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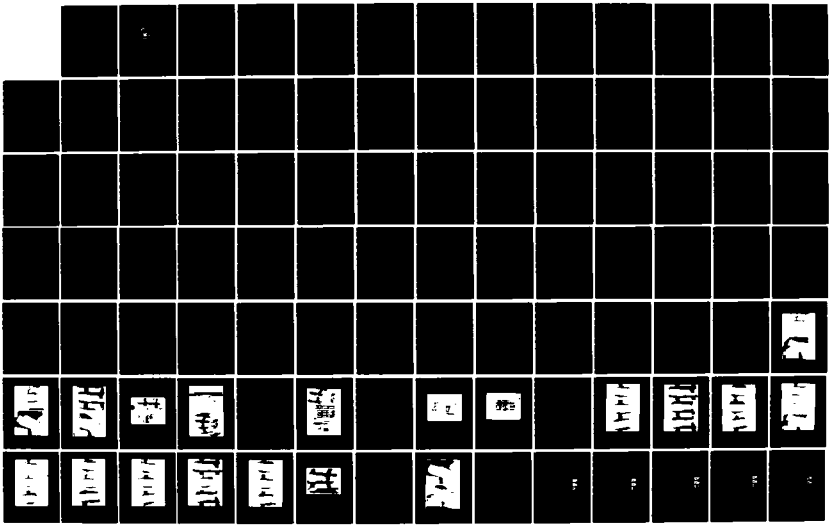

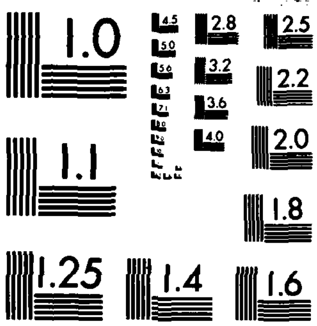

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

WIND TUNNEL DRAG EVALUATIONS OF
HELICOPTER NOSE SECTIONS

by

Robert S. Mair

March 1985

Thesis Advisor: Donald M. Layton

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Wind Tunnel Drag Evaluations of Helicopter Nose Sections

by

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Major, United States Army
B.S., United States Military Academy, 1973

Submitted in partial fulfillment of the requirement for the degree of

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March 1985

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I. INTRODUCTION

A. COORDINATION OF EFFORT

Successful and safe operation of a wind tunnel project requires at least two people in full-time involvement, either the investigator and an assistant/technician, or co-investigators. Inasmuch as this was an unfunded project, there was no full-time technician support available and, as a result, a coordinated effort was conducted with the thesis project of another Masters of Science in Aeronautical Engineering student, CPT Sargent. [Ref. 1]

Even though a deliberate effort was made to seperate the majority of the functions in the two projects, e.g., design of the balance - Sargent and the design of the test and calibration equipment - Mair, when two people work closely together, much of the output is the result of proposals and counter-proposals, and it is therefore quite difficult to define completely down to every little detail what each member of the team contributed.

The differences, however, in the scope and outcomes of the experiments dictate that the results of these efforts, no matter how great the coordination, be presented as two seperate theses.

B. BACKGROUND

1. History of the Project

Aerodynamic drag on an aircraft or a vehicle is a major concern to an aerodynamicist. Since the dawn of aviation, an aircraft designer had to be concerned with the efficiency of the design of an airframe. In simplistic terms, the power that is provided by the engine must be sufficient to overcome the power required to provide lift and/or thrust and overcome friction.

The vehicle moves through air and because air is a viscous medium it imparts a retarding force on the vehicle (not unlike friction) that acts against the lift and/or thrust forces. Common sense would lead one to agree that a design that reduces the drag on a vehicle would provide more available power to apply to the generation of lift and/or thrust forces. This would make the design more efficient. Drag is related to many different aspects: skin roughness, shape of the object, drag due to lift (induced drag), compressibility and shock effects to name a few. When dealing with subsonic, low speed drag on fuselage shapes, the compressibility and Mach effects can be ignored. The effects of different shapes on drag can be investigated if models are compared with different shapes as the only varying parameter. General size, skin friction, velocity and air properties are constants. Induced drag is that generation of lift and parasitic drag is that portion of the total drag that remains.

Dr. Sighard F. Hoerner [Ref. 2] conducted extensive studies of aerodynamic drag where many types of solid bodies were subjected to drag studies. He first published his works in 1951 and it is the most frequently referenced book to be found in a literary search on the subject of aerodynamic drag.

It may be physically impossible to duplicate the actual full size aircraft phenomenon in the laboratory. However, using the principle of similitude, scaled models can be tested and the results related to the actual aircraft shapes through the use of independent dimensionless products (Reynolds number, Mach number, Pressure coefficients) and dimensionless shape factors [Ref. 3]. The drag coefficient is a type of pressure coefficient. The measurement of drag can be accomplished in many different ways. Since drag is a force, it can be measured in pounds (lbf). One technique is to measure the amount of drag force through the use of strain gages attached to a model. The strain gages are calibrated and indexed to read pounds force enabling drag force analysis under varying conditions. The process is in common use in aircraft wind tunnel testing.

2. Motivation for the Project

This project was undertaken as an adjunct to a basic helicopter design course. It would serve as a viable wind tunnel experiment allowing a student to become familiar with one of the basic research tool of the aeronautical engineer and provide meaningful data to be used in the fuselage design phase of a helicopter conceptual design project report.

B. GOALS

1. Project's Desired Accomplishments

The purpose of this thesis project was the use of the results of a wind tunnel experiment to produce data that would allow a student to quantitatively determine drag parameters of three selected fuselage nose shapes. In conjunction with a collateral thesis on tail shapes [Ref. 1], nine general shapes were possible.

The wind tunnel experiments allow the student to see the interrelationships of fuselage shape (in this case nose shapes) with the lift and drag characteristics while keeping the general volumes approximately the same. The structural aspects of the fuselage are not covered in detail because it is too much material for a one-semester course. [Ref.4]

Generic shapes were chosen instead as a scout/sleek nose of the S-76 Sikorsky helicopter, the blunt/rounded nose of the H-53 Sikorsky helicopter and the angled/attack nose of the AH-64 Hughes attack helicopter to give a wide range of contrasting shapes.

2. Projected End-Use of Information

The drag data would be used in the fuselage design phase to determine the equivalent flat plate area for the chosen prototype configuration. This value would then be used throughout the remainder of the design.

3. Project Shaped by Projected End-Use

A one-semester or one-quarter helicopter design course has a limited amount of time to devote to the fuselage design phase of a basic helicopter design report. In the past, canned data or data from outside resources was used to determine the drag coefficients or equivalent flat plate areas. The scope of the experiments was restricted to lift and drag components, ignoring the pitching moment contributions because of the limited amount of material that could be covered in a one-semester course. The selection of only three nose sections was limited by the amount of construction shop time allocated to this thesis project. The three different nose configurations are representative of helicopters and sufficiently different to hopefully differentiate the results for comparison.

II. APPROACH TO THE PROBLEM

A. BASIC LINE OF APPROACH

The basic line of approach of this thesis was to determine by experimentation the drag parameters of selected helicopter models in a wind tunnel. Various model configurations were fixed to a sting support system attached to an internal strain gage balance mounted into the common center section of the fuselage of the models. The experiment was conducted at different angles of attack and at various airspeeds. The raw electronic information from the strain gages was converted to counts of axial and normal force on the balance. The axial and normal components are then reduced to drag and lift components (in pounds) with the aid of a Fortran computer program that also corrects the model configuration to account for strain gage interaction. The data acquisition presupposes the availability of the models, balance, support system, wind tunnel and electronic test equipment. The reduced data was plotted with the use of Disspla plotting routine on the Naval Postgraduate School's IBM 3033 mainframe computer.

B. DETAILED METHODS

Additional engineering drawings of the balance and the models can be found in reference 1.

1. Models

All the model pieces had to be designed, manufactured, and assembled at the Naval Postgraduate School for the project. The basic generic shapes for the nose sections were designated smooth or scout (Fig. 1), blunt (Fig. 2), and attack (Fig. 3) for reference. A common center section (Fig. 4) was designed to provide a housing for the balance and attaching points for the nose and tail sections.

2. Balance

The balance was designed by Sargent as an internal strain gage balance that would be fixed to the model through the center fuselage section and attached to a sting mount that would support the entire weight of the model inside the wind tunnel (Fig. 5). The balance was constructed from Sargent's design by both Sargent and Mair at the Naval Postgraduate School. The balance consists of twelve strain gages in four bridges (Fig. 6) to measure three axes. The pitch axis was ignored [Ref. 5]. The sleeve housing for the balance was an elaborate design to accept a NASA Mark 34, 3/4 inch balance that was planned to be used in the experiment but rejected when the financial liability could not be accepted by the Naval Postgraduate School. The sleeve secures the balance to the center section at the center of gravity of the model.

3. Support System

The support system was constructed to provide structural support to the model and provide a means to change the angle of attack of the model while the wind tunnel was in operation (Fig 7.).

4. Wind Tunnel

The wind tunnel was the only piece of equipment that was available prior to the start of the project. However, it had seen very little recent use since its construction. It has a three and one half foot by five foot test section (Fig. 7). Built entirely of wood in 1957. It is powered by electric motors connected to sets of blades. One set of blades was removed for repair leaving only one set of blades driven by one motor for the project. The models were large in comparison to the tunnel test section. No wall effects were taken into consideration in the calculation and reduction of data.

5. Test Equipment

The test equipment (Fig. 8) consisted of an electronic amplifier box with four channels to provide signal amplification of the three strain gage channels and a channel for the angle of attack measuring device. The angle of attack was measured by an accelerometer (Fig. 5) attached to the inside of the center common fuselage where the sting attached to the balance. A signal conditioner was connected to the amplified strain gage output to account for the vibration in the tunnel transmitted to the model. Finally, the conditioned and raw unconditioned strain gage amplified output signal was observed on the voltmeters. The pictures that appear in Appendix D were taken by a 35mm camera with black and white 400 ASA film pushed to 1200 ASA (Fig. 9). The models are painted black and the tufts of string are white.

C. LIMITATIONS ON APPROACH

The major limitation on the approach was the finite amount of time to complete the thesis experimentation project and the possible use of the data (and collection of data) by a basic helicopter design student with a very limited block of time to devote to data collection and reduction.

1. <u>Models</u>

a. Inhibited

The limitations due to the amount of shop time available and the capabilities of the wood shop may have inhibited the method of approach. Refinement of the model design was limited to one prototype for three sections.

b. Assisted

The limitation of only three nose sections limited the scope of the experiment to a manageable level. This allowed the timely collection of data to complete the project in the alloted time.

2. Balance

a. Inhibited

The method of approach was limited when the NASA balance was disapproved. This required the design and construction of a balance that set the experimental time table back 90 days. The capability of the machine shop and the limited amount of shop time allotted to the project limited the refinements to the balance design and manufacture.

b. Assisted

The limited machine and design capability forced a three component balance construction as opposed to the six component NASA balance. Only two of the channels (components) were ever needed (lift and drag). Therefore the complexity of the component resolution was greatly simplified. However, calibration and strain gage interaction were unknown.

3. Support System

a. Inhibited

The support that was constructed was attached directly to the tunnel test section. This inhibited the approach by transmitting the tunnel vibrations to the balance.

b. Assisted

The support system allowed the angle of attack (AOA) to be varied while the wind tunnel was in operation without changing the vertical or horizontal position of the model's center of gravity.

4. Wind Tunnel

a. Inhibited

The wind tunnel was limited to a maximum dynamic pressure of 70 psf. This limited the method of approach to low speed testing with no capability to scale the speed to the required Reynolds number for full size fuselage comparisons of drag parameters [Ref. 6: p. 265]. The tunnel also had 25% turbulence due to design and construction errors that were never corrected. Swirl in the tunnel was found to be considerable (Fig. 10). The effect of the turbulence and swirl were not explored due to the limited amount of time available to complete the thesis. Wall effects were not considered.

b. Assisted

The wind tunnel was the major tool of the experiment and allowed the variation of wind speed or relative wind. The construction or correction of the tunnels deficiencies were beyond the scope of the thesis and could not have been accomplished in the allotted amount of time to complete the experiments.

5. Test Equipment

The intermediate calibration procedure (Appendix A) was required because of the limitation on the use of a balance design over the NASA balance and greatly inhibited the method of approach. It was extremely time consuming to re-zero the instrumentation that was necessary due to the drift in the amplified signal or to the thermal induced expansion of the balance. The bridge design had temperature compensation but variations in data were experienced with temperature changes of four to five degrees F.

III. THE SOLUTION

A. ACTUAL SOLUTION METHODS

The models, balance and support system were constructed and assembled into nine possible configurations by varying the nose/tail combinations. The combinations were designated:

No. 1	Attack/high	Fig. 11
No. 2	Attack/middle	Fig. 12
No. 3	Attack/low	Fig. 13
No. 4	Blunt/high	Fig. 14
No. 5	Blunt/middle	Fig. 15
No. 6	Blunt/low	Fig. 16
No. 7	Smooth/high	Fig. 17
No. 8	Smooth/middle	Fig. 18
No. 9	Smooth/low	Fig. 19

A single data run consisted of one model configuration assembled and attached to the support system. The center section was initially calibrated prior to any data runs to determine the extent of the strain gage balance interaction. The model combination was calibrated again using the intermediate calibration procedure in Appendix A. The testing started at eight degrees positive angle of attack at the lowest speed (Q = 10 psf). Data was recorded manually every two degrees angle of attack as the angle was decreased to minus ten degrees. Then the speed was increased (Q = 30,50,70) and data was taken again until Q = 70 psf was recorded as the last data run for a combination. The original data appears in Appendix C listed as nose/tail = No. and remarks state the combination type. All nine data set were tabulated, and then reduced to computer data files (Data File 1 thru Data File 9 are Table 1 thru Table 9).

A Fortran computer program (Appendix B) was written to reduce the raw data (counts of axial and normal force) to lift and drag coefficients (Appendix C, Table 12 - 20). A Disspla computer graphics program was added to the Fortran program to plot the reduced data (Appendix D, Fig. 24 - 35).

A qualitative method using tufted models (white string taped to the model) was attempted to provide some additional information about the flow field around the model configurations [Ref. 7: p. 73]. Black and white pictures were taken of all the model configurations at Q = 30 and Q = 70 psf at positive eight, zero, and negative ten degrees angle of attack (Appendix D, Fig. 24 - 35).

B. DETAILED TECHNIQUES

1. Initial Strain Gage Interaction Calibration

The intent of the initial strain gage calibration was to determine the extent of the interaction between the axial and normal strain gage bridges on the balance and to develop a method to account for the interaction so that the reduced data would take the interaction into account [Ref. 7: p. 313]. A calibration rig was developed by the author consisting of aluminum sheet metal pans suspended by cables from the center of gravity of the center section for the normal component and a similar pan turned by a pulley at the rear of the sting support to load the axial component (Fig. 20). When the center section was at zero degrees angle of attack, the axial channel amplifier and the normal channel amplifier were zeroed. A twenty pound of weight was placed on the normal calibration rig pans and the span was set to 200 counts on the normal channel amplifier. The twenty pound weight was removed from the normal calibration rig and added to the axial calibration rig pans. The span of the axial channel amplifier was set to 200 counts. The weight was removed from the rig and all channels re-zeroed. The spans were checked again if the zero had changed. The procedure was repeated until there was no drift in either zero or span. Then a one pound of weight was added to the normal channel. The corresponding counts of normal force and axial force were recorded. One additional pound of normal weight was added and the corresponding counts were recorded. This procedure was repeated until twenty pounds of known normal weight data were recorded. Then the procedure was repeated with one pound of known normal weight and one pound of axial weight. The normal weight was again increased pound by pound to twenty pounds weight with the corresponding counts of axial and normal channels recorded for each pound of weight added to the normal channel. The procedure was then repeated with two pounds of known axial weight varying the normal weight from zero to twenty pounds. This procedure was followed until the known axial weight reached twenty pounds.

