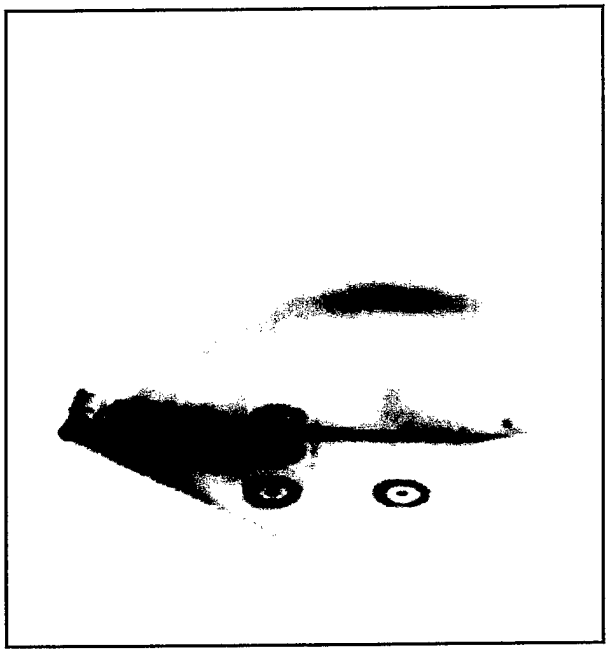
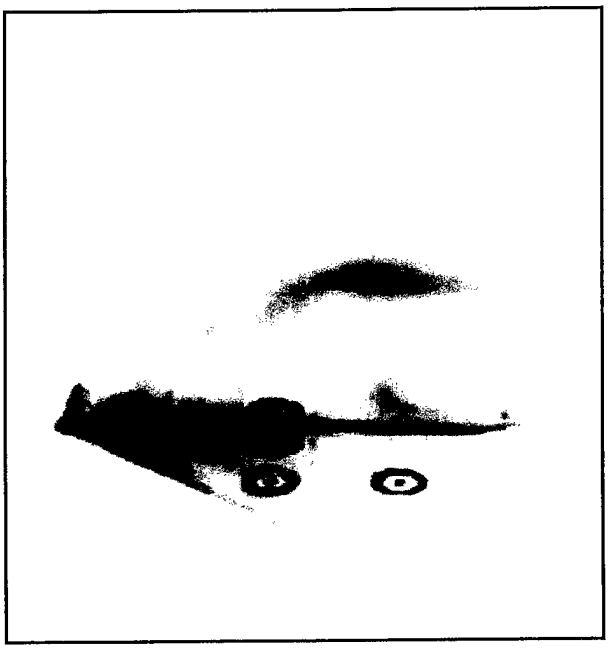


Figure 4.15 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 78.75 deg and 84.38 deg



Sheet Position 9, Alpha = 19.46 deg
(Run ID = 73, Frame = 113)



Sheet Position 9, Alpha = 20.72 deg
(Run ID = 73, Frame = 114)

Figure 4.16 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 78.75 Deg and 84.38 Deg

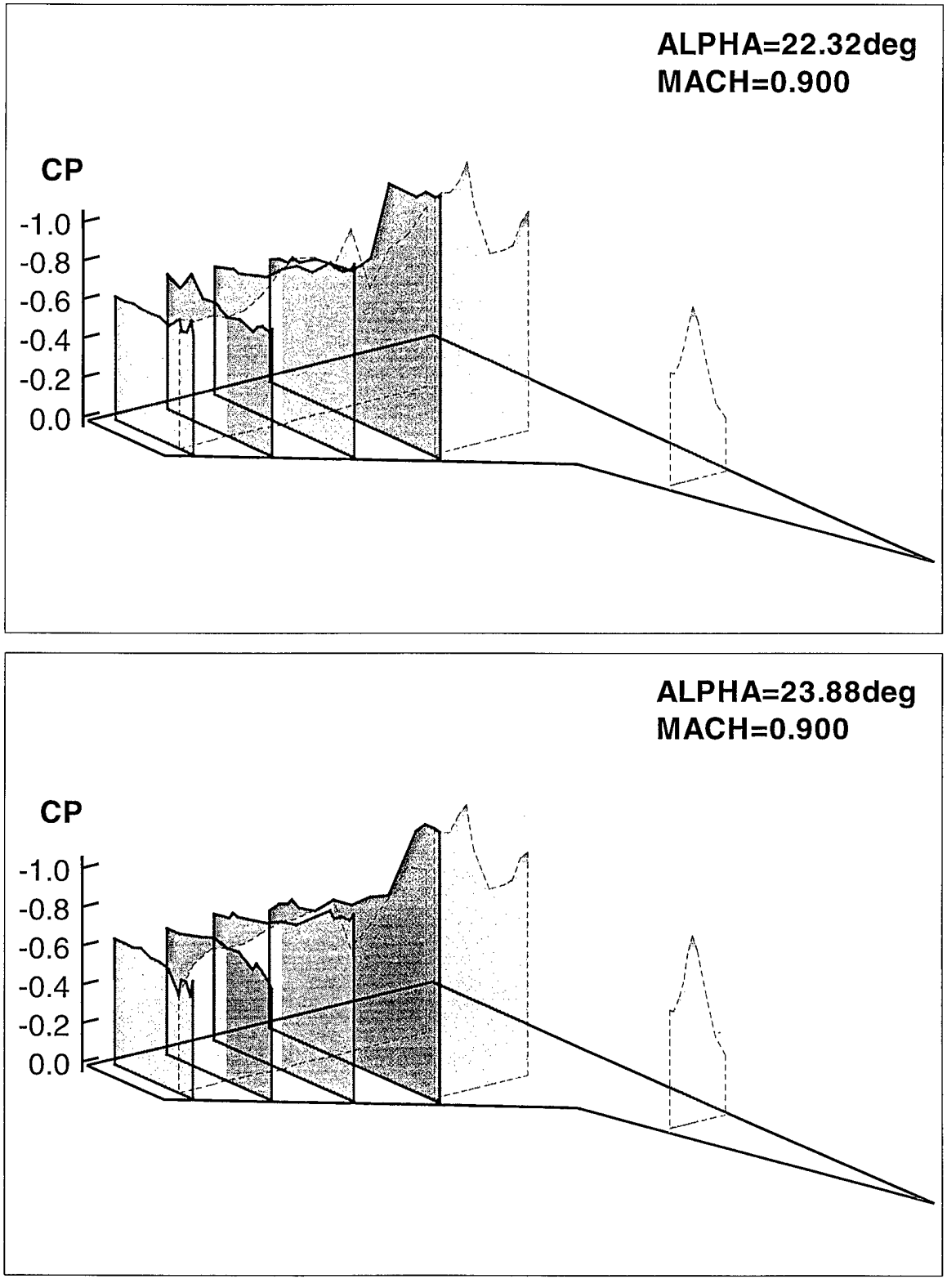
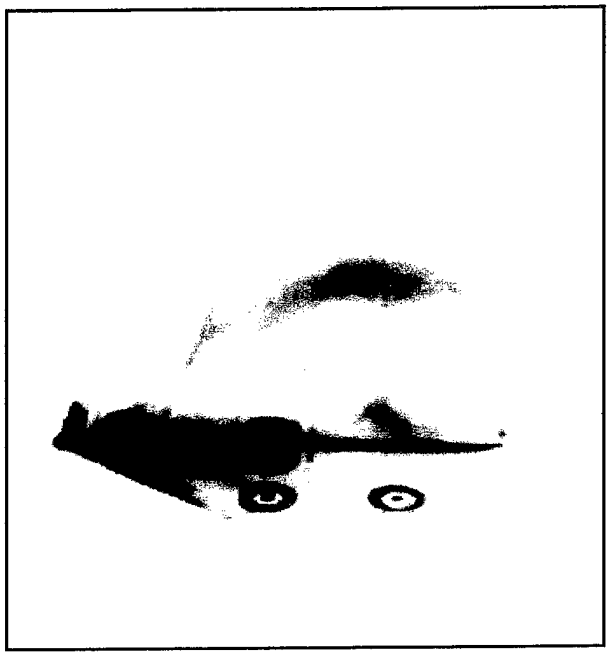


Figure 4.17 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 90.00 deg and 95.62 deg



Sheet Position 9, Alpha = 21.99 deg
(Run ID = 73, Frame = 115)

Sheet Position 9, Alpha = 23.26 deg
(Run ID = 73, Frame = 116)

Figure 4.18 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 90.00 Deg and 95.62 Deg

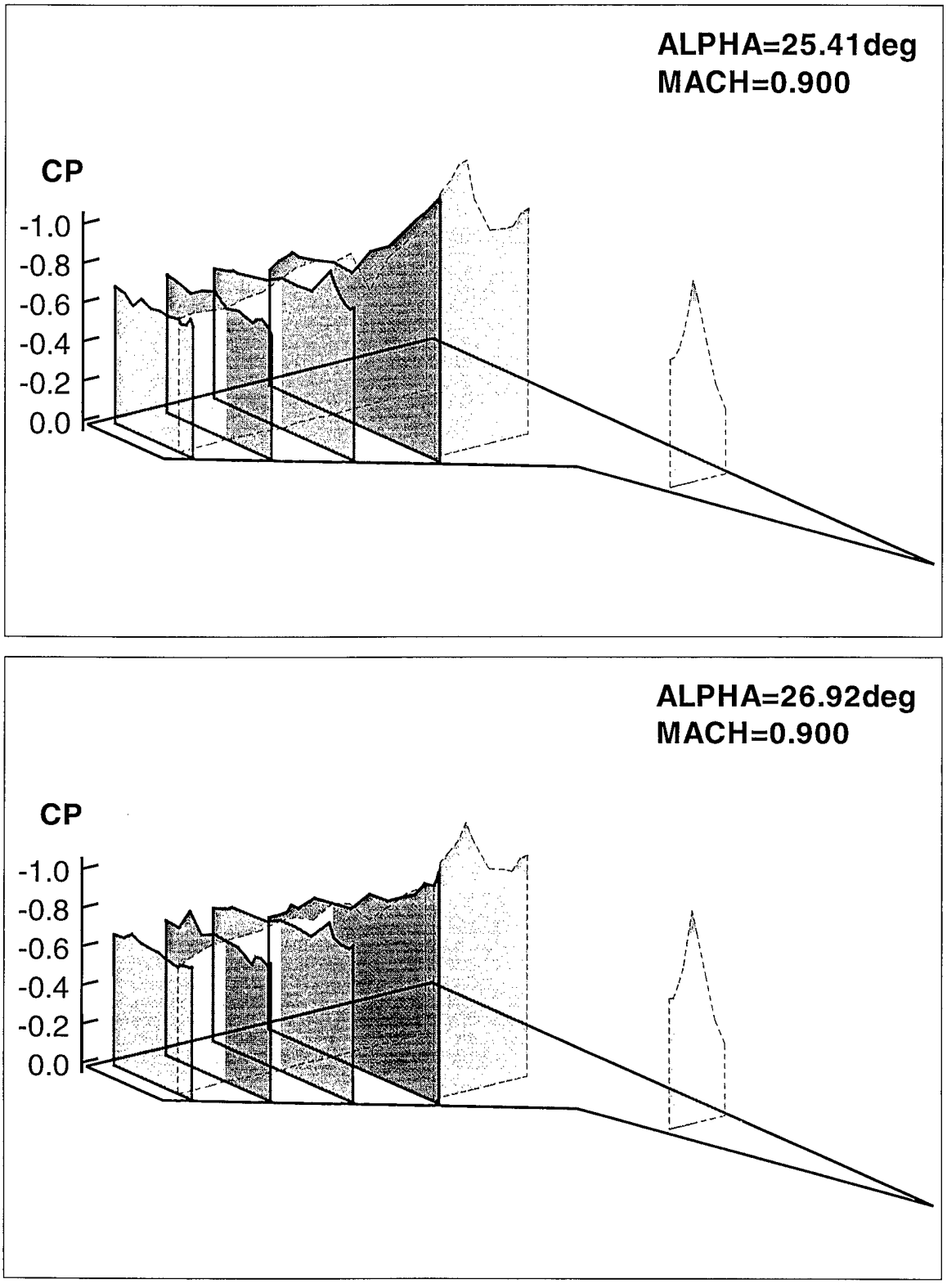
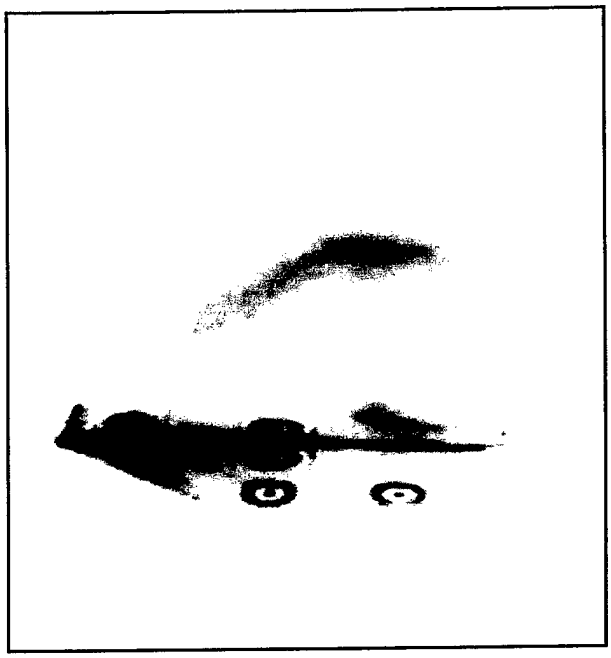
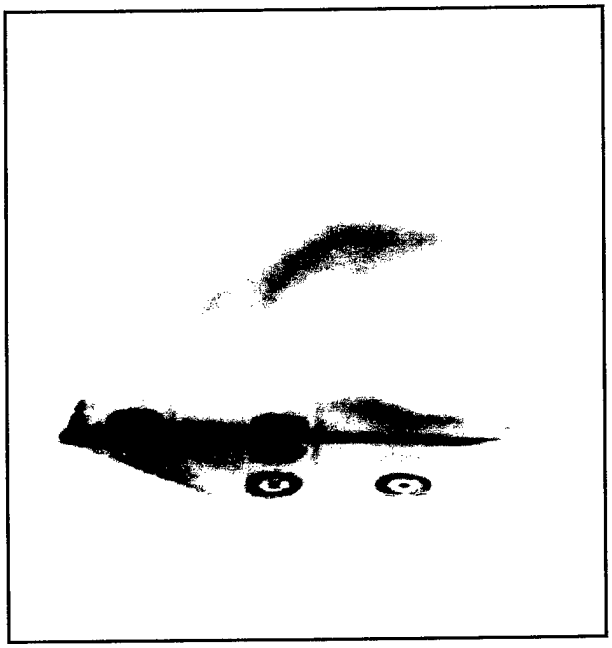


Figure 4.19 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 101.25 deg and 106.88 deg



Sheet Position 9, Alpha = 24.52 deg
(Run ID = 73, Frame = 117)



Sheet Position 9, Alpha = 25.76 deg
(Run ID = 73, Frame = 118)

Figure 4.20 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 101.25 Deg and 106.88 Deg

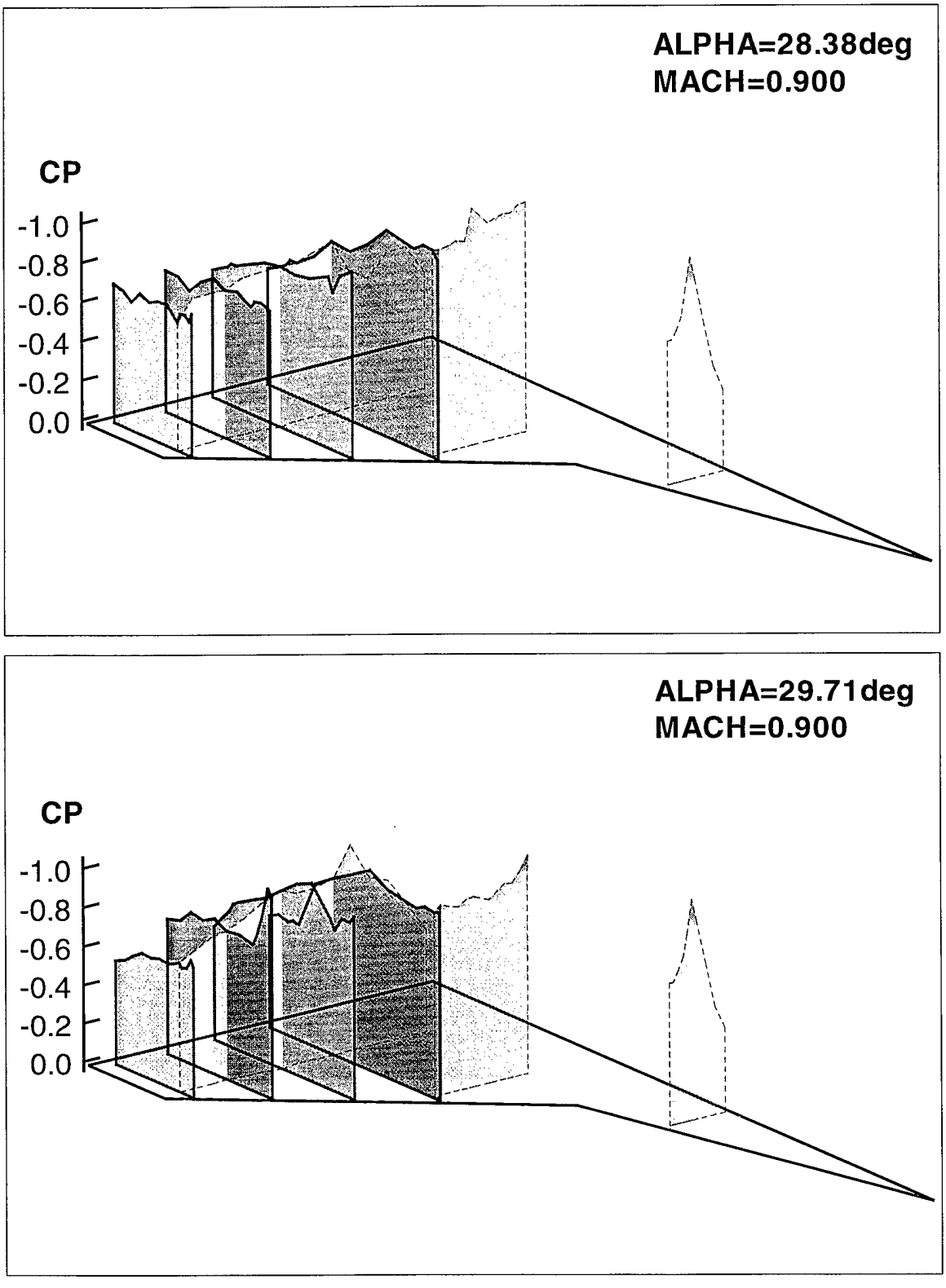
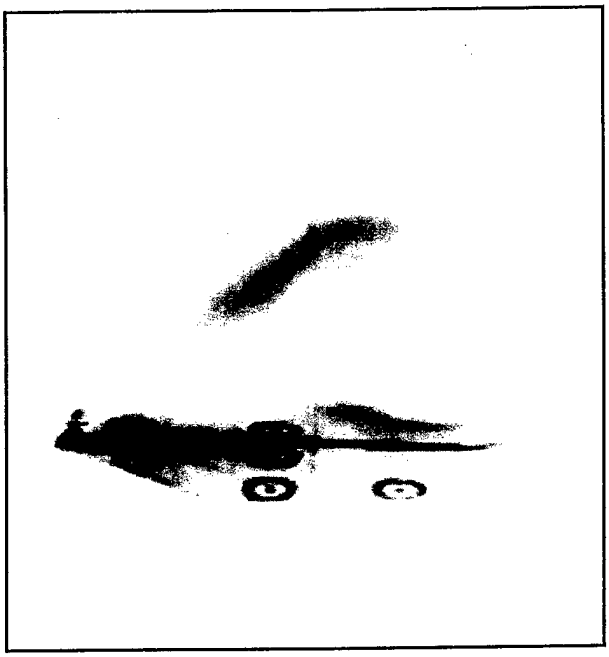
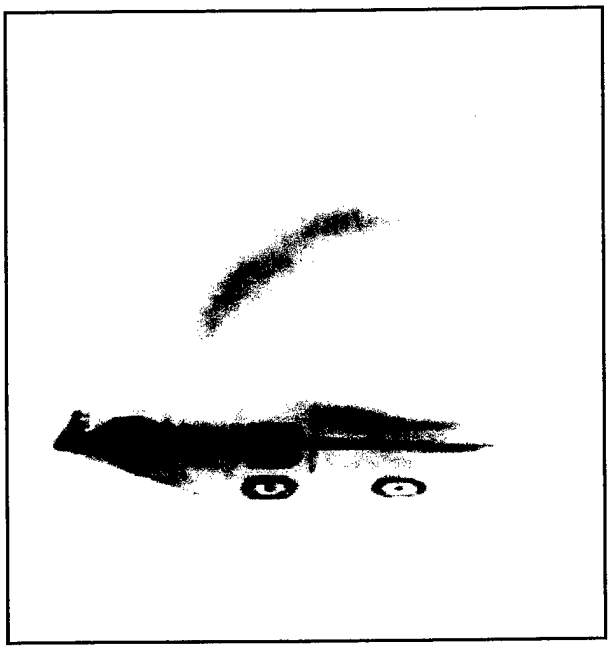


Figure 4.21 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 112.50 deg and 118.12 deg



Sheet Position 9, Alpha = 26.96 deg
(Run ID = 73, Frame = 119)



Sheet Position 9, Alpha = 28.11 deg
(Run ID = 73, Frame = 120)

Figure 4.22 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 112.50 Deg and 118.12 Deg

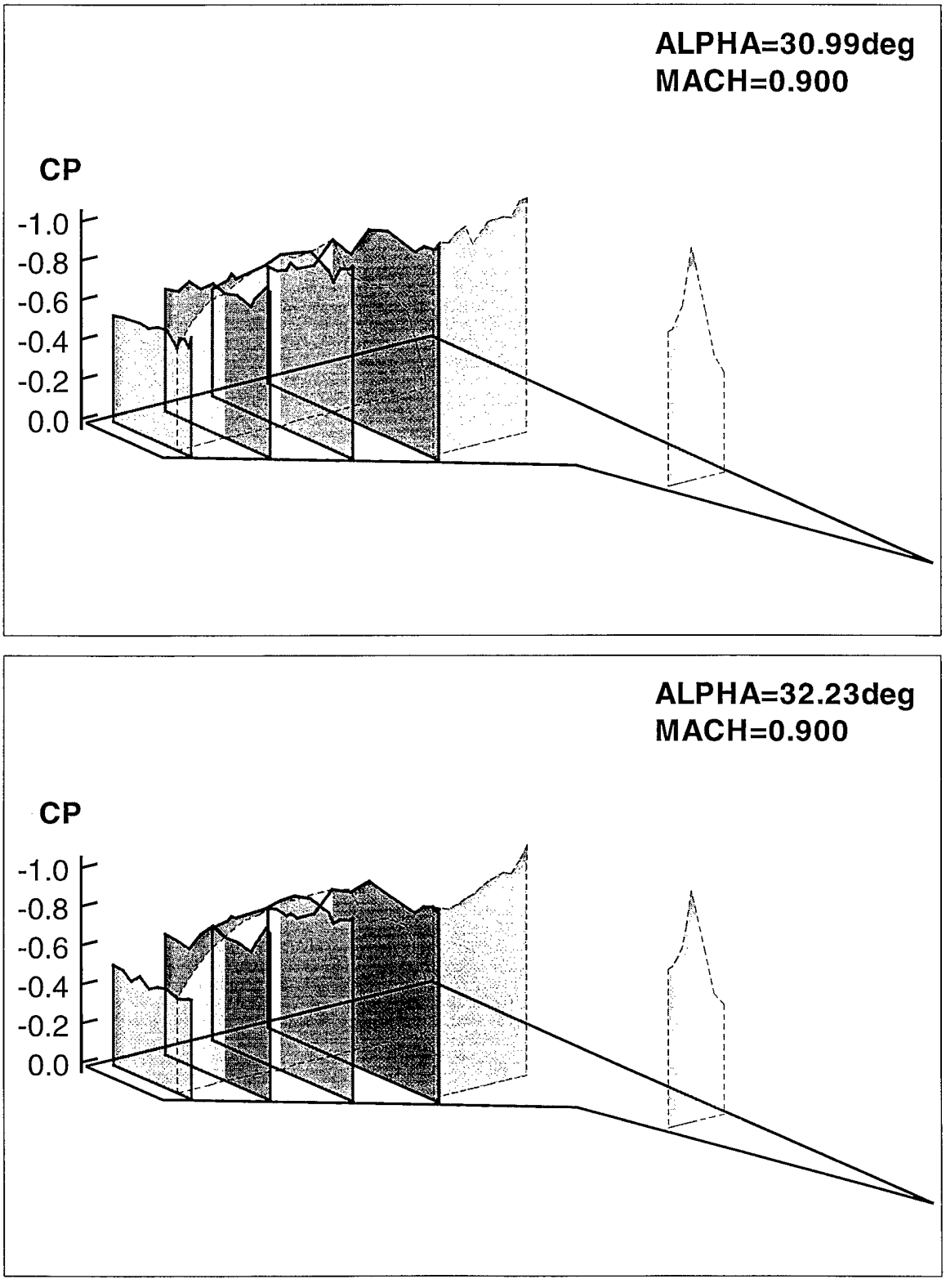
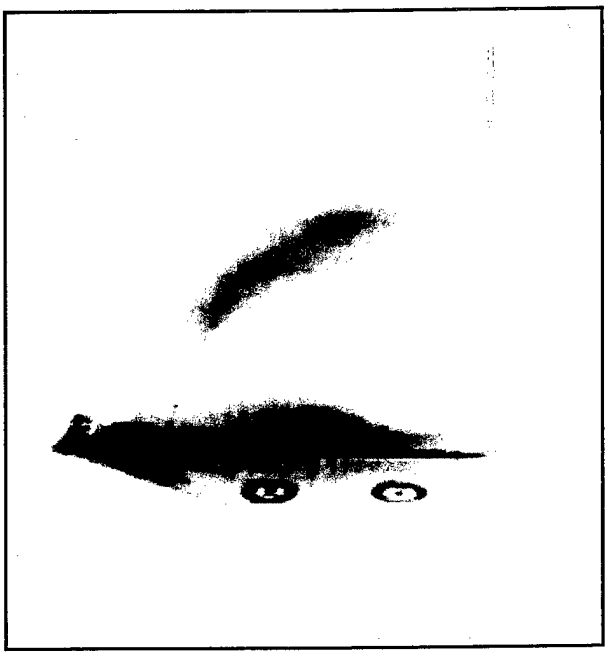
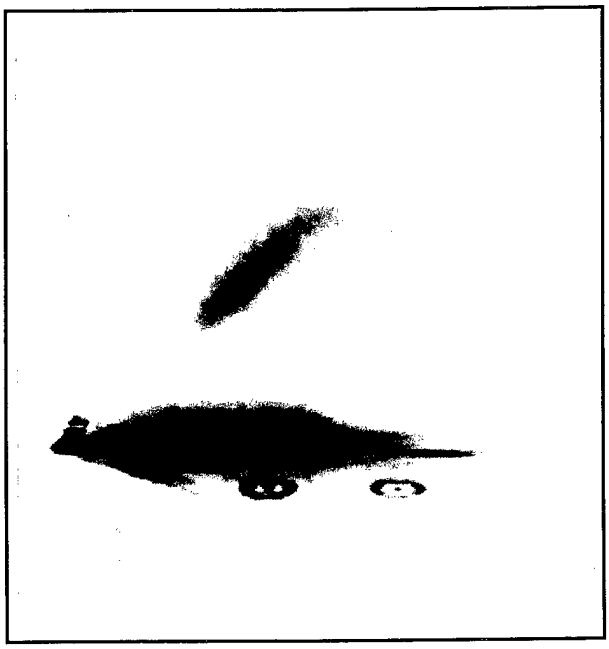


Figure 4.23 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 123.75 deg and 129.38 deg



Sheet Position 9, Alpha = 29.20 deg
(Run ID = 73, Frame = 121)



Sheet Position 9, Alpha = 30.22 deg
(Run ID = 73, Frame = 122)

Figure 4.24 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 123.75 Deg and 129.38 Deg

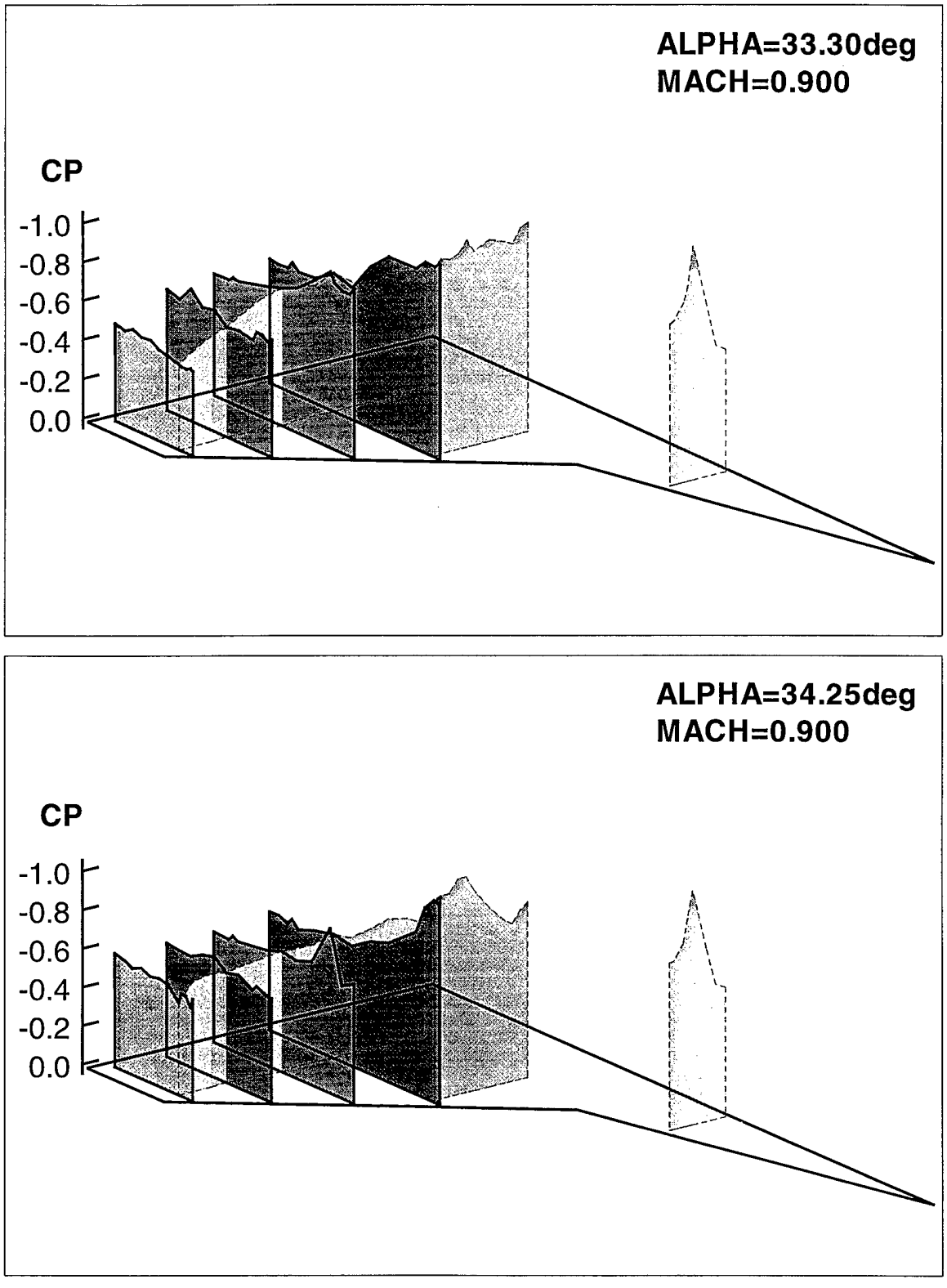
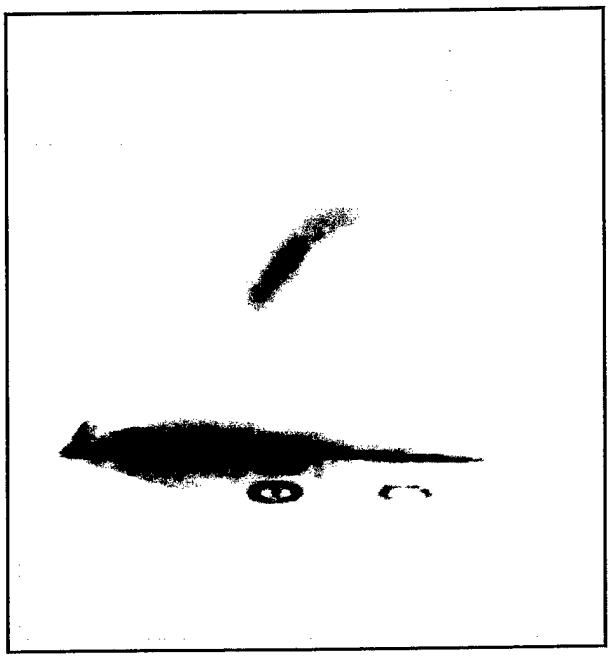
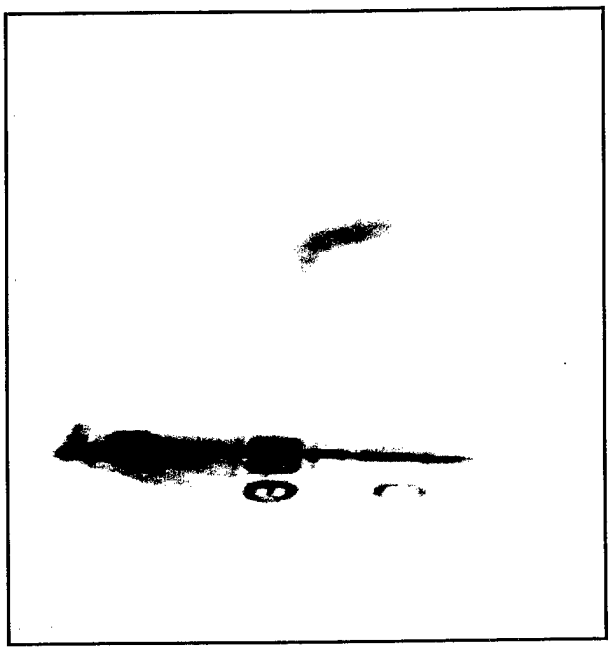