The recorded data generated a 21 by 21 matrix, with normal force of zero to twenty pounds and axial force varied from zero to twenty pounds. The 21 x 21 matrix is only the third and fourth quadrants of the required solution matrix if negative axial and positive normal forces are encountered. The 21 x 21 matrix was mirrored to the first and second quadrants to account for positive axial forces. This assumes that the strain gages respond to tension in the same manner as they respond to compression only with a negative sign. Table 10 is the 41 x 41 solution matrix for the normal readout when loaded. The number of axial pounds of force indicates the proper column to search. One can find the closest reading or interpolate to find the proper corresponding corrected normal force in pounds at the extreme left of the table with an input of normal counts. Since the normal component was much more consistent than the axial component, the raw normal component was used to determine the corrected axial component (Table 11), and the corrected normal component was determined from the corrected axial component. However, the corrected normal component was found to round nicely to the raw normal component upon comparison. This observation verified that the normal component was not as sensitive to strain gage interaction as the axial component and should be the independent variable to determine the calibrated axial component.

The corrected search procedure to determine the corrected normal and axial counts can be outlined in six steps:

Step 1. Assume raw normal count is accurate. Round to the nearest one pound of normal force where ten counts equals one pound. Example.... 106 counts → 10.6 pounds → 11 pounds.

Step 2. Locate the column relating to the normal count using the Axial Calibration Table (Table 11). Example... 11 pounds → column 12. Note that column 1 → zero pounds.

Step 3. Remaining within the located column, search this column from top to bottom until the raw axial count is bracketed with higher value above and lower value below.

Step 4. Interpolate to position raw axial count between these values.

Step 5. Now move to extreme left column remaining between the same two rows from step 3. Interpolate between column one (extreme left column) values to obtain "corrected" axial count.

Step 6. The axial count is now corrected for strain gage interaction. Using the axial corrected count, go to the Normal Calibration Table (Table 10) and round axial count to nearest one pound equivalent of axial force. Then repeat procedure from Step 1. thru Step 5. but use the normal table.

2. Resolution of Forces

The forces diagram is shown in Figure 21. The purpose of this diagram is to show the relationship of the axial and normal forces to the resolved lift and drag forces. Axial force is considered positive in the direction of nose to tail of the model (+ →). Normal force is considered positive when 90° from and normal to the axial component (+ ↑). The drag component is in the same direction as the relative wind [Ref. 8: p. 147]. The lift component is normal to the drag component and positive up. The weight of the model opposes the lift of the model. Essentially, the axial and normal forces must be converted the lift and drag forces taking into account the angle of attack and the weight of the model.

3. Computer Program

The Fortran computer program is given in Appendix B. The program computes the corrected axial and normal forces, converts to drag and lift forces, calculates the coefficients of lift and drag, Reynolds number, and the weights of model configuration. The Disspla portion of the program plots the coefficeint of drag versus the angle of attack, coefficient of drag versus coefficient of lift, and the coefficient of lift squared versus coefficient of drag for the different model configurations. Subroutines reader and writer are used to read the original data files (Data Files 1 thru Data Files 9) while subroutines "rdr" and "wrdr" are used to read and write the calibrated normal and axial tables. The generated numerical computer output of the program is in Appendix C, Table 12 thru Table 21. The graphical output is in Appendix D, Fig. 24 thru Fig. 35.

4. <u>Test Equipment</u>

The test equipment is shown in Fig. 8. The wire bundle from the balance was connected to the amplifier which provided the zero and span capability on each of four channels. Channel 1 was for pitching moment which was not used. Channel 2 was the the normal counts and channel 3 was the axial count. Channel 4 was the angle of attack. Two digital voltmeters were connected to the amplifier thru a switching box, that allowed selection of raw channel output or conditioned output from a signal conditioner (not shown) and the addition of an oscilloscope to investigate vibration frequency.

5. <u>Qualitative Method</u>

Black and white 35mm photographs were taken with a 35mm reflex camera at F5.6 and 1/30 shutter speed using a 62mm macro zoom lens (1:3.5-4.5, f=28-80mm). The models were painted black for contrast against the white string. The models were tufted with white string taped to the model surface. The intent of the tufting is to show the turbulent sections or sections of separated flow along the model surface to gain some insight on the developing and changing flow around the model. The photographs were developed by the Naval Postgraduate School Photo Lab. Half tones of the photographs appear in Appendix D. The pictures were taken at various angles of attack and at different airspeeds (Q). In Figure 11 are the pictures of the attack/high configuration at positive eight degrees angle of attack, zero degrees angle of attack, and minus ten degrees angle of attack. Figure 22 shows the attack nose at different camera angles to view the tufting at different aspect angles. The tufting directly behind the nose protusions is turbulent depicting detached flow. Figure 14 thru Figure 19 did not reveal and such detached flow around the noses. The detail on the half tones is not sufficient to see any real difference in the tufts at Q = 30 and Q = 70. Therefore the best of the photographs at Q = 30 and 70 was selected for Appendix D.

IV. RESULTS

A. ULTIMATE OUTCOME OF PROJECT

The ultimate outcome of the project can be divided into three categories. These are the construction and setup of the equipment, the quantitative results, and the qualitative results.

1. Construction and Setup of Equipment

The construction of the models, support system and the balance took in excess of 400 manhours to complete with constant modifications to integrate the different pieces into a workable system. The models turned out well with additional provisions for the application of landing gear and wings on the center fuselage section and tail cone sections on the different tail sections.

An oscillation was observed to occur when the wind tunnel was in operation. The model visibly moved up and down and occasionally sideways. The digital output also fluctuated with the model oscillations. An oscilloscope was added to the output and the frequency determined to be in the range of 5 hz. The model was excited by hand without the tunnel running and the frequency was verified to by 5 hz. A signal conditioner was then added to the circuit with a low pass filter set to .5 hz to eliminate the output fluctuation [Ref. 9]. Any signal over .5 hz was eliminated. See Fig. 23 for a diagram of the principle of a low pass filter.

The various other pieces of testing equipment were gathered together from within the Aeronautical Engineering Department at the Naval Postgraduate School. Numerous trial and error sessions were performed until the equipment was integrated and producing reasonable data. The data collection was accomplished by manually reading the channel output on the digital voltmeters and logging the results on paper. The data was later input to the Fortran computer program thru the use of data files.

The type of strain gage used on the balance was EA-06-060LZ-120 made by Micro-Measurements, Measurements Group, Raleigh, North Carolina. These are student gages with 120.0 ± 0.3% resistance in ohms and a gage factor at 75°F of 2.04 ± 0.5%. The gages were attached to the stainless steel balance with M-bond 200 adhesive that drying time of 5 min also form Micro-Measurements.

2. Quantitative Results

The quantitative results are Tables 12 thru 20 shown in Appendix C. Appendix D, Fig. 24 - 35 are the graphical result of the tables in Appendix C. The graphs show coefficient of drag versus angle of attack, then coefficient of drag versus coefficient of lift, and coefficient of drag versus coefficient of lift squared for angles of attack of

+8° to -10° at Q of 70 psf and 30 psf. The Q of 10 psf was deleted due to insensitivity of the balance at the low speed (Q=10 psf). Graphs of Q = 50 psf were not included because there were no noticeable differences in the trends from the Q = 70 psf. The graphs allow a student to determine the proper coefficient of drag with a given angle of attack provided one knows the type of nose section desired for a Q (speed) of 30 psf (Fig. 24) or 70 psf (Fig. 25). With the coefficient of drag selected the student can then select the coefficient of lift (Fig. 26 & Fig. 27). The coefficient of lift can also be used to determine the coefficient of lift squared (Fig. 28 & Fig. 29). Additional figures (Fig. 30 thru Fig. 35) are provided from Sargent [Ref. 1] to provide insight with the nose section held constant and the tail sections varied. The coefficient of drag, coefficient of lift, and coefficient of lift squared are used by the student as parameters in the basic design of the helicopter configuration similar to the selected nose configuration selected. If the student does not know the tail configuration, then the values selected should be between the lines shown of Figure 24.

3. Qualitative Results

The pictures of the tufted models are located in Appendix D. The attack nose (Fig. 22) showed a significant amount of detached flow at the top front of the nose behind the protrusion. This would indicate turbulent flow in this region. The blunt nose (Fig. 14 - 17) and the smooth nose (Fig. 17 - 19) did not depict any region of detached flow around the nose. This would lead one to believe that the attack nose would have the largest coefficient of drag when compared to the other nose configurations. This was not always the case as depicted by Figure 24 and Figure 25. There was not any visible difference between the pictures taken at Q = 30 and Q = 70.

B. FINISHED PROJECT DIFFERENCES

1. Balance

The original project was to use a six component balance provided by NASA Ames. The Naval Postgraduate School could not assume the liability for this equipment, therefore a three component balance was designed and constructed at the Naval Postgraduate School. The calibration of the balance and the proper interface of all the associated test equipment required much more time than would have been required with the Nasa balance with its well documented calibration data.

2. Quantitative Results

The original data was planned to be collected with a strain gage scanner attached to the raw output of the strain gage balance. The vibration and resulting induced model oscillations produced fluctuations in the data requiring a signal conditioner that negated the use of a strain gage scanner. The scanner would have provided near real time data reduction of the strain gage output to force components.

3. <u>Qualitative Results</u>

The tufting was to be done with mini-tufts of monofilament nylon fiber. The tufts are visible with fluorescene photography. All the required equipment was available except a 2000 joules per flash lamp. White string tufting was substituted to allow completion of the project.

C. VALIDITY OF OUTCOME

The tufting or qualitative technique did nothing to support the quantitative results. The white string tufts may be too stiff to react to small changes in the flow field around the models. The black and white photos did not produce the desired resolution to permit detailed analysis of the tufts.

Consideration of the fuselage shapes as airfoils shows a trend that the fuselages resemble cambered airfoils. The drag polars are similar but the magnitude of coefficient of drag appears to be an order of magnitude larger for the fuselage shape. One would expect a bucket shape of the fuselage drag polar. The left side of the plots for the fuselage shapes in Appendix D (Fig. 24 - 27) are not as negative in slope as might be expected. This may be due to the similarity of the fuselages to a cambered airfoil that produces some lift at negative angles of attack. However, for the coefficient of drag versus the angle of attack the bucket is clearly not apparent. One reason may be due to the weight component of the model at negative angles of attack. The weight of the models was accounted for in the equations for the resolution of forces but may not fully account for the tensile force experienced by the strain gages and the associated interaction. Compressive force was adequately tested and calibrated. The tensile force was assumed to react in a like manner. This may have been a bad assumption. Since the wind tunnel runs at a low Q or airspeed, it is not useful to try to compare the output to an actual helicopter.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The three nose sections were constructed and mated to the center section. The center section was completed with provisions for the attachment of all three noses. Additional mounting provisions were made to allow the installation of wings and landing gear at a later time. The strain gage balance was assembled and fitted to the center section. The support system was built and assembled in the wind tunnel. An electric motor was incorporated in the support system to allow variation in the angle of attack while the tunnel was in operation. A calibration and test rig was designed and constructed to load the model/balance combinations. The calibration procedure was established and conducted on the center section and model configurations. All the electronic testing and data collection equipment was gathered together, integrated, and debugged in the attempt to acquire meaningful data. The data was collected for nine model combinations at various angles of attack and airspeeds (Q). A Fortran computer program was developed to reduce the data to aerodynamic coefficients. A Disspla plotting computer routine was added to the Fortran program to plot the resulting aerodynamic coefficients. The Disspla program plotted coefficient of drag versus angle of attack, coefficient of lift, and coefficient of lift squared. The models were tufted with white string in an attempt to validate the quantitative results with qualitative photographs of the flow field around the models.

B. SHORTCOMINGS AND STRONG POINTS

1. Shortcomings

The vibration encountered from the tunnel caused fluctuations in the data requiring a signal conditioner with a low pass filter. This technique may have introduced errors to the output data.

The calibration took a great deal of time to complete and may be of dubious value. The interaction of the strain gages had such a dramatic effect that the output may be undecipherable. A student would have a limited amount of time to spend on the calibration.

The wind tunnel vibration, turbulence, and swirl was not completely understood or documented.

The wetted area of the model combinations was taken as the frontal cross sectional area. This allowed the same general area to be used for every model. The wetted area may have been an order of magnitude too small. This would account for the larger drag coefficient values.

The validity of the output curves is questionable. The coefficient of drag versus the angle of attack curve should show a bucket, instead of an increasing slope.

2. Strong Points

The use of the wind tunnel and the strain gage balance as a tool for the aeronautical engineer along with an appreciation for the problems associated with their usage are the positive learning experiences for the student.

Once the equipment is in place, setup, calibrated, and working properly the student can collect and analyze data in a relatively short period of time.

The student can see the relationship between shape and drag in graphic form and later select the appropriate aerodynamic coefficients for his nose configuration.

C. RECOMMENDATIONS

1. Strain Gage Balance

The strain gage balance should be re-designed to eliminate or reduce as much as possible the interaction between the strain gage bridges. This would simplify the calibration procedure and reduce the amount of time devoted to calibration. A single axis gage might be used effectively if drag is the only aerodynamic coefficient to be investigated. Different strain gages should be used on the balance. The EA-06-060LZ-120 gages were the best available off the shelf at the Naval Postgraduate School at the time. Gages made to be used with stainless steel and bonded with epoxy would be better suited to the model environment.

2. Support System

The support system should be isolated from the tunnel to eliminate the tunnel vibration from attenuating thru the model causing the fluctuations in the data.

3. Data Collection System

A digital data collection system could be attached to the strain gage output. All the data collection and data reduction would be accomplished in a fraction of the time required to manually record the data and manually transfer the data to a computer for data reduction. An IBM-PC-AT would be sufficient. The data could be displayed in graphical form near real time at the tunnel.

4. Additional Projects

The models were constructed with provisions for attaching tail cones, vertical stabilizers, wing, and landing gear. Additional projects could be accomplished to add these parameters to a design and calculate the resulting aerodynamic coefficients.

5. Center of Gravity

Additional studies should be conducted to determine the extent of the effect of changing the center of gravity of the model on the output of the strain gages.

6. Wind Tunnel

A comprehensive wind tunnel survey must be accomplished to completely understand the tunnel deficiencies.

7. Mini-Tufting

Mini-tufting should be used to provide flow field visualization around the models. The string tufting is not sensitive enough and the quality of the photographs is not sufficient to make any meaningful conclusions. [Ref. 10]

8. Validation

The strain gage output should be validated with some corresponding testing, possibly with pitot static testing to determine if the results are accurate.

APPENDIX A : INTERMEDIATE CALIBRATION AND EQUIPMENT SETUP

Step No.

1. Turn on all electrical equipment for approximately 10 min.

2. Zero angle of attack reading (AOA).

3. Record model configuration.

4. Install calibration rigging.

5. Zero normal axial component reading on channel #2 amplifier.

6. Zero raw axial component reading on channel #3 amplifier.

7. Zero normal & axial signal conditioner LP adjustment.

8. Place 10 lbs. weight under model on rigging to set Raw normal channel to span of -.0100 counts on voltmeter #1.
   RN: -10# = -.0100

9. Check & record conditioned normal signal.
   CN: .0100 approximately.

10. Place 10 lbs. weight on axial rigging to set raw axial channel to span of +.0100 on voltmeter #2.
    RN: +10# = +.0100

11. Record as counts: conditioned normal (CN).
    example: -.0100 is -100 counts.
    conditioned axial (CA).
    example: +.0100 is 100 counts.

12. Remove calibration rigging from model.

13. Re-zero angle of attack (AOA).

14. Re-zero raw normal & raw axial channels (should check conditioned normal & conditioned axial to ensure close to raw readings).

15. Use DATA RECORD provided and note nose/tail combination number in the first line.

16. Set junction box switches to conditioned normal (CN) and conditioned axial (CA). Both should read ".0000".

17. Ensure all tools and loose equipment is removed from the tunnel and doors are secure.

18. Start tunnel with model at eight degrees AOA.

19. Set Q (speed) of the tunnel. (10,30,50,70)

20. Vary AOA and record counts axial & normal (conditioned).

21. Return model to zero AOA and turn off tunnel motors.

22. Re-zero normal & raw axial channels if necessary.

23. Check and record temperature of the tunnel. Allow tunnel to cool to approximately the same temperature as the start up temperature of the tunnel.
    *note: axial channel is very susceptible to large temperature variations.

24. When temperature stabilizes, prepare to continue to next higher Q (speed).

25. Go to step #16 and continue.

APPENDIX B : COMPUTER PROGRAM

```
C         ROBERT S. MAIR, MAJOR, US ARMY
C         THESIS TOPIC: "WIND TUNNEL DRAG EVALUATION OF
C                             HELICOPTER NOSE SECTIONS"
C
C         FORTRAN PROGRAM TO REDUCE WIND TUNNEL DATA TO
C         USEABLE FORM FOR USE IN GRAGHICS PROGRAMS AND
C         DATA TABLES.
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      DEFINITION OF VARIABLES USED IN THIS PROGRAM
C
C      AA       ANGLE OF ATTACK IN RADIANS
C      AREAD    AREA USED FOR COEFFICIENT OF DRAG. IS
C               CROSSECTIONAL AREA OF FUSELAGE. SAME FOR ALL
C               9 MODELS
C      AREAL    AREA USED FOR COEFFICIENT OF LIFT. IS WETTED
C               AREA OF FUSE LAGE- DIFFERENT FOR EACH
C               COMBINATION
C      AOA      ANGLE OF ATTACK
C      CALN,    TABLE OF BALANCE DATA THAT HAS BEEN "MIRRORED"
C               TO ALLOW FOR CORRECTING CN & CA. WHEN BALANCE
C               WAS CALIBRATED IT WAS ONLY LOADED IN ONE
C               DIRECTION (+ AXIAL,- NORMAL) AND A MIRRORED
C               TABLE WAS GENERATED ASSUMING ELASTIC
C               PROPERTIES WOULD PRODUCE THE SAME RESULTS
C               UNDER COMPRESSIVE AS WELL AS TENSIL FORCES
C      CCN,     CN & CA CORRECTED FOR BALANCE IMPERFECTION
C      CCA
C      CFN,     CORRECTON FACTOR USED TO BRING LOW PASS FILTER
C               READING
C      CFA      IN LINE WITH RAW DATA READING BEFORE EACH DATA
C               RUN
C      CN,CA    NUMBER OF COUNTS FROM DIGITAL READOUT TAKEN
C               FOR A PRATCULAR MODEL AT AN ANGLE OF ATTACK
C               AND WIND SPEED
C      ICNTSL,COUNTS OF NORMAL AND AXIAL FORCE CONVERTED TO
C      ICNTSD COUNT OF LIFT AND DRAG
C      K,L,N,   COUNTERS USED IN VARIOUS LOOPS
C      J
C      NT       NOSE/TAIL COMBINATION USED IN WIND TUNNEL
C      RCA,     COUNTS CONVERTED TO REAL NUMBERS
C      RCN
C
C
C
C
C
C
       INTEGER NT(29),CFN(29,1),CFA(29,1),ZFN(29,1),
     *ZFA(29,1),CN(29,41),CA(29,41),ICNTSL(29,40),
     *ICNTSD(29,40),AOA(29,40),J,K,L,N,QQ,CALN(41,21),
     *CALA(41,21),CCN(29,40),CCA(29,40)
C
       REAL M,AA(29,40),RCN(29,40),RCA(29,40),CNTSL(29,40),
     *CNTSD(29,40),RE(29,40),X(10),Y(10),COEFFL(29,40),
     *COEFFD(29,40),Q(29,40),LL,INTER,RCCA(29,40)
C
       COMMON WORK(5000)
C
```

```
      DO 5 L = 21,29
      CALL READER(NT,CFN,CFA,ZFN,ZFA,AOA,CN,CA,L)
    5 CONTINUE
C
C     DO 6 L = 21,29
C     CALL WRITER(NT,CFN,CFA,ZFN,ZFA,AOA,CN,CA,L)
C   6 CONTINUE
C
      DO 57 L = 1,41
         CALL RDR2(CALN,CALA,L)
   57 CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DO 100 N = 21,29
      NN = N - 20
      WRITE(3,48)NN
   48 FORMAT('1',/,20X,'NOSE/TAIL COMBINATION',I3)
      WRITE(3,39)
   39 FORMAT(1X,/,1X,'    AOA  CN   CA CCN CCA   IL   ID    CL
     *'CD         RE        Q    WEIGHT',/)
CCCC  WEIGHTS OF NOSE/ TAIL COMBINATIONS CCCCCCCCCCCCCCCCC
      A = 6. + 128./453.6
      B = 4. + 374./453.6
      S = 4. + 139./453.6
      H = 6. + 120./453.6
      M = 4. + 163./453.6
      LL= 6. + 120./453.6
      C = 12.+  67./453.6
      IF(N.EQ.21) W = A+C+H
      IF(N.EQ.22) W = A+C+M
      IF(N.EQ.23) W = A+C+LL
      IF(N.EQ.24) W = B+C+H
      IF(N.EQ.25) W = B+C+M
      IF(N.EQ.26) W = B+C+LL
      IF(N.EQ.27) W = S+C+H
      IF(N.EQ.28) W = S+C+M
      IF(N.EQ.29) W = S+C+LL
CCCC  CENTER OF GRAVITY DATA (CONVERTED FROM INS TO FT) CCCC
C     NOTE: DATUM PLANE FOR CG COMPUTATIONS IS INTERSECTION
C           OF NOSE AND CENTER SECTIONS, POSITIVE TO REAR.
C     IF(N.EQ.21) CG = 3.57 / 12.
C     IF(N.EQ.22) CG = 3.57 / 12.
C     IF(N.EQ.23) CG = 2.45 / 12.
C     IF(N.EQ.24) CG = 4.03 / 12.
C     IF(N.EQ.25) CG = 4.03 / 12.
C     IF(N.EQ.26) CG = 2.89 / 12.
C     IF(N.EQ.27) CG = 4.04 / 12.
C     IF(N.EQ.28) CG = 4.04 / 12.
C     IF(N.EQ.29) CG = 2.88 / 12.
CCCCCCCCC  REYNOLDS NUMBERS FOR Q'S OF 10,30,50,70 CCCCCCCCC
      RHO = .002377
      RLNGTH = 3.
      RMU = .00000037373
      V1 = 91.73
      V2 = 158.9
      V3 = 205.1
      V4 = 242.7
      DO 25 K = 1,40
      IF(K.LE.40) RE(N,K) = (RHO*V4*RLNGTH)/RMU
      IF(K.LE.30) RE(N,K) = (RHO*V3*RLNGTH)/RMU
      IF(K.LE.20) RE(N,K) = (RHO*V2*RLNGTH)/RMU
      IF(K.LE.10) RE(N,K) = (RHO*V1*RLNGTH)/RMU
CCCCCCCCC  ASSIGNING Q VALUES  CCCCCCCCCCCCCCCCCCCCCCCCCCCC
      IF(K.LE.40) Q(N,K) = 70.
      IF(K.LE.30) Q(N,K) = 50.
      IF(K.LE.20) Q(N,K) = 30.
      IF(K.LE.10) Q(N,K) = 10.
```

```
CCCCCCCCCCC  CREATES "MIRROR" OF BALANCE CALIBRATION DATA
C        FOR CALNOR AND CALAXS. ALLOWS FOR POSITIVE &
C        NEGATIVE CORRECTIONS OF NORMAL & AXIAL COUNTS
C        BEFORE MODEL WEIGHT CORRECTIONS AER MADE.
C        TWO ROWS OF ZERO WEIGHT ARE CREATED, ONE MUST BE
C        DELETED.
C
C
C        CALL RDR(CALNCR,CALAXS)
C        DO 7 N = 1,21
C           DO 8 K = 1,21
C              CALN(N,K) = -1 * CALNOR(22-N,K)
C              CALN(N+21,K) = CALNOR(N,K)
C              CALA(N,K) = CALAXS(22-N,K)
C              CALA(N+21,K) = -1 * CALAXS(N,K)
C    8      CONTINUE
C    7   CCNTINUE
CCCCCCCCCC  CORRECTING COLLECTED DATA FOR BALANCE ERROR.
C              USING CALN & CALA TABLES TO SEARCH.
C              CN & CA CHANGED TC REAL NUMBERS.
      RCN(N,K) = FLCAT(CN(N,K))
      RCA(N,K) = FLCAT(CA(N,K))
CCCCCCCCCC  CORRECTION FOR AXIAL COUNT INITIALLY ASSUMING
C              NORMAL COUNT IS ACCURATE.
C              J IS CCLUMN IN CALN THAT RELATES CN &
C              CALIBRATION WEIGHT, E.G., 50 COUNTS BECOMES
C              COLUMN 6(5 LBS USED IN CALIBRATION)
         J = (INT(ABS(RCN(N,K))/10.-.5)) + 2
         IF(RCN(N,K).LE.-5.) J = INT(ABS(RCN(N,K)/10.)-.5) + 1
         DO 220 L = 1,40
         IF(RCA(N,K).LE.CALA(L,J).AND.RCA(N,K).GT.CALA(L+1,J))
        *GO TO 215
         GO TO 220
  215    INTER = (CALA(L,J)-RCA(N,K))/(CALA(L,J)-CALA(L+1,J))
         CCA(N,K) = INT((CALA(L,1)-INTER*10.)-.5)+1
  220    CCNTINUE
C        WRITE(3,228) J
C  228   FORMAT(1X,I10)
CCCCCCCCCC  CORRECTION FOR NORMAL COUNT HAVING CORRECTED
C              AXIAL CCUNT
         J = INT(ABS(CCA(N,K)/10.)-.5) + 2
         IF(CCA(N,K).LE.-5.) J = INT(ABS(CCA(N,K)/10.)-.5) + 1
         DO 200 L = 1,40
         IF(RCN(N,K).LE.CALN(L,J).AND.RCN(N,K).GT.CALN(L+1,J))
        *GO TO 205
         GO TO 200
  205    INTER = (CALN(L,J)-RCN(N,K))/(CALN(L,J)-CALN(L+1,J))
         CCN(N,K) = INT((CALN(L,1)-INTER*10.)-.5)+1
  200    CONTINUE
C        WRITE(3,222) J,CN(N,K),CCN(N,K),CA(N,K),CCA(N,K)
C  222   FORMAT('+',5I10)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCC  CONVERTING TO COUNTS OF LIFT AND DRAG FROM COUNTS
C           OF NORMAL AND AXIAL FORCE.
         AA(N,K)   =((FLOAT(AOA(N,K)))/180.)*3.14159
         CNTSL(N,K)=(FLOAT(CCN(N,K))-((W-W*COS(AA(N,K)))*10.))
        *              *COS(AA(N,K))
        *              -(FLOAT(CCA(N,K))-((  W*SIN(AA(N,K)))*10.))
        *              *SIN(AA(N,K))
         CNTSD(N,K)=(FLOAT(CCN(N,K))-((W-W*COS(AA(N,K)))*10.))
        *              *SIN(AA(N,K))
        *              +(FLOAT(CCA(N,K))-((  W*SIN(AA(N,K)))*10.))
        *              *CCS(AA(N,K))
         ICNTSL(N,K) = INT(CNTSL(N,K)-.5)+1
         IF(CNTSL(N,K).LE.0.5) ICNTSL(N,K) = INT(CNTSL(N,K)-.5)
         ICNTSD(N,K) = INT(CNTSD(N,K)-.5)+1
         IF(CNTSD(N,K).LE.0.5) ICNTSD(N,K) = INT(CNTSD(N,K)-.5)
```

```
      AREAD = 60./144.
      AREAL = 160./144.
      COEFFD(N,K) = (CNTSD(N,K)/10.)/(Q(N,K)*AREAD)
      COEFFL(N,K) = (CNTSL(N,K)/10.)/(Q(N,K)*AREAL)
      QQ = INT(Q(N,K))
      WRITE(3,40)AOA(N,K),CN(N,K),CA(N,K)
     *,CCN(N,K),CCA(N,K),ICNTSL(N,K),ICNTSD(N,K),
     *COEFFL(N,K),COEFFD(N,K),RE(N,K),QQ,W
   40 FORMAT(1X,I5,1X,6I4,2F7.3,1X,E10.3,1X,I4,F8.2)
      IF(K.EQ.10.OR.K.EQ.20.OR.K.EQ.30) WRITE(3,45)
   45 FORMAT(1X,' ')
   25 CONTINUE
  100 CONTINUE
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      CALL TEK618
      CALL COMPRS
      CALL MEDBUF
      CALL HWROT ('AUTO')
      CALL HWSCAL ('SCREEN')
C     CALL BLOWUP(.7)
      CALL PAGE(8.5,11.0)
      CALL SWISSM
      CALL SHDCHR(90.,1,0.002,1)
      CALL PHYSOR(2.,7.5)
      CALL AREA2D(5.0,2.5)
      CALL MESSAG('ATTACK NOSE$',11,.5,2.0)
      CALL MESSAG('Q = 30 PSF$',10,1.9,2.3)
      CALL XNAME('            $',100)
      CALL YNAME('                          $',100)
      CALL XINTAX
      CALL YINTAX
      CALL GRAF(-12.,2.,12.,-.05,.1,.4)
      CALL GRID(1,1)
      CALL THKCRV(.02)
      DO 101 L = 21,23
      IF(L.EQ.22) CALL DASH
      IF(L.EQ.23) CALL DOT
      CALL CURVES(X,Y,AA,COEFFD,L)
C     WRITE(3,80)X(1),X(2),X(3),X(4),Y(1),Y(2),Y(3),Y(4)
C  80 FORMAT(1X,4F12.2,/,4F12.2)
      CALL BCOMON(5000)
      CALL SMOOTH
      CALL CURVE(X,Y,10,1)
  101 CONTINUE
      CALL RESET('DOT')
      CALL ENDGR(0)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      CALL PHYSOR(2.0,4.7)
      CALL AREA2D(5.0,2.5)
      CALL MESSAG('BLUNT NOSE$',10,.5,2.0)
      CALL XNAME('              $',100)
      CALL YNAME('COEFFICIENT OF DRAG$',100)
      CALL XINTAX
      CALL YINTAX
      CALL RESET('THKCRV')
      CALL GRAF(-12.,2.,12.,-.05,.1,.4)
      CALL GRID(1,1)
      CALL THKCRV(.02)
      DO 102 L = 24,26
      IF(L.EQ.25) CALL DASH
      IF(L.EQ.26) CALL DOT
      CALL CURVES(X,Y,AA,COEFFD,L)
      CALL CURVE(X,Y,10,1)
  102 CONTINUE
      CALL RESET('DOT')
      CALL ENDGR(0)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
      CALL PHYSOR(2.0,1.8)
      CALL AREA2D(5.0,2.5)
      CALL MESSAG('SMOOTH NOSE$',11,.5,2.0)
      CALL XNAME('             $',100)
      CALL YNAME('                    $',100)
      CALL MESSAG('ANGLE OF ATTACK(DEGS)$',21,1.3,-0.5)
C     CALL MESSAG('FIG. -.- CC VS AOA (Q=70)$',25,1.C,-2.)
      CALL XINTAX
      CALL YINTAX
      CALL RESET('THKCRV')
      CALL GRAF(-12.,2.,12.,-.05,.1,.4)
      CALL GRID(1,1)
      CALL THKCRV(.02)
      DO 103 L = 27,29
      IF(L.EQ.28) CALL DASH
      IF(L.EQ.29) CALL DOT
      CALL CURVES(X,Y,AA,COEFFD,L)
      CALL CURVE(X,Y,10,1)
  1C3 CONTINUE
      CALL ENDGR(0)
      CALL PAGE(8.5,11.0)
      CALL SWISSM
      CALL SHDCHR(90.,1,0.002,1)
      CALL PHYSOR(2.0,7.2)
      CALL AREA2D(5.0,2.5)
      CALL ENDPL(0)
      CALL DONEPL
      STOP
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE READER(NT,CFN,CFA,ZFN,ZFA,AOA,CN,CA,L)
      INTEGER NT(29),CFN(29,1),CFA(29,1),ZFN(29,1),
     *ZFA(29,1),AOA(29,40),CN(29,40),CA(29,40),K,L,N
      READ(L,19)   NT(L)
      READ(L,20) CFN(L,1),CFA(L,1)
      READ(L,21) ZFN(L,1),ZFA(L,1)
      READ(L,22) (AOA(L,K),CN(L,K),CA(L,K),K=1,40)
   19 FORMAT(10X,I1)
   20 FORMAT(1X,/,1X,I3,6X,I3)
   21 FORMAT(1X,I3,6X,I3)
   22 FORMAT(1X,/,/,10(1X,I3,5X,I4,7X,I4,/),
     *          /,/,10(1X,I3,5X,I4,7X,I4,/),
     *          /,/,10(1X,I3,5X,I4,7X,I4,/),
     *          /,/, 9(1X,I3,5X,I4,7X,I4,/),1X,I3,5X,I4,7X,
     *          I4)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE WRITER(NT,CFN,CFA,ZFN,ZFA,AOA,CN,CA,L)
      INTEGER NT(29),CFN(29,1),CFA(29,1),ZFN(29,1),ZFA(29,1)
     *,CN(29,40),CA(29,40),AOA(29,40),K,L,N
      WRITE(3,9)   NT(L)
      WRITE(3,10) CFN(L,1),CFA(L,1)
      WRITE(3,11) ZFN(L,1),ZFA(L,1)
      WRITE(3,12) (AOA(L,K),CN(L,K),CA(L,K),K=1,40)
    9 FORMAT('1',10X,I1)
   10 FORMAT(1X,/,1X,I3,6X,I3)
   11 FORMAT(1X,I3,6X,I3)
   12 FORMAT(1X,/,/,10(1X,I3,5X,I4,7X,I4,/),
     *          /,/,10(1X,I3,5X,I4,7X,I4,/),
     *          /,/,10(1X,I3,5X,I4,7X,I4,/),
     *          /,/, 9(1X,I3,5X,I4,7X,I4,/),1X,I3,5X,I4,7X,
     *I4)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE CURVES(X,Y,AA,COEFFD,L)
```

```
      REAL X(10),Y(10),AA(29,40),COEFFD(29,40)
      INTEGER L
      X(1) = AA(L,1)*(180/3.14159)
      X(2) = AA(L,2)*(180/3.14159)
      X(3) = AA(L,3)*(180/3.14159)
      X(4) = AA(L,4)*(180/3.14159)
      X(5) = AA(L,5)*(180/3.14159)
      X(6) = AA(L,6)*(180/3.14159)
      X(7) = AA(L,7)*(180/3.14159)
      X(8) = AA(L,8)*(180/3.14159)
      X(9) = AA(L,9)*(180/3.14159)
      X(10)= AA(L,10)*(180/3.14159)
      Y(1) = COEFFD(L,11)
      Y(2) = COEFFD(L,12)
      Y(3) = COEFFD(L,13)
      Y(4) = COEFFD(L,14)
      Y(5) = COEFFD(L,15)
      Y(6) = COEFFD(L,16)
      Y(7) = COEFFD(L,17)
      Y(8) = COEFFD(L,18)
      Y(9) = COEFFD(L,19)
      Y(10)= COEFFD(L,20)
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE RDR(CALNOR,CALAXS)
      INTEGER CALNOR(21,21),CALAXS(21,21)
      DO 59 N=1,21
         READ(8,20) (CALNOR(N,K),K=1,21)
   59 CONTINUE
      DO 9 N=1,21
         READ(9,20) (CALAXS(N,K),K=1,21)
    9 CONTINUE
   20 FORMAT(1X,21(I4))
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE WRTR(CALNOR,CALAXS,CALN,CALA)
      INTEGER CALNOR(21,21),CALAXS(21,21),CALN(42,21),
     *CALA(42,21)
      DO 39 N=1,21
      WRITE(4,19) (CALNOR(N,K),K=1,21)
   39 CONTINUE
      DO 40 N=1,21
      WRITE(4,19) (CALAXS(N,K),K=1,21)
   40 CONTINUE
      DO 41 N=1,42
      WRITE(4,19) (CALN(N,K),K=1,21)
   41 CONTINUE
      DO 42 N=1,42
      WRITE(4,19) (CALA(N,K),K=1,21)
   42 CONTINUE
   19 FORMAT(1X,21(I4))
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE RDR2(CALN,CALA,N)
      INTEGER CALN(41,21),CALA(41,21),N
      READ(8,119) (CALN(N,K),K=1,21)
C     WRITE(3,119)(CALN(N,K),K=1,21)
      READ(9,119) (CALA(N,K),K=1,21)
  119 FORMAT(1X,21(I4))
      RETURN
      END
```