Figure 4.25 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 135.00 deg and 140.62 deg



Sheet Position 9, Alpha = 31.17 deg
(Run ID = 73, Frame = 123)



Sheet Position 9, Alpha = 32.02 deg
(Run ID = 73, Frame = 124)

Figure 4.26 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 135.00 Deg and 140.62 Deg

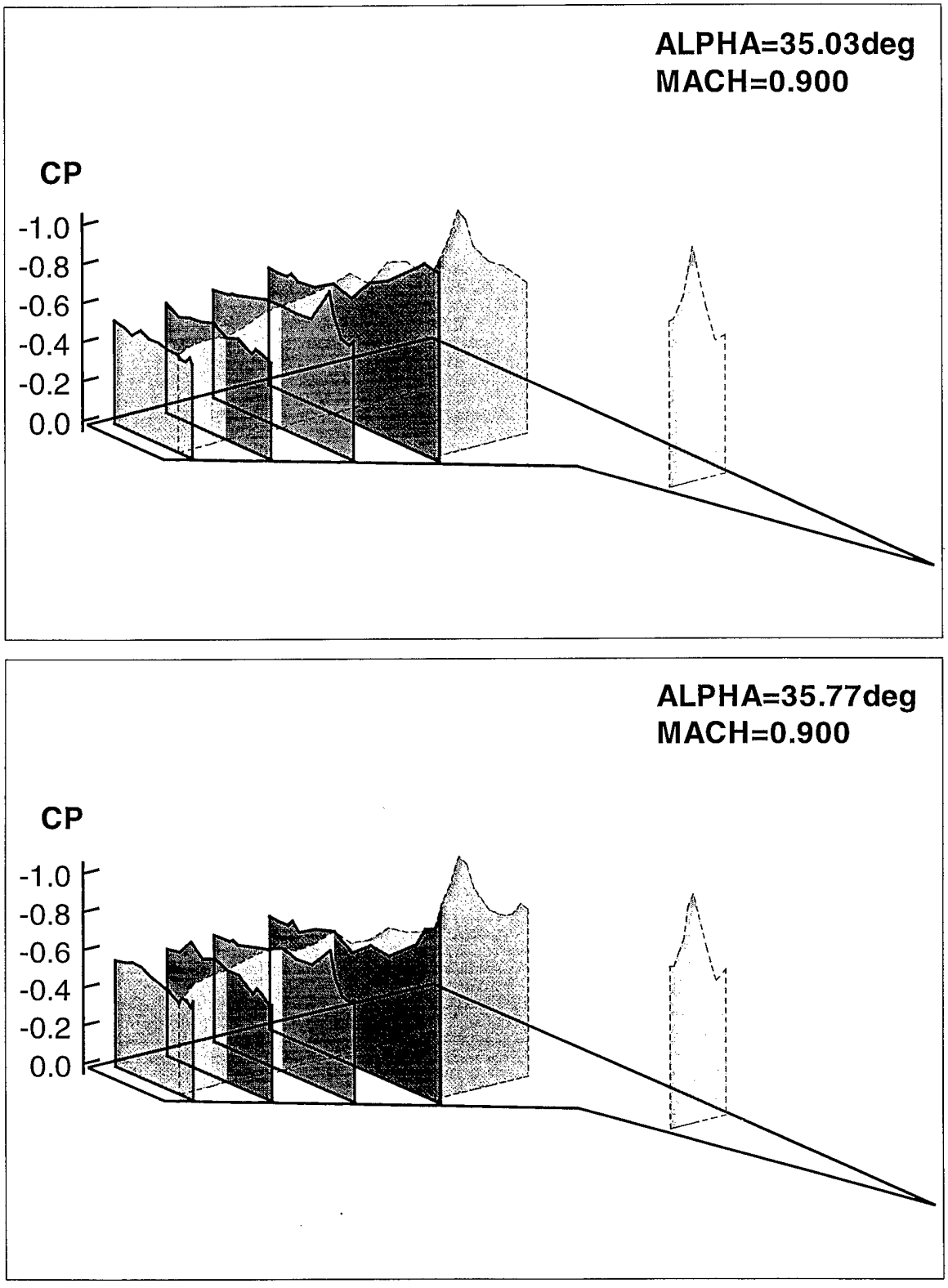
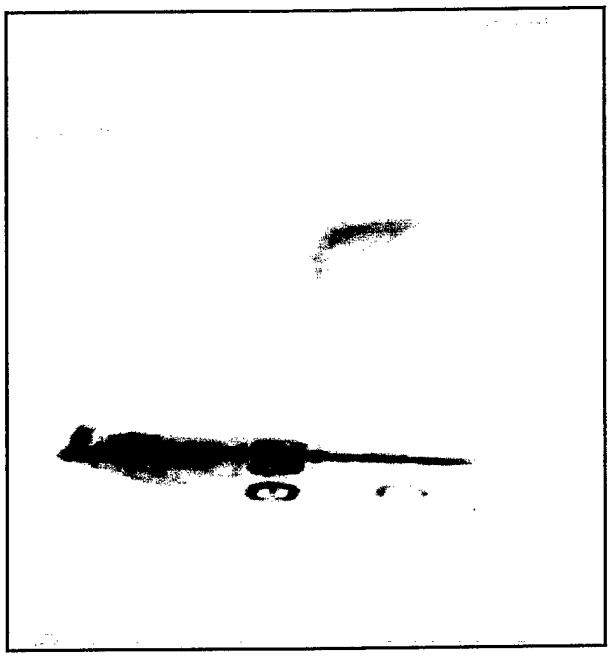
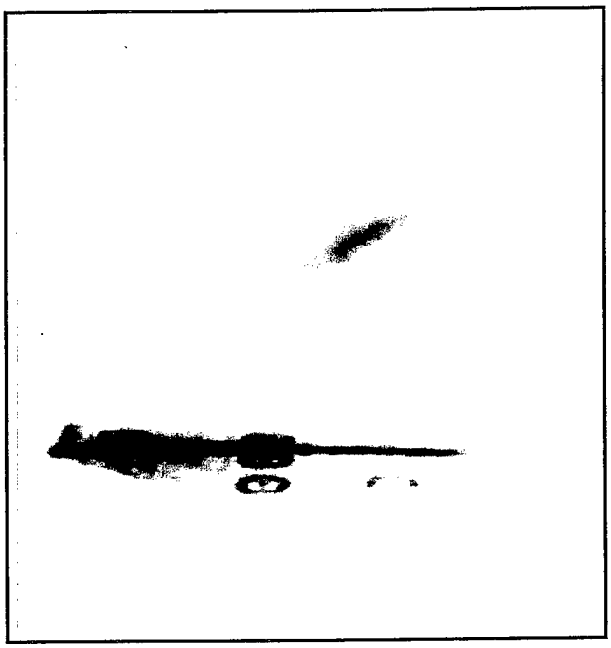


Figure 4.27 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 146.25 deg and 151.88 deg



Sheet Position 9, Alpha = 32.78 deg
(Run ID = 73, Frame = 125)



Sheet Position 9, Alpha = 33.44 deg
(Run ID = 73, Frame = 126)

Figure 4.28 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 146.25 Deg and 151.88 Deg

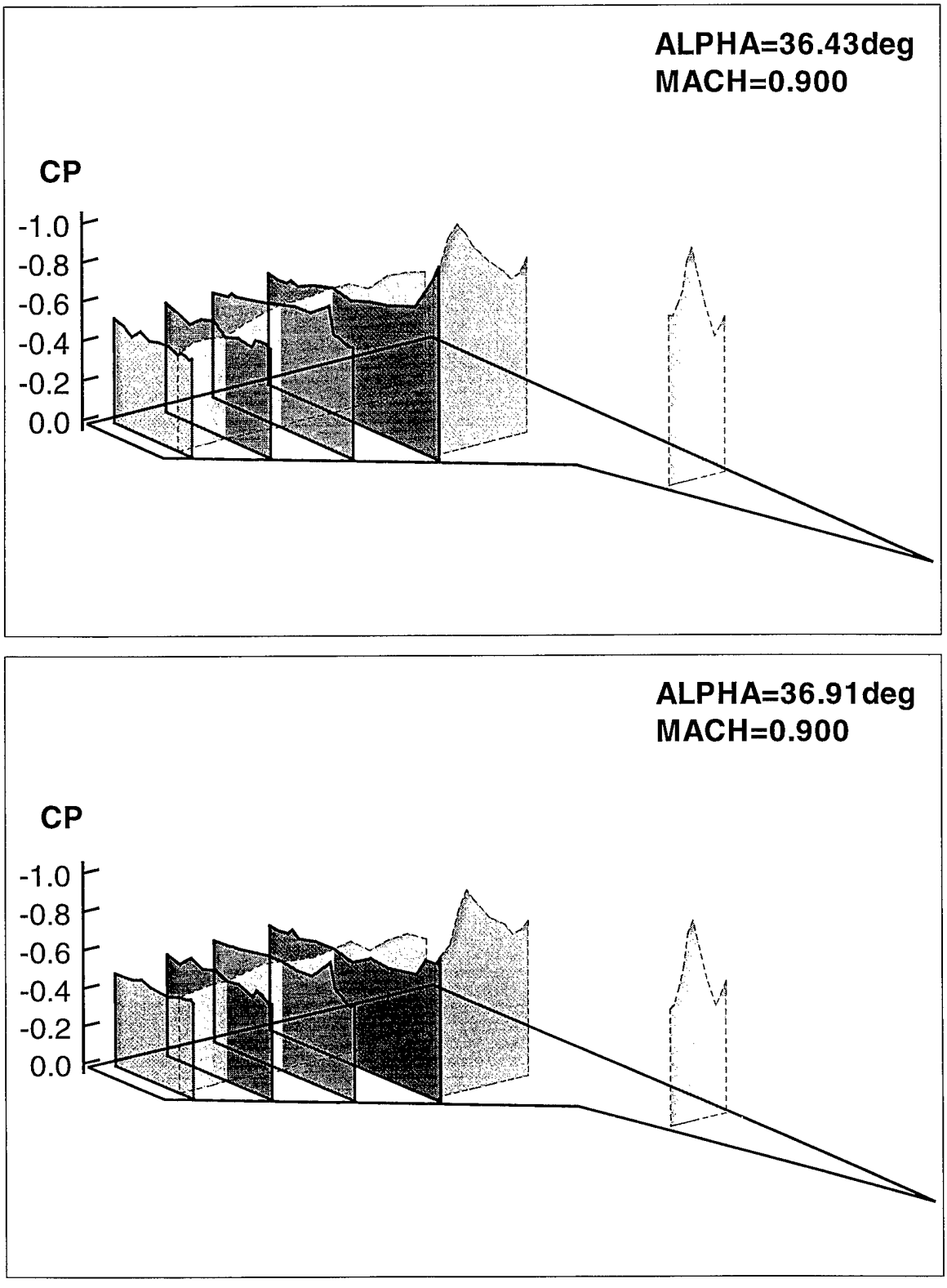
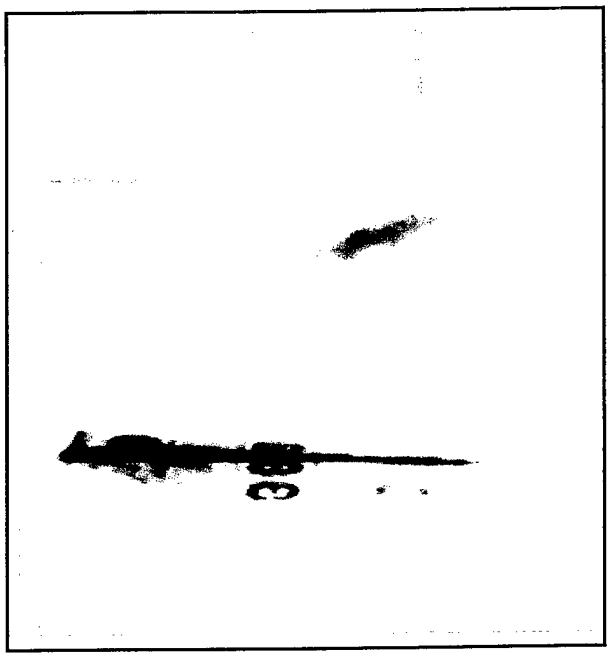
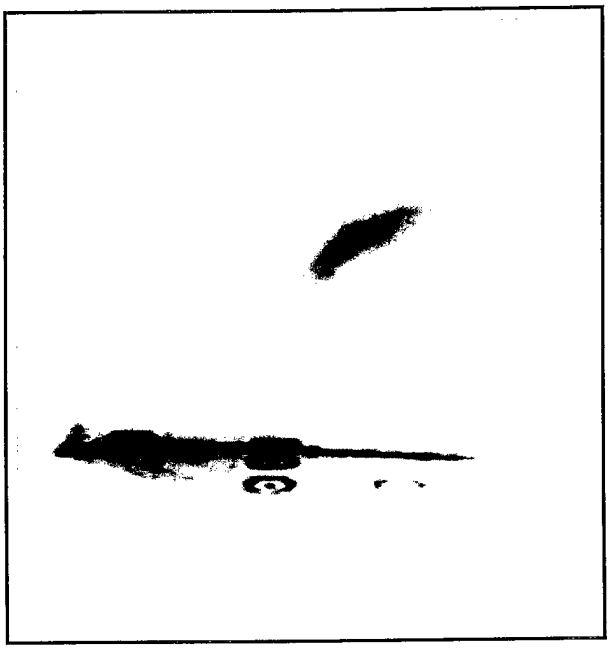


Figure 4.29 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 157.50 deg and 163.12 deg



Sheet Position 9, Alpha = 33.98deg
(Run ID = 73, Frame = 127)



Sheet Position 9, Alpha = 34.41 deg
(Run ID = 73, Frame = 128)

Figure 4.30 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 157.50 Deg and 163.12 Deg

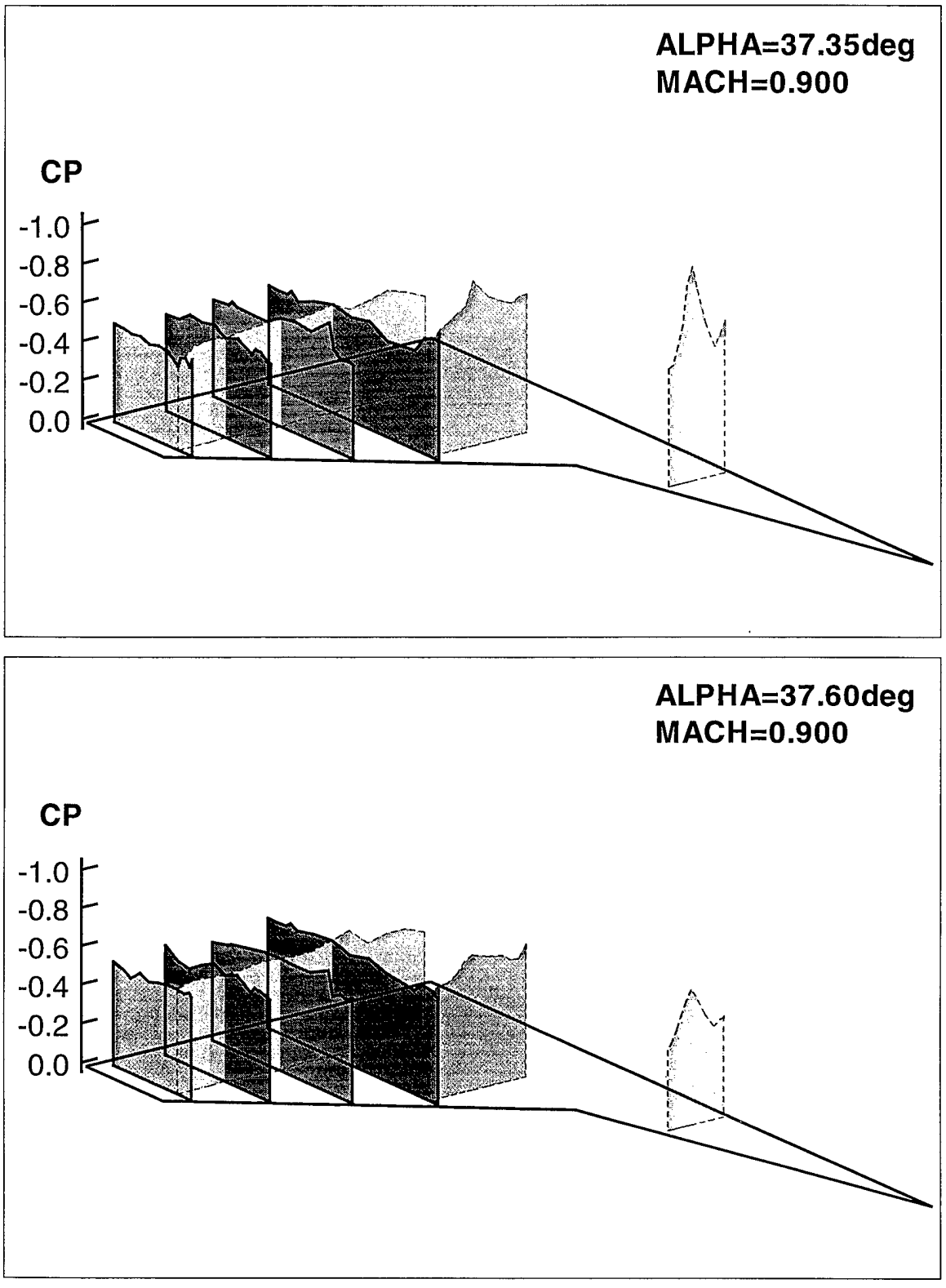
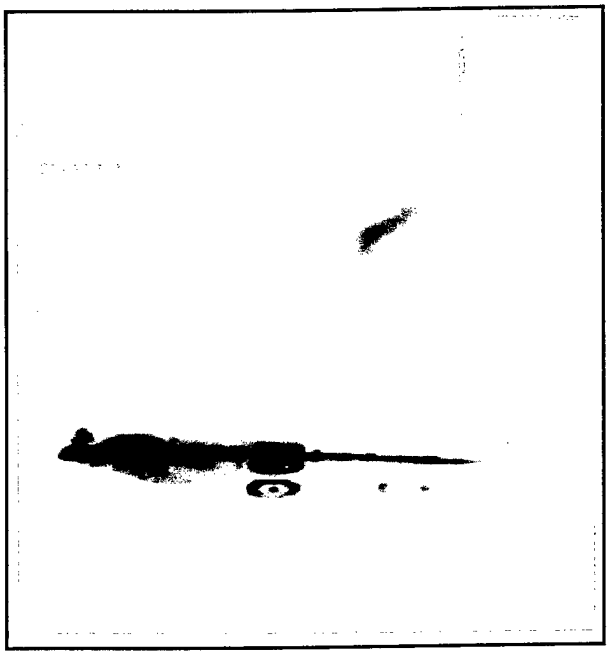
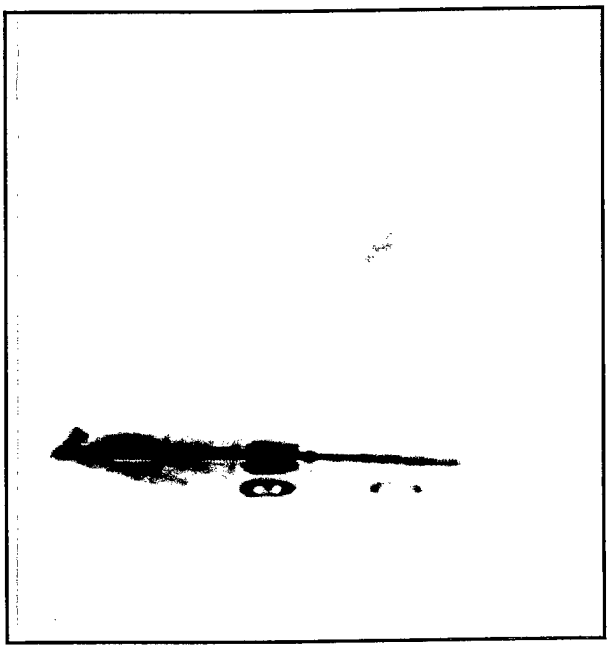


Figure 4.31 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 168.75 deg and 174.38 deg



Sheet Position 9, Alpha = 34.72 deg
(Run ID = 73, Frame = 129)



Sheet Position 9, Alpha = 34.91 deg
(Run ID = 73, Frame = 130)

Figure 4.32 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 168.75 Deg and 174.38 Deg

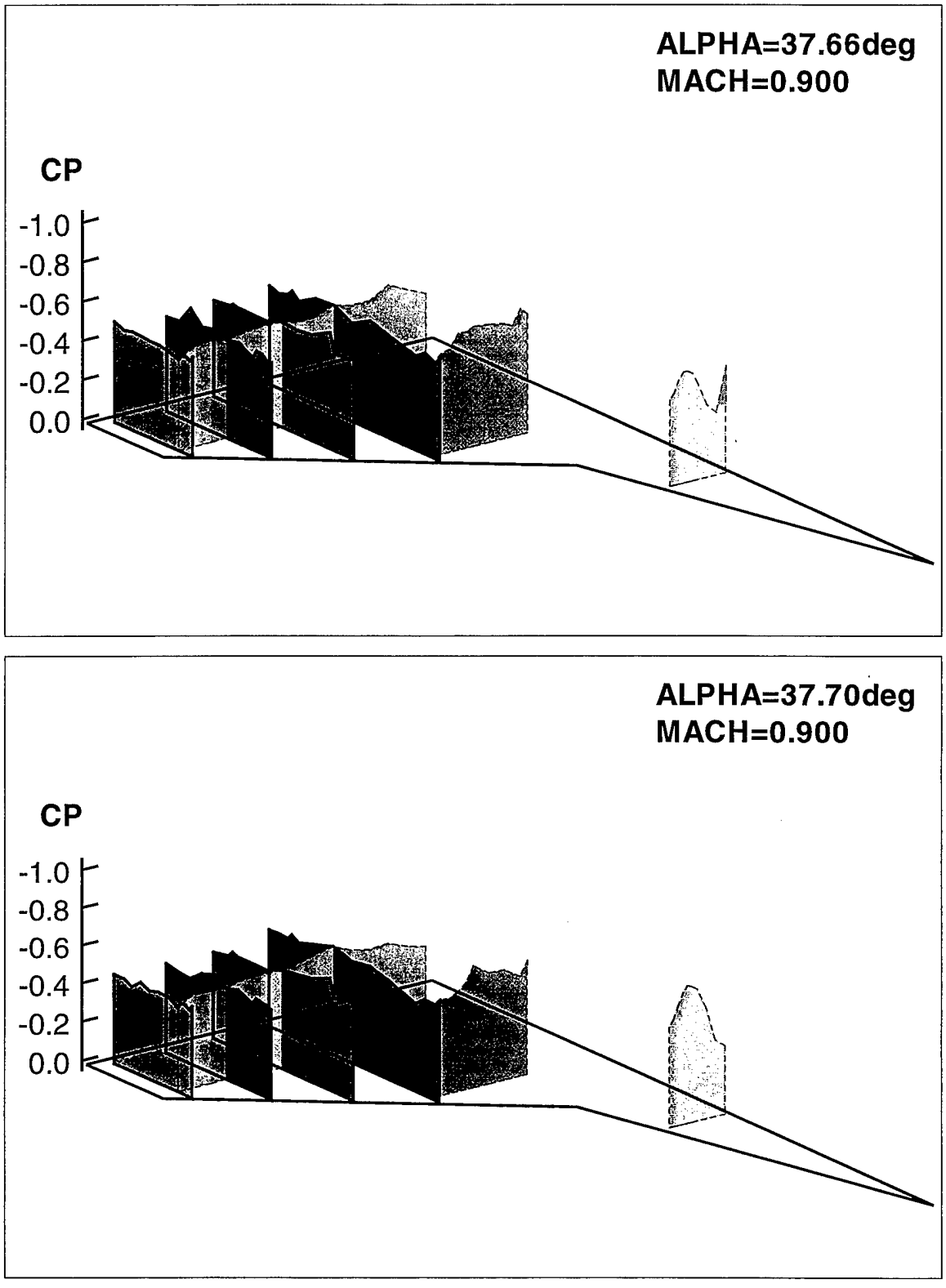
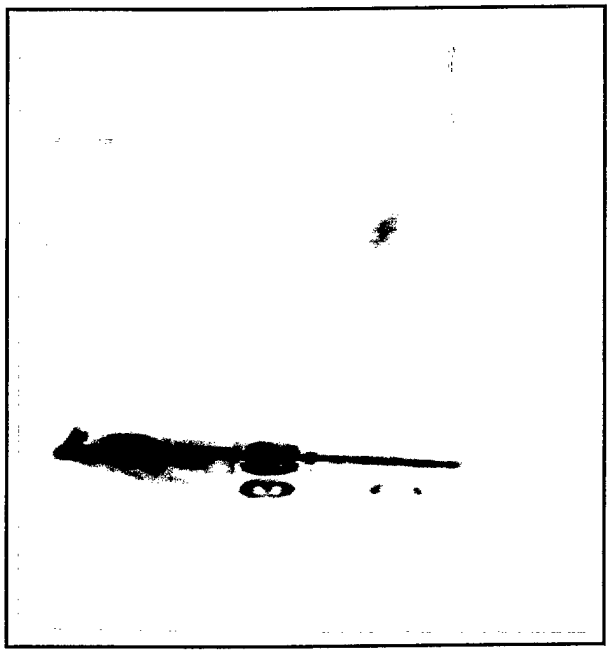
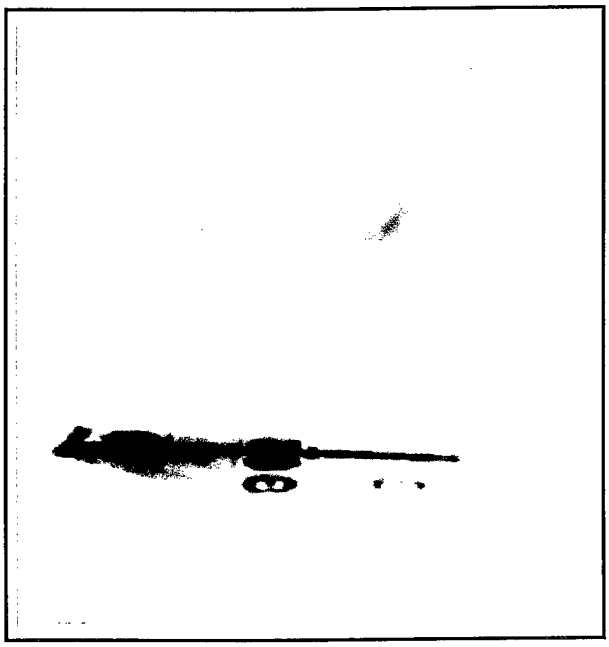


Figure 4.33 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 180.00 deg and 185.62 deg



Sheet Position 9, Alpha = 34.97 deg
(Run ID = 73, Frame = 131)



Sheet Position 9, Alpha = 34.91 deg
(Run ID = 73, Frame = 132)

Figure 4.34 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 180.00Deg and 185.62 Deg

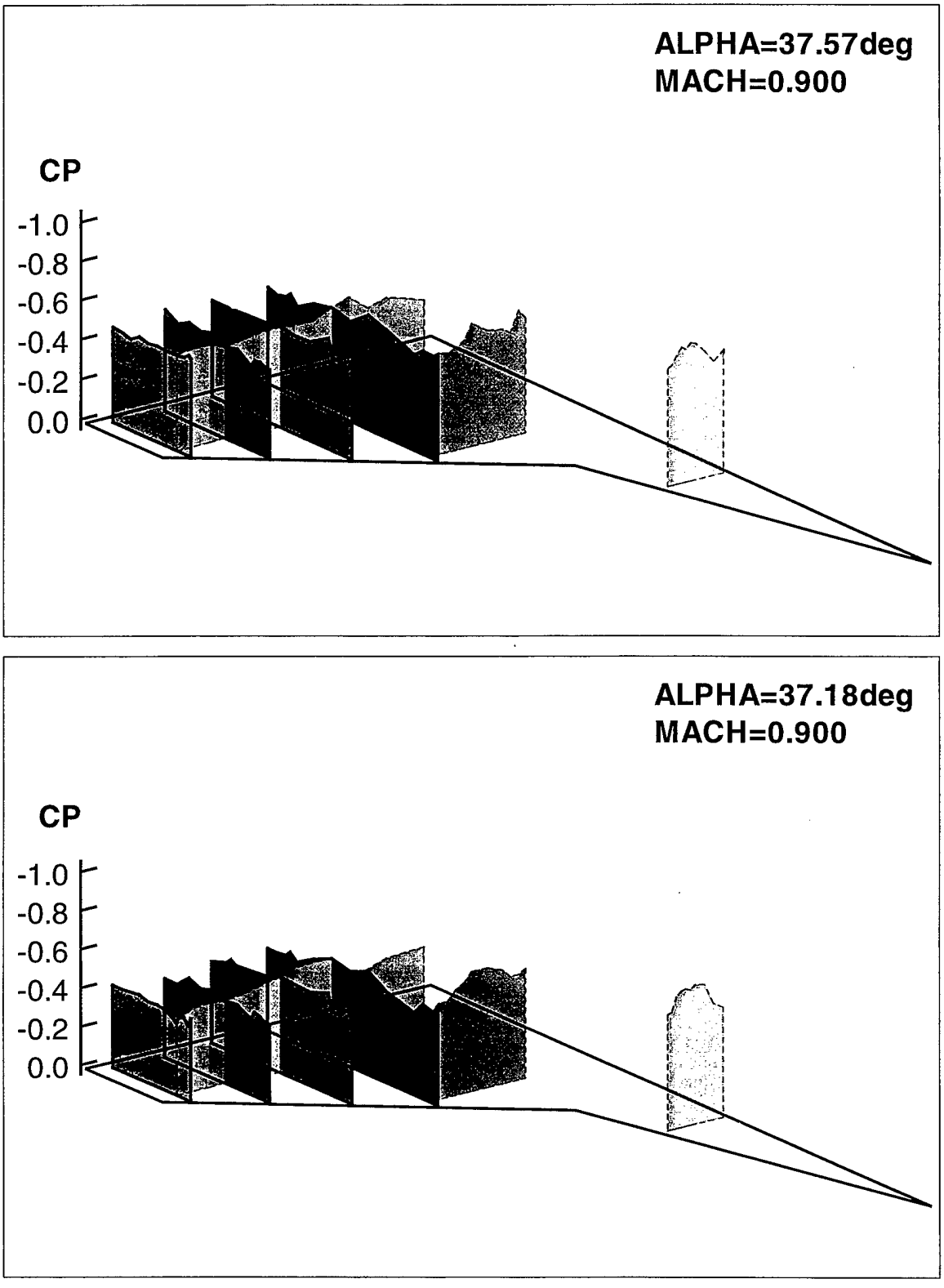
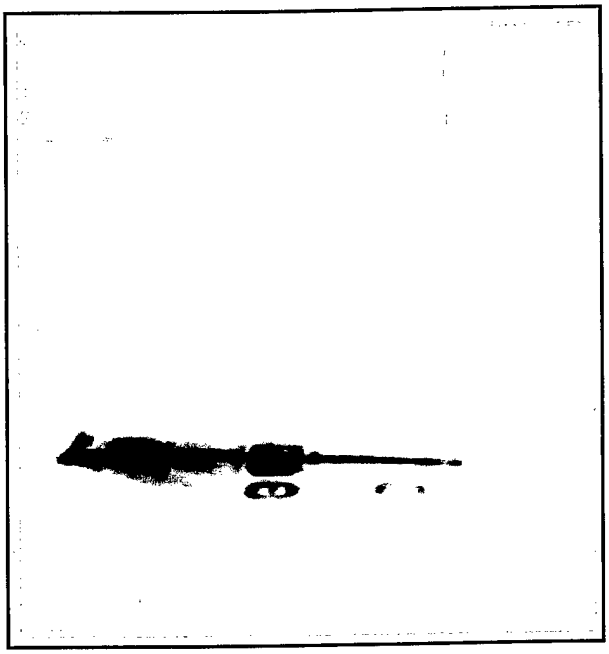
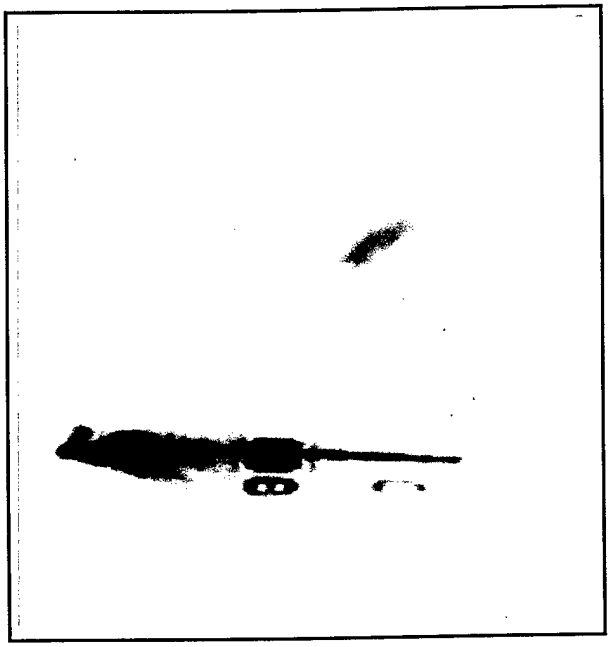


Figure 4.35 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 191.25 deg and 196.88 deg



Sheet Position 9, Alpha = 34.72 deg
(Run ID = 73, Frame = 133)



Sheet Position 9, Alpha = 34.41 deg
(Run ID = 73, Frame = 134)

Figure 4.36 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 191.25 Deg and 196.88 Deg