TABLE 10 NORMAL CALIBRATION

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	POUNDS OF NORMAL FORCE
200	201	201	200	201	200	200	201	200	200	200	200	200	200	199	199	200	198	198	199	200	20
191	191	191	191	191	190	191	191	190	190	190	190	190	190	189	189	199	198	189	199	190	19
180	181	181	180	181	180	181	181	180	180	180	181	180	180	178	178	179	178	178	178	179	18
170	171	171	171	171	170	171	170	170	170	170	170	170	170	168	168	169	168	167	168	168	17
160	161	161	161	161	160	161	160	160	160	159	160	160	160	158	158	159	158	157	158	159	16
150	151	151	150	151	151	151	150	150	150	149	150	150	150	148	149	148	149	147	148	149	15
140	140	141	140	141	140	140	140	141	140	139	140	140	140	138	138	139	139	138	139	139	14
130	130	131	130	130	130	130	130	130	130	130	130	130	130	129	128	129	127	127	128	128	13
120	120	121	120	120	120	120	120	121	120	120	120	120	120	118	118	119	117	117	118	118	12
110	110	110	110	110	110	110	110	110	110	110	110	109	110	108	108	109	107	107	108	107	11
100	100	100	100	100	100	100	100	100	100	100	100	99	100	97	96	98	97	97	96	98	10
92	91	91	90	90	90	90	90	90	90	90	89	88	90	89	87	87	87	88	87	88	9
81	81	81	80	80	80	80	79	79	80	80	78	78	80	78	77	76	76	77	77	78	8
71	70	70	70	70	69	70	69	70	70	69	69	68	70	68	68	67	67	67	67	68	7
61	60	60	60	59	60	60	59	60	60	59	59	58	60	57	57	57	57	58	56	58	6
50	50	50	50	50	50	50	49	50	50	49	49	49	50	47	48	46	47	48	46	48	5
40	41	41	40	40	40	40	40	39	40	39	39	39	39	37	37	36	37	39	36	37	4
30	31	30	30	30	30	30	29	28	30	29	29	29	29	28	27	27	26	28	26	27	3
20	21	20	20	20	19	19	18	18	20	19	18	18	18	16	17	17	16	18	17	17	2
10	10	10	10	10	10	10	9	9	9	9	7	7	8	7	7	7	6	8	6	7	1
0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	3	3	0
-10	-10	-10	-10	-10	-10	-10	-9	-9	-9	-9	-7	-7	-8	-7	-7	-7	-6	-8	-6	-7	-1
-20	-21	-20	-20	-20	-19	-19	-18	-18	-20	-19	-18	-18	-18	-16	-17	-17	-16	-18	-17	-17	-2
-30	-31	-30	-30	-30	-30	-30	-29	-28	-30	-29	-29	-29	-29	-28	-27	-27	-26	-28	-26	-27	-3
-40	-41	-41	-40	-40	-40	-40	-40	-39	-40	-39	-39	-39	-39	-37	-37	-36	-37	-39	-36	-37	-4
-50	-50	-50	-50	-50	-50	-50	-49	-50	-50	-49	-49	-49	-50	-47	-48	-46	-47	-48	-46	-48	-5
-61	-60	-60	-60	-59	-60	-60	-59	-60	-60	-59	-59	-58	-60	-57	-57	-57	-57	-58	-56	-58	-6
-71	-70	-70	-70	-70	-69	-70	-69	-70	-70	-69	-69	-68	-70	-68	-69	-67	-67	-67	-67	-68	-7
-81	-81	-81	-80	-80	-80	-80	-79	-79	-80	-80	-78	-78	-80	-78	-77	-76	-76	-77	-77	-78	-8
-92	-91	-91	-90	-90	-90	-90	-90	-90	-90	-90	-89	-88	-90	-89	-87	-87	-87	-88	-87	-88	-9
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-99	-100	-97	-96	-98	-97	-97	-96	-98	-10
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-109	-110	-108	-108	-109	-107	-107	-108	-107	-11
-120	-120	-121	-120	-120	-120	-120	-120	-121	-120	-120	-120	-120	-120	-118	-118	-119	-117	-117	-118	-118	-12
-130	-130	-131	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-128	-128	-129	-127	-127	-128	-128	-13
-140	-140	-141	-140	-141	-140	-140	-140	-141	-140	-139	-140	-140	-140	-138	-138	-139	-139	-139	-139	-139	-14
-150	-151	-151	-150	-151	-151	-151	-150	-150	-150	-149	-150	-150	-150	-148	-148	-148	-149	-147	-148	-149	-15
-160	-161	-161	-161	-161	-160	-161	-160	-160	-160	-159	-160	-160	-160	-158	-158	-159	-158	-157	-158	-158	-16
-170	-171	-171	-171	-171	-170	-171	-170	-170	-170	-170	-170	-170	-170	-168	-168	-169	-168	-167	-168	-168	-17
-180	-181	-181	-180	-181	-180	-181	-181	-180	-180	-180	-181	-180	-180	-178	-178	-179	-178	-178	-178	-179	-18
-191	-191	-191	-191	-191	-190	-191	-191	-190	-190	-190	-190	-190	-190	-189	-189	-189	-188	-198	-189	-190	-19
-200	-201	-201	-200	-201	-200	-200	-201	-200	-200	-200	-200	-200	-200	-199	-199	-200	-198	-198	-199	-200	-20

POUNDS OF AXIAL FORCE

THIS TABLE INDICATES THE 'NORMAL' READOUT, IN COUNTS, WHEN THE BALANCE WAS LOADED UNDER THE ABOVE CONDITIONS. THE NEGATIVE OUTPUT WAS MIRRORED TO PRODUCE A POSITIVE QUADRANT. THE MAPPING THAT RESULTED WAS USED TO CORRECT THE AXIAL DATA COLLECTED DURING TEST RUNS.

TABLE 11 AXIAL CALIBRATION

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	POUNDS OF AXIAL FORCE
200	158	198	198	196	196	195	194	194	134	193	190	188	188	186	185	184	184	184	183	183	20
190	189	188	188	187	187	186	186	185	184	183	182	179	178	177	176	176	173	173	173	172	19
180	180	179	177	176	176	176	175	174	173	171	169	168	167	165	164	163	160	159	158	158	18
170	170	170	170	169	168	168	167	166	165	162	161	160	160	158	156	156	154	152	150	149	17
160	160	160	157	156	154	153	152	151	150	150	150	149	149	148	146	145	144	143	142	141	16
151	150	151	150	148	146	145	144	141	139	137	139	138	137	137	136	135	134	133	131	130	15
140	140	139	139	138	137	137	137	135	134	131	131	131	130	130	130	129	128	126	125	123	14
130	130	130	130	129	129	129	129	128	127	126	124	123	122	120	120	118	118	116	115	114	13
120	120	120	120	119	119	119	116	115	115	113	112	111	109	108	106	106	105	105	105	104	12
110	110	108	109	107	106	106	106	104	104	104	103	104	103	102	101	98	96	93	92	91	11
100	100	99	98	97	96	95	94	95	93	91	90	89	89	88	88	86	84	83	83	82	10
90	90	89	89	89	88	88	87	86	85	83	83	82	81	80	79	79	78	77	77	77	9
80	80	79	78	78	76	76	75	75	74	73	72	71	70	69	66	65	65	64	63	62	8
70	70	69	68	67	66	66	65	65	65	63	60	60	59	58	57	56	55	54	53	52	7
60	60	59	59	58	57	56	56	55	54	54	54	50	50	50	49	49	47	46	46	45	6
50	48	48	46	46	45	44	43	42	41	40	40	40	39	39	38	36	34	33	33	32	5
40	41	40	39	38	37	37	36	35	35	34	32	30	28	27	26	24	23	23	23	23	4
30	30	30	30	27	27	26	26	24	23	23	21	20	19	18	17	16	16	15	14	14	3
20	20	20	20	20	19	18	16	15	15	14	13	12	12	12	11	10	9	8	7	6	2
10	10	10	8	7	6	5	4	3	3	2	1	1	0	0	-1	-1	-2	-2	-2	-3	1
0	0	0	0	0	-1	-2	-3	-4	-4	-4	-4	-5	-7	-9	-9	-10	-12	-13	-13	-14	0
-10	-10	-10	-8	-7	-6	-5	-4	-3	-3	-2	-1	-1	0	0	1	1	2	2	2	3	-1
-20	-20	-20	-20	-20	-19	-18	-16	-15	-15	-14	-13	-12	-12	-12	-11	-10	-9	-8	-7	-6	-2
-30	-30	-30	-30	-27	-27	-26	-26	-24	-23	-23	-21	-20	-19	-18	-17	-16	-16	-15	-14	-14	-3
-40	-41	-40	-35	-38	-37	-37	-36	-35	-35	-34	-32	-30	-28	-27	-26	-24	-23	-23	-23	-23	-4
-50	-48	-48	-46	-46	-45	-44	-43	-42	-41	-40	-40	-40	-39	-39	-38	-36	-34	-33	-33	-32	-5
-60	-60	-59	-59	-58	-57	-56	-56	-55	-54	-54	-54	-50	-50	-50	-49	-49	-47	-46	-46	-45	-6
-70	-70	-69	-68	-67	-66	-66	-65	-65	-65	-63	-60	-60	-59	-58	-57	-56	-55	-54	-53	-52	-7
-80	-80	-79	-78	-78	-76	-76	-75	-75	-74	-73	-72	-71	-70	-69	-66	-65	-65	-64	-63	-62	-8
-90	-90	-89	-89	-89	-88	-88	-87	-86	-85	-83	-83	-82	-81	-80	-79	-79	-78	-77	-77	-77	-9
-100	-100	-99	-98	-97	-96	-95	-94	-95	-93	-91	-90	-89	-89	-88	-88	-86	-84	-83	-83	-82	-10
-110	-110	-108	-109	-107	-106	-106	-106	-104	-104	-104	-103	-104	-103	-102	-101	-98	-96	-93	-92	-91	-11
-120	-120	-120	-120	-119	-119	-119	-116	-115	-115	-113	-112	-111	-109	-108	-106	-106	-105	-105	-105	-104	-12
-130	-130	-130	-130	-129	-129	-129	-129	-128	-127	-126	-124	-123	-122	-120	-120	-118	-118	-116	-115	-114	-13
-140	-140	-139	-139	-138	-137	-137	-137	-135	-134	-131	-131	-131	-130	-130	-130	-129	-128	-126	-125	-123	-14
-151	-150	-151	-150	-148	-146	-145	-144	-141	-139	-137	-139	-138	-137	-137	-136	-135	-134	-133	-131	-130	-15
-160	-160	-160	-157	-156	-154	-153	-152	-151	-150	-150	-150	-149	-149	-148	-146	-145	-144	-143	-142	-141	-16
-170	-170	-170	-170	-169	-168	-168	-167	-166	-165	-162	-161	-160	-160	-158	-156	-156	-154	-152	-150	-149	-17
-180	-180	-179	-177	-176	-176	-176	-175	-174	-173	-171	-169	-168	-167	-165	-164	-163	-160	-159	-158	-158	-18
-190	-189	-188	-188	-187	-187	-186	-186	-185	-184	-183	-182	-179	-178	-177	-176	-176	-173	-173	-173	-172	-19
-200	-198	-198	-198	-196	-196	-195	-194	-194	-194	-193	-190	-188	-188	-186	-185	-184	-184	-184	-183	-183	-20

POUNDS OF NORMAL FORCE

THIS TABLE INDICATES THE 'AXIAL' READOUT, IN COUNTS, WHEN THE BALANCE WAS LOADED UNDER THE ABOVE CONDITIONS. THE NEGATIVE OUTPUT WAS MIRRORED TO PRODUCE A POSITIVE QUADRANT. THE MAPPING THAT RESULTED WAS USED TO CORRECT THE NORMAL DATA COLLECTED DURING TEST RUNS.