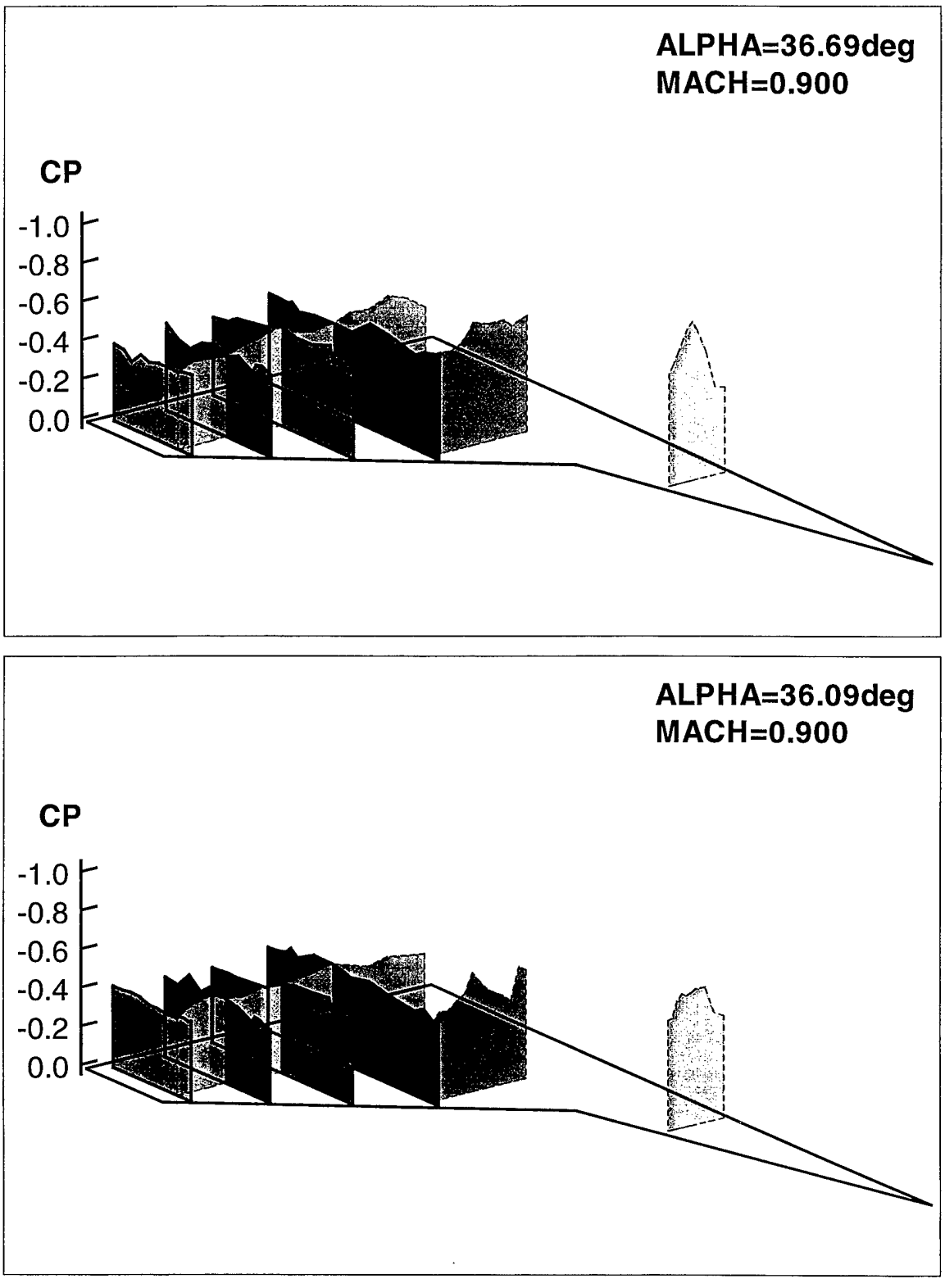
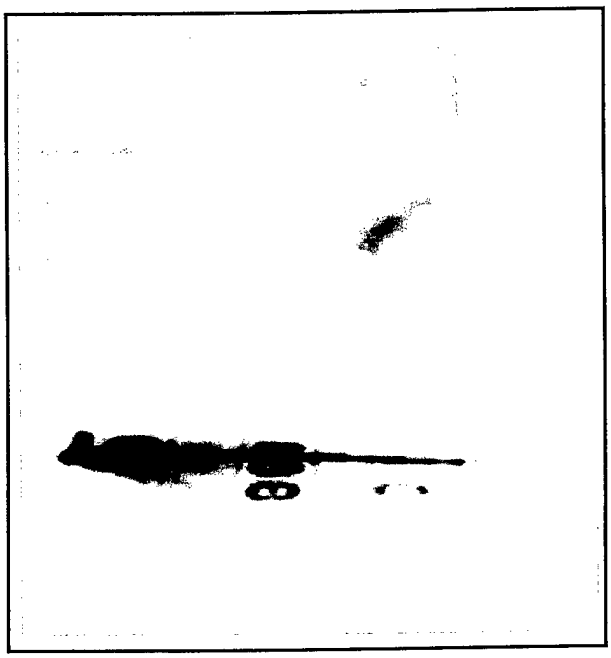
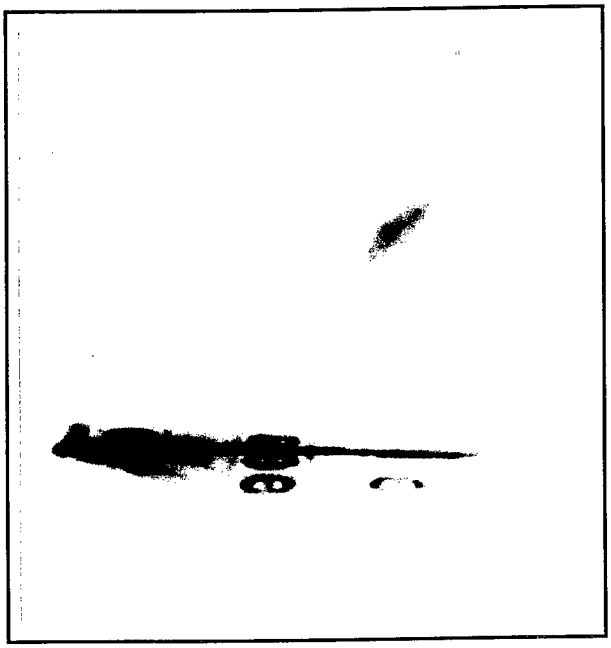


Figure 4.37 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 202.50 deg and 208.12 deg



Sheet Position 9, Alpha = 33.98 deg
(Run ID = 73, Frame = 135)



Sheet Position 9, Alpha = 33.44 deg
(Run ID = 73, Frame = 136)

Figure 4.38 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 202.50 Deg and 208.12 Deg

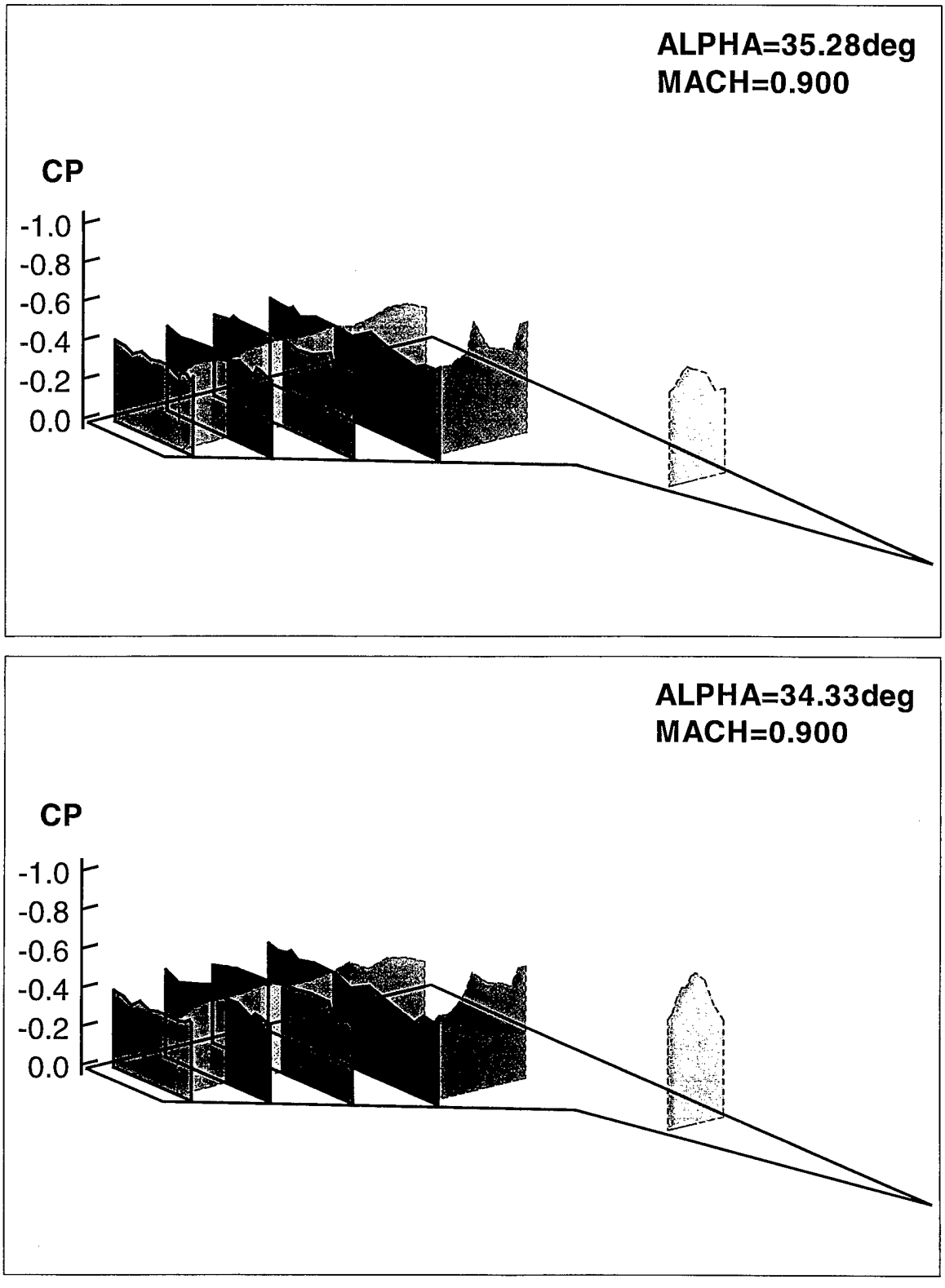
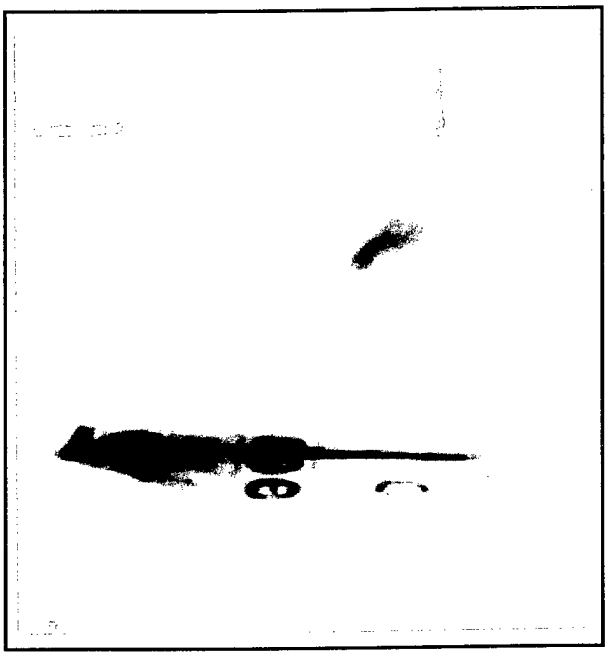
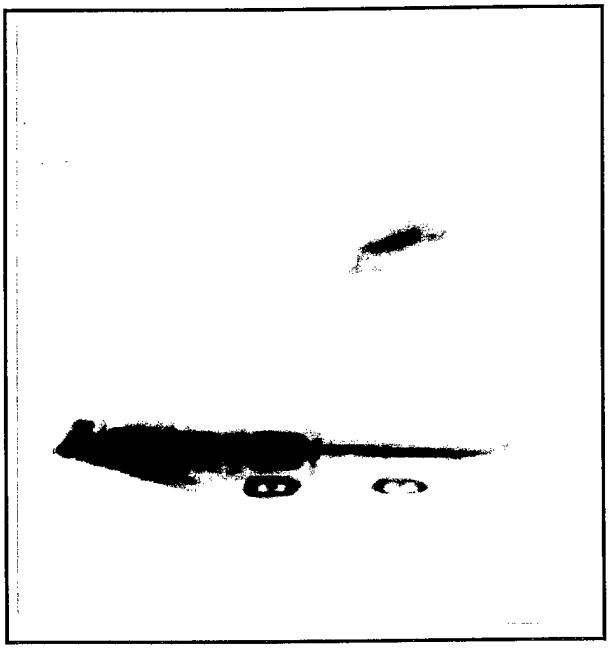


Figure 4.39 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 213.75 deg and 219.38 deg



Sheet Position 9, Alpha = 32.78 deg
(Run ID = 73, Frame = 137)



Sheet Position 9, Alpha = 32.02 deg
(Run ID = 73, Frame = 138)

Figure 4.40 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 213.75 Deg and 219.38 Deg

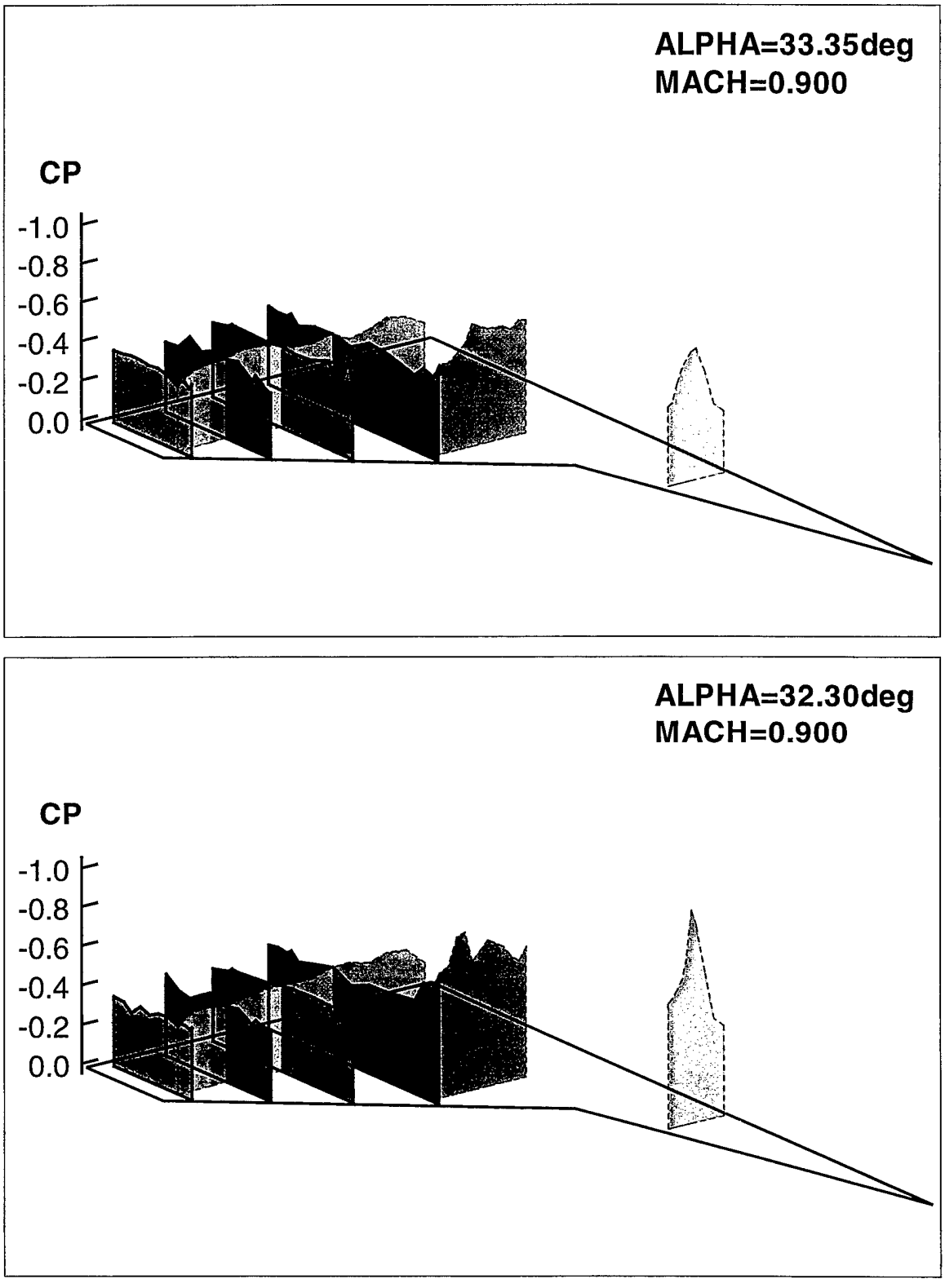
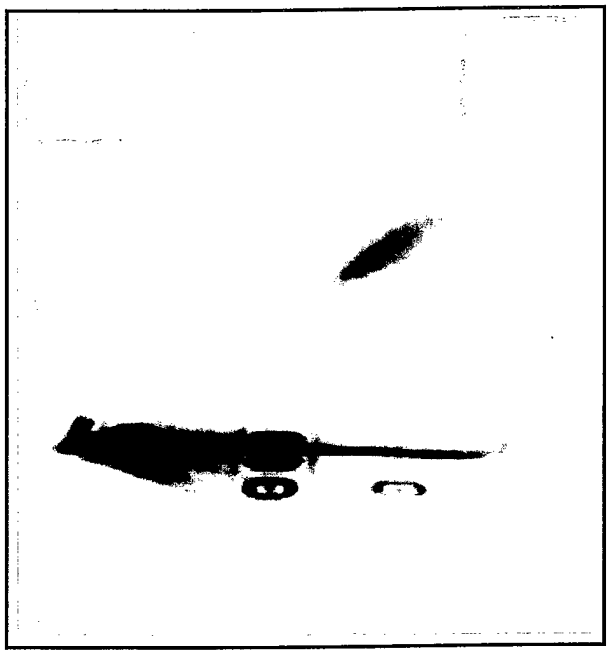
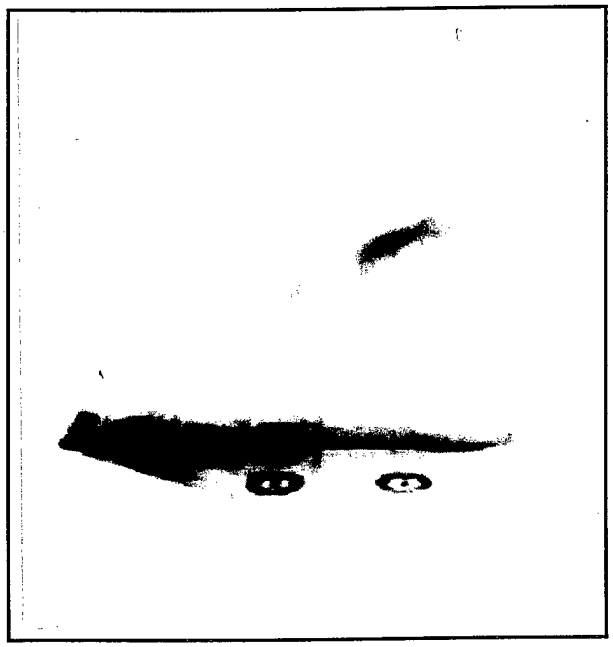


Figure 4.41 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 225.00 deg and 230.62 deg

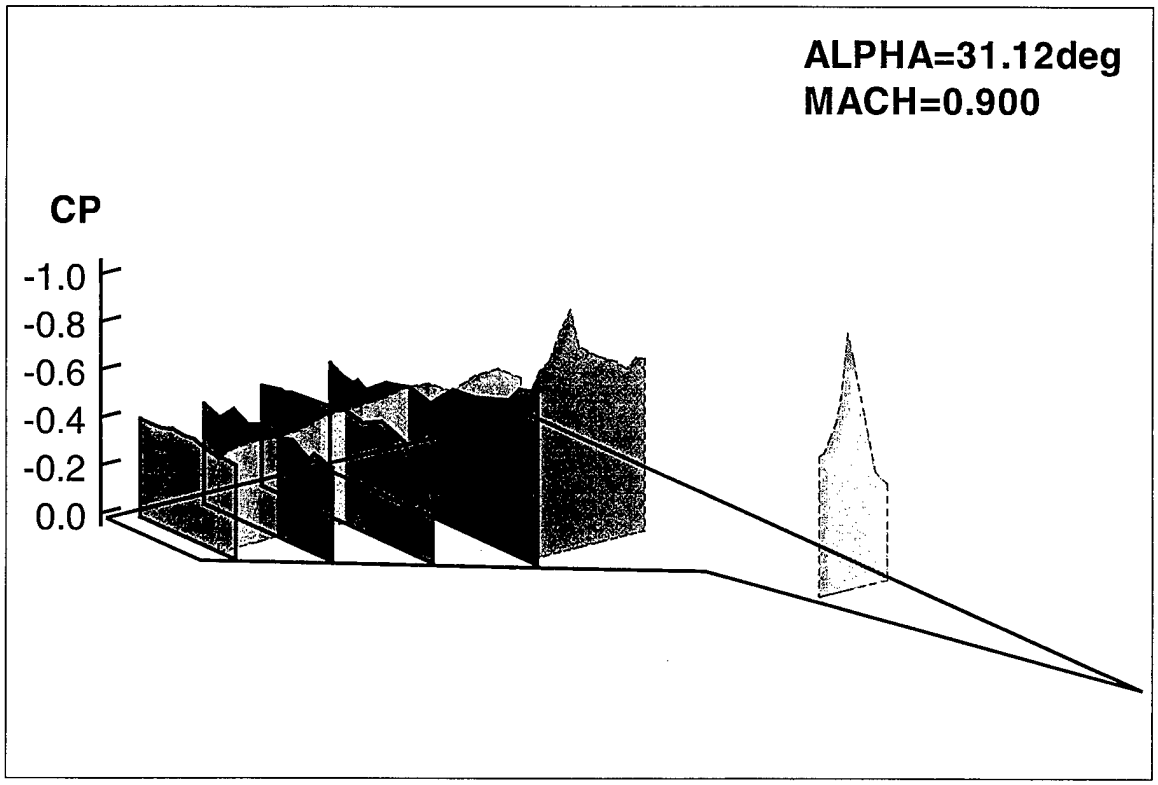


Sheet Position 9, Alpha = 31.17 deg
(Run ID = 73, Frame = 139)



Sheet Position 9, Alpha = 30.22 deg
(Run ID = 73, Frame = 140)

Figure 4.42 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 225.00 Deg and 230.62 Deg



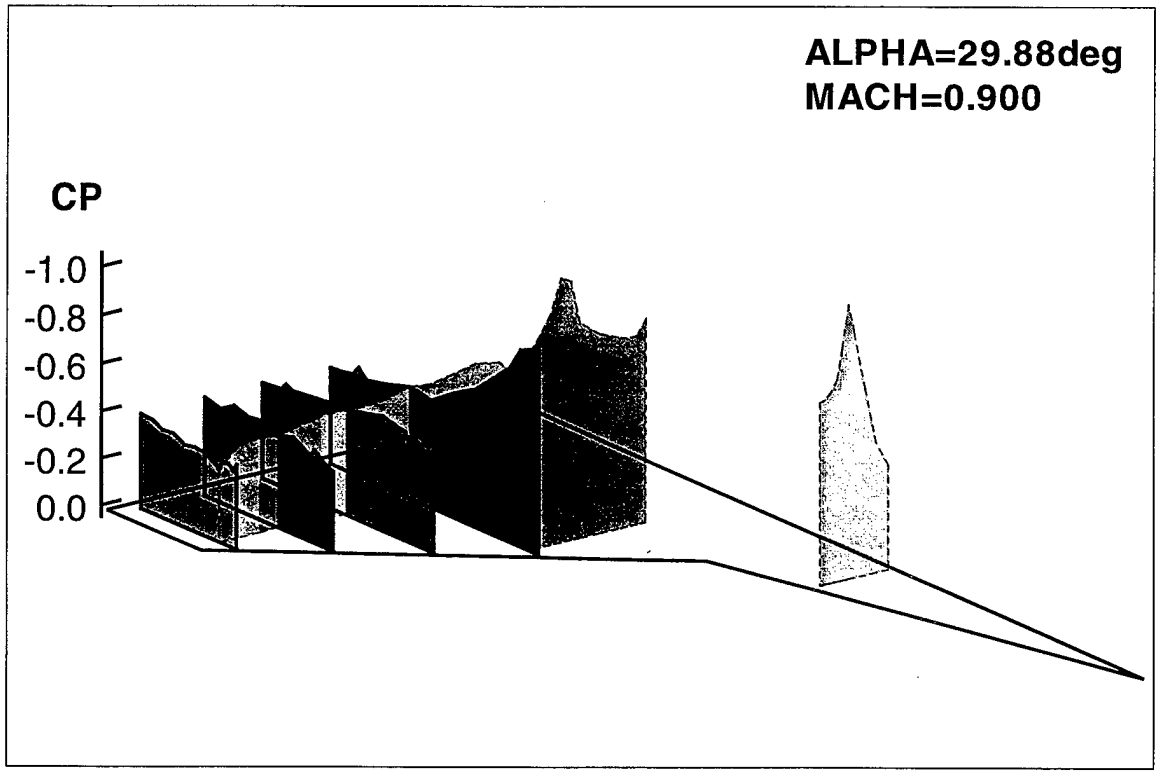
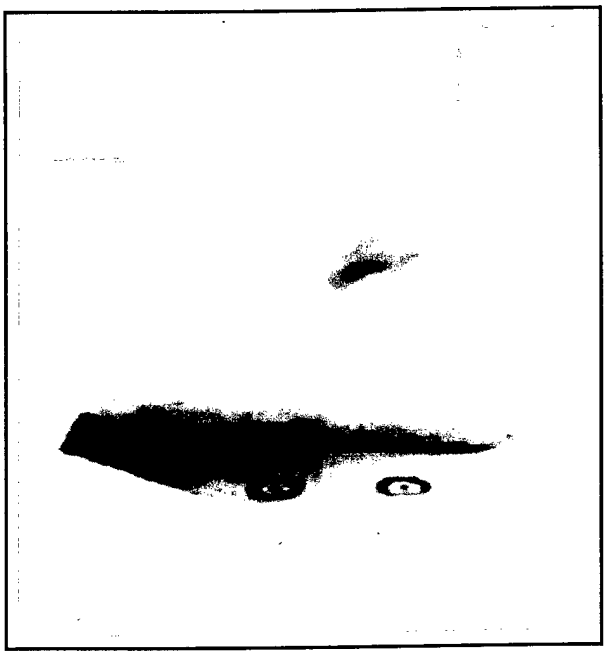
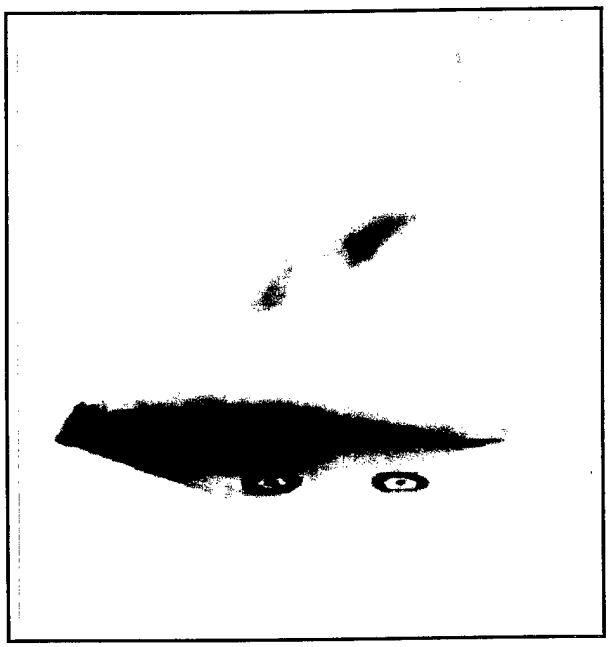


Figure 4.43 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 236.25 deg and 241.88 deg



Sheet Position 9, Alpha = 29.20 deg
(Run ID = 73, Frame = 141)



Sheet Position 9, Alpha = 28.11 deg
(Run ID = 73, Frame = 142)

Figure 4.44 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 236.25 Deg and 241.88 Deg

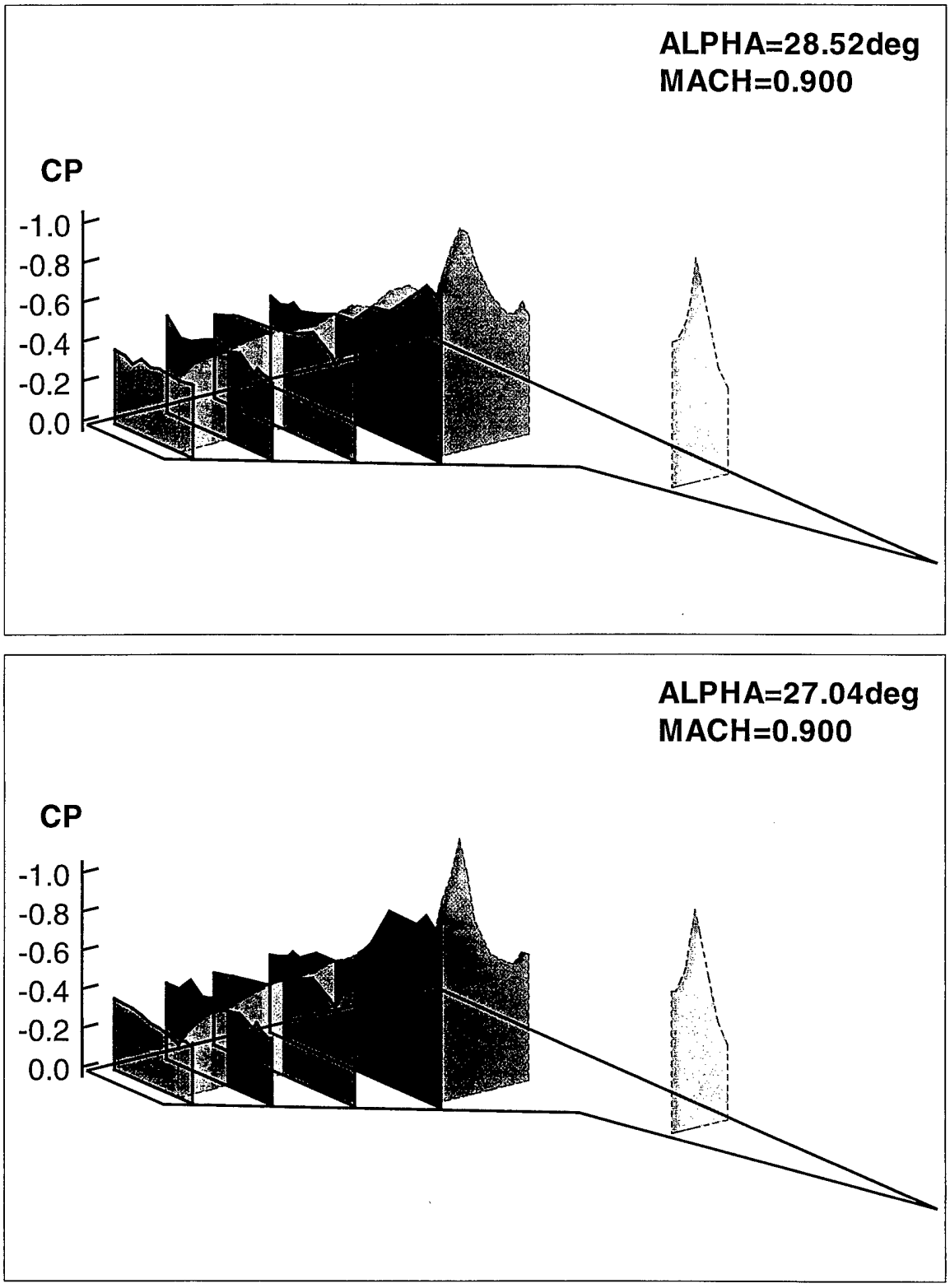
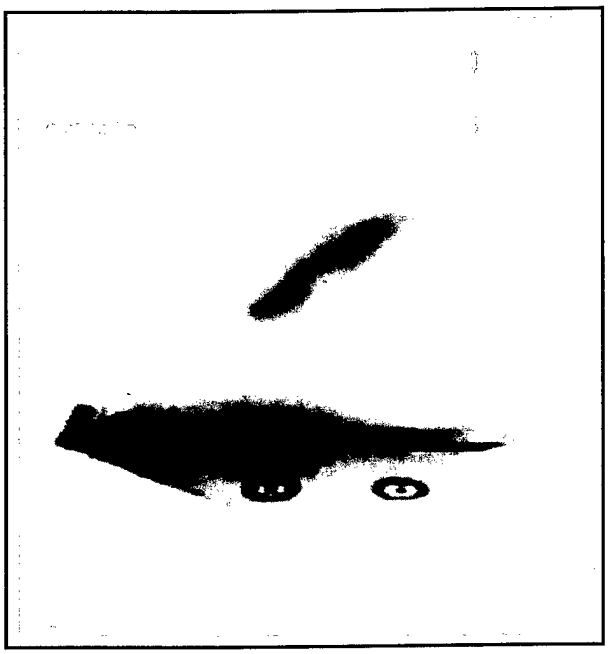
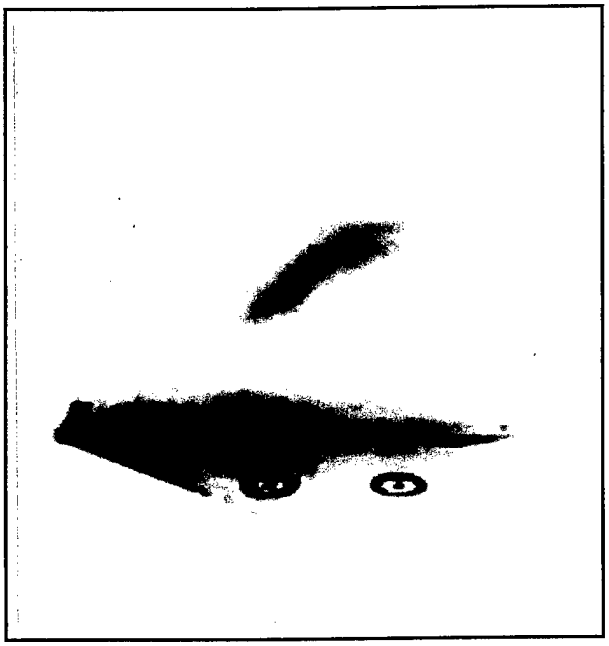


Figure 4.45 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 247.50 deg and 253.12 deg



Sheet Position 9, Alpha = 29.96 deg 26.96
(Run ID = 73, Frame = 143)



Sheet Position 9, Alpha = 25.76 deg
(Run ID = 73, Frame = 144)

Figure 4.46 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 247.50 Deg and 253.12 Deg

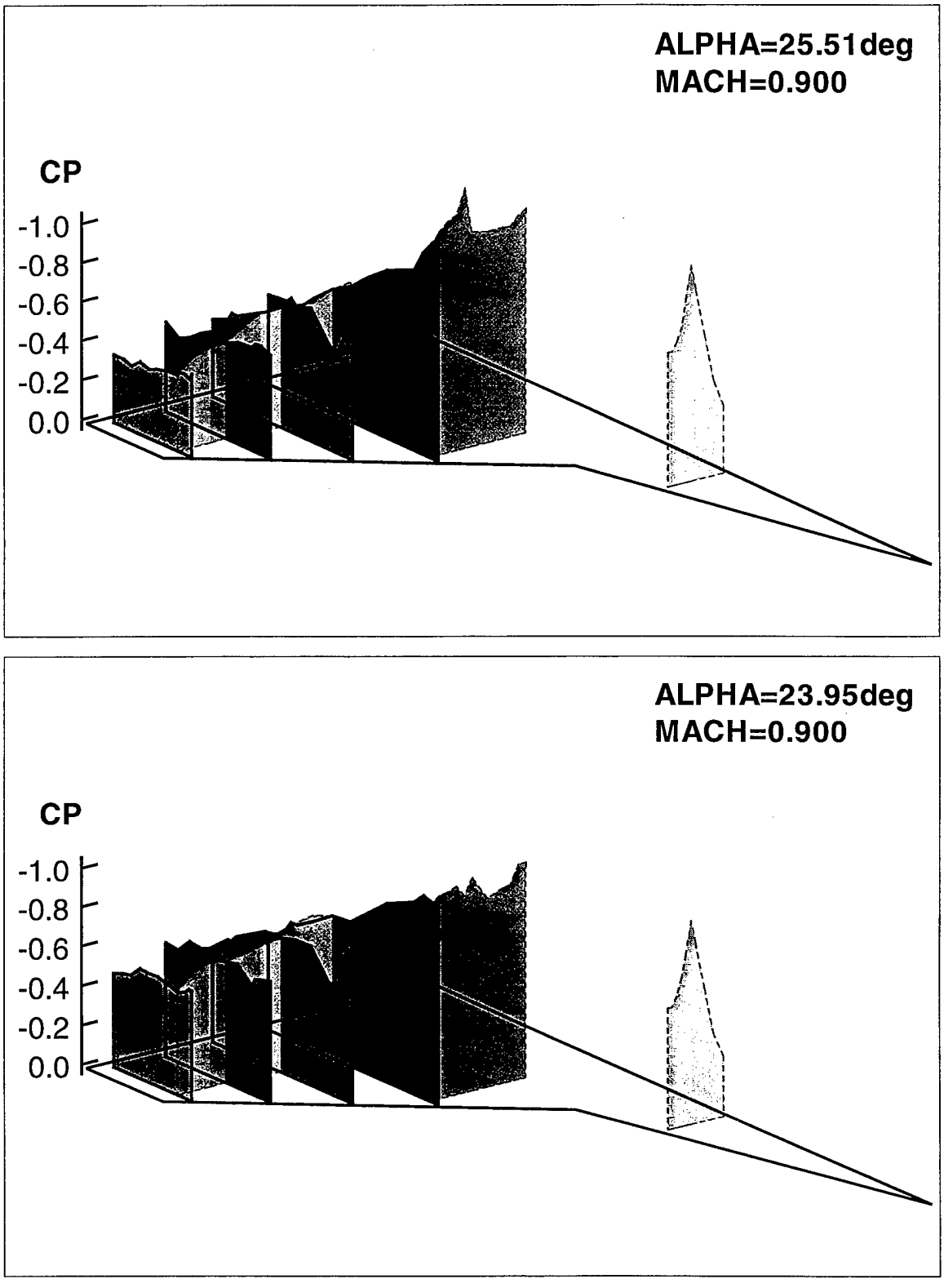
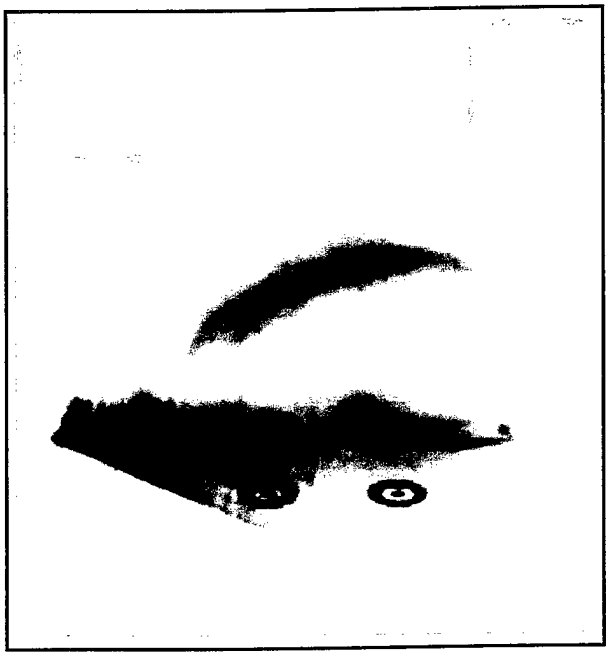
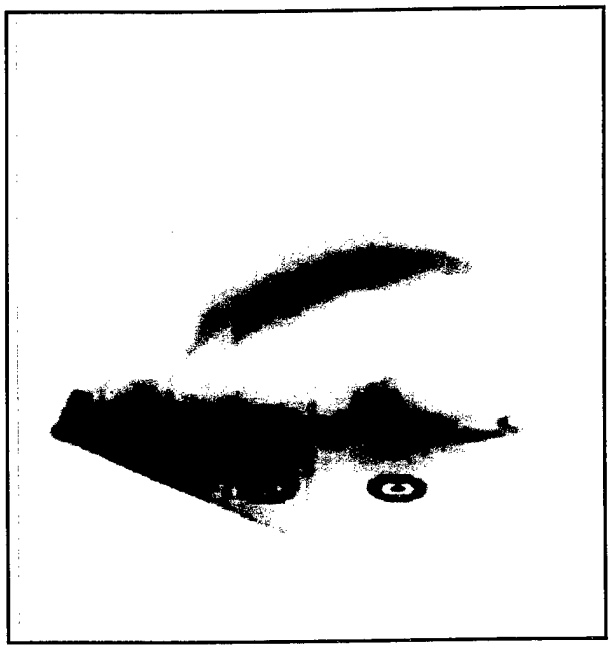


Figure 4.47 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 258.75 deg and 264.38 deg



Sheet Position 9, Alpha = 24.52 deg
(Run ID = 73, Frame = 145)



Sheet Position 9, Alpha = 23.26 deg
(Run ID = 73, Frame = 146)

Figure 4.48 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 258.75 Deg and 264.38 Deg

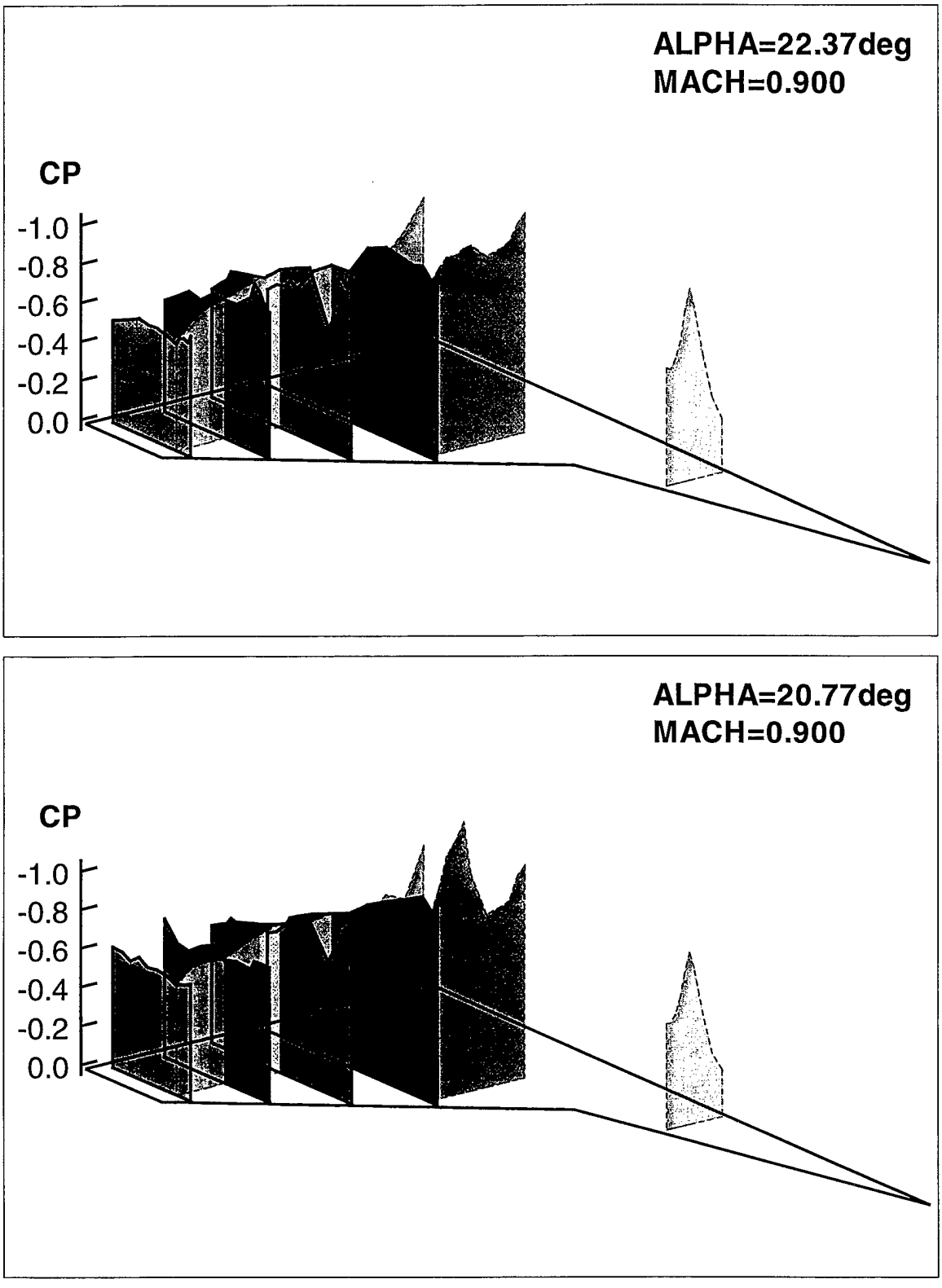
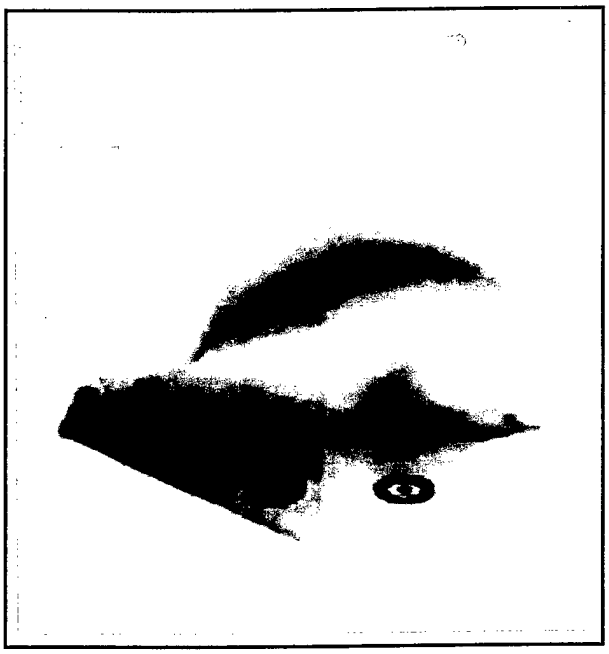
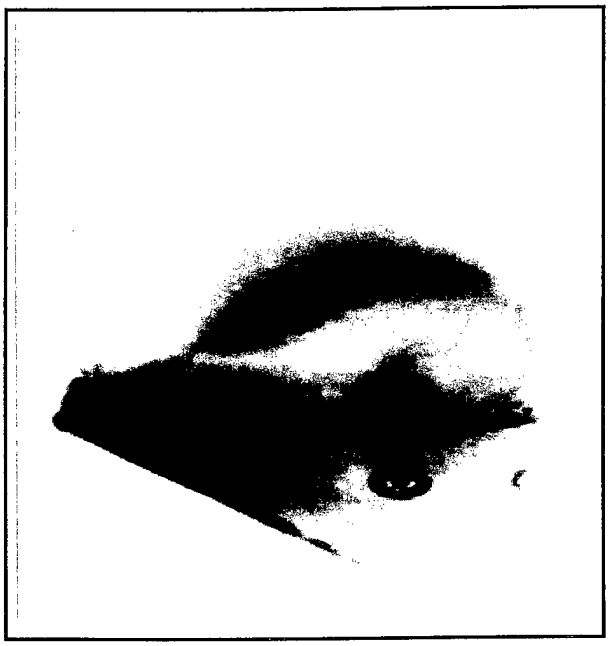


Figure 4.49 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 270.00 deg and 275.62 deg



Sheet Position 9, Alpha = 21.99 deg
(Run ID = 73, Frame = 147)



Sheet Position 9, Alpha = 20.72 deg
(Run ID = 73, Frame = 148)

Figure 4.50 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 270.00 Deg and 275.62 Deg

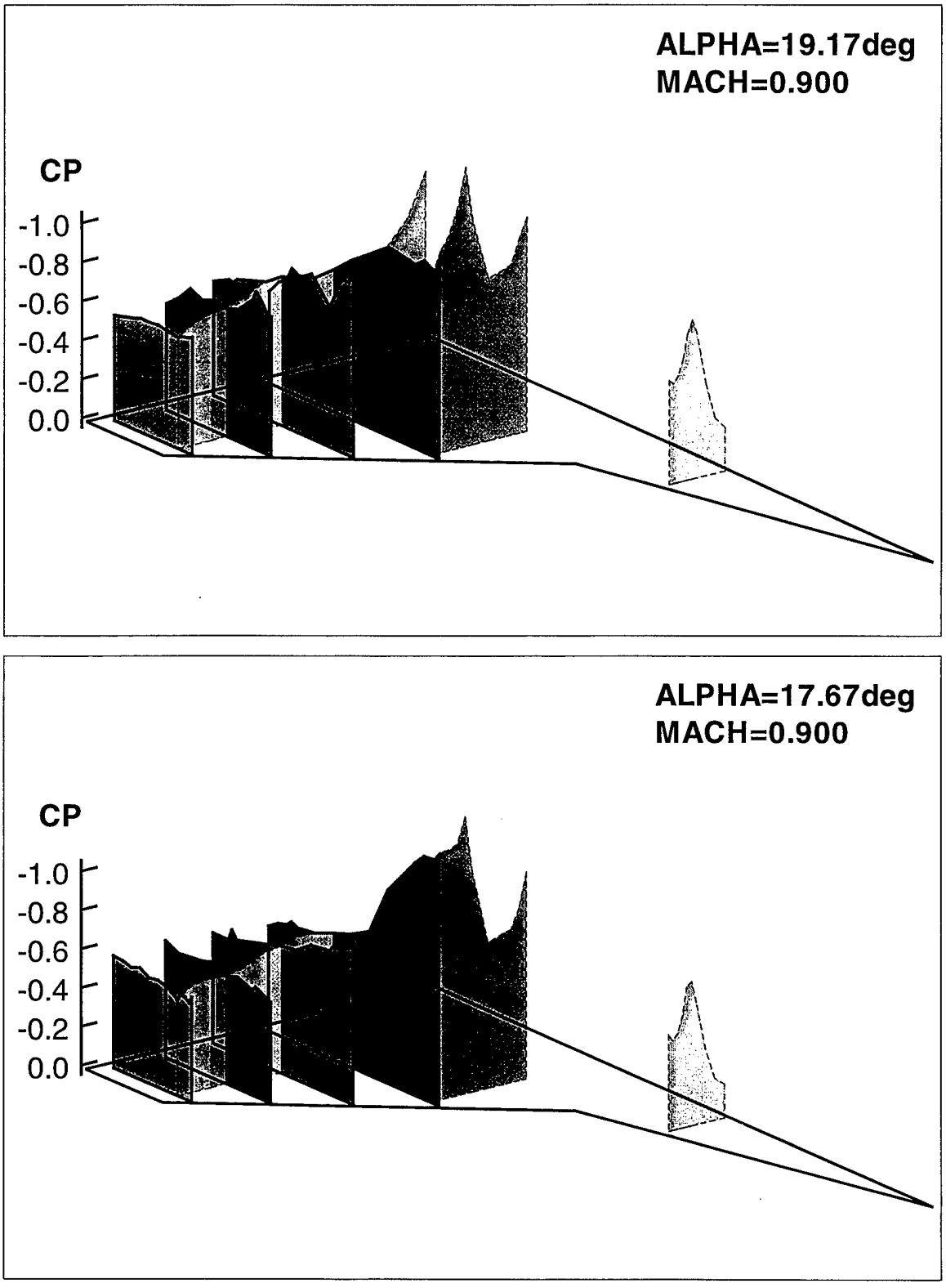
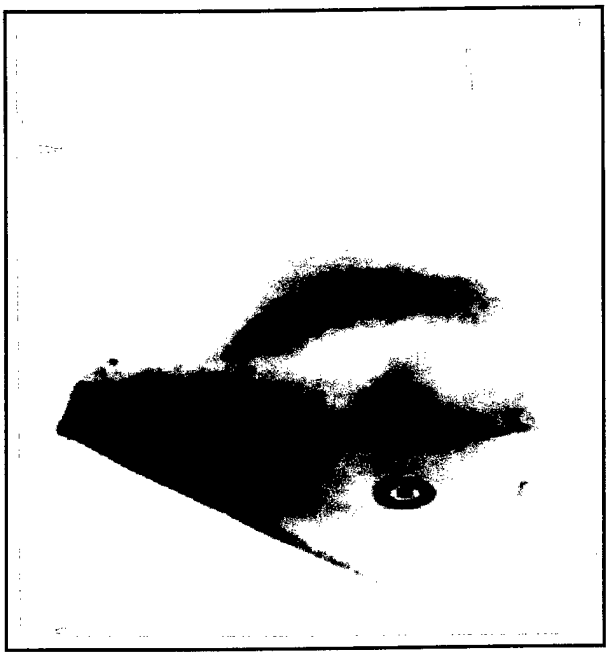
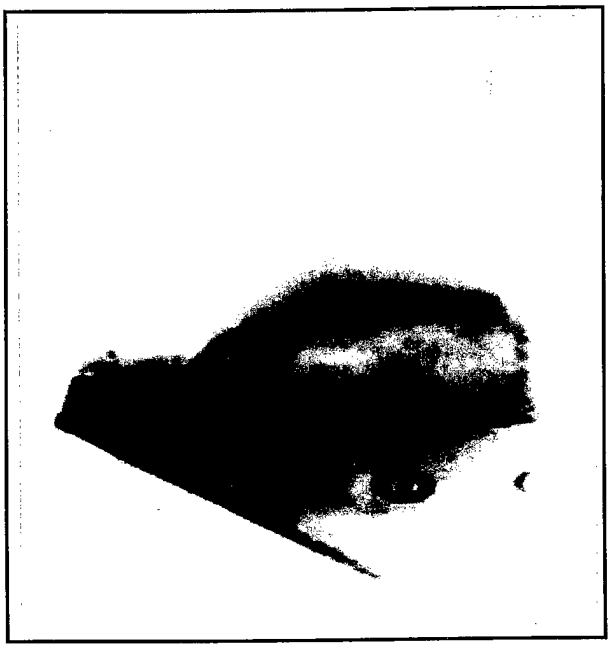


Figure 4.51 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 281.25 deg and 286.88 deg



Sheet Position 9, Alpha = 19.46 deg
(Run ID = 73, Frame = 149)



Sheet Position 9, Alpha = 18.22 deg
(Run ID = 73, Frame = 150)

Figure 4.52 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 281.25 Deg and 286.88 Deg

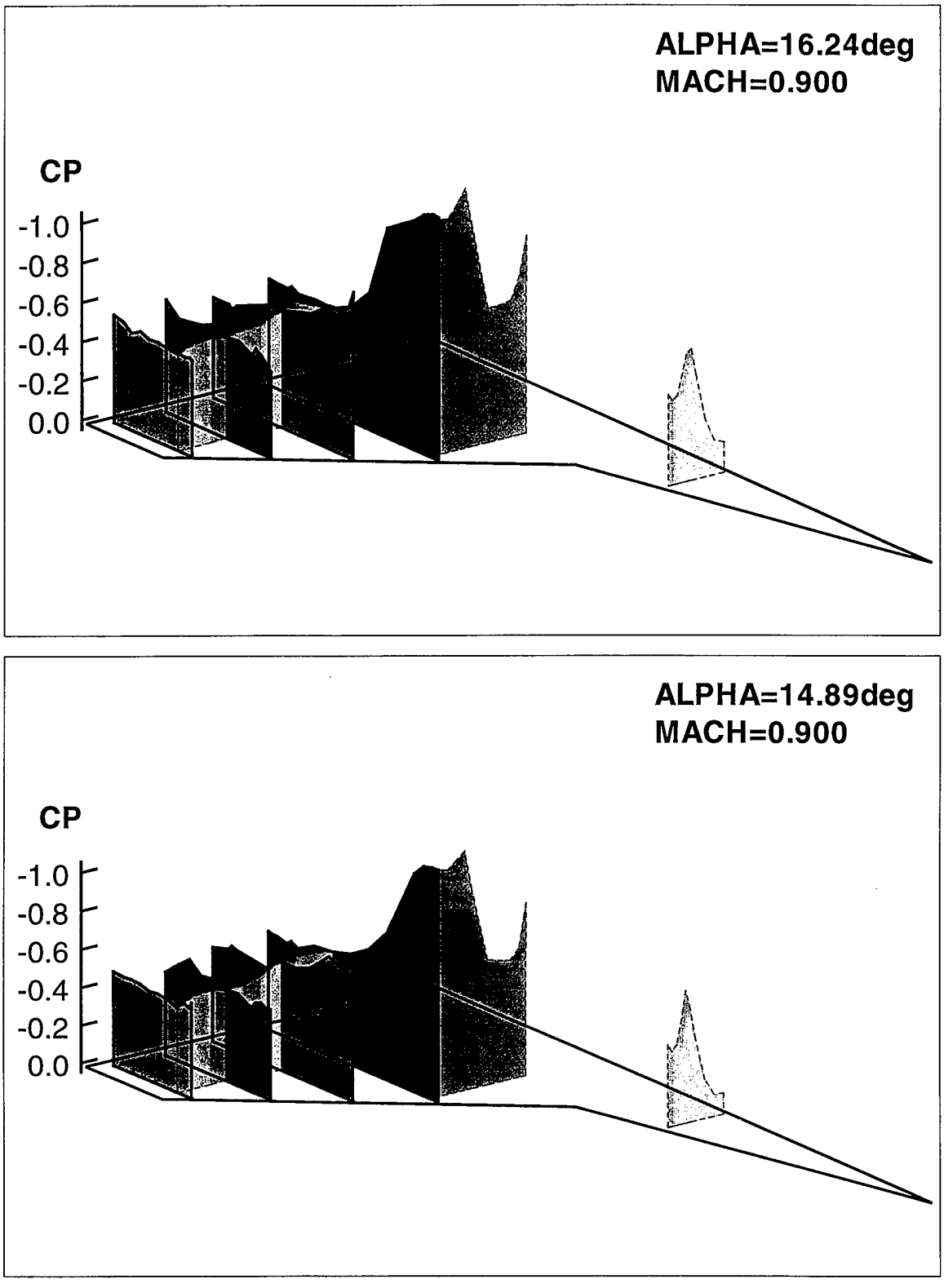
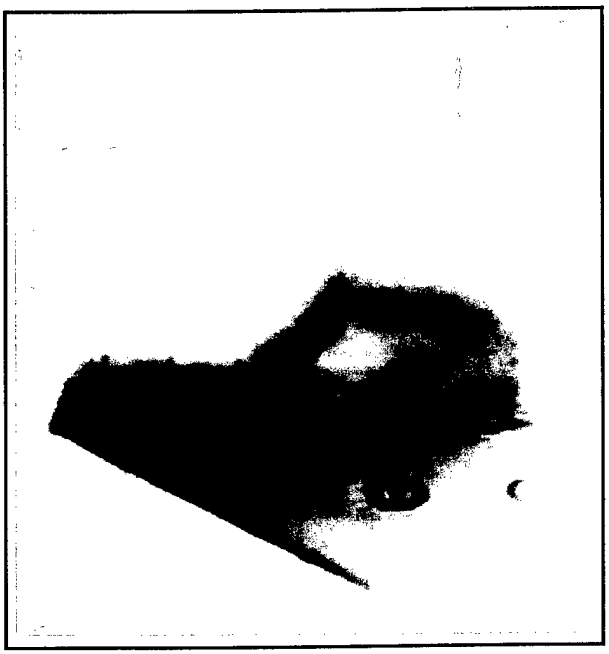
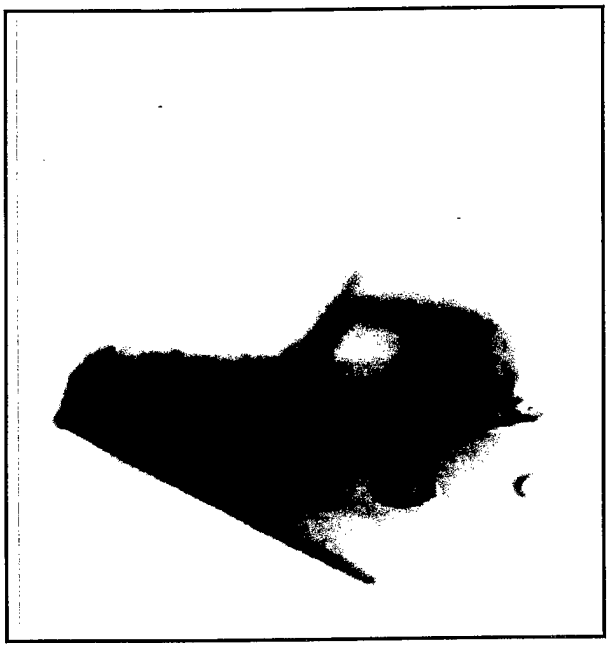


Figure 4.53 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 292.50 deg and 298.12 deg



Sheet Position 9, Alpha = 17.02 deg
(Run ID = 73, Frame = 151)



Sheet Position 9, Alpha = 15.87 deg
(Run ID = 73, Frame = 152)

Figure 4.54 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 292.50 Deg and 298.12 Deg

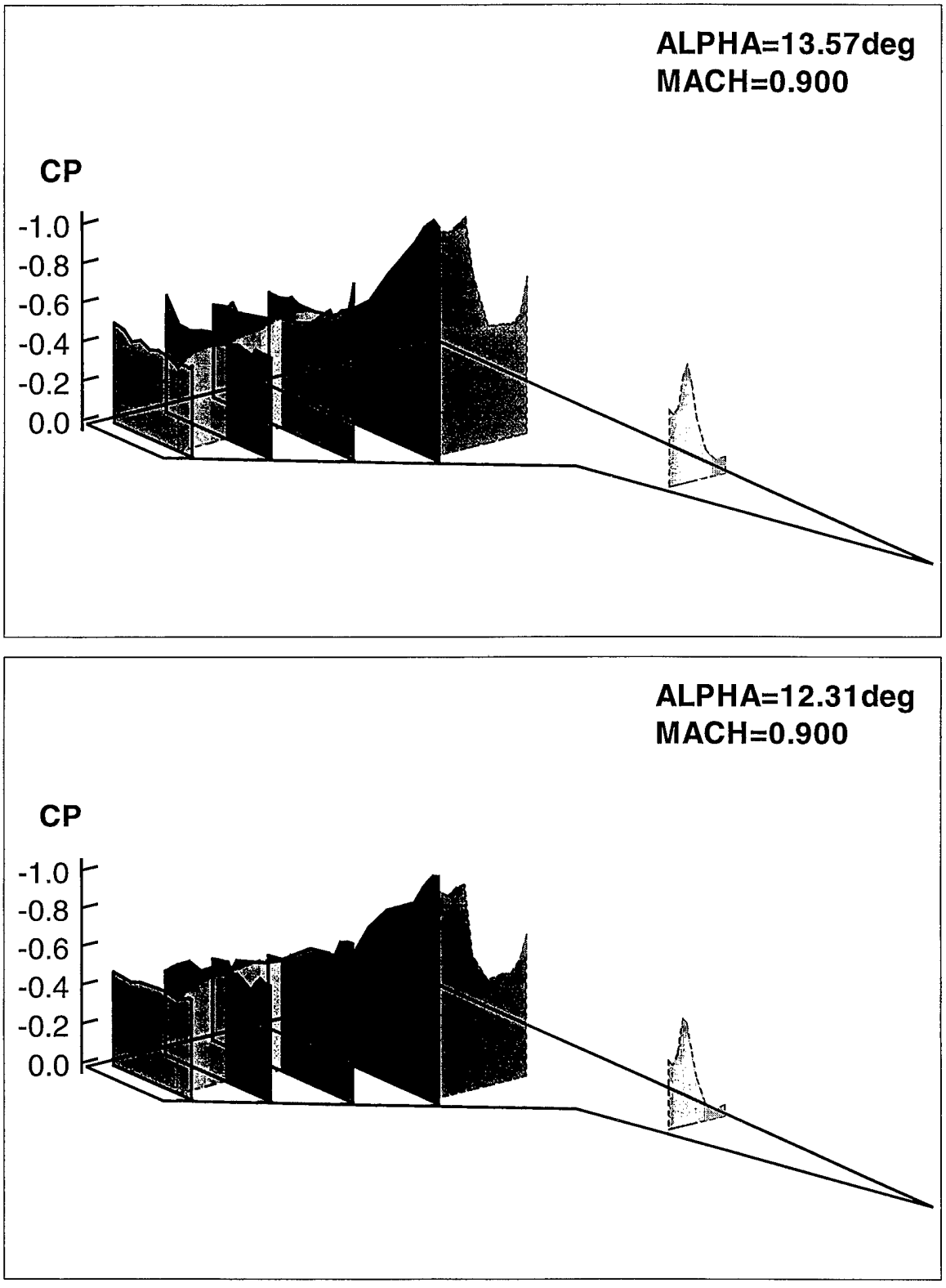
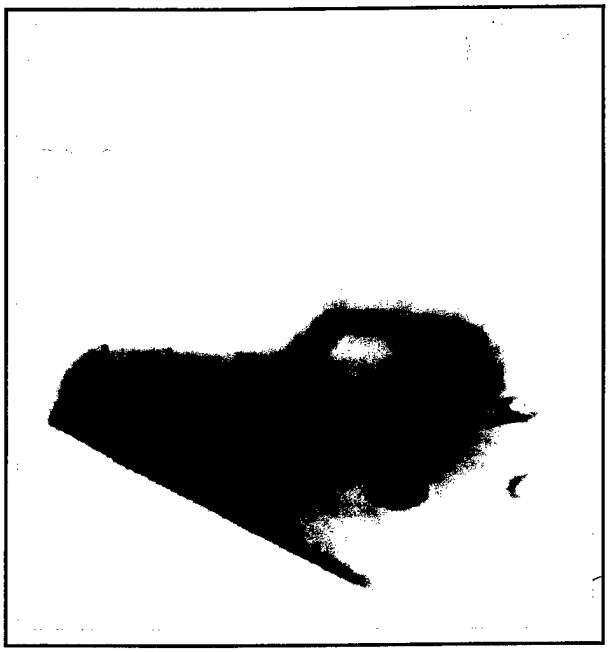
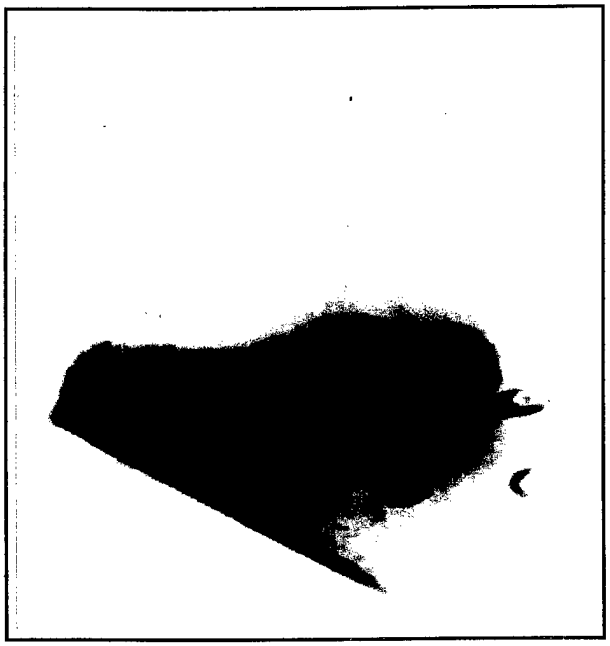


Figure 4.55 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 303.75 deg and 309.38 deg



Sheet Position 9, Alpha = 14.78 deg
(Run ID = 73, Frame = 153)



Sheet Position 9, Alpha = 13.76 deg
(Run ID = 73, Frame = 154)

Figure 4.56 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 303.75 Deg and 309.38 Deg