APPENDIX C : TABLES

TABLE 1 INPUT DATA FILE 1

NOSE/TAIL=1/ REMARKS: RUN#1___ATTACK/HIGH______

NORMAL	AXIAL	
100/	100/	(CORRECTION FACTOR)
0/	0/	(AFTER-RUN OFF-ZERO READING)

Q=10

AOA	NORMAL	AXIAL
8/	6/	38/
6/	3/	28/
4/	-1/	20/
2/	-2/	8/
0/	-5/	2/
-2/	-8/	-3/
-4/	-9/	-12/
-6/	-10/	-22/
-8/	-12/	-30/
-10/	-14/	-45/

Q=30

AOA	NORMAL	AXIAL
8/	20/	60/
6/	13/	52/
4/	6/	42/
2/	-1/	32/
0/	-10/	20/
-2/	-18/	10/
-4/	-25/	2/
-6/	-32/	-10/
-8/	-41/	-21/
-10/	-50/	-35/

Q=50

AOA	NORMAL	AXIAL
8/	34/	89/
6/	17/	80/
4/	5/	74/
2/	-5/	62/
0/	-19/	58/
-2/	-30/	45/
-4/	-43/	35/
-6/	-57/	23/
-8/	-72/	10/
-10/	-88/	-3/

Q=70

AOA	NORMAL	AXIAL
8/	52/	98/
6/	31/	90/
4/	11/	71/
2/	-7/	56/
0/	-24/	40/
-2/	-43/	25/
-4/	-60/	18/
-6/	-82/	-4/
-8/	-104/	-38/
-10/	-127/	-45/

TABLE 2 INPUT DATA FILE 2

```
NOSE/TAIL=2/     REMARKS: RUN#1___ATTACK/MIDDLE_____
NORMAL    AXIAL
  100/     100/    (CORRECTION FACTOR)
    0/       0/    (AFTER-RUN OFF-ZERO READING)
-----------Q=10------------------------
  AOA     NORMAL        AXIAL
    8/        9/          41/
    6/        6/          29/
    4/        0/          23/
    2/       -1/          14/
    0/       -3/           6/
   -2/       -4/           0/
   -4/       -5/          -7/
   -6/       -8/         -19/
   -8/       -9/         -26/
  -10/      -12/         -34/
-----------Q=30-------------   -----
  AOA     NORMAL        AXIAL
    8/       21/          55/
    6/       11/          49/
    4/        6/          40/
    2/        0/          30/
    0/       -8/          20/
   -2/      -14/          13/
   -4/      -20/           6/
   -6/      -26/          -5/
   -8/      -35/         -12/
  -10/      -48/         -29/
-----------Q=50------------------------
  AOA     NORMAL        AXIAL
    8/       34/          78/
    6/       21/          73/
    4/        8/          63/
    2/        0/          55/
    0/      -12/          49/
   -2/      -21/          43/
   -4/      -33/          35/
   -6/      -46/          29/
   -8/      -60/          12/
  -10/      -77/           0/
-----------Q=70------------------------
  AOA     NORMAL        AXIAL
    8/       50/          99/
    6/       30/          80/
    4/       15/          70/
    2/        1/          54/
    0/      -16/          45/
   -2/      -31/          25/
   -4/      -46/          15/
   -6/      -65/           6/
   -8/      -92/         -16/
  -10/     -115/         -37/
```

TABLE 3 INPUT DATA FILE 3

```
NOSE/TAIL=3/      REMARKS: RUN#1___ATTACH/LOW_____
NORMAL    AXIAL
   98/      98/    (CORRECTION FACTOR)
    0/       0/    (AFTER-RUN OFF-ZERO READING)
-----------Q=10--------------------
 AOA     NORMAL         AXIAL
   8/       11/           42/
   6/        7/           30/
   4/        4/           22/
   2/        0/            8/
   0/       -2/           -3/
  -2/       -4/           -7/
  -4/       -6/          -15/
  -6/       -7/          -27/
  -8/       -9/          -38/
 -10/      -11/          -48/
-----------Q=30--------------------
 AOA     NORMAL         AXIAL
   8/       30/           55/
   6/       22/           48/
   4/       13/           38/
   2/        5/           27/
   0/       -1/           14/
  -2/       -9/            6/
  -4/      -15/            2/
  -6/      -21/          -13/
  -8/      -32/          -28/
 -10/      -38/          -40/
-----------Q=50--------------------
 AOA     NORMAL         AXIAL
   8/       50/           82/
   6/       36/           73/
   4/       20/           62/
   2/        8/           46/
   0/       -2/           36/
  -2/      -14/           30/
  -4/      -27/           20/
  -6/      -39/           13/
  -8/      -54/           -3/
 -10/      -68/          -15/
-----------Q=70--------------------
 AOA     NORMAL         AXIAL
   8/       71/           99/
   6/       51/           90/
   4/       29/           75/
   2/       10/           60/
   0/       -8/           40/
  -2/      -23/           27/
  -4/      -45/           10/
  -6/      -60/           -9/
  -8/      -82/          -30/
 -10/     -104/          -50/
```

TABLE 4 INPUT DATA FILE 4

NOSE/TAIL=4/ REMARKS: RUN#1___BLUNT/HIGH_____

NORMAL	AXIAL	
100/	99/	(CORRECTION FACTOR)
0/	0/	(AFTER-RUN OFF-ZERO READING)

-----------Q=10-----------------

AOA	NORMAL	AXIAL
8/	8/	40/
6/	3/	29/
4/	0/	23/
2/	-2/	10/
0/	-4/	7/
-2/	-8/	-4/
-4/	-10/	-10/
-6/	-12/	-18/
-8/	-15/	-29/
-10/	-17/	-36/

-----------Q=30-----------------

AOA	NORMAL	AXIAL
8/	30/	55/
6/	20/	50/
4/	12/	40/
2/	4/	33/
0/	-4/	22/
-2/	-12/	14/
-4/	-19/	4/
-6/	-28/	-6/
-8/	-34/	-15/
-10/	-43/	-25/

-----------Q=50-----------------

AOA	NORMAL	AXIAL
8/	48/	89/
6/	32/	79/
4/	19/	70/
2/	6/	65/
0/	-5/	57/
-2/	-20/	41/
-4/	-32/	30/
-6/	-45/	22/
-8/	-59/	13/
-10/	-74/	0/

-----------Q=70-----------------

AOA	NORMAL	AXIAL
8/	65/	110/
6/	43/	100/
4/	22/	94/
2/	6/	73/
0/	-8/	62/
-2/	-30/	40/
-4/	-49/	23/
-6/	-68/	10/
-8/	-89/	0/
-10/	-108/	-15/

TABLE 5 INPUT DATA FILE 5

```
NOSE/TAIL=5/      REMARKS: RUN#1___BLUNT/MIDDLE_____
NORMAL    AXIAL
 100/      100/    (CORRECTION FACTOR)
   0/        0/    (AFTER-RUN OFF-ZERO READING)
-----------Q=10-------------------------
 AOA    NORMAL         AXIAL
   8/       8/           33/
   6/       4/           28/
   4/       1/           22/
   2/      -1/           13/
   0/      -2/            5/
  -2/      -4/           -3/
  -4/      -7/           -9/
  -6/      -8/          -22/
  -8/     -10/          -30/
 -10/     -11/          -37/
-----------Q=30-------------------------
 AOA    NORMAL         AXIAL
   8/      24/           60/
   6/      16/           48/
   4/       9/           40/
   2/       3/           30/
   0/      -3/           21/
  -2/     -10/           13/
  -4/     -17/            0/
  -6/     -25/          -10/
  -8/     -32/          -24/
 -10/     -40/          -34/
-----------Q=50-------------------------
 AOA    NORMAL         AXIAL
   8/      47/           88/
   6/      29/           78/
   4/      18/           67/
   2/       6/           58/
   0/      -2/           45/
  -2/     -15/           36/
  -4/     -28/           18/
  -6/     -40/            2/
  -8/     -53/           -5/
 -10/     -68/          -22/
-----------Q=70-------------------------
 AOA    NORMAL         AXIAL
   8/      63/          126/
   6/      44/          108/
   4/      27/           96/
   2/      10/           75/
   0/      -3/           62/
  -2/     -21/           40/
  -4/     -42/           20/
  -6/     -61/            0/
  -8/     -78/           -4/
 -10/    -101/          -20/
```

TABLE 6 INPUT DATA FILE 6

```
NOSE/TAIL=6/      REMARKS: RUN#1___BLUNT/LOW_____
NORMAL    AXIAL
 100/      100/    (CORRECTION FACTOR)
   0/        0/    (AFTER-RUN OFF-ZERO READING)
----------Q=10-------------------
 AOA     NORMAL          AXIAL
   8/        11/            47/
   6/         7/            40/
   4/         4/            30/
   2/         1/            22/
   0/        -1/            15/
  -2/        -3/             5/
  -4/        -5/             0/
  -6/        -7/            -5/
  -8/        -8/           -18/
 -10/        -9/           -25/
----------Q=30-------------------
 AOA     NORMAL          AXIAL
   8/        36/            56/
   6/        24/            48/
   4/        17/            40/
   2/        10/            30/
   0/         2/            21/
  -2/        -6/            12/
  -4/       -13/             3/
  -6/       -20/            -3/
  -8/       -30/           -17/
 -10/       -37/           -25/
----------Q=50-------------------
 AOA     NORMAL          AXIAL
   8/        60/            85/
   6/        47/            75/
   4/        35/            65/
   2/        20/            56/
   0/         6/            47/
  -2/        -3/            38/
  -4/       -17/            30/
  -6/       -30/            20/
  -8/       -45/             8/
 -10/       -53/             0/
----------Q=70-------------------
 AOA     NORMAL          AXIAL
   8/        87/            94/
   6/        68/            84/
   4/        49/            70/
   2/        28/            59/
   0/         5/            40/
  -2/       -12/            20/
  -4/       -30/             3/
  -6/       -50/           -10/
  -8/       -68/           -23/
 -10/       -92/           -45/
```

TABLE 7 INPUT DATA FILE 7

NOSE/TAIL=7/ REMARKS: RUN#1___SMOOTH/HIGH_____

NORMAL	AXIAL	
100/	100/	(CCRRECTION FACTOR)
0/	0/	(AFTER-RUN CFF-ZERO READING)

----------Q=10-------------------

AOA	NORMAL	AXIAL
8/	8/	40/
6/	4/	34/
4/	1/	26/
2/	-2/	20/
0/	-6/	7/
-2/	-9/	2/
-4/	-10/	-4/
-6/	-13/	-18/
-8/	-16/	-23/
-10/	-18/	-32/

----------Q=30-------------------

AOA	NORMAL	AXIAL
8/	15/	44/
6/	8/	33/
4/	1/	28/
2/	-2/	18/
0/	-8/	7/
-2/	-15/	-3/
-4/	-19/	-12/
-6/	-25/	-22/
-8/	-30/	-33/
-10/	-37/	-43/

----------Q=50-------------------

AOA	NORMAL	AXIAL
8/	42/	92/
6/	27/	78/
4/	13/	70/
2/	1/	63/
0/	-13/	45/
-2/	-26/	35/
-4/	-41/	17/
-6/	-56/	3/
-8/	-70/	-8/
-10/	-82/	-20/

----------Q=70-------------------

AOA	NORMAL	AXIAL
8/	65/	114/
6/	39/	90/
4/	20/	80/
2/	0/	58/
0/	-20/	45/
-2/	-40/	25/
-4/	-63/	5/
-6/	-84/	-12/
-8/	-105/	-20/
-10/	-128/	-37/

TABLE 8 INPUT DATA 8

```
NOSE/TAIL=8/      REMARKS: RUN#1___SMOOTH/MIDDLE_____
NORMAL    AXIAL
 100/      100/   (CORRECTION FACTOR)
   0/        0/   (AFTER-RUN OFF-ZERO READING)
-----------Q=10--------------------
 AOA     NORMAL       AXIAL
   8/        6/         38/
   6/        4/         32/
   4/        0/         20/
   2/       -1/         12/
   0/       -5/          4/
  -2/       -6/         -2/
  -4/      -10/        -13/
  -6/      -10/        -20/
  -8/      -12/        -30/
 -10/      -13/        -40/
-----------Q=30--------------------
 AOA     NORMAL       AXIAL
   8/       27/         65/
   6/       19/         50/
   4/        9/         48/
   2/        3/         38/
   0/       -3/         24/
  -2/      -11/         15/
  -4/      -21/          2/
  -6/      -30/         -8/
  -8/      -39/        -18/
 -10/      -49/        -39/
-----------Q=50--------------------
 AOA     NORMAL       AXIAL
   8/       36/         87/
   6/       23/         78/
   4/       10/         67/
   2/       -2/         58/
   0/      -13/         42/
  -2/      -27/         33/
  -4/      -40/         17/
  -6/      -53/          3/
  -8/      -67/         -5/
 -10/      -83/        -22/
-----------Q=70--------------------
 AOA     NORMAL       AXIAL
   8/       55/        111/
   6/       38/         98/
   4/       16/         79/
   2/        0/         61/
   0/      -15/         42/
  -2/      -35/         25/
  -4/      -56/          3/
  -6/      -80/        -13/
  -8/     -102/        -28/
 -10/     -121/        -55/
```

TABLE 9 INPUT DATA FILE 9

NOSE/TAIL=9/ REMARKS: RUN#1___SMOOTH/LOW_____

NORMAL	AXIAL	
98/	100/	(CORRECTION FACTOR)
0/	0/	(AFTER-RUN OFF-ZERO READING)

----------Q=10--------------------

AOA	NORMAL	AXIAL
8/	12/	42/
6/	9/	29/
4/	5/	20/
2/	2/	7/
0/	0/	2/
-2/	-2/	-7/
-4/	-4/	-19/
-6/	-6/	-24/
-8/	-7/	-38/
-10/	-9/	-45/

----------Q=30--------------------

AOA	NORMAL	AXIAL
8/	38/	60/
6/	29/	52/
4/	20/	40/
2/	10/	29/
0/	4/	18/
-2/	-2/	2/
-4/	-12/	-12/
-6/	-21/	-22/
-8/	-30/	-33/
-10/	-36/	-47/

----------Q=50--------------------

AOA	NORMAL	AXIAL
8/	58/	83/
6/	44/	77/
4/	27/	63/
2/	14/	54/
0/	1/	39/
-2/	-13/	26/
-4/	-29/	18/
-6/	-43/	3/
-8/	-57/	-12/
-10/	-72/	-28/

----------Q=70--------------------

AOA	NORMAL	AXIAL
8/	83/	109/
6/	62/	90/
4/	40/	80/
2/	19/	54/
0/	0/	35/
-2/	-21/	20/
-4/	-42/	0/
-6/	-64/	-21/
-8/	-84/	-42/
-10/	-105/	-65/

TABLE 12 OUTPUT FILE 1

NOSE/TAIL 1 (ATTACK/HIGH) WEIGHT = 24.7 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	6	38	6	37	3	3	0.029	0.075	0.031
6	3	28	3	28	1	2	0.013	0.056	0.023
4	-1	20	0	20	-1	3	-0.007	0.065	0.027
2	-2	8	-1	8	-1	-1	-0.010	-0.016	-0.007
0	-5	2	-4	2	-4	2	-0.036	0.048	0.020
-2	-8	-3	-7	-2	-7	7	-0.062	0.165	0.069
-4	-9	-12	-8	-11	-8	7	-0.073	0.163	0.068
-6	-10	-22	-9	-21	-10	6	-0.088	0.141	0.059
-8	-12	-30	-11	-29	-13	7	-0.113	0.172	0.072
-10	-14	-45	-13	-44	-17	2	-0.150	0.043	0.018

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	20	60	21	61	15	29	0.044	0.232	0.097
6	13	52	13	53	9	28	0.026	0.226	0.094
4	6	42	6	41	4	24	0.011	0.193	0.080
2	-1	32	0	32	-1	23	-0.003	0.187	0.07[illegible]
0	-10	20	-9	20	-9	20	-0.027	0.160	0.06[illegible]
-2	-18	10	-16	10	-15	19	-0.046	0.153	0.064
-4	-25	2	-23	2	-22	21	-0.067	0.167	0.069
-6	-32	-10	-31	-9	-30	20	-0.091	0.161	0.067
-8	-41	-21	-39	-20	-39	20	-0.117	0.160	0.067
-10	-50	-35	-49	-36	-51	16	-0.152	0.127	0.053

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	34	89	34	90	24	59	0.042	0.286	0.119
6	17	80	19	81	12	57	0.021	0.272	0.113
4	5	74	6	74	1	57	0.003	0.274	0.114
2	-5	62	-4	62	-6	53	-0.011	0.255	0.106
0	-19	58	-19	58	-19	58	-0.034	0.278	0.116
-2	-30	45	-29	46	-27	56	-0.049	0.267	0.111
-4	-43	35	-42	36	-39	56	-0.070	0.269	0.112
-6	-57	23	-56	25	-52	57	-0.093	0.271	0.113
-8	-72	10	-72	14	-67	58	-0.121	0.280	0.117
-10	-88	-3	-86	-9	-83	49	-0.149	0.235	0.098

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	52	98	54	102	42	74	0.054	0.254	0.106
6	31	90	31	91	23	68	0.029	0.233	0.097
4	11	71	12	71	8	54	0.010	0.187	0.078
2	-7	56	-6	56	-8	47	-0.010	0.162	0.067
0	-24	40	-23	39	-23	39	-0.030	0.134	0.056
-2	-43	25	-42	25	-41	35	-0.053	0.120	0.050
-4	-60	18	-60	19	-58	40	-0.074	0.138	0.058
-6	-82	-4	-81	-9	-80	25	-0.103	0.087	0.036
-8	-104	-38	-103	-44	-106	5	-0.136	0.018	0.007
-10	-127	-45	-126	-54	-130	12	-0.167	0.040	0.017

AOA	ANGLE OF ATTACK
CN	RAW NORMAL COUNTS
CA	RAW AXIAL COUNTS
CCN	CN CORRECTED FOR BALANCE INTERACTION
CCA	CA CORRECTED FOR BALANCE INTERACTION
IL	COUNTS OF LIFT
ID	COUNTS OF DRAG
CL	COEFFICIENT OF LIFT
CD	COEFFICIENT OF DRAG
RE	REYNOLDS NUMBER
Q	DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA	EQUIVALENT FLAT PLATE AREA(SQ FT)

TABLE 13 OUTPUT FILE 2

NOSE/TAIL 2 (ATTACK/SYMMETRIC) WEIGHT = 22.8 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	9	41	9	40	6	9	0.050	0.220	0.091
6	6	29	6	29	4	6	0.038	0.136	0.056
4	0	23	1	23	0	7	-0.000	0.171	0.071
2	-1	14	0	14	0	6	-0.003	0.145	0.060
0	-3	6	-2	6	-2	6	-0.018	0.144	0.060
-2	-4	0	-3	1	-3	9	-0.025	0.217	0.091
-4	-5	-7	-4	-6	-4	10	-0.035	0.245	0.102
-6	-8	-19	-7	-18	-8	7	-0.068	0.160	0.067
-8	-9	-26	-8	-25	-9	8	-0.083	0.194	0.081
-10	-12	-34	-11	-33	-13	9	-0.118	0.216	0.090

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	21	55	22	56	16	27	0.049	0.214	0.089
6	11	49	11	51	7	28	0.021	0.224	0.093
4	6	40	6	39	4	23	0.011	0.187	0.078
2	0	30	1	30	0	22	0.000	0.177	0.074
C	-8	20	-7	20	-7	20	-0.021	0.160	0.067
-2	-14	13	-13	13	-12	21	-0.037	0.171	0.071
-4	-20	6	-18	6	-17	23	-0.051	0.185	0.077
-6	-26	-5	-24	-4	-23	22	-0.069	0.179	0.075
-8	-35	-12	-34	-12	-33	25	-0.099	0.197	0.082
-10	-48	-29	-47	-31	-48	17	-0.145	0.138	0.057

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	34	78	35	80	26	52	0.046	0.251	0.105
6	21	73	23	74	16	52	0.029	0.250	0.104
4	8	63	8	63	4	48	0.007	0.228	0.095
2	0	55	1	56	-1	48	-0.001	0.231	0.096
0	-12	49	-11	49	-11	49	-0.020	0.235	0.098
-2	-21	43	-20	43	-18	52	-0.033	0.248	0.103
-4	-33	35	-32	35	-29	53	-0.052	0.255	0.106
-6	-46	29	-45	32	-40	60	-0.072	0.290	0.121
-8	-60	12	-60	15	-55	55	-0.099	0.264	0.110
-10	-77	0	-76	4	-71	57	-0.127	0.272	0.113

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	50	99	52	103	39	78	0.051	0.266	0.111
6	30	80	32	82	25	61	0.032	0.209	0.087
4	15	70	17	71	13	56	0.016	0.192	0.080
2	1	54	1	55	-1	47	-0.001	0.161	0.067
C	-16	45	-16	46	-16	46	-0.021	0.158	0.066
-2	-31	25	-30	25	-29	34	-0.037	0.117	0.049
-4	-46	15	-45	16	-43	35	-0.056	0.120	0.05C
-6	-65	6	-65	11	-62	42	-0.080	0.142	0.059
-8	-92	-16	-92	-20	-92	25	-0.118	0.085	0.035
-10	-115	-37	-114	-45	-117	15	-0.150	0.052	0.022

AOA	ANGLE OF ATTACK
CN	RAW NORMAL COUNTS
CA	RAW AXIAL COUNTS
CCN	CN CORRECTED FOR BALANCE INTERACTION
CCA	CA CORRECTED FOR BALANCE INTERACTION
IL	COUNTS OF LIFT
ID	COUNTS CF DRAG
CL	COEFFICIENT OF LIFT
CD	COEFFICIENT OF DRAG
RE	REYNOLDS NUMBER
Q	DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA	EQUIVALENT FLAT PLATE AREA(SQ FT)

TABLE 14 OUTPUT FILE 3

NOSE/TAIL 3 (ATTACK/LOW) WEIGHT = 24.7 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	11	42	11	41	8	8	0.068	0.186	0.078
6	7	30	7	30	5	5	0.047	0.114	0.048
4	4	22	4	22	3	5	0.028	0.120	0.050
2	0	8	1	8	1	-1	0.008	-0.014	-0.006
0	-2	-3	-1	-2	-1	-2	-0.009	-0.048	-0.020
-2	-4	-7	-3	-6	-3	3	-0.028	0.065	0.027
-4	-6	-15	-5	-14	-5	4	-0.048	0.087	0.036
-6	-7	-27	-6	-26	-7	1	-0.066	0.014	0.006
-8	-9	-38	-8	-37	-11	-1	-0.096	-0.028	-0.012
-10	-11	-48	-10	-47	-14	-2	-0.128	-0.040	-0.017

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	30	55	30	57	24	26	0.073	0.210	0.088
6	22	48	23	50	19	26	0.057	0.211	0.088
4	13	38	13	37	11	21	0.033	0.165	0.069
2	5	27	5	27	4	19	0.013	0.148	0.062
0	-1	14	0	14	0	14	0.0	0.112	0.047
-2	-9	6	-8	6	-8	15	-0.023	0.119	0.050
-4	-15	2	-14	2	-13	20	-0.040	0.162	0.067
-6	-21	-13	-20	-12	-20	16	-0.059	0.128	0.053
-8	-32	-28	-31	-27	-32	12	-0.096	0.096	0.040
-10	-38	-40	-37	-40	-40	10	-0.119	0.079	0.033

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	50	82	50	85	40	57	0.072	0.272	0.114
6	36	73	37	75	30	53	0.055	0.253	0.105
4	20	62	21	63	17	47	0.031	0.226	0.094
2	8	46	8	47	7	39	0.012	0.185	0.077
0	-2	36	-1	35	-1	35	-0.002	0.168	0.070
-2	-14	30	-13	30	-12	39	-0.021	0.187	0.078
-4	-27	20	-26	20	-24	39	-0.043	0.187	0.078
-6	-39	13	-37	14	-34	44	-0.061	0.209	0.087
-8	-54	-3	-53	-3	-50	39	-0.091	0.186	0.078
-10	-68	-15	-68	-17	-66	38	-0.119	0.182	0.076

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	71	99	73	104	60	79	0.077	0.270	0.113
6	51	90	52	93	43	72	0.056	0.247	0.103
4	29	75	31	77	26	62	0.034	0.212	0.088
2	10	60	10	60	8	52	0.010	0.177	0.074
0	-8	40	-7	40	-7	40	-0.009	0.137	0.057
-2	-23	27	-22	27	-21	36	-0.027	0.125	0.052
-4	-45	10	-43	12	-41	32	-0.053	0.110	0.046
-6	-60	-9	-58	-11	-57	21	-0.074	0.072	0.030
-8	-82	-30	-81	-33	-82	13	-0.106	0.044	0.019
-10	-104	-50	-103	-56	-107	6	-0.138	0.019	0.008

AOA	ANGLE OF ATTACK
CN	RAW NORMAL COUNTS
CA	RAW AXIAL COUNTS
CCN	CN CORRECTED FOR BALANCE INTERACTION
CCA	CA CORRECTED FOR BALANCE INTERACTION
IL	COUNTS OF LIFT
ID	COUNTS OF DRAG
CL	COEFFICIENT OF LIFT
CD	COEFFICIENT OF DRAG
RE	REYNOLDS NUMBER
Q	DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA	EQUIVALENT FLAT PLAT AREA(SQ FT)

TABLE 15 OUTPUT FILE 4

NOSE/TAIL 4 (BLUNT/HIGH) WEIGHT = 23.2 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	8	40	8	39	5	7	0.043	0.177	0.074
6	3	29	3	29	1	5	0.011	0.117	0.049
4	0	23	1	23	0	7	-0.000	0.163	0.068
2	-2	10	-1	10	-1	2	-0.011	0.044	0.018
0	-4	7	-3	7	-3	7	-0.027	0.168	0.070
-2	-8	-4	-7	-3	-7	5	-0.063	0.129	0.054
-4	-10	-10	-9	-9	-9	8	-0.081	0.189	0.079
-6	-12	-18	-11	-17	-11	9	-0.103	0.205	0.085
-8	-15	-29	-14	-28	-15	7	-0.139	0.157	0.066
-10	-17	-36	-16	-34	-18	10	-0.163	0.231	0.096

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	30	55	30	57	24	28	0.072	0.226	0.094
6	20	50	21	52	17	30	0.050	0.237	0.099
4	12	40	12	39	10	24	0.029	0.188	0.078
2	4	33	4	33	3	25	0.009	0.200	0.083
0	-4	22	-3	22	-3	22	-0.009	0.176	0.073
-2	-12	14	-11	14	-10	22	-0.031	0.180	0.075
-4	-19	4	-17	4	-16	21	-0.048	0.171	0.071
-6	-28	-6	-27	-5	-26	22	-0.078	0.177	0.074
-8	-34	-15	-33	-14	-32	23	-0.097	0.185	0.077
-10	-43	-25	-41	-24	-41	24	-0.123	0.191	0.079

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	48	89	48	91	37	64	0.067	0.309	0.129
6	32	79	34	81	27	60	0.048	0.287	0.120
4	19	70	21	71	17	56	0.030	0.269	0.112
2	6	65	7	65	5	57	0.009	0.274	0.114
0	-5	57	-4	57	-4	57	-0.007	0.274	0.114
-2	-20	41	-19	40	-17	49	-0.031	0.234	0.097
-4	-32	30	-31	30	-28	48	-0.051	0.232	0.097
-6	-45	22	-43	23	-39	52	-0.070	0.248	0.103
-8	-59	13	-58	15	-53	55	-0.096	0.265	0.111
-10	-74	0	-74	3	-69	56	-0.124	0.270	0.112

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	65	110	67	114	53	90	0.068	0.308	0.128
6	43	100	44	103	34	83	0.044	0.284	0.118
4	22	94	23	95	17	80	0.022	0.275	0.115
2	6	73	7	73	5	65	0.006	0.223	0.093
0	-8	62	-7	62	-7	62	-0.009	0.213	0.089
-2	-30	40	-29	40	-27	49	-0.035	0.168	0.070
-4	-49	23	-48	24	-46	43	-0.059	0.149	0.062
-6	-68	10	-68	14	-65	45	-0.083	0.155	0.065
-8	-89	0	-88	6	-84	51	-0.108	0.173	0.072
-10	-108	-15	-107	-20	-105	39	-0.135	0.135	0.056

AOA ANGLE OF ATTACK
CN RAW NORMAL COUNTS
CA RAW AXIAL COUNTS
CCN CN CORRECTED FOR BALANCE INTERACTION
CCA CA CORRECTED FOR BALANCE INTERACTION
IL COUNTS OF LIFT
ID COUNTS OF DRAG
CL COEFFICIENT OF LIFT
CD COEFFICIENT OF DRAG
RE REYNOLDS NUMBER
Q DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA EQUIVALENT FLAT PLATE AREA(SQ FT)

TABLE 16 OUTPUT FILE 5

NOSE/TAIL 5 (BLUNT/SYMMETRIC) WEIGHT = 21.3 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	8	33	8	33	5	4	0.049	0.099	0.041
6	4	28	4	28	2	6	0.020	0.143	0.060
4	1	22	1	22	0	7	-0.000	0.171	0.071
2	-1	13	0	13	0	6	-0.003	0.133	0.055
0	-2	5	-1	5	-1	5	-0.009	0.120	0.050
-2	-4	-3	-3	-2	-3	6	-0.026	0.133	0.056
-4	-7	-9	-6	-8	-6	7	-0.054	0.176	0.073
-6	-8	-22	-7	-21	-8	2	-0.072	0.051	0.021
-8	-10	-30	-9	-29	-11	2	-0.098	0.053	0.022
-10	-11	-37	-10	-36	-13	3	-0.116	0.080	0.033

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	24	60	25	61	18	34	0.055	0.274	0.114
6	16	48	17	50	13	29	0.039	0.234	0.097
4	9	40	9	39	7	25	0.020	0.197	0.082
2	3	30	3	30	2	23	0.006	0.181	0.075
0	-3	21	-2	21	-2	21	-0.006	0.168	0.070
-2	-10	13	-9	13	-8	21	-0.025	0.166	0.069
-4	-17	0	-15	1	-14	17	-0.043	0.135	0.056
-6	-25	-10	-24	-9	-24	16	-0.071	0.127	0.053
-8	-32	-24	-30	-23	-31	11	-0.092	0.089	0.037
-10	-40	-34	-38	-33	-40	11	-0.120	0.089	0.037

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	47	88	47	90	36	66	0.065	0.317	0.132
6	29	78	31	80	24	61	0.043	0.290	0.121
4	18	67	20	68	16	54	0.028	0.261	0.109
2	6	58	6	58	4	51	0.007	0.244	0.101
0	-2	45	-1	46	-1	46	-0.002	0.221	0.092
-2	-15	36	-14	35	-13	43	-0.023	0.206	0.086
-4	-28	18	-27	18	-25	35	-0.045	0.167	0.069
-6	-40	2	-38	3	-36	29	-0.065	0.140	0.059
-8	-53	-5	-52	-6	-50	31	-0.090	0.149	0.062
-10	-68	-22	-68	-24	-68	25	-0.122	0.121	0.050

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	63	126	64	127	48	105	0.061	0.360	0.150
6	44	108	45	111	34	93	0.044	0.318	0.133
4	27	96	28	98	22	85	0.028	0.291	0.121
2	10	75	11	75	9	68	0.011	0.233	0.097
0	-3	62	-2	62	-2	62	-0.003	0.213	0.089
-2	-21	40	-20	39	-18	47	-0.024	0.162	0.067
-4	-42	20	-40	20	-38	38	-0.049	0.129	0.054
-6	-61	0	-61	1	-59	30	-0.076	0.102	0.042
-8	-78	-4	-77	-9	-75	31	-0.097	0.108	0.045
-10	-101	-20	-100	-25	-100	30	-0.128	0.102	0.043

AOA ANGLE OF ATTACK
CN RAW NORMAL COUNTS
CA RAW AXIAL COUNTS
CCN CN CORRECTED FOR BALANCE INTERACTION
CCA CA CORRECTED FOR BALANCE INTERACTION
IL COUNTS OF LIFT
ID COUNTS OF DRAG
CL COEFFICIENT OF LIFT
CD COEFFICIENT OF DRAG
RE REYNOLDS NUMBER
Q DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA EQUIVALENT FLAT PLATE AREA(SQ FT)