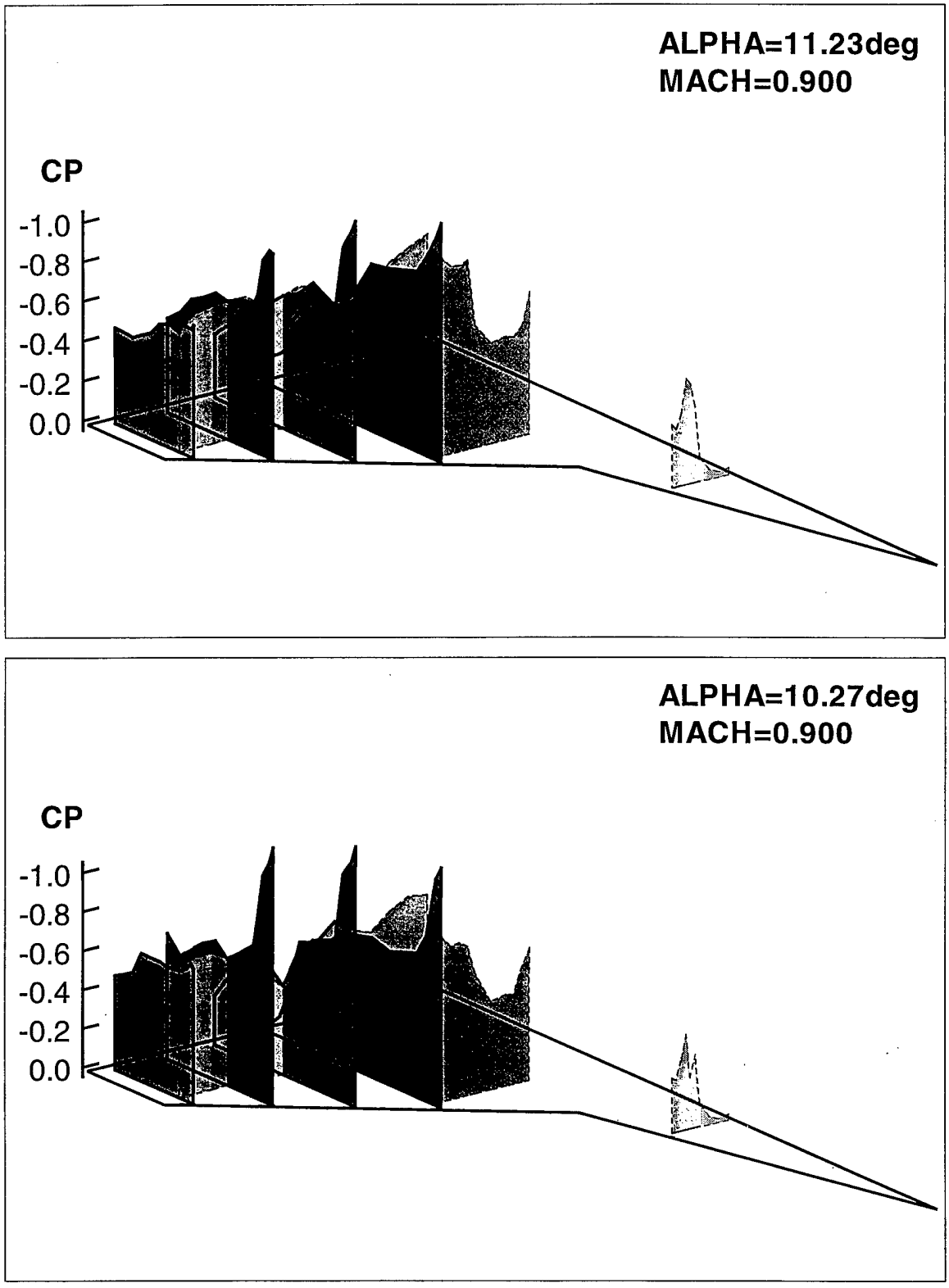
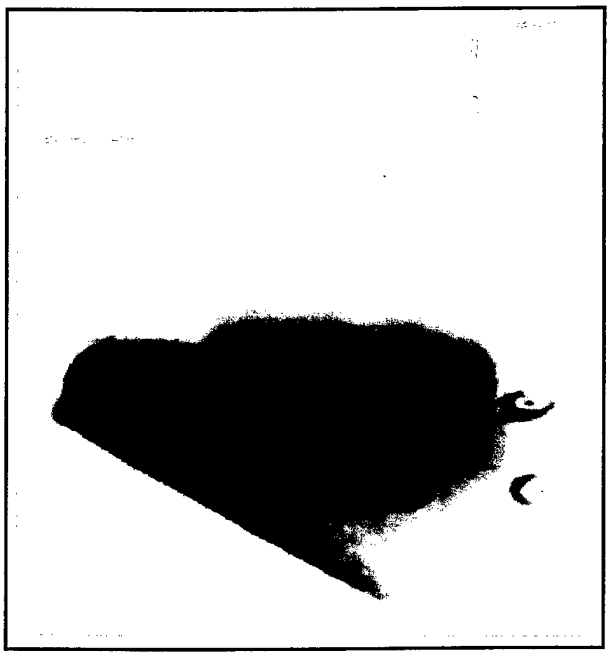
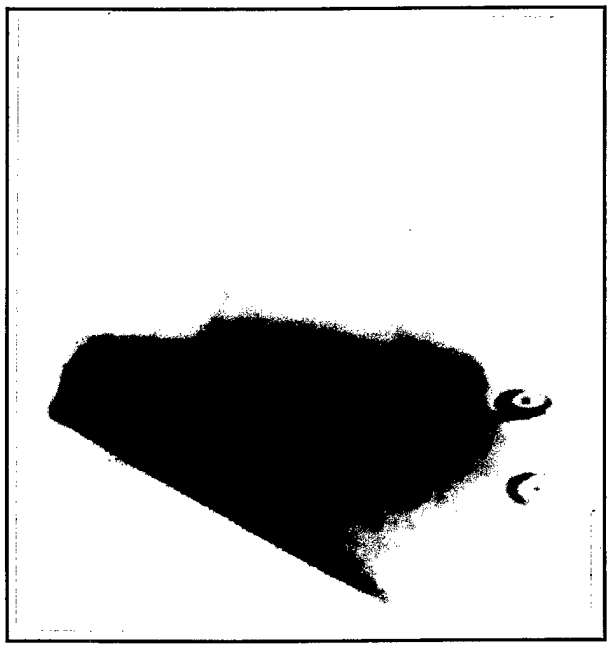


Figure 4.57 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 315.00 deg and 320.62 deg



Sheet Position 9, Alpha = 12.81 deg
(Run ID = 73, Frame = 155)



Sheet Position 9, Alpha = 11.96 deg
(Run ID = 73, Frame = 156)

Figure 4.58 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 315.00 Deg and 320.62 Deg

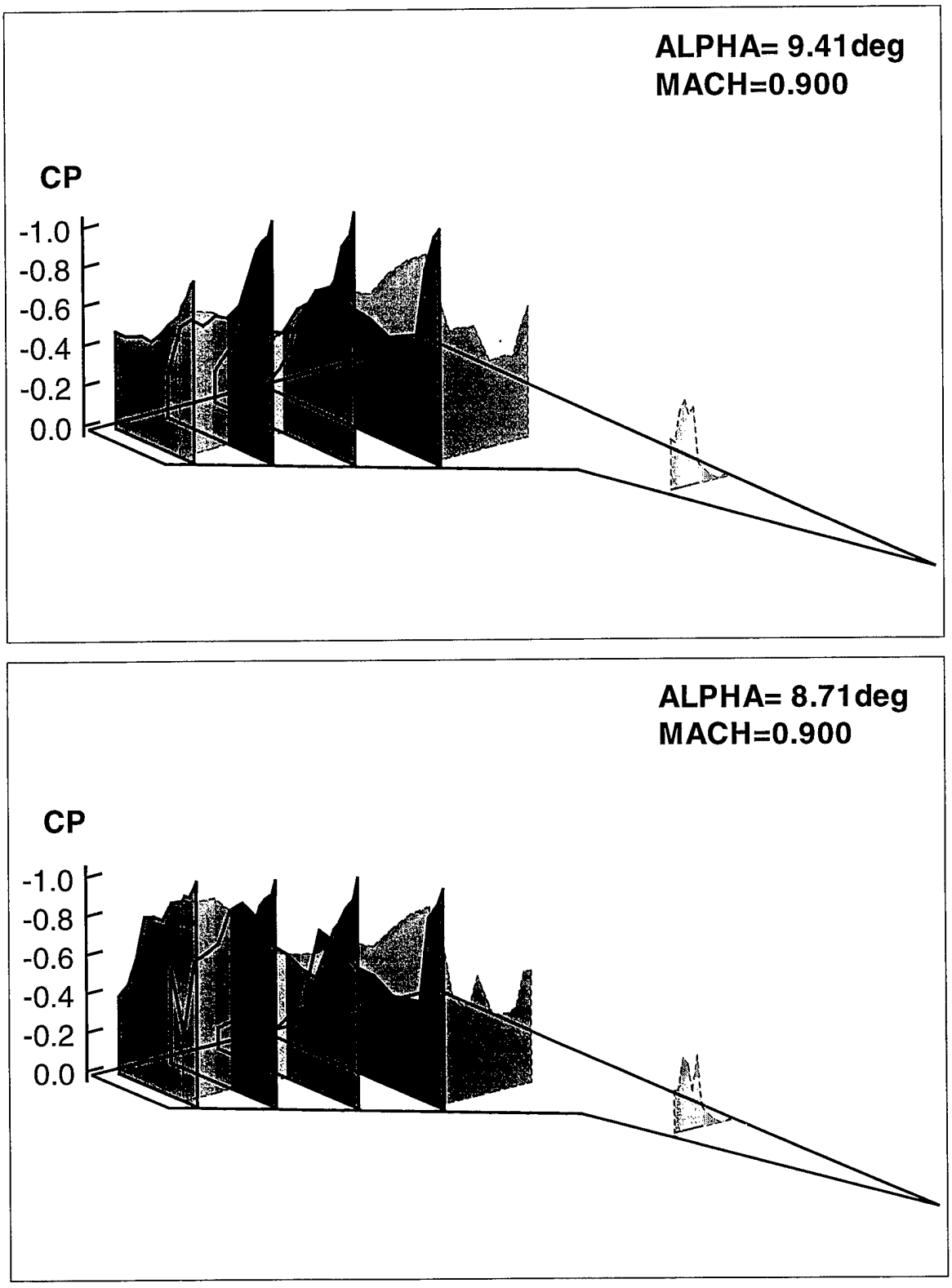
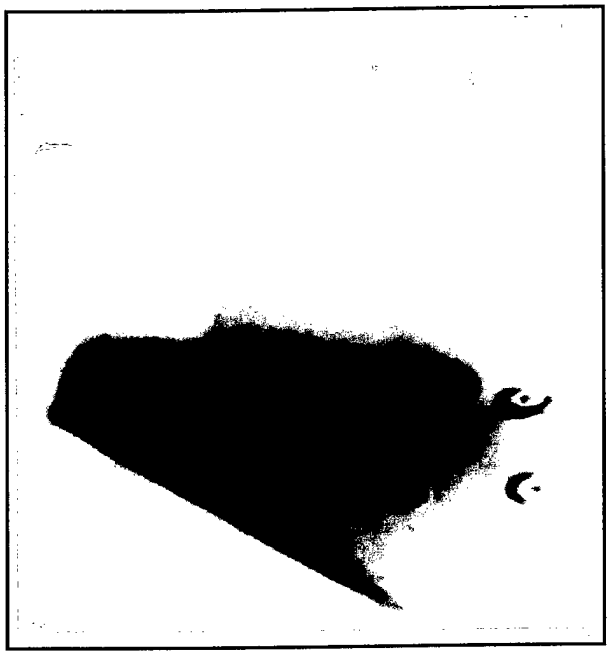
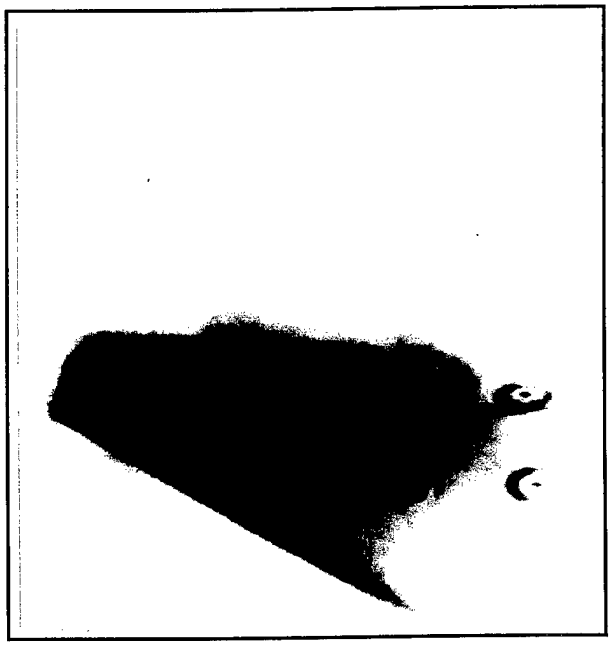


Figure 4.59 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 326.25 deg and 331.88 deg



Sheet Position 9, Alpha = 11.20 deg
(Run ID = 73, Frame = 157)



Sheet Position 9, Alpha = 10.54 deg
(Run ID = 73, Frame = 158)

Figure 4.60 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 326.25 Deg and 331.88 Deg

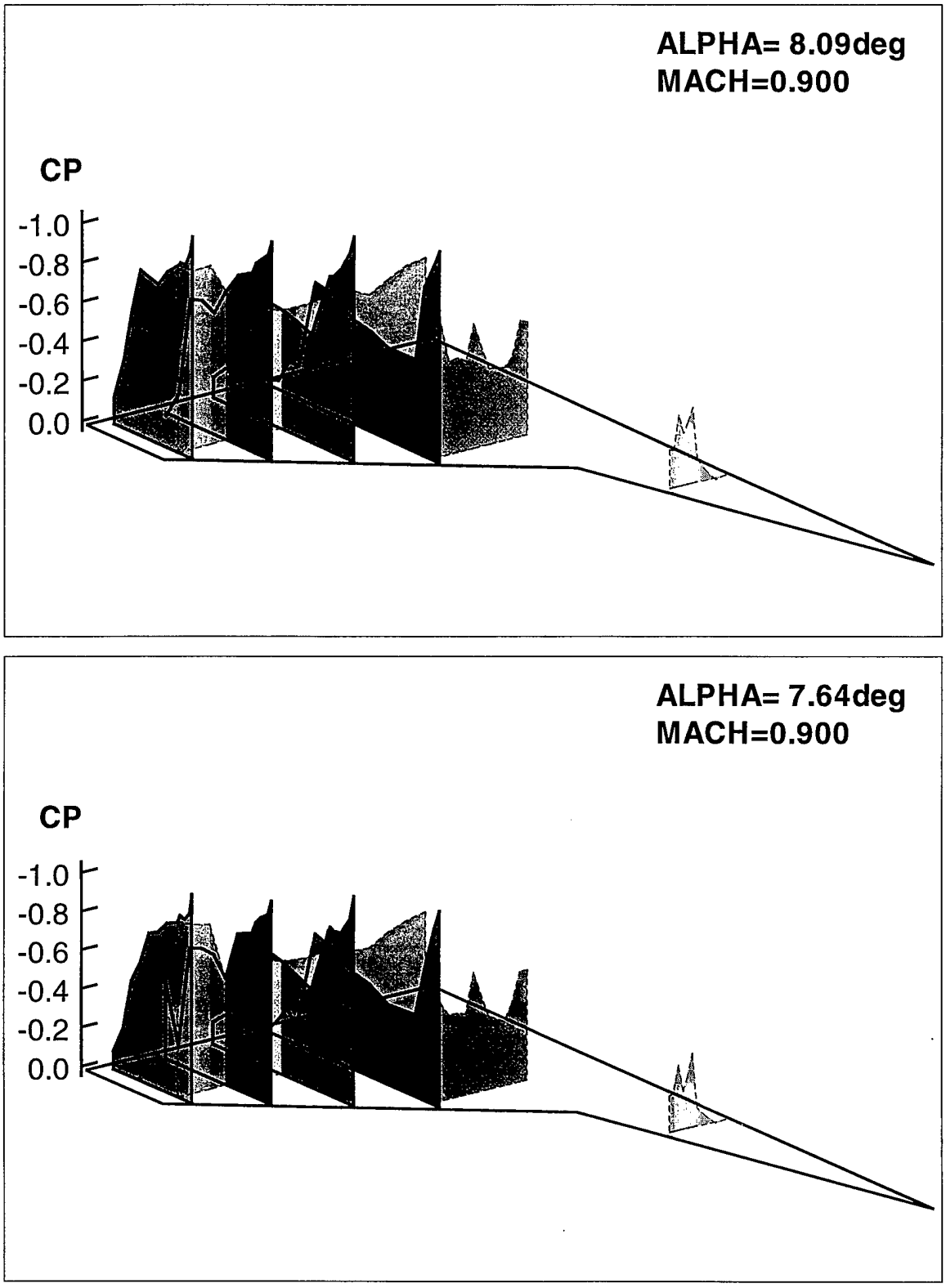
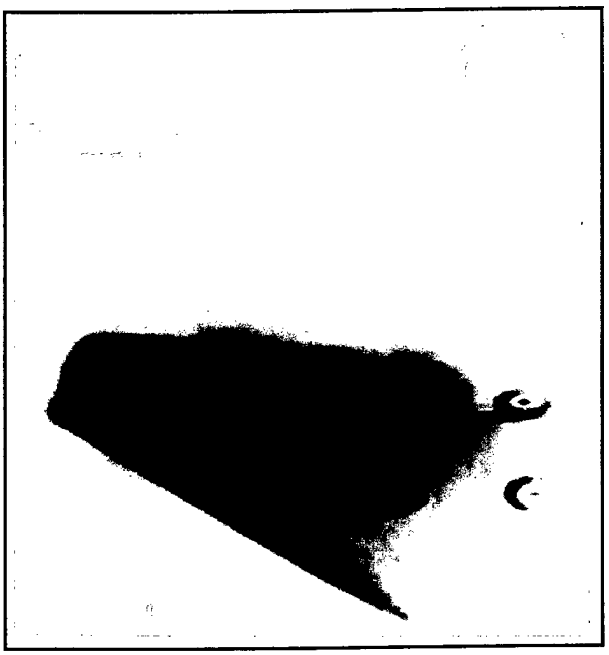
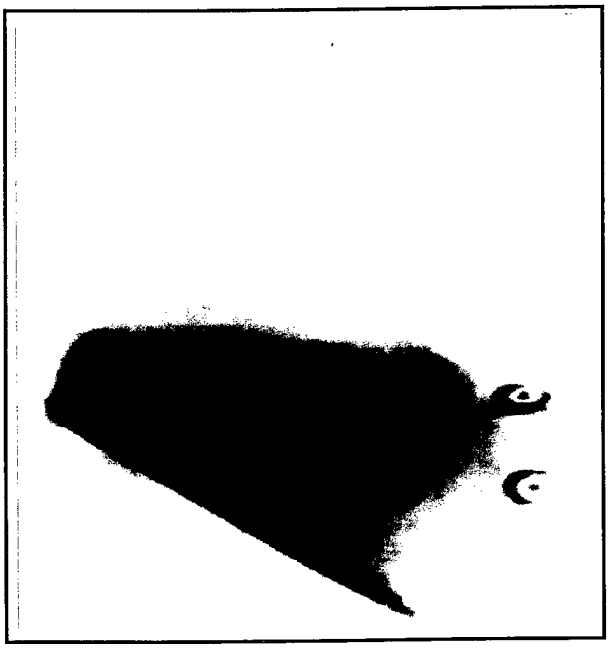


Figure 4.61 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 337.50 deg and 343.12 deg



Sheet Position 9, Alpha = 10.00 deg
(Run ID = 73, Frame = 159)



Sheet Position 9, Alpha = 9.57 deg
(Run ID = 73, Frame = 160)

Figure 4.62 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 337.50 Deg and 343.12 Deg

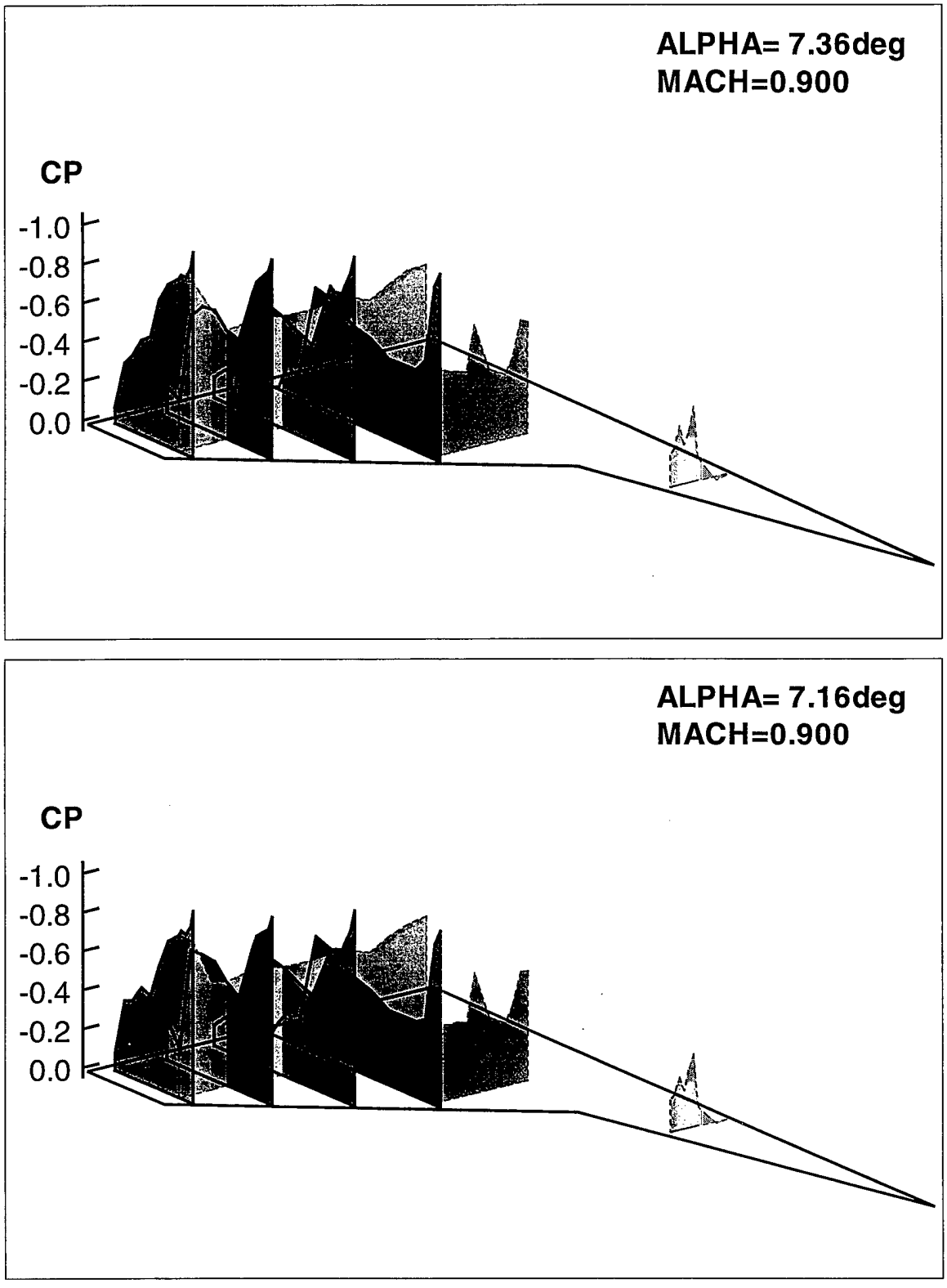
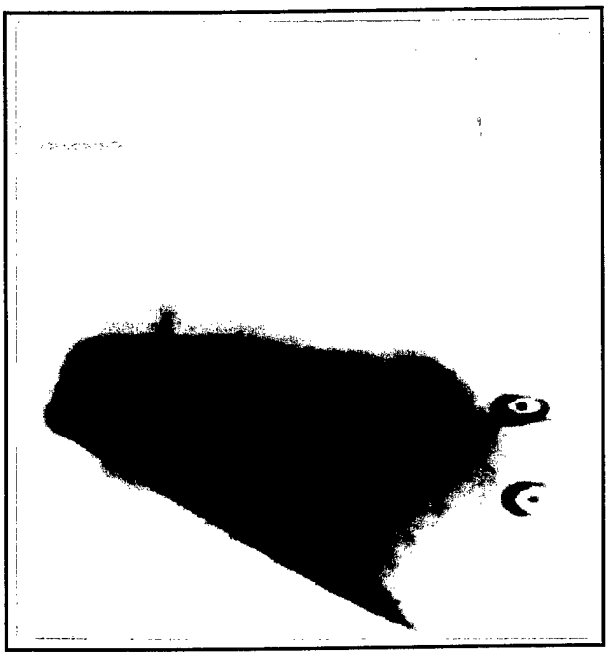
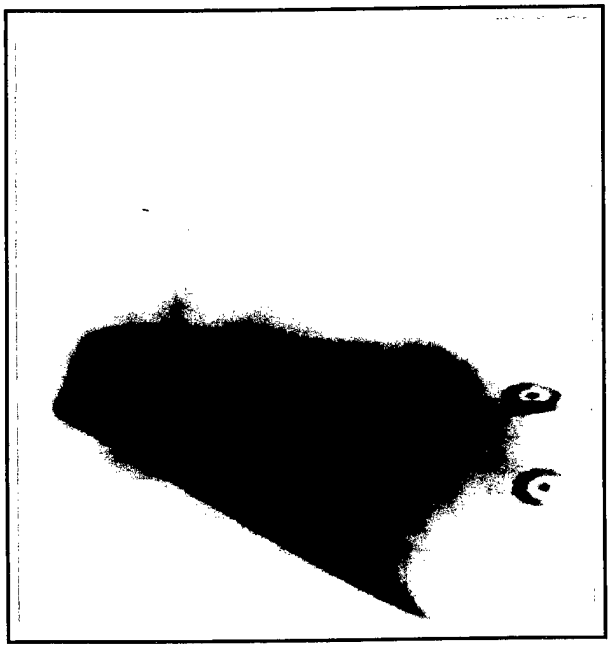


Figure 4.63 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 348.75 deg and 354.38 deg



Sheet Position 9, Alpha = 9.26 deg
(Run ID = 73, Frame = 161)



Sheet Position 9, Alpha = 9.07 deg
(Run ID = 73, Frame = 162)

Figure 4.64 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 348.75 Deg and 354.38 Deg

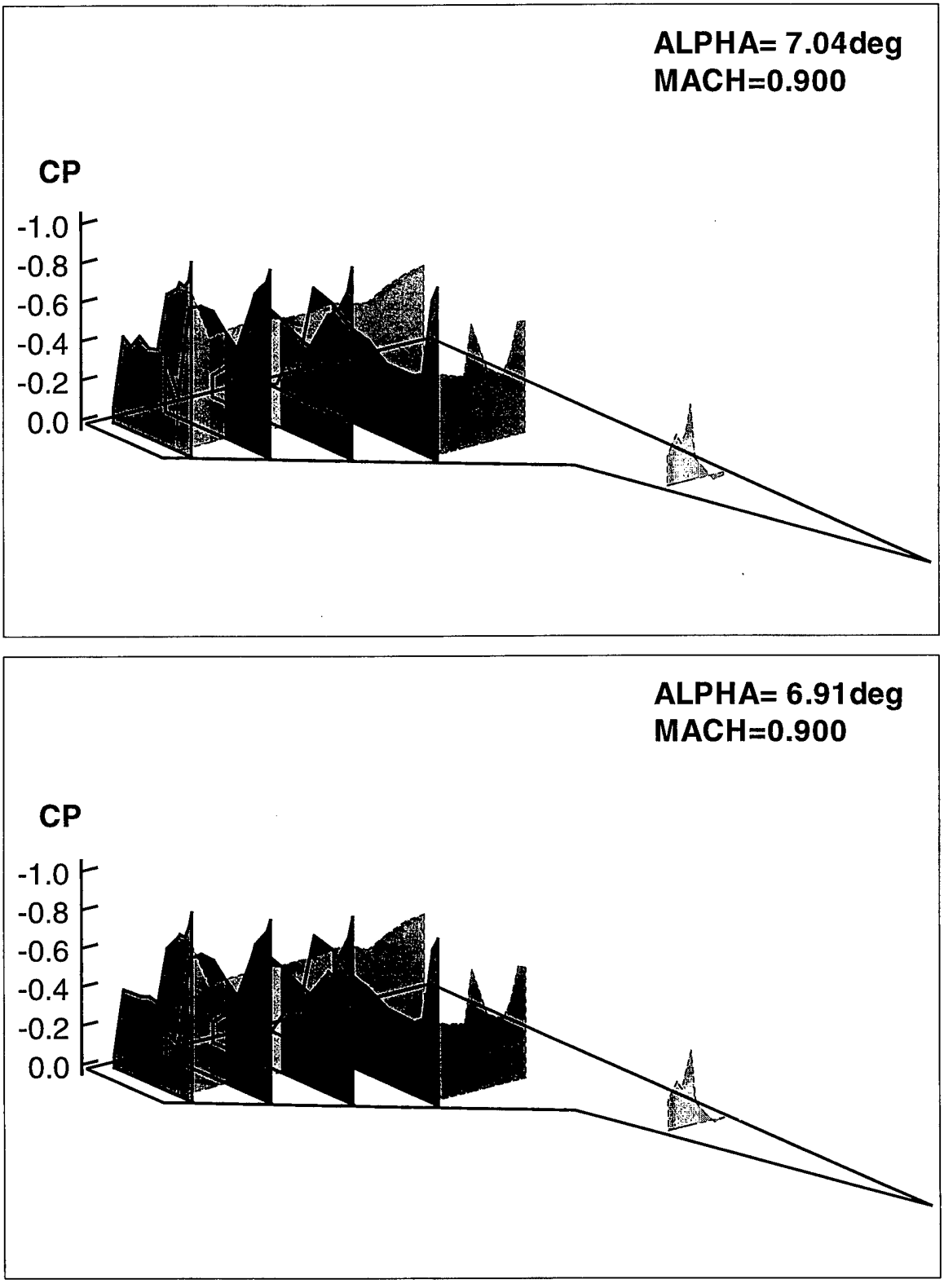
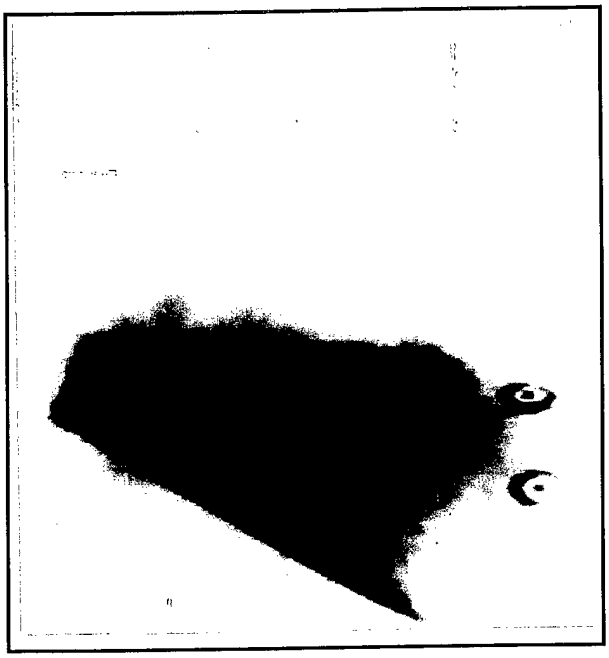
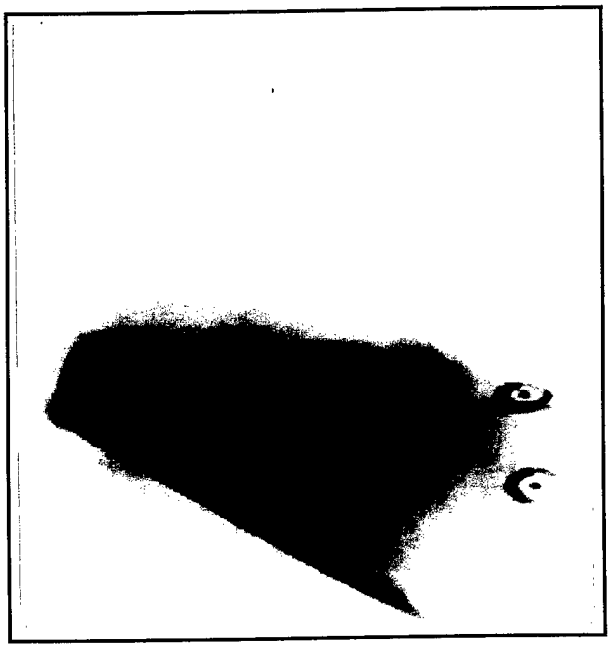


Figure 4.65 - Unsteady Pressure Distributions During Pitching Motion from 7.2 deg to 37.7 deg to 7.1 deg at Phase Angles of 360.00 deg and 365.62 deg



Sheet Position 9, Alpha = 9.01 deg
(Run ID = 73, Frame = 163)



Sheet Position 9, Alpha = 9.07 deg
(Run ID = 73, Frame = 164)

Figure 4.66 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.9 During Pitching Motion From 9.01 Deg to 34.97 Deg, Phase Angles of 360.00 Deg and 365.62 Deg

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3.0 HIGH SPEED VIDEO UNSTEADY LCO FLOW VISUALIZATION FOR THE CLEAN WING AT M = 0.9, OSCILLATING AT ±0.5 DEG AND VARYING MEAN ANGLES

Individual frames from the high speed video data base for LCO-type conditions are presented in this section for three spanwise sheet positions 11, 12, and 13, as shown in Figure 5, below. (Note: Position 11 is the same as 9, except that it is focused on the outer wing panel). The frame rate was 576 frames per second, which was synchronized to give 16 frames per cycle at the model oscillation frequency of 36Hz. These data are available on the high speed video VHS tape and selected frames in the digital data base (see Reference 2). The data shown in this section in Figures 6.01 through 6.03 are from the digital data base. Four phase angles were chosen during a cycle of oscillation at ±0.5 deg amplitude corresponding to (1) 0 deg pitching up through the mean angle, (2) 90 deg at maximum angle, (3) 180 deg pitching down through the mean angle, and (4) 270 deg at minimum angle.

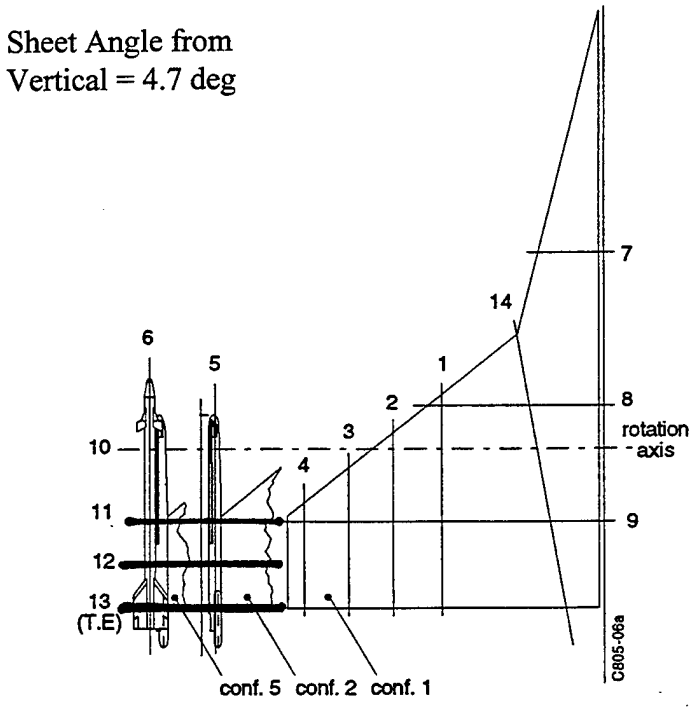


Figure 5 - Flow Visualization Locations for Figures 6, LCO Conditions, Clean Wing, M = 0.9, Oscillating at ±0.5 deg

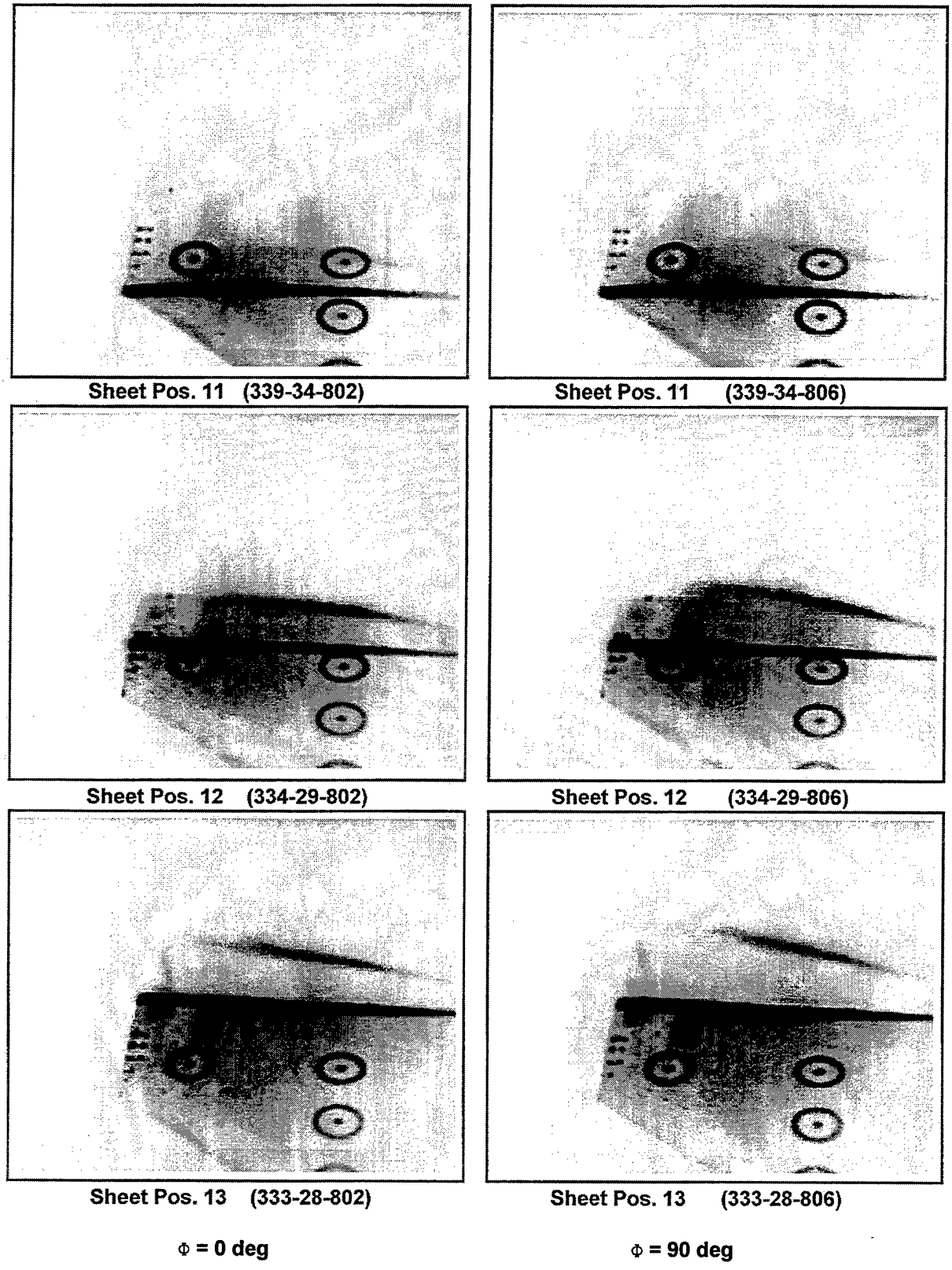
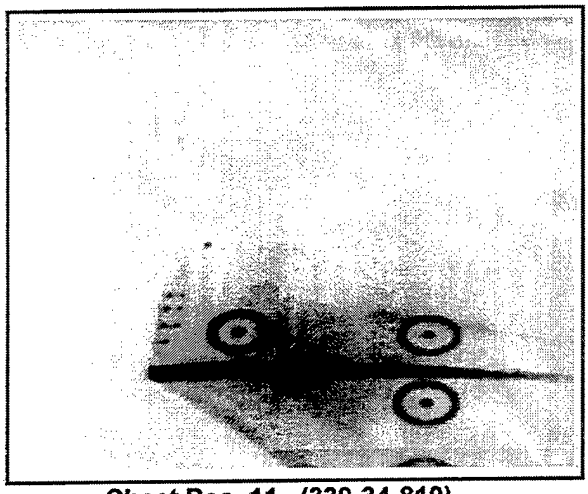
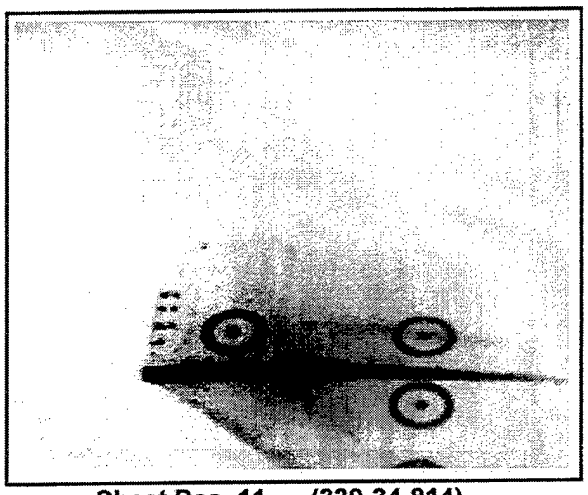


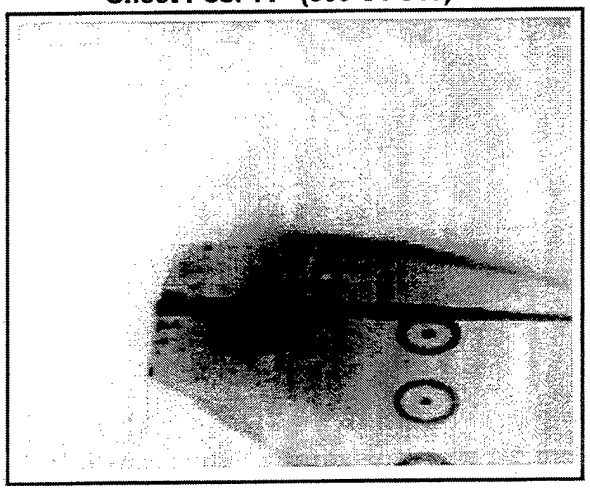
Figure 6.01 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.90, α = 8.0 deg, dα = 0.5 deg, f = 36Hz; Clean Wing Configuration



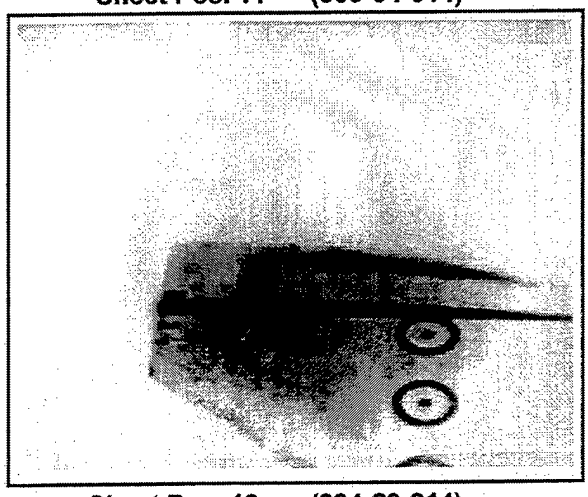
Sheet Pos. 11 (339-34-810)



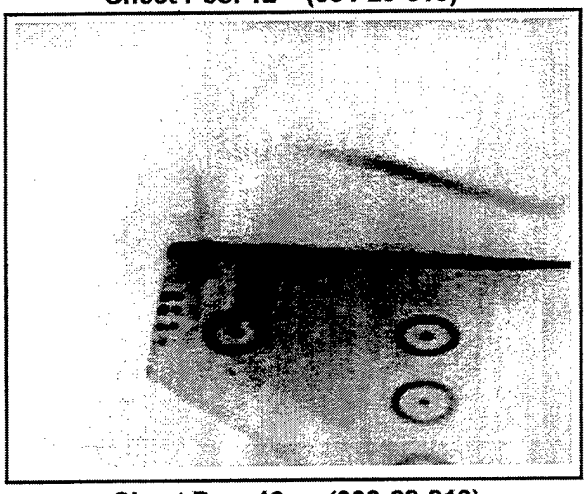
Sheet Pos. 11 (339-34-814)



Sheet Pos. 12 (334-29-810)

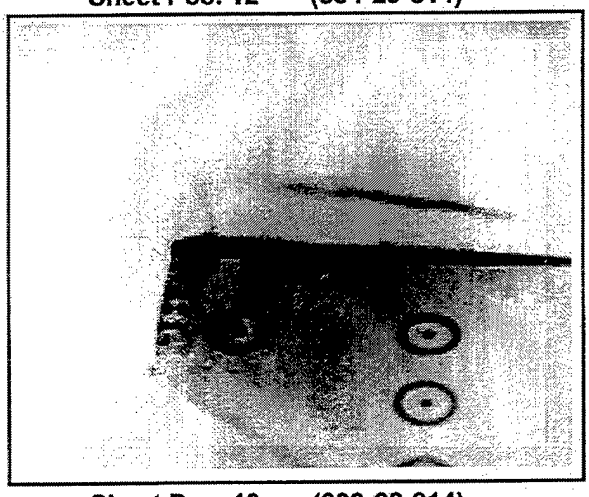


Sheet Pos. 12 (334-29-814)



Sheet Pos. 13 (333-28-810)

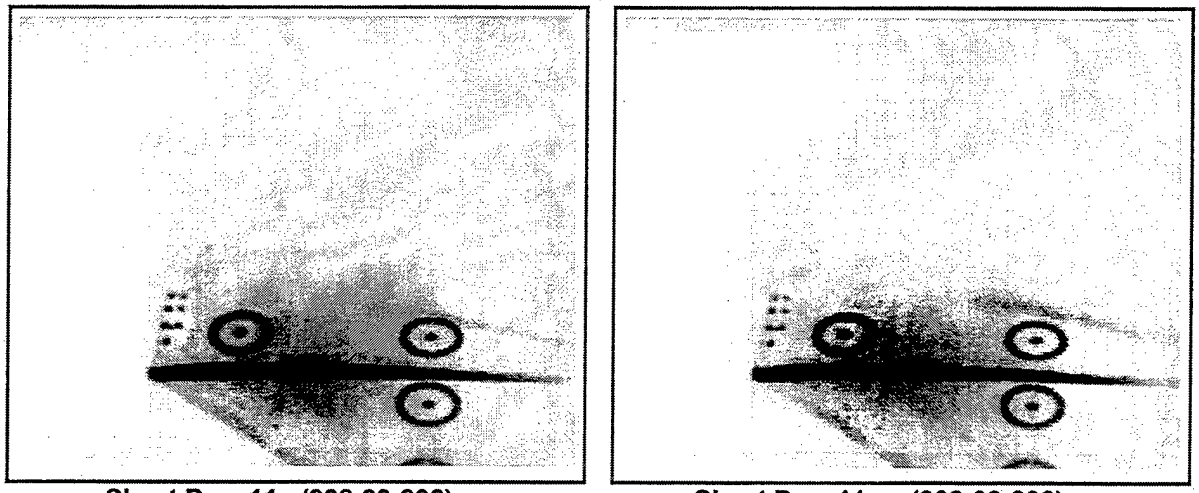
Φ = 180 deg



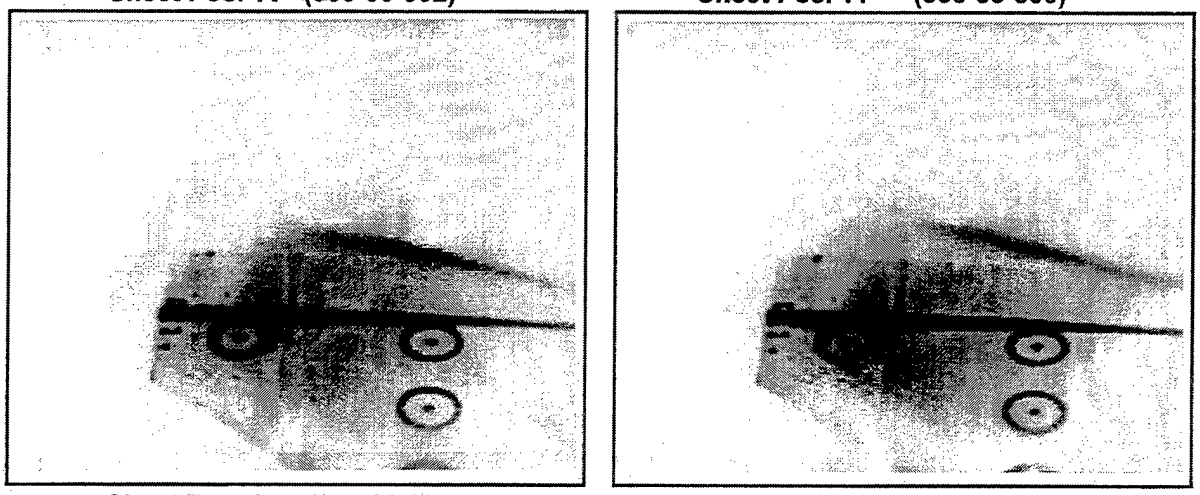
Sheet Pos. 13 (333-28-814)

Φ = 270 deg

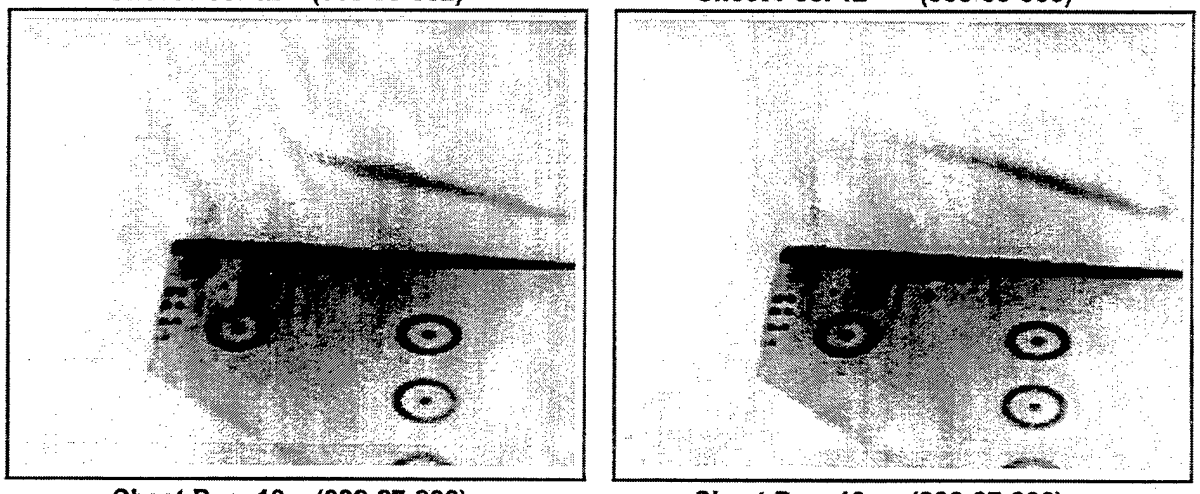
Figure 6.01 - (Concluded)



Sheet Pos. 11 (338-33-802) Sheet Pos. 11 (338-33-806)



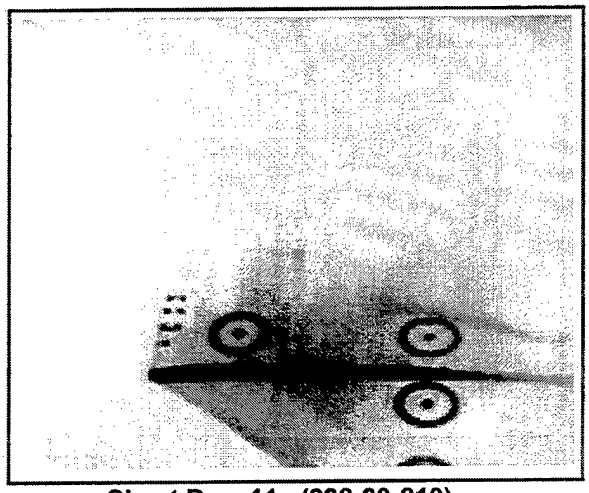
Sheet Pos. 12 (335-30-802) Sheet Pos. 12 (335-30-806)



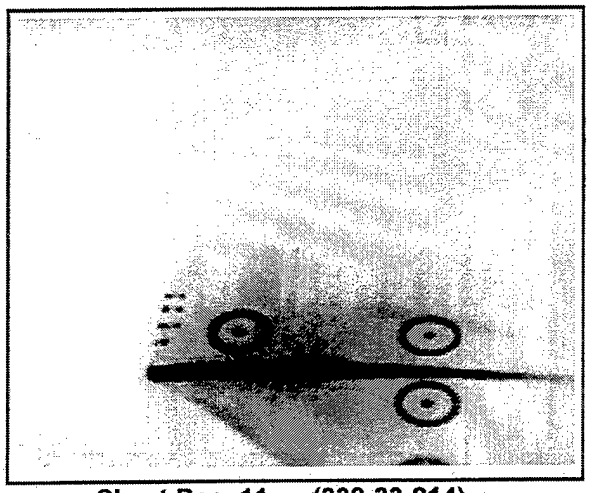
Sheet Pos. 13 (332-27-802) Sheet Pos. 13 (332-27-806)

Φ = 0 deg Φ = 90 deg

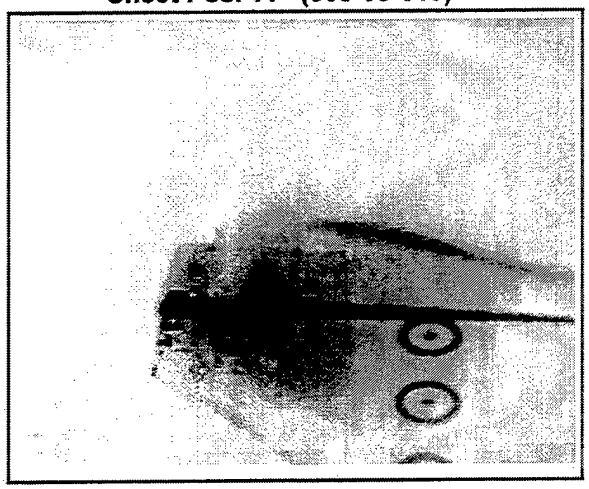
Figure 6.02 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.90, α = 9.0 deg, dα = 0.5 deg, f = 36Hz; Clean Wing Configuration



Sheet Pos. 11 (338-33-810)



Sheet Pos. 11 (338-33-814)



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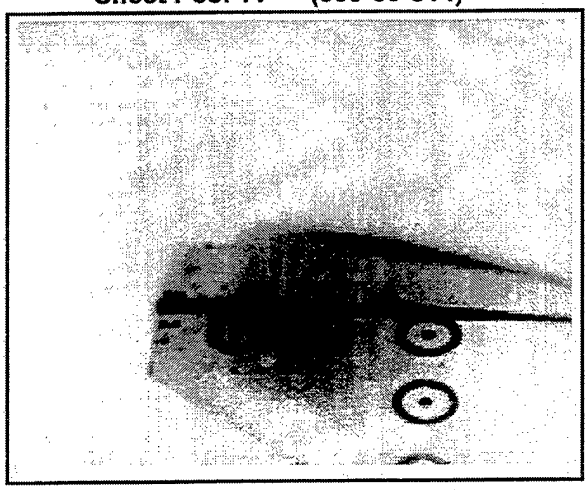
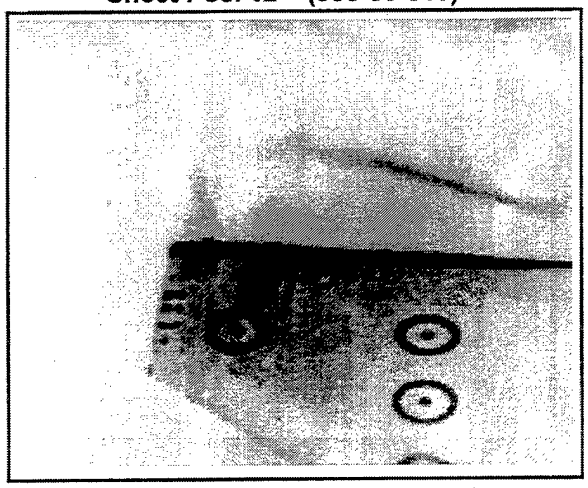
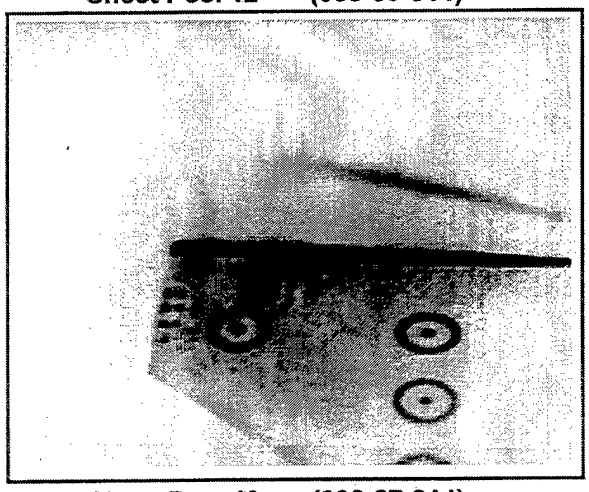


Sheet Pos. 12 (335-30-814)



Sheet Pos. 13 (332-27-810)

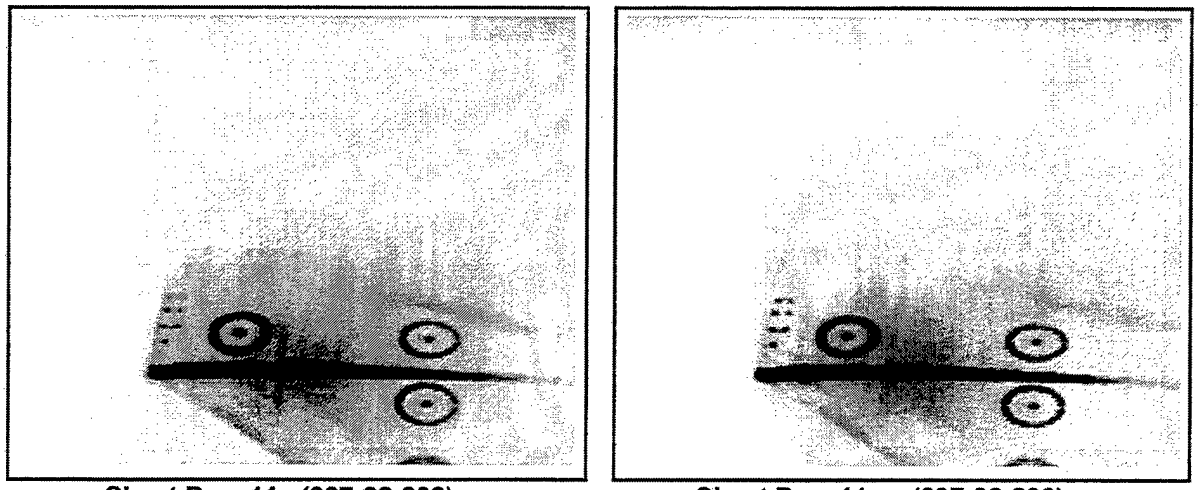
Φ = 180 deg



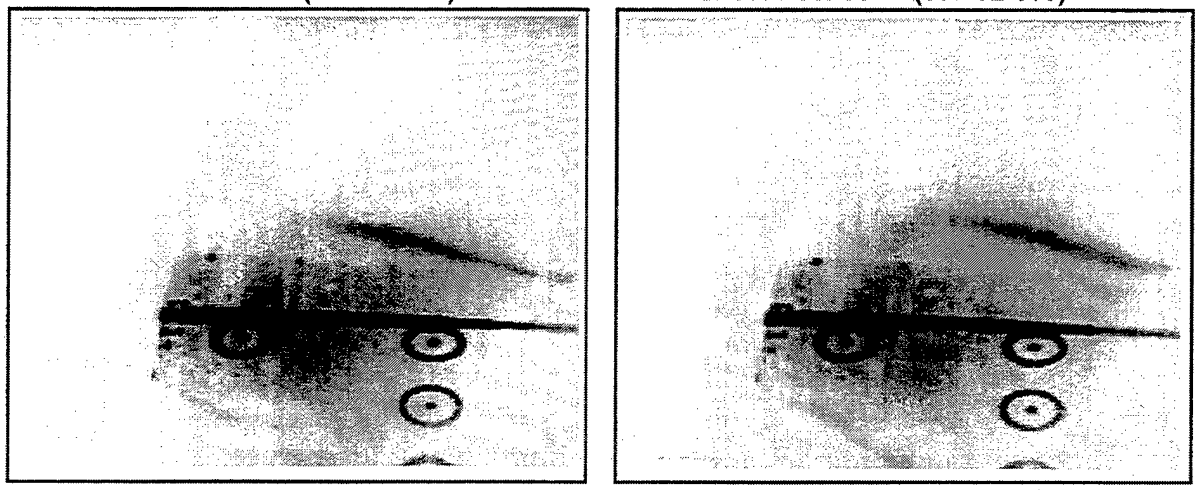
Sheet Pos. 13 (332-27-814)

Φ = 270 deg

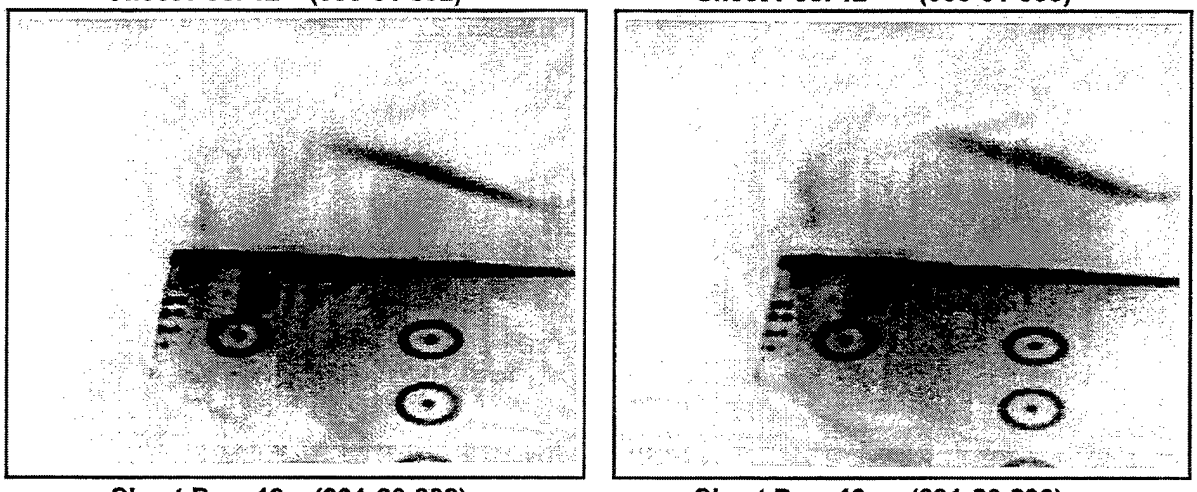
Figure 6.02 - (Concluded)



Sheet Pos. 11 (337-32-802) Sheet Pos. 11 (337-32-806)



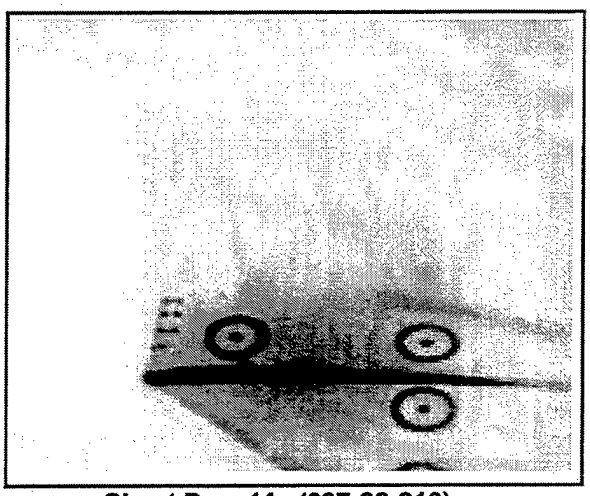
Sheet Pos. 12 (336-31-802) Sheet Pos. 12 (336-31-806)



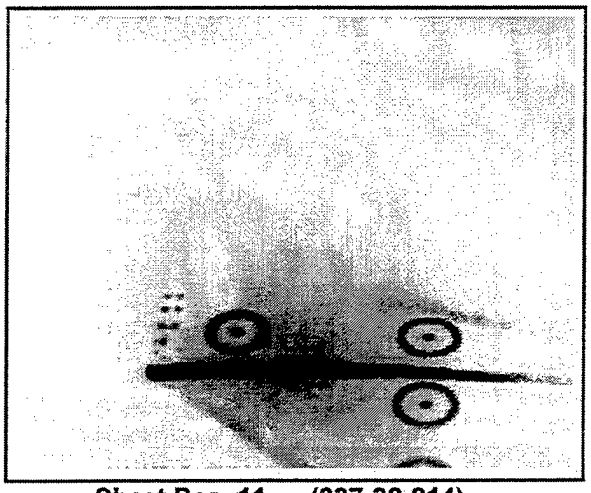
Sheet Pos. 13 (331-26-802) Sheet Pos. 13 (331-26-806)

Φ = 0 deg Φ = 90 deg

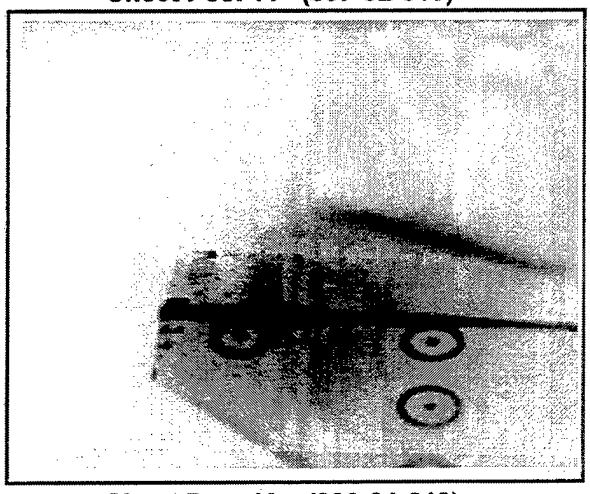
Figure 6.03 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.90, α = 10.0 deg, dα = 0.5 deg, f = 36Hz; Clean Wing Configuration



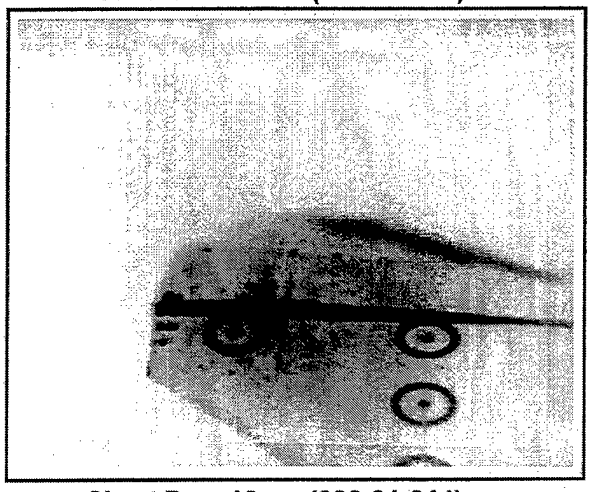
Sheet Pos. 11 (337-32-810)



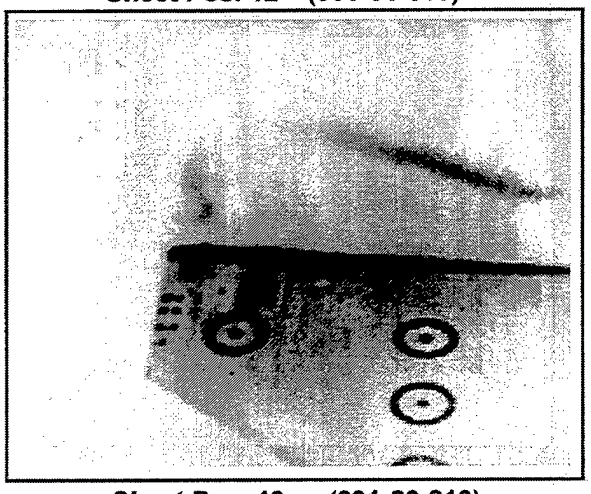
Sheet Pos. 11 (337-32-814)



Sheet Pos. 12 (336-31-810)



Sheet Pos. 12 (336-31-814)



Sheet Pos. 13 (331-26-810)

Φ = 180 deg

NO DATA

Sheet Pos. 13 (xxx-xx-xxx)

Φ = 270 deg

Figure 6.03 - (Concluded)

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4.0 HIGH SPEED VIDEO UNSTEADY LCO FLOW VISUALIZATION FOR THE WING WITH TIP MISSILE AT M = 0.85 AND 0.9, OSCILLATING AT ±0.5 DEG AND VARYING MEAN ANGLES

The presentation of unsteady LCO flow visualization data in this section for the wing with tip missile is identical to that in Section 3.0 for the clean wing. The sheet position rows, 11, 12, and 13 are also the same as shown in Figure 7 , below. Results at M = 0.9 are presented in Figures 8.01 through 8.03 and at M = 0.85 in Figure 9.01.