TABLE 17 OUTPUT FILE 6

NOSE/TAIL 6 (BLUNT/LOW) WEIGHT = 23.2 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	11	47	11	49	6	18	0.057	0.425	0.177
6	7	40	7	39	4	15	0.037	0.365	0.152
4	4	30	4	30	2	14	0.022	0.336	0.140
2	1	22	1	22	0	14	0.003	0.334	0.139
0	-1	15	0	15	0	15	0.0	0.360	0.150
-2	-3	5	-2	5	-2	13	-0.015	0.316	0.132
-4	-5	0	-4	1	-3	17	-0.030	0.420	0.175
-6	-7	-5	-6	-4	-5	21	-0.046	0.503	0.209
-8	-8	-18	-7	-17	-7	16	-0.063	0.395	0.165
-10	-9	-25	-8	-24	-9	18	-0.077	0.434	0.181

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	36	56	36	58	30	30	0.090	0.241	0.100
6	24	48	25	50	21	28	0.063	0.224	0.094
4	17	40	17	40	15	25	0.044	0.199	0.083
2	10	30	10	30	9	22	0.027	0.178	0.074
0	2	21	2	21	2	21	0.006	0.168	0.070
-2	-6	12	-5	12	-4	20	-0.013	0.162	0.068
-4	-13	3	-12	3	-11	20	-0.034	0.160	0.067
-6	-20	-3	-18	-2	-17	24	-0.051	0.193	0.081
-8	-30	-17	-28	-16	-28	20	-0.083	0.163	0.068
-10	-37	-25	-35	-24	-35	23	-0.105	0.182	0.076

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	60	85	61	88	50	63	0.091	0.304	0.127
6	47	75	47	79	40	59	0.072	0.284	0.118
4	35	65	35	68	31	54	0.055	0.260	0.108
2	20	56	21	57	19	50	0.034	0.238	0.099
0	6	47	6	49	6	49	0.011	0.235	0.098
-2	-3	38	-2	37	-1	45	-0.001	0.217	0.090
-4	-17	30	-16	30	-13	47	-0.024	0.227	0.095
-6	-30	20	-29	20	-25	47	-0.046	0.227	0.094
-8	-45	8	-43	11	-39	49	-0.070	0.236	0.098
-10	-53	0	-52	1	-48	50	-0.086	0.242	0.101

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	87	94	89	101	76	80	0.098	0.275	0.114
6	68	84	69	88	61	70	0.078	0.242	0.101
4	49	70	50	74	45	61	0.058	0.209	0.087
2	28	59	28	60	26	53	0.033	0.181	0.075
0	5	40	5	39	5	39	0.006	0.134	0.056
-2	-12	20	-11	20	-10	28	-0.013	0.098	0.041
-4	-30	3	-28	3	-27	21	-0.035	0.073	0.030
-6	-50	-10	-49	-11	-49	18	-0.062	0.063	0.026
-8	-68	-23	-68	-25	-69	17	-0.088	0.058	0.024
-10	-92	-45	-93	-51	-97	6	-0.125	0.022	0.009

AOA ANGLE OF ATTACK
CN RAW NORMAL COUNTS
CA RAW AXIAL COUNTS
CCN CN CORRECTED FOR BALANCE INTERACTION
CCA CA CORRECTED FOR BALANCE INTERACTION
IL COUNTS OF LIFT
ID COUNTS OF DRAG
CL COEFFICIENT OF LIFT
CD COEFFICIENT OF DRAG
RE REYNOLDS NUMBER
Q DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA EQUIVALENT FLAT PLATE AREA(SQ FT)

TABLE 18 OUTPUT FILE 7

NOSE/TAIL 7 (SMOOTH/HIGH) WEIGHT = 22.7 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	8	40	8	39	5	8	0.042	0.195	0.081
6	4	34	4	34	2	10	0.015	0.252	0.105
4	1	26	1	26	0	10	-0.002	0.244	0.102
2	-2	20	-1	20	-2	12	-0.014	0.289	0.120
0	-6	7	-5	7	-5	7	-0.045	0.168	0.070
-2	-9	2	-8	2	-8	10	-0.070	0.245	0.102
-4	-10	-4	-9	-3	-9	13	-0.078	0.324	0.135
-6	-13	-18	-12	-17	-12	8	-0.112	0.194	0.081
-8	-16	-23	-14	-22	-15	12	-0.132	0.283	0.118
-10	-18	-32	-17	-31	-19	12	-0.168	0.285	0.119

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	15	44	16	45	12	15	0.035	0.121	0.051
6	8	33	8	33	6	10	0.017	0.079	0.033
4	1	28	1	28	0	12	-0.001	0.097	0.041
2	-2	18	-1	18	-1	10	-0.004	0.080	0.033
0	-8	7	-7	7	-7	7	-0.021	0.056	0.023
-2	-15	-3	-14	-2	-14	6	-0.042	0.051	0.021
-4	-19	-12	-18	-11	-18	6	-0.055	0.049	0.020
-6	-25	-22	-23	-21	-24	5	-0.071	0.042	0.018
-8	-30	-33	-29	-32	-31	4	-0.093	0.032	0.013
-10	-37	-43	-36	-45	-40	1	-0.119	0.011	0.005

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	42	92	42	94	31	67	0.055	0.323	0.135
6	27	78	29	80	22	59	0.039	0.282	0.118
4	13	70	14	70	10	55	0.017	0.264	0.110
2	1	63	1	63	-1	55	-0.002	0.264	0.110
0	-13	45	-12	45	-12	45	-0.022	0.216	0.090
-2	-26	35	-25	35	-24	44	-0.043	0.210	0.088
-4	-41	17	-39	18	-37	37	-0.067	0.175	0.073
-6	-56	3	-55	6	-53	35	-0.095	0.170	0.071
-8	-70	-8	-69	-11	-68	30	-0.122	0.146	0.061
-10	-82	-20	-81	-23	-80	31	-0.145	0.148	0.062

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	65	114	68	118	53	95	0.068	0.325	0.135
6	39	90	39	91	31	71	0.039	0.243	0.101
4	20	80	22	81	17	66	0.022	0.228	0.095
2	0	58	1	58	-1	50	-0.001	0.172	0.072
0	-20	45	-20	46	-20	46	-0.026	0.158	0.066
-2	-40	25	-39	25	-38	34	-0.049	0.118	0.049
-4	-63	5	-63	9	-62	29	-0.079	0.100	0.042
-6	-84	-12	-83	-16	-83	17	-0.107	0.057	0.024
-8	-105	-20	-104	-26	-104	20	-0.134	0.070	0.029
-10	-128	-37	-127	-46	-130	16	-0.167	0.056	0.023

AOA	ANGLE OF ATTACK
CN	RAW NORMAL COUNTS
CA	RAW AXIAL COUNTS
CCN	CN CORRECTED FOR BALANCE INTERACTION
CCA	CA CORRECTED FOR BALANCE INTERACTION
IL	COUNTS OF LIFT
ID	COUNTS OF DRAG
CL	COEFFICIENT OF LIFT
CD	COEFFICIENT OF DRAG
RE	REYNOLDS NUMBER
Q	DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA	EQUIVALENT FLAT PLATE AREA (SQ FT)

TABLE 19 OUTPUT FILE 8

NOSE/TAIL 8 (SMOOTH/SYMMETRIC) WEIGHT = 20.8 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	6	38	6	37	3	9	0.025	0.204	0.085
6	4	32	4	32	2	10	0.016	0.252	0.105
4	0	20	1	20	0	6	0.001	0.132	0.055
2	-1	12	0	12	0	5	-0.003	0.113	0.047
0	-5	4	-4	4	-4	4	-0.036	0.096	0.040
-2	-6	-2	-5	-1	-5	6	-0.044	0.155	0.064
-4	-10	-13	-9	-12	-9	3	-0.084	0.076	0.032
-6	-10	-20	-9	-19	-10	4	-0.088	0.091	0.038
-8	-12	-30	-11	-29	-13	2	-0.116	0.043	0.018
-10	-13	-40	-12	-39	-15	0	-0.139	-0.004	-0.002

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	27	65	28	67	20	41	0.061	0.330	0.138
6	19	50	20	52	16	32	0.047	0.256	0.107
4	9	48	9	50	6	36	0.018	0.288	0.120
2	3	38	3	37	2	30	0.006	0.239	0.099
0	-3	24	-2	24	-2	24	-0.006	0.192	0.080
-2	-11	15	-10	15	-9	23	-0.028	0.181	0.075
-4	-21	2	-19	2	-18	18	-0.055	0.143	0.059
-6	-30	-8	-29	-7	-28	18	-0.085	0.143	0.059
-8	-39	-18	-37	-17	-37	17	-0.111	0.138	0.058
-10	-49	-39	-48	-40	-51	5	-0.153	0.041	0.017

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	36	87	36	88	25	63	0.046	0.303	0.126
6	23	78	25	79	18	59	0.032	0.285	0.119
4	10	67	11	67	7	53	0.012	0.255	0.106
2	-2	58	-1	58	-3	51	-0.005	0.243	0.101
0	-13	42	-12	42	-12	42	-0.022	0.202	0.084
-2	-27	33	-26	33	-25	41	-0.044	0.198	0.082
-4	-40	17	-38	18	-36	35	-0.065	0.169	0.070
-6	-53	3	-52	4	-50	31	-0.090	0.150	0.062
-8	-67	-5	-66	-9	-65	29	-0.116	0.140	0.058
-10	-83	-22	-82	-25	-82	26	-0.147	0.124	0.052

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	55	111	57	114	43	92	0.055	0.315	0.131
6	38	98	39	101	29	83	0.038	0.284	0.118
4	16	79	18	80	13	67	0.017	0.228	0.095
2	0	61	1	61	-1	54	-0.001	0.184	0.077
0	-15	42	-14	41	-14	41	-0.018	0.141	0.059
-2	-35	25	-34	25	-33	33	-0.042	0.115	0.048
-4	-56	3	-55	6	-54	24	-0.069	0.083	0.035
-6	-80	-13	-79	-17	-79	13	-0.102	0.045	0.019
-8	-102	-28	-101	-33	-103	10	-0.132	0.035	0.015
-10	-121	-55	-120	-61	-126	-3	-0.161	-0.011	-0.004

AOA	ANGLE OF ATTACK
CN	RAW NORMAL COUNTS
CA	RAW AXIAL COUNTS
CCN	CN CORRECTED FOR BALANCE INTERACTION
CCA	CA CORRECTED FOR BALANCE INTERACTION
IL	COUNTS OF LIFT
ID	COUNTS OF DRAG
CL	COEFFICIENT OF LIFT
CD	COEFFICIENT OF DRAG
RE	REYNOLDS NUMBER
Q	DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA	EQUIVALENT FLAT PLATE AREA(SQ FT)

TABLE 20 OUTPUT FILE 9

NOSE/TAIL 9 (SMOOTH/LOW) WEIGHT = 22.7 LBS

Q=10 RE=.175E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	12	42	12	41	8	11	0.075	0.256	0.107
6	9	29	9	29	7	6	0.064	0.145	0.060
4	5	20	5	20	4	4	0.037	0.107	0.045
2	2	7	2	7	2	-1	0.017	-0.021	-0.009
0	0	2	1	2	1	2	0.009	0.048	0.020
-2	-2	-7	-1	-6	-1	2	-0.010	0.047	0.020
-4	-4	-19	-3	-18	-4	-2	-0.033	-0.046	-0.019
-6	-6	-24	-5	-23	-6	1	-0.055	0.034	0.014
-8	-7	-38	-6	-37	-9	-4	-0.080	-0.100	-0.042
-10	-9	-45	-8	-44	-12	-2	-0.109	-0.060	-0.025

Q=30 RE=.303E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	38	60	38	62	31	35	0.094	0.281	0.117
6	29	52	29	55	24	34	0.073	0.272	0.113
4	20	40	20	40	18	25	0.053	0.204	0.085
2	10	29	10	29	9	21	0.027	0.171	0.071
0	4	18	4	18	4	18	0.012	0.144	0.060
-2	-2	2	-1	2	-1	10	-0.002	0.080	0.033
-4	-12	-12	-11	-11	-11	6	-0.034	0.045	0.019
-6	-21	-22	-19	-21	-20	5	-0.060	0.039	0.016
-8	-30	-33	-29	-32	-31	4	-0.093	0.032	0.013
-10	-36	-47	-35	-50	-40	-4	-0.119	-0.030	-0.012

Q=50 RE=.391E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	58	83	59	86	49	62	0.088	0.296	0.124
6	44	77	45	79	38	60	0.068	0.286	0.119
4	27	63	27	64	23	50	0.041	0.239	0.100
2	14	54	14	55	12	48	0.022	0.228	0.095
0	1	39	1	38	1	38	0.002	0.182	0.076
-2	-13	26	-12	26	-11	34	-0.020	0.165	0.069
-4	-29	18	-28	18	-26	36	-0.047	0.172	0.072
-6	-43	3	-41	4	-39	32	-0.070	0.154	0.064
-8	-57	-12	-55	-14	-54	25	-0.098	0.122	0.051
-10	-72	-28	-72	-31	-73	21	-0.131	0.103	0.043

Q=70 RE=.463E+07

AOA	CN	CA	CCN	CCA	IL	ID	CL	CD	EFPA
8	83	109	87	115	72	94	0.093	0.324	0.135
6	62	90	63	93	54	75	0.070	0.258	0.108
4	40	80	41	82	36	69	0.046	0.236	0.098
2	19	54	20	55	18	48	0.023	0.164	0.068
0	0	35	1	35	1	35	0.001	0.120	0.050
-2	-21	20	-20	20	-19	29	-0.025	0.098	0.041
-4	-42	0	-40	1	-39	20	-0.051	0.067	0.028
-6	-64	-21	-64	-22	-65	9	-0.083	0.029	0.012
-8	-84	-42	-84	-48	-88	-4	-0.113	-0.014	-0.006
-10	-105	-65	-104	-71	-111	-12	-0.143	-0.043	-0.018

AOA	ANGLE OF ATTACK
CN	RAW NORMAL COUNTS
CA	RAW AXIAL COUNTS
CCN	CN CORRECTED FOR BALANCE INTERACTION
CCA	CA CORRECTED FOR BALANCE INTERACTION
IL	COUNTS OF LIFT
ID	COUNTS OF DRAG
CL	COEFFICIENT OF LIFT
CD	COEFFICIENT OF DRAG
RE	REYNOLDS NUMBER
Q	DYNAMIC PRESSURE,Q, IN POUNDS PER SQUARE FOOT
EFPA	EQUIVALENT FLAT PLATE AREA(SQ FT)