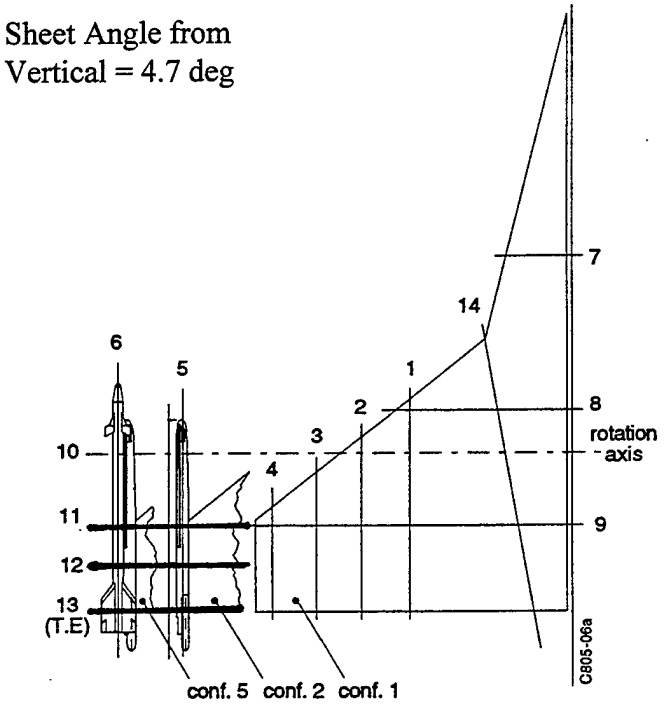


Figure 7 - Flow Visualization Locations for Figures 8 and 9, LCO Conditions, Wing With Tip Missile, M = 0.85 and 0.9, Oscillating at ±0.5 deg

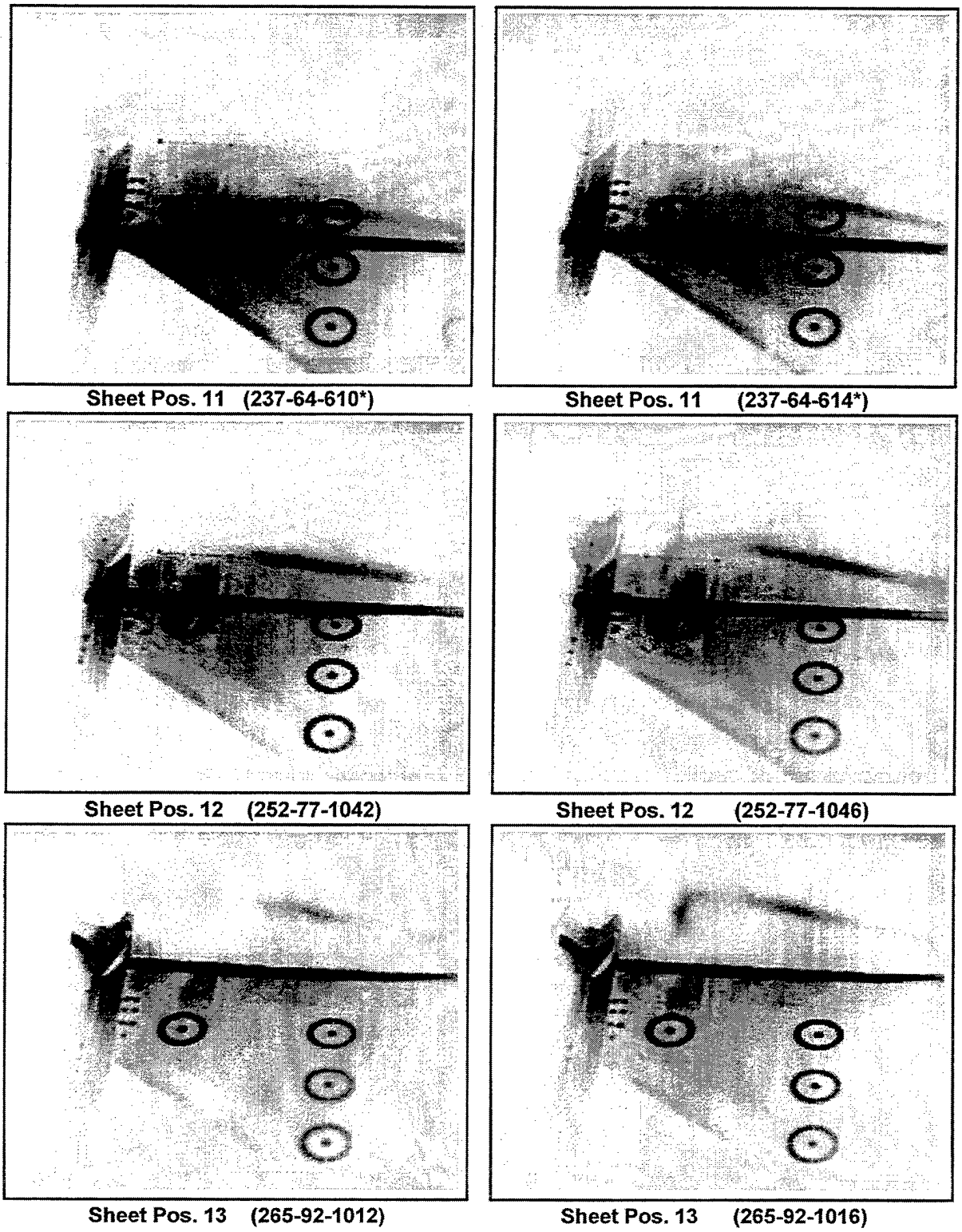
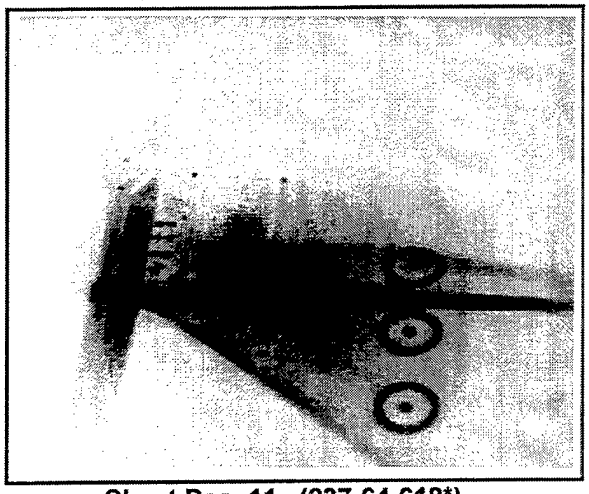
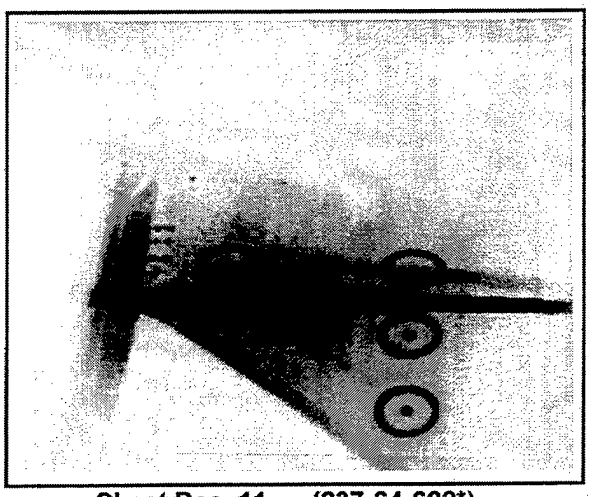


Figure 8.01 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.90, α = 8.0 deg, dα = 0.5 deg, f = 36Hz; Tip Launcher/Missile Configuration

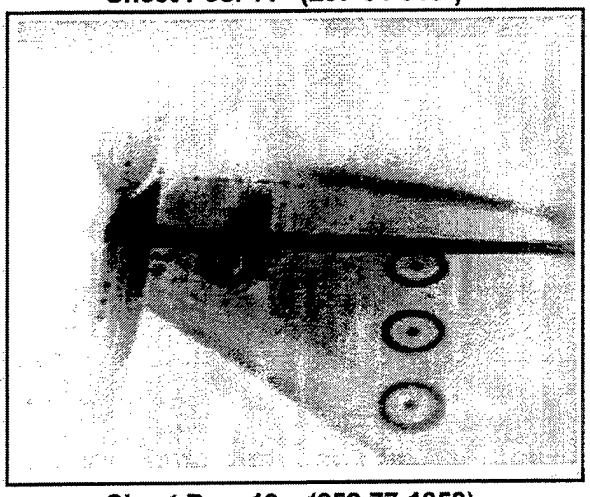
(*α = 7.5 deg)



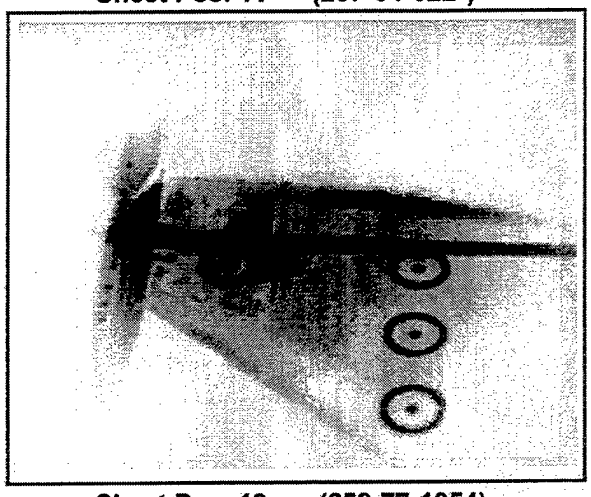
Sheet Pos. 11 (237-64-618*)



Sheet Pos. 11 (237-64-622*)



Sheet Pos. 12 (252-77-1050)



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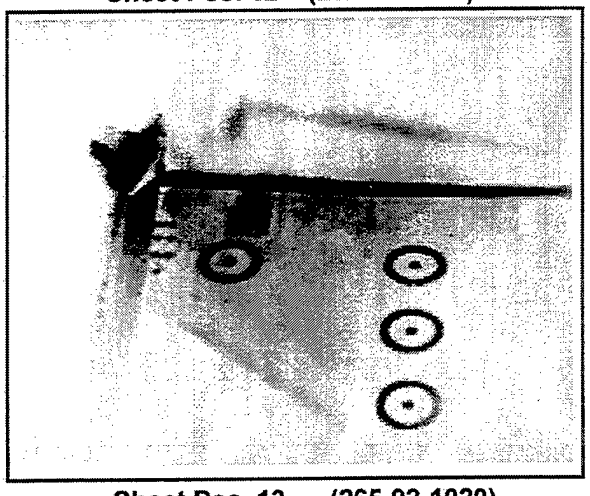
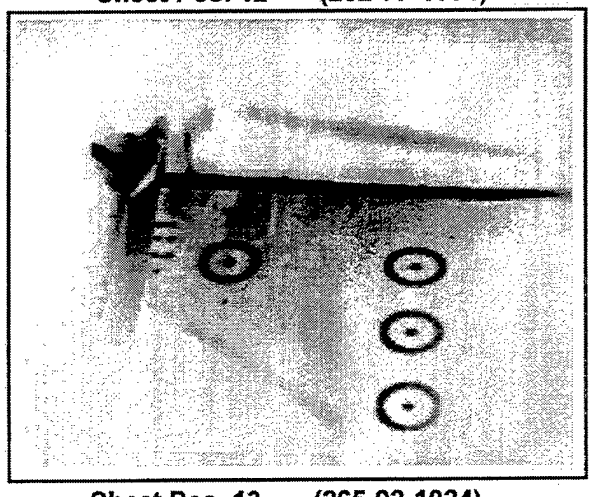


Sheet Pos. 13 (265-92-1020)

Φ = 180 deg

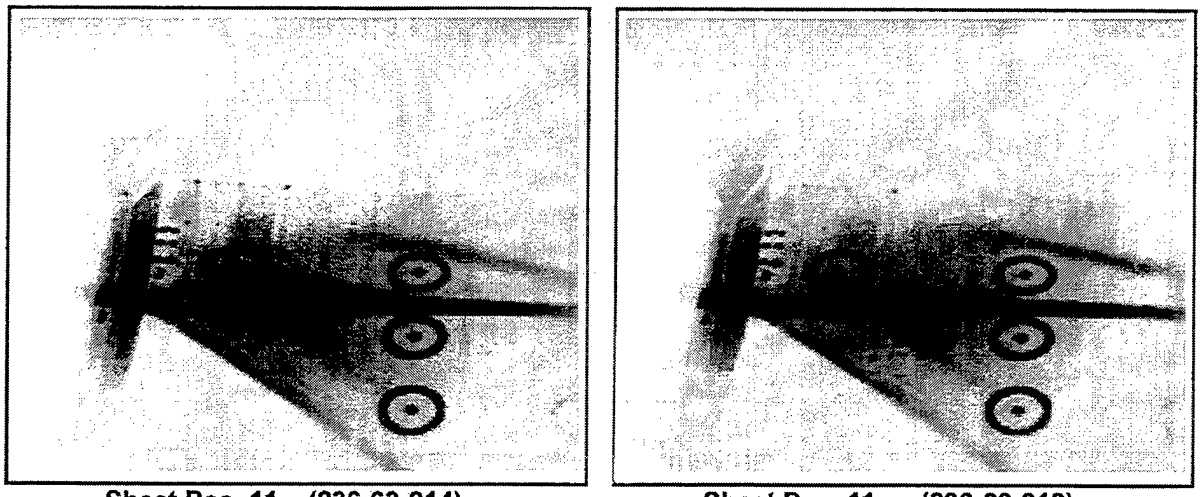


Sheet Pos. 13 (265-92-1024)

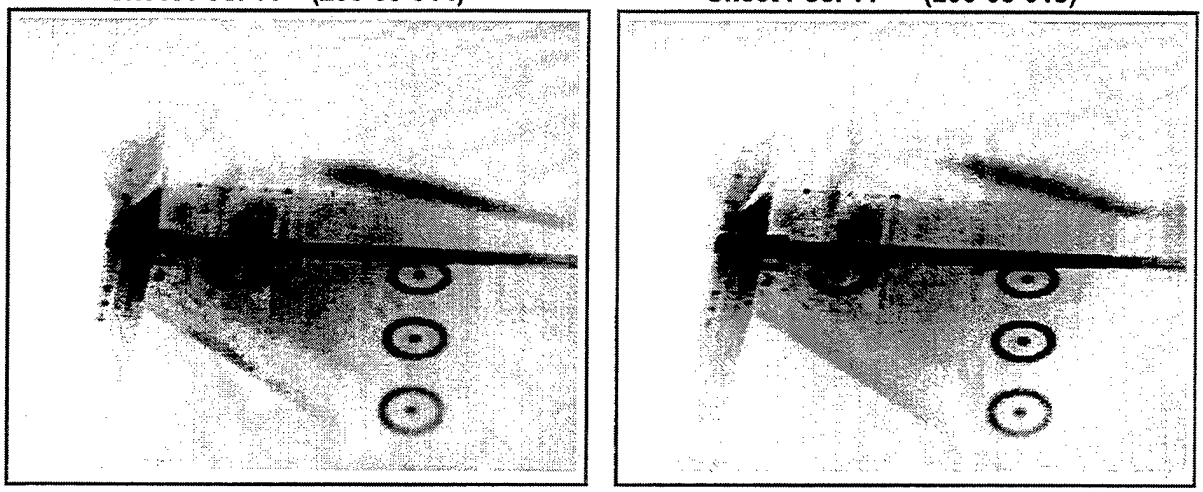
Φ = 270 deg

Figure 8.01 - (Concluded)

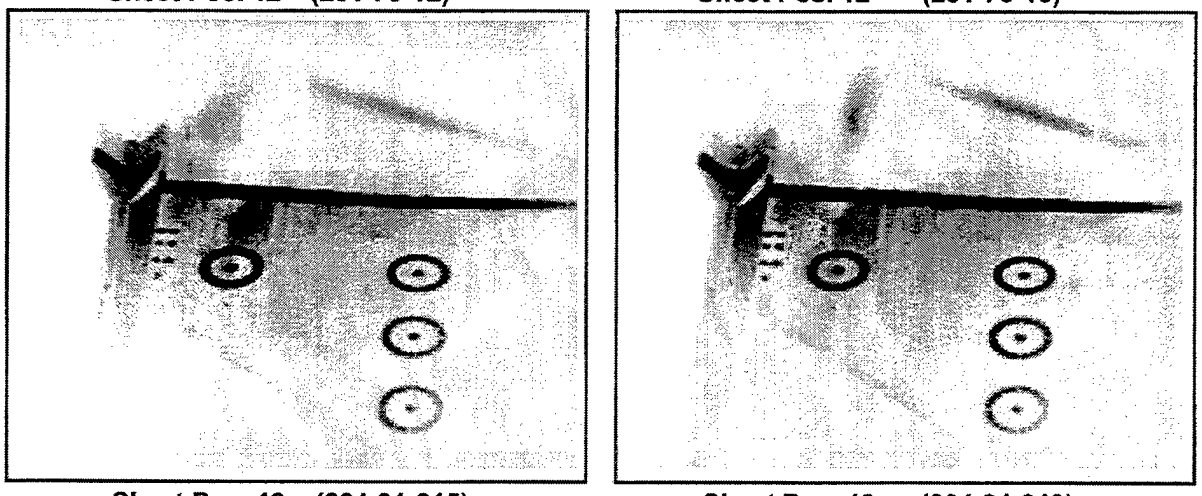
(*α = 7.5 deg)



Sheet Pos. 11 (236-63-914) Sheet Pos. 11 (236-63-918)



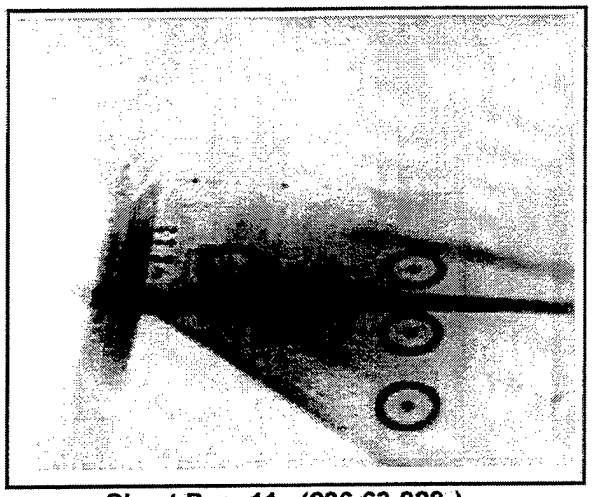
Sheet Pos. 12 (251-76-12) Sheet Pos. 12 (251-76-16)



Sheet Pos. 13 (264-91-915) Sheet Pos. 13 (264-91-919)

Φ = 0 deg Φ = 90 deg

Figure 8.02 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.90, α = 9.0 deg, dα = 0.5 deg, f = 36Hz; Tip Launcher/Missile Configuration



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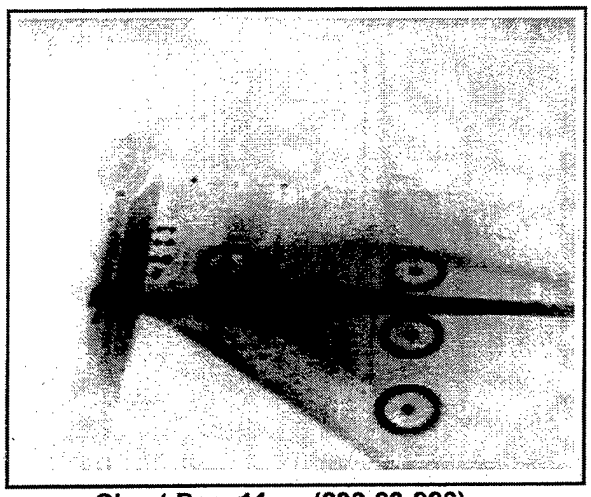
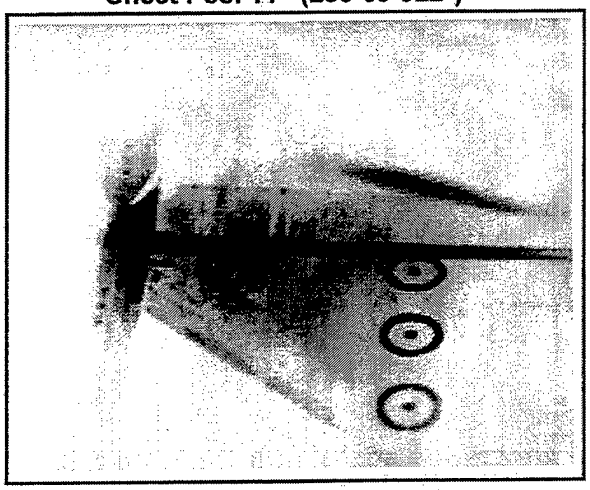


Sheet Pos. 11 (236-63-926)



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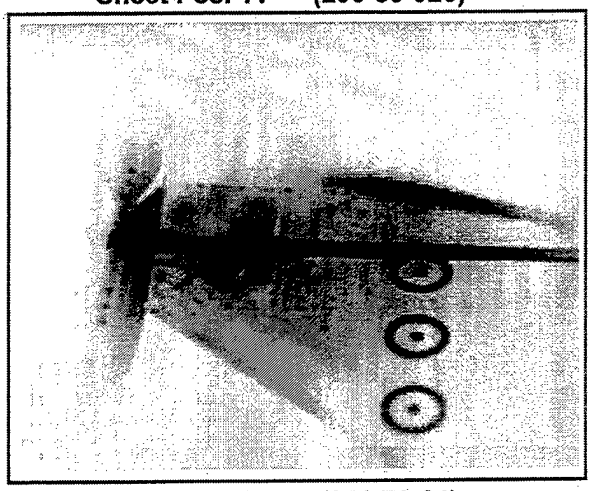

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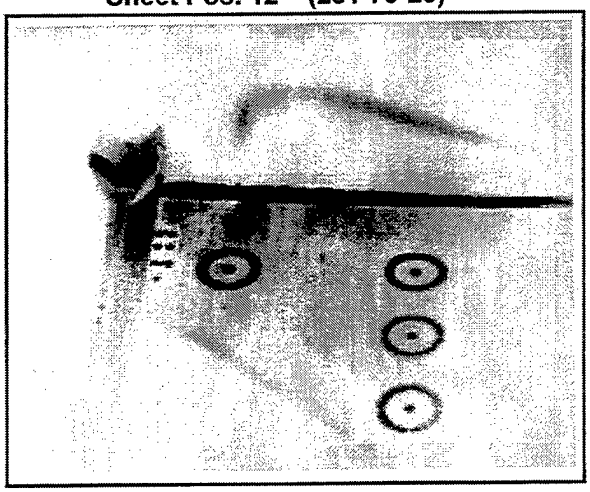
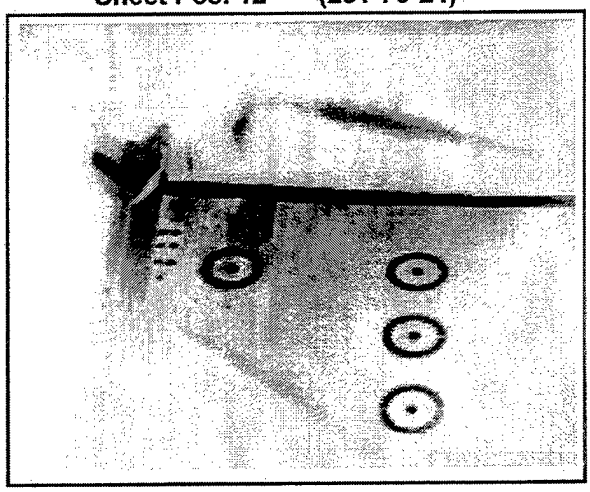


Sheet Pos. 13 (264-91-891)

Φ = 180 deg



Sheet Pos. 13 (264-91-895)

Φ = 270 deg

Figure 8.02 - (Concluded)

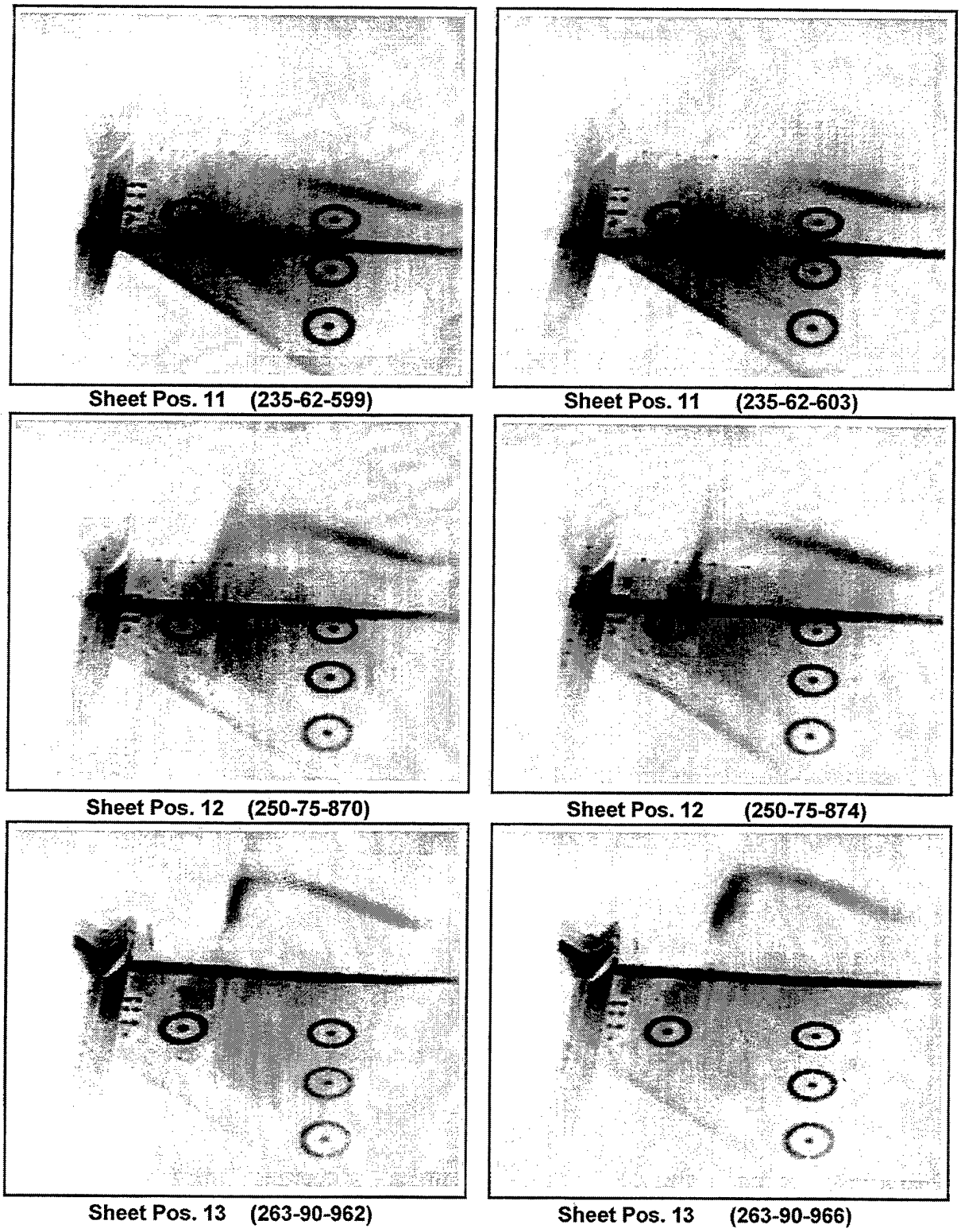
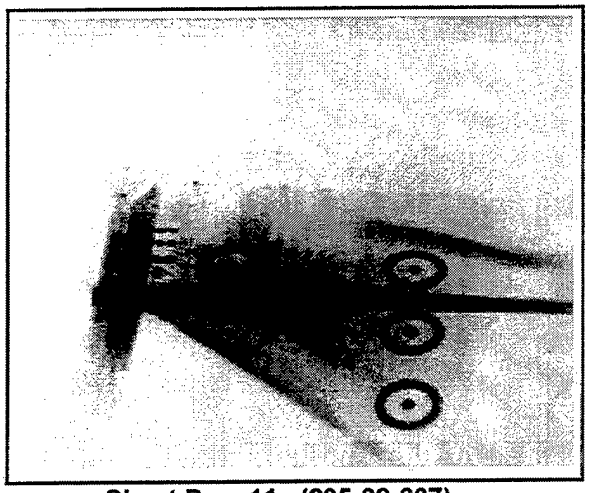


Figure 8.03 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.90, α = 10.0 deg, dα = 0.5 deg, f = 36Hz; Tip Launcher/Missile Configuration



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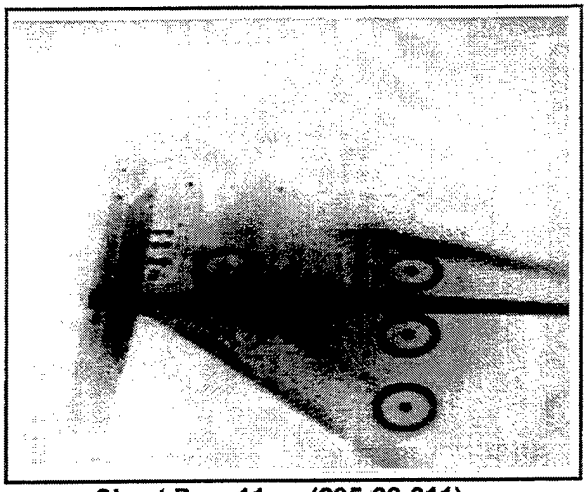

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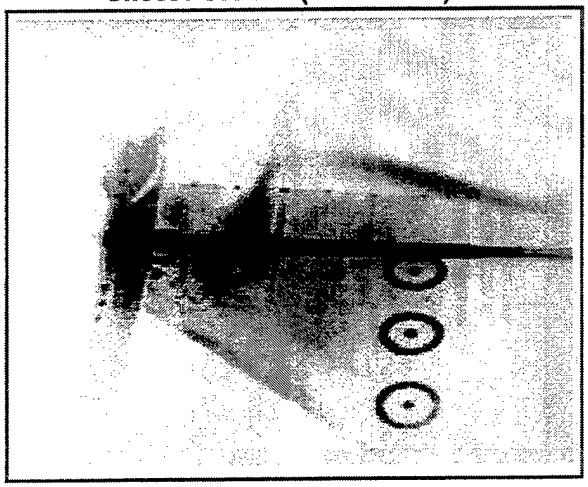

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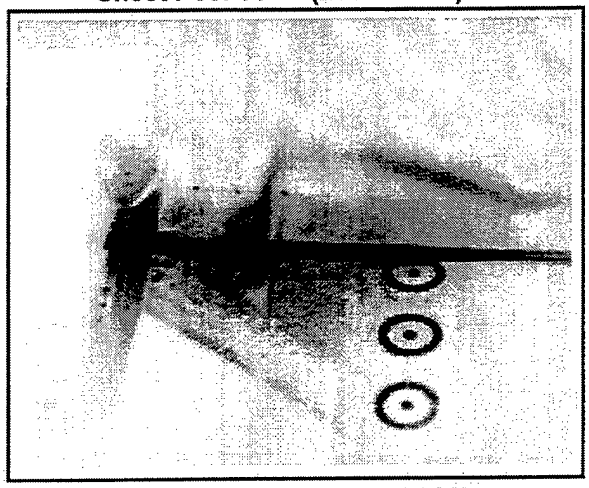

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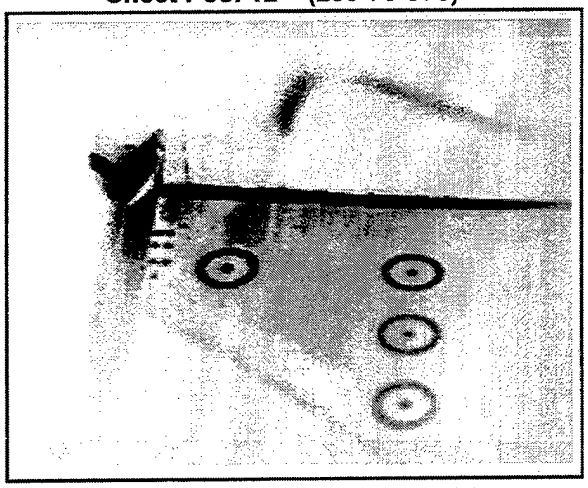
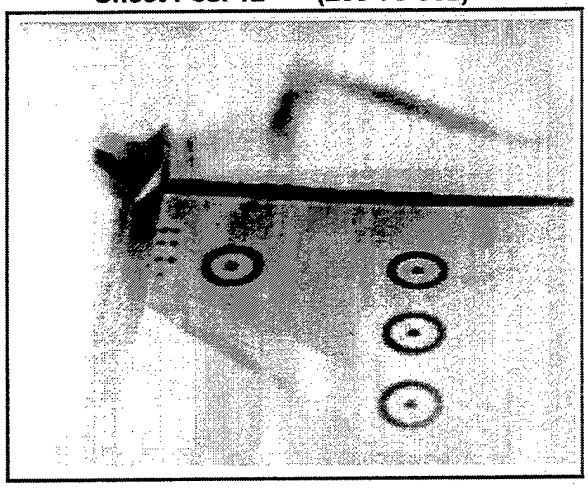


Sheet Pos. 13 (263-90-970)

Φ = 180 deg



Sheet Pos. 13 (263-90-974)

Φ = 270 deg

Figure 8.03 - (Concluded)

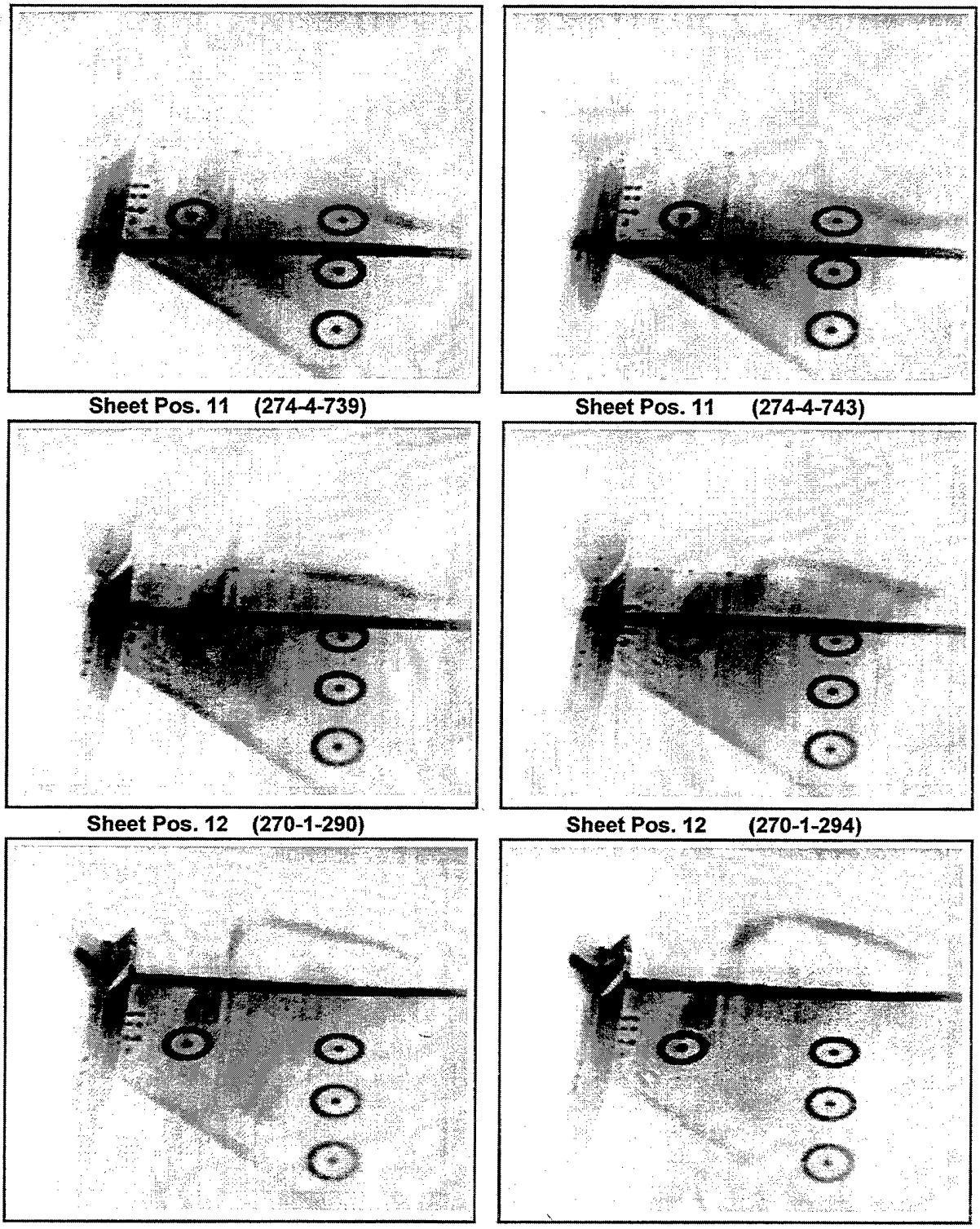
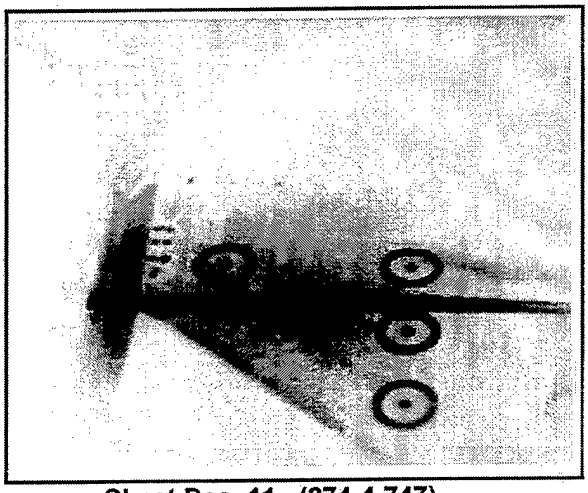


Figure 9.01 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.85, α = 9.0 deg, dα = 0.5 deg, f = 36Hz; Tip Launcher/Missile Configuration



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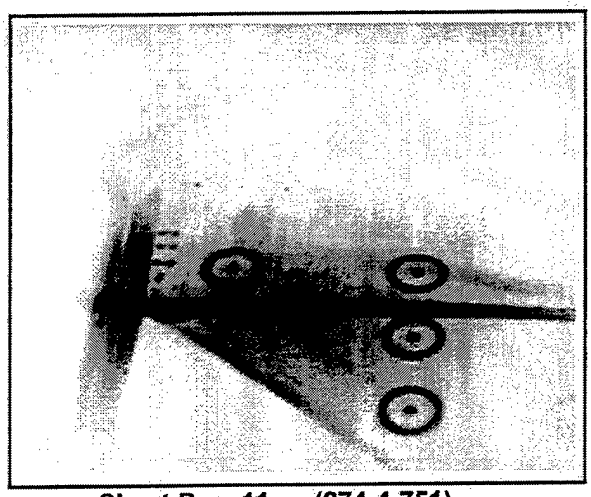

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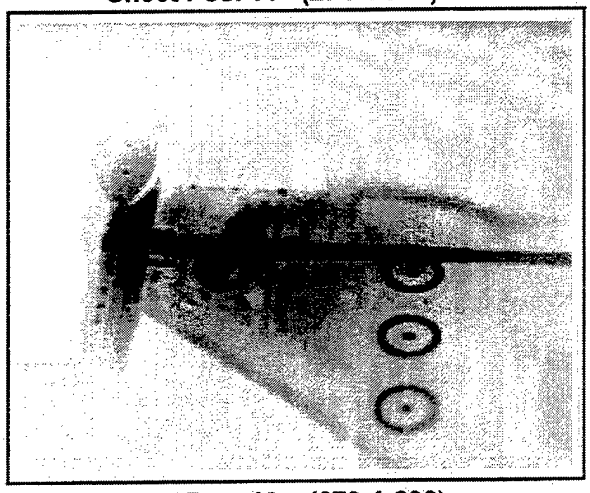
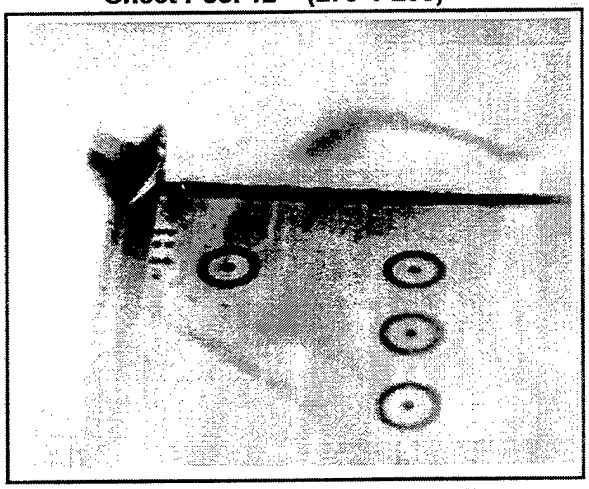


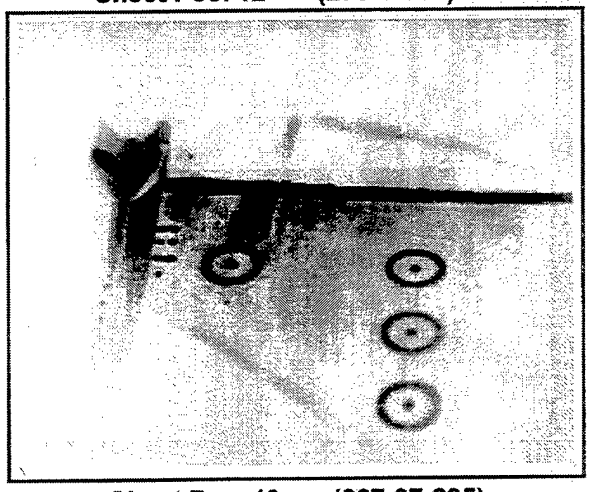
Sheet Pos. 12 (270-1-298)

Sheet Pos. 12 (270-1-302)



Sheet Pos. 13 (267-97-291)

Φ = 180 deg



Sheet Pos. 13 (267-97-295)

Φ = 270 deg

Figure 9.01 - (Concluded)

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5.0 HIGH SPEED VIDEO LCO FLOW VISUALIZATION FOR THE WING WITH TIP LAUNCHER AT M = 0.85, OSCILLATING AT ±0.5 DEG AND VARYING MEAN ANGLES

The presentation of unsteady LCO flow visualization data in this section for the wing with tip launcher is also identical to that in Sections 3.0 and 4.0. The sheet positions are also 11, 12, and 13, as shown in Figure 10. Results at M = 0.85 are presented in Figures 11.01 and 11.02. (The limitations imposed on this configuration were a result of severe limit cycle oscillations actually encountered on the model. This was not the case for the tip missile or clean wing configurations.)

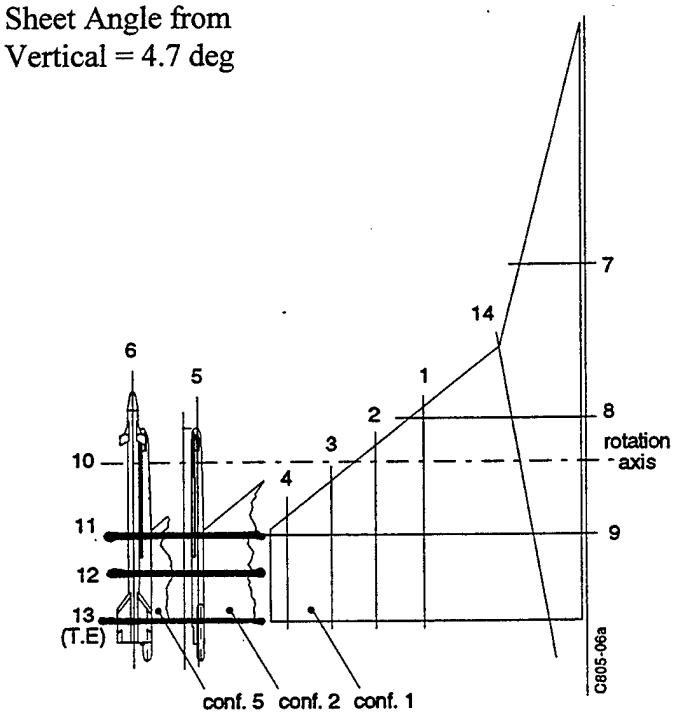


Figure 10 - Flow Visualization Locations for Figures 11, LCO Conditions, Wing With Tip Launcher, M = 0.85, Oscillating at ±0.5 deg

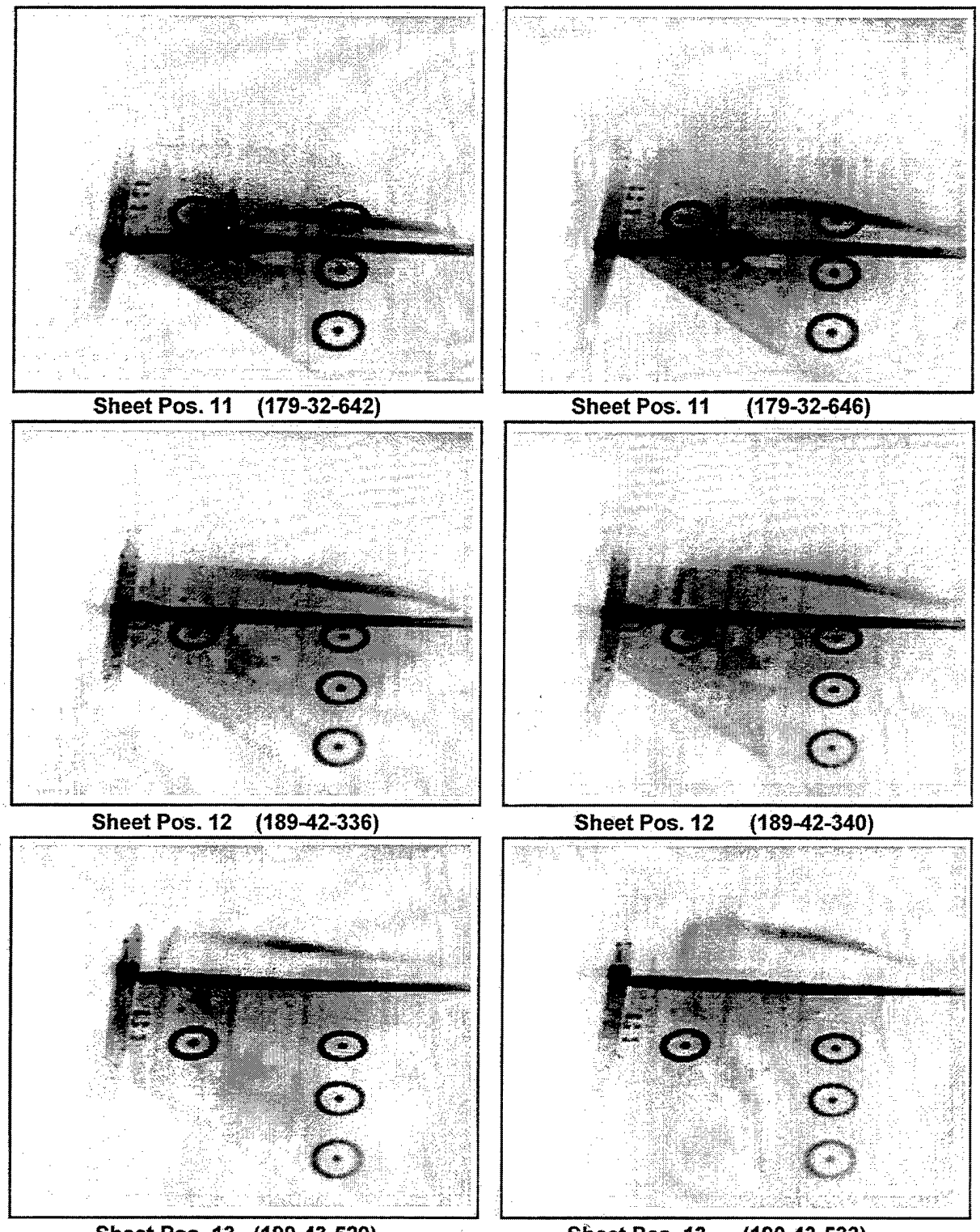
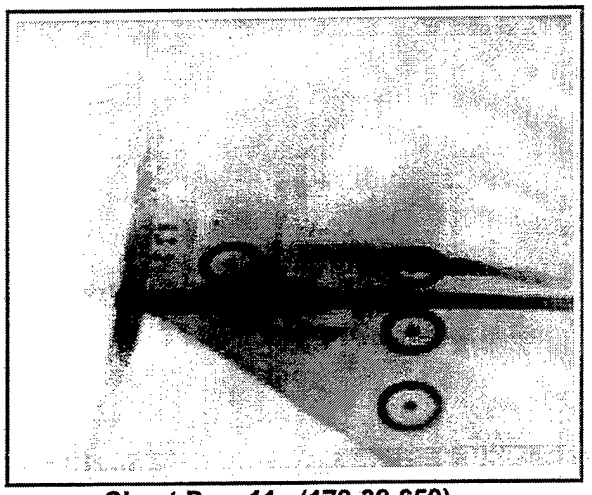


Figure 11.01 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.85, α = 7.5 deg, dα = 0.5 deg, f = 36Hz; Tip Launcher Configuration



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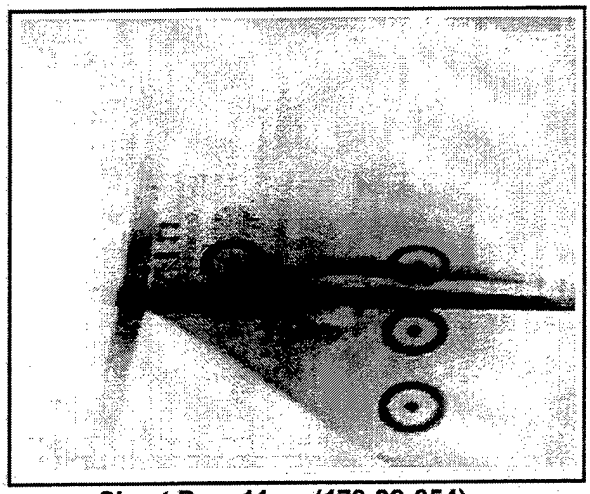
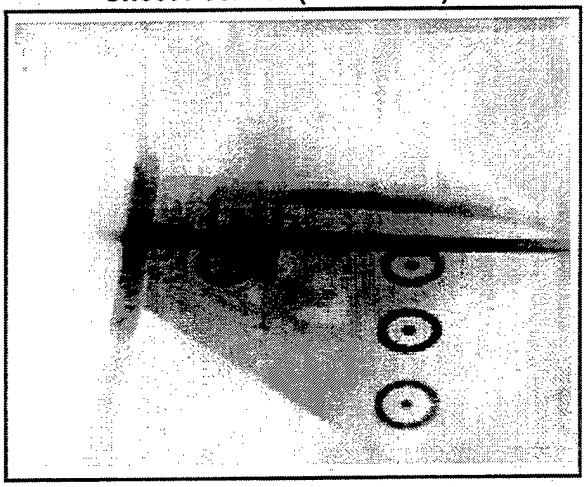
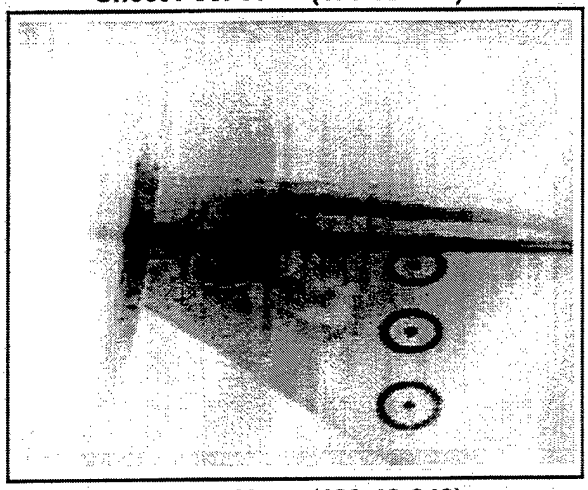


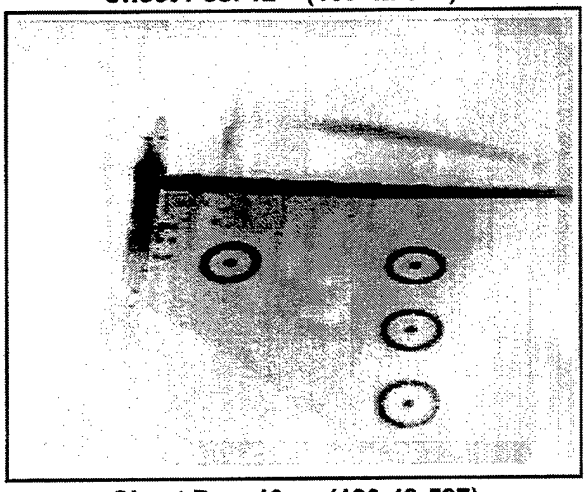
Sheet Pos. 11 (179-32-654)



Sheet Pos. 12 (189-42-344)

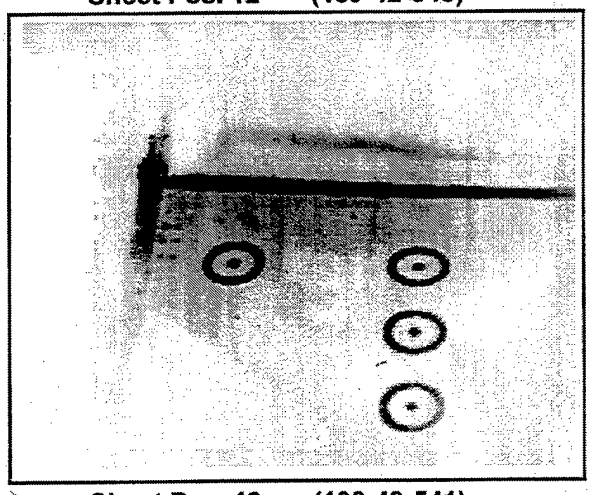


Sheet Pos. 12 (189-42-348)



Sheet Pos. 13 (190-43-537)

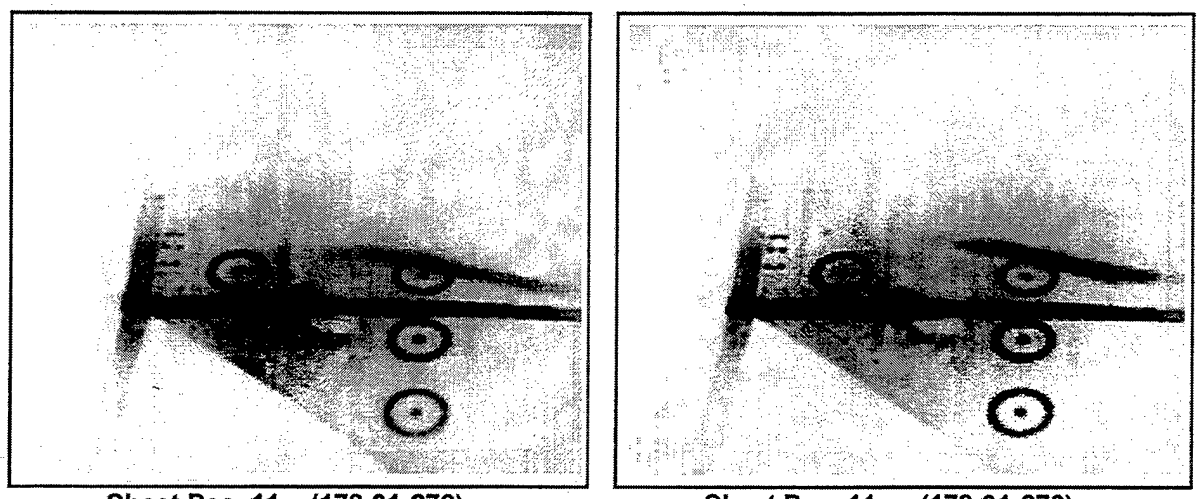
Φ = 180 deg



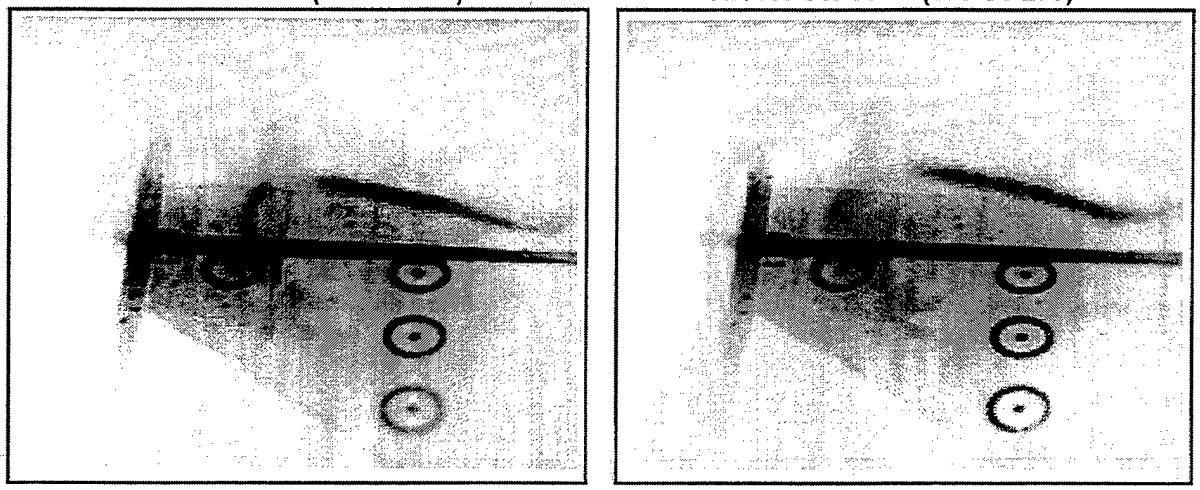
Sheet Pos. 13 (190-43-541)

Φ = 270 deg

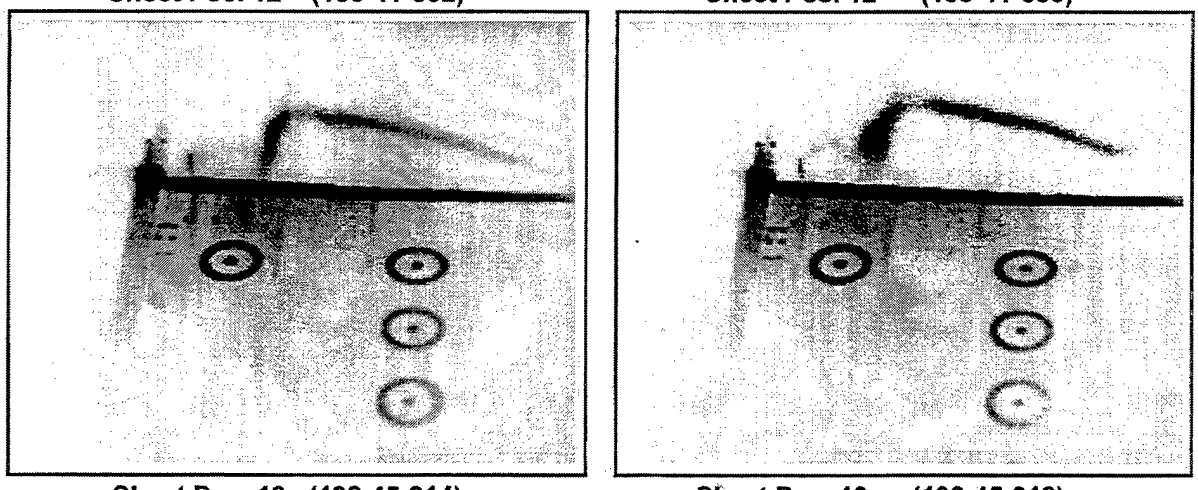
Figure 11.01 - (Concluded)



Sheet Pos. 11 (178-31-272) Sheet Pos. 11 (178-31-276)



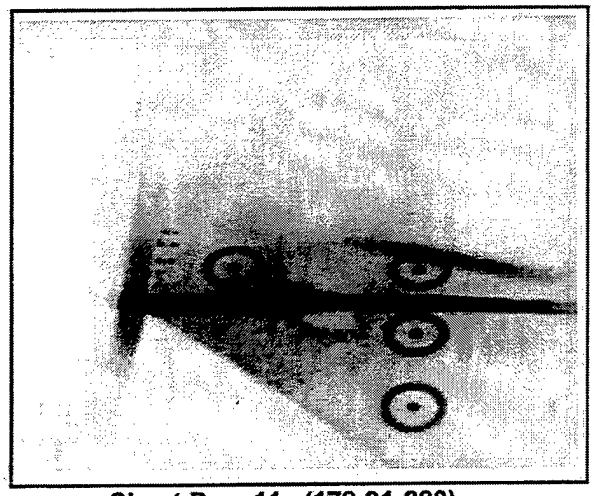
Sheet Pos. 12 (188-41-882) Sheet Pos. 12 (188-41-886)



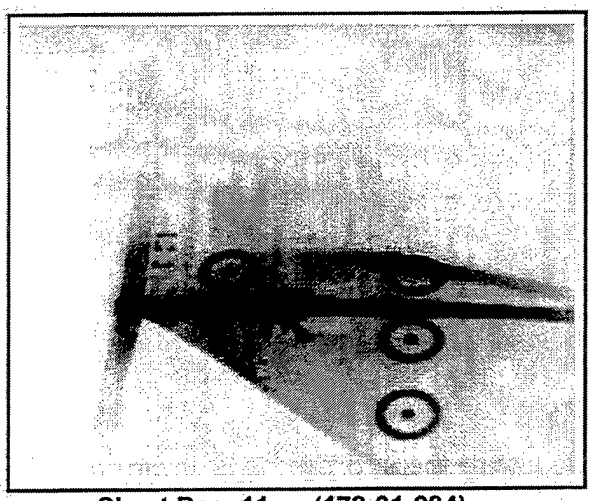
Sheet Pos. 13 (192-45-914) Sheet Pos. 13 (192-45-918)

Φ = 0 deg Φ = 90 deg

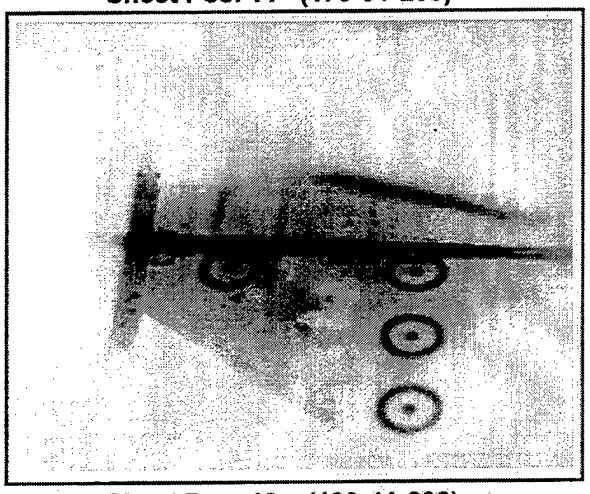
Figure 11.02 - High Speed Camera View of Spanwise Laser Light Sheet at M = 0.85, α = 8.5 deg, dα = 0.5 deg, f = 36Hz; Tip Launcher Configuration



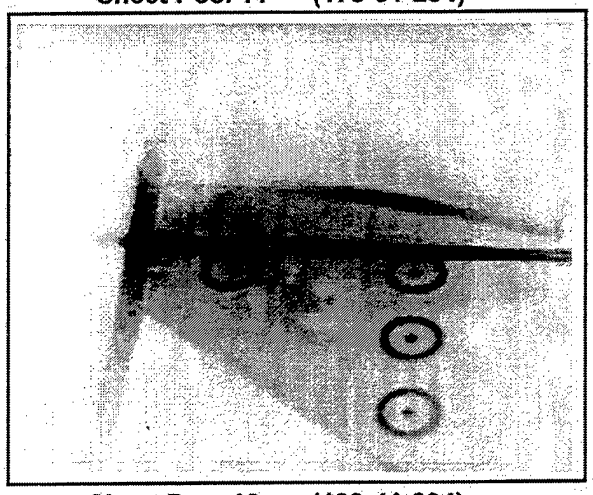
Sheet Pos. 11 (178-31-280)



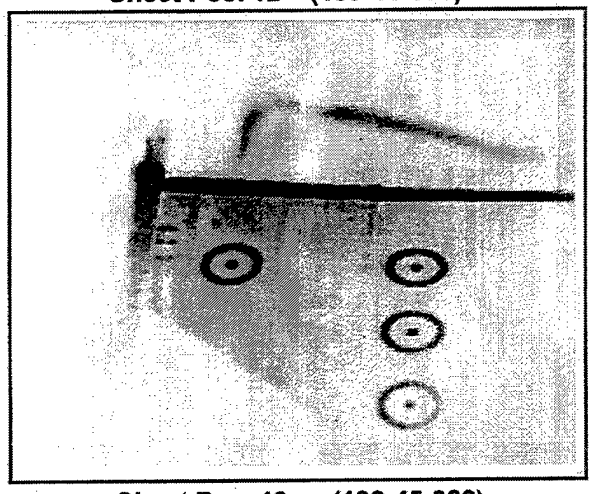
Sheet Pos. 11 (178-31-284)



Sheet Pos. 12 (189-41-890)

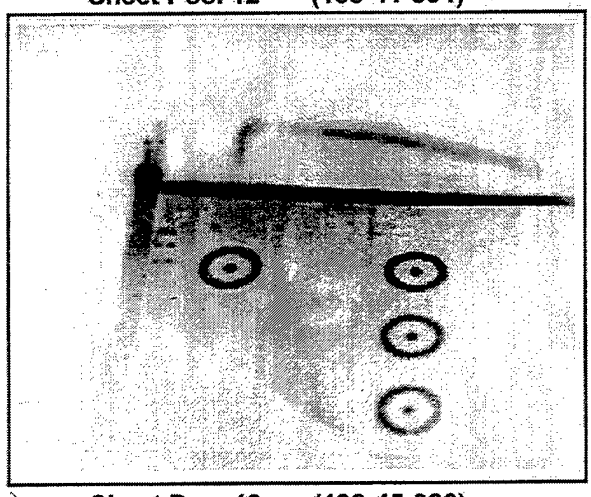


Sheet Pos. 12 (188-41-894)



Sheet Pos. 13 (192-45-922)

Φ = 180 deg



Sheet Pos. 13 (192-45-926)

Φ = 270 deg

Figure 11.02 - (Concluded)

6.0 REFERENCES

1. Cunningham, A. M., Jr. and den Boer, R. G.: Overview of Unsteady Transonic Wind Tunnel Test on a Semispan Straked Delta Wing Oscillating /n Pitch, WL-TR-94-3017 (Additional Wind Tunnel Reports WL - TR-94-3094, WL-TR-94-3095 and WL-TR-94-3096), August 1994

2. Cunningham, A. M., Jr.; Geurtz, E. G. M.; Dogger, C.S.G.; and Persoon, A.J.: Transonic Wind Tunnel Test on the Flow-Visualization of a Semi-Span Simple Straked Delta Wing Model, National Aerospace Laboratory (NLR) Contract Report, CR 97577L, Parts I and II, February 1998