APPENDIX D : FIGURES

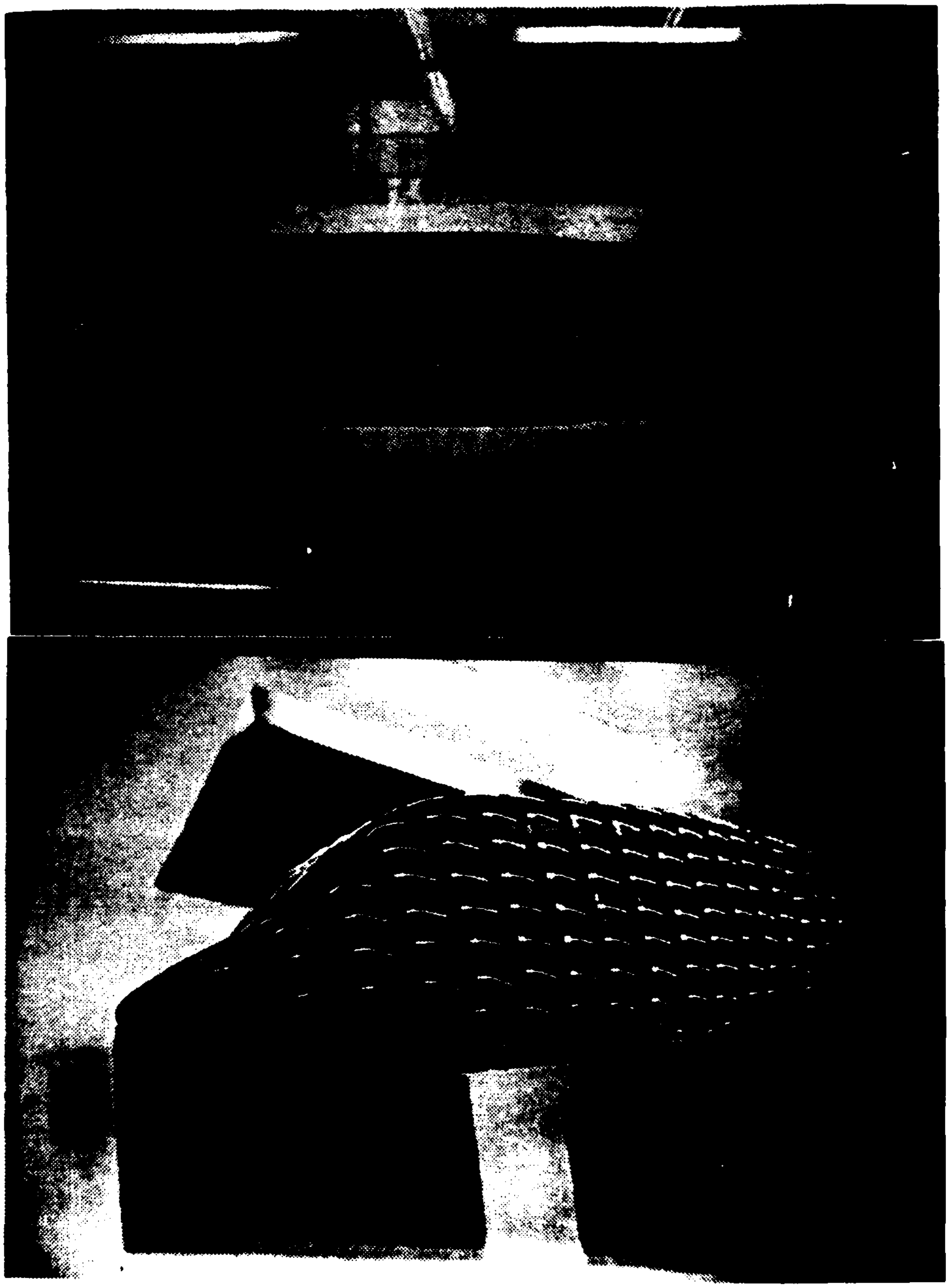


Fig. 1 Smooth/Scout Nose

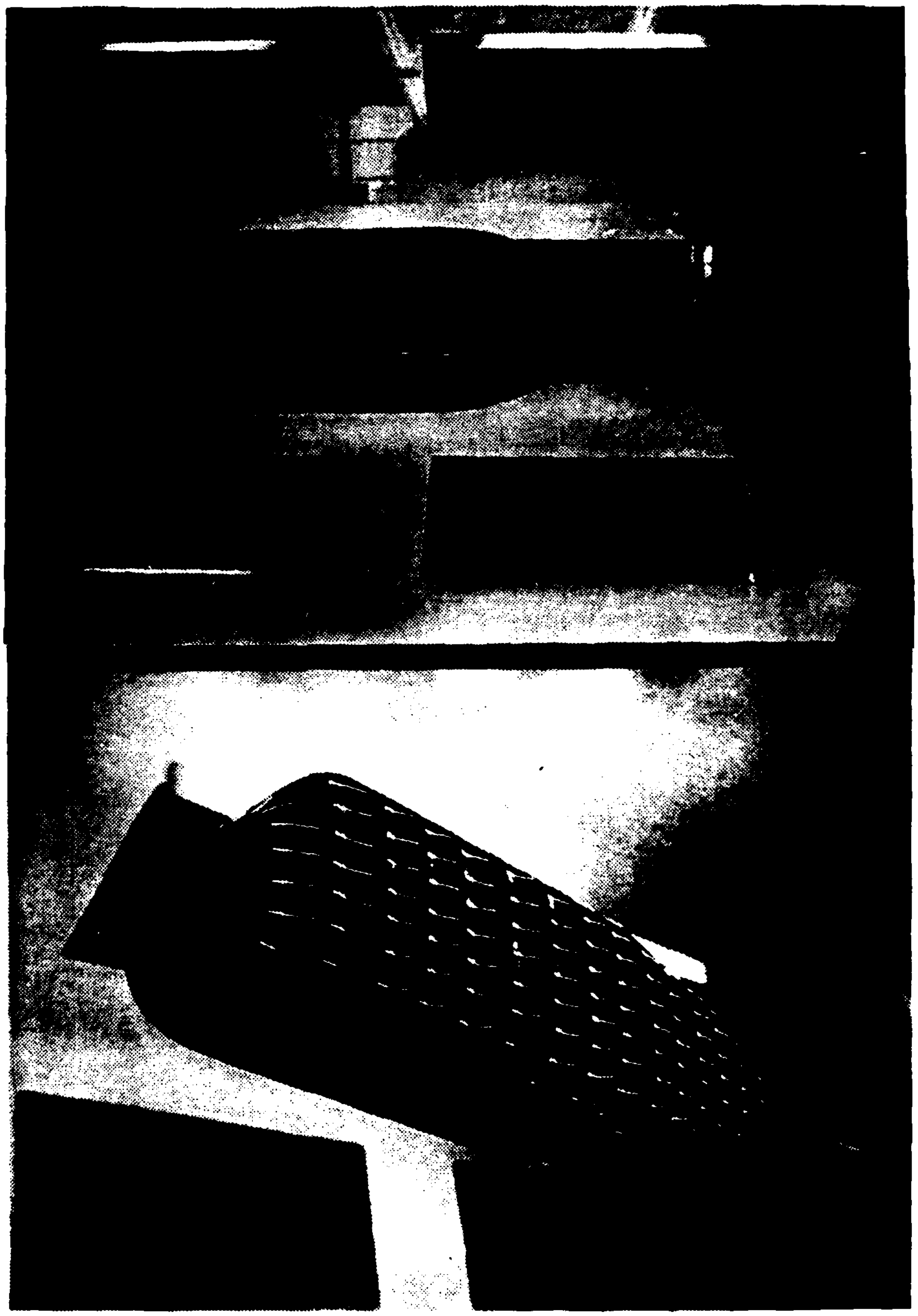


Fig . 2 Blunt Nose

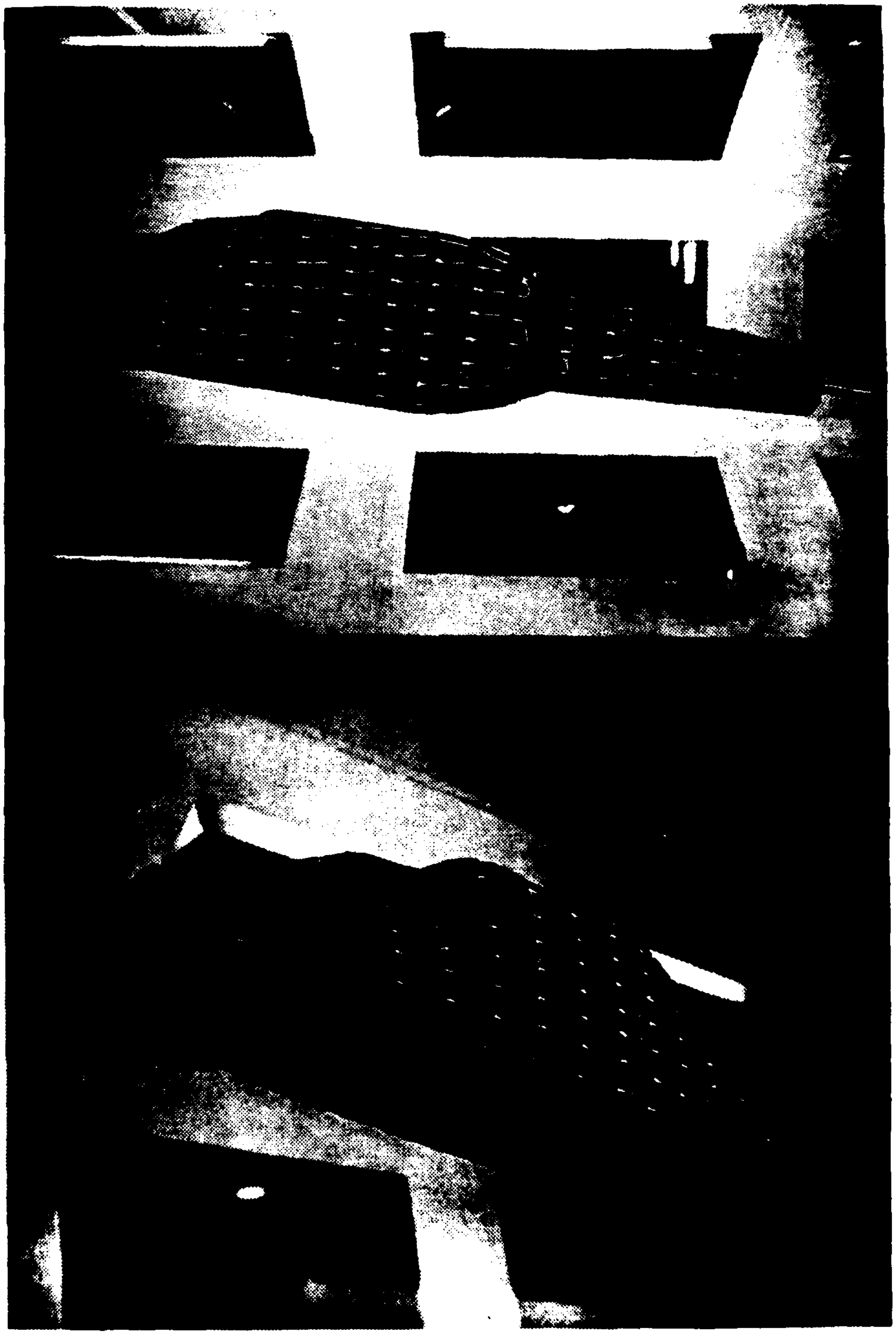


Fig. 3 Attack Nose

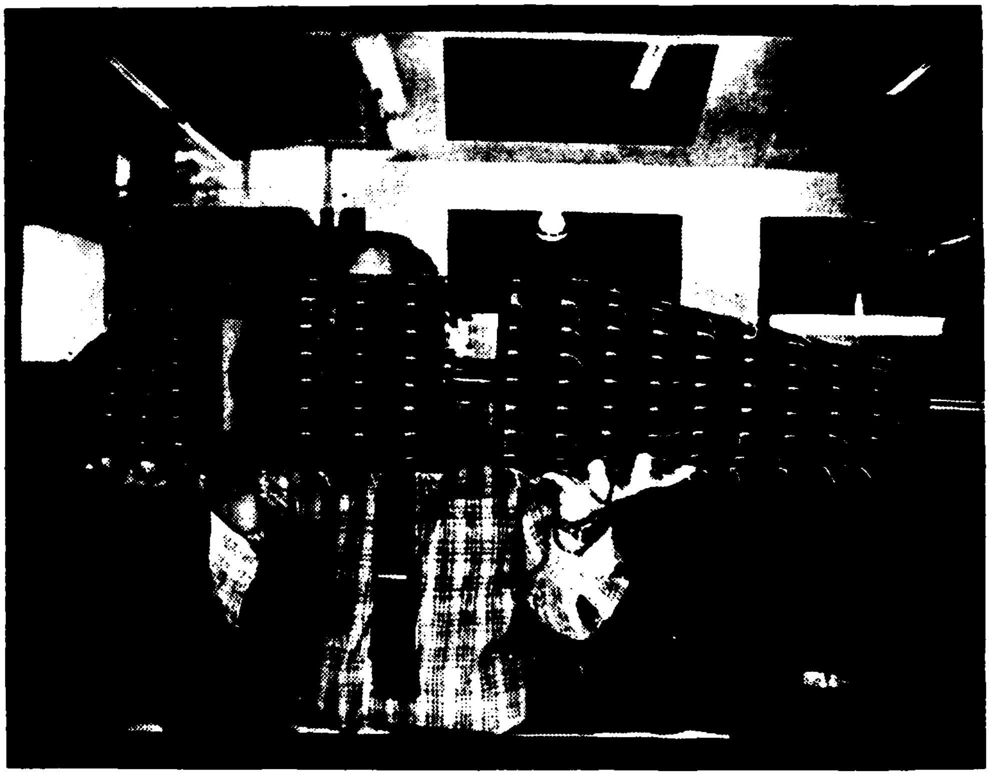


Fig. 4 Center Section

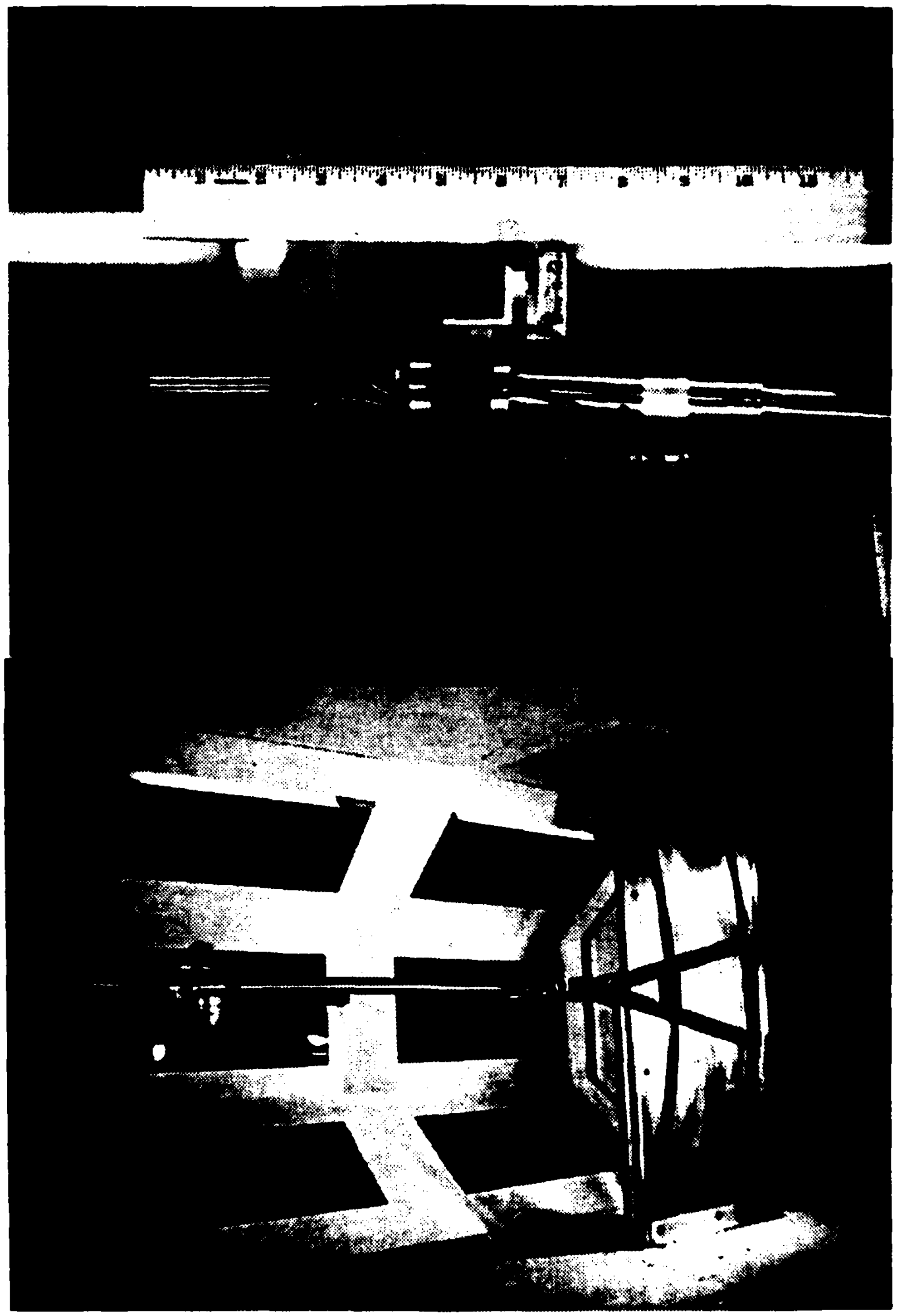


Fig. 5 Balance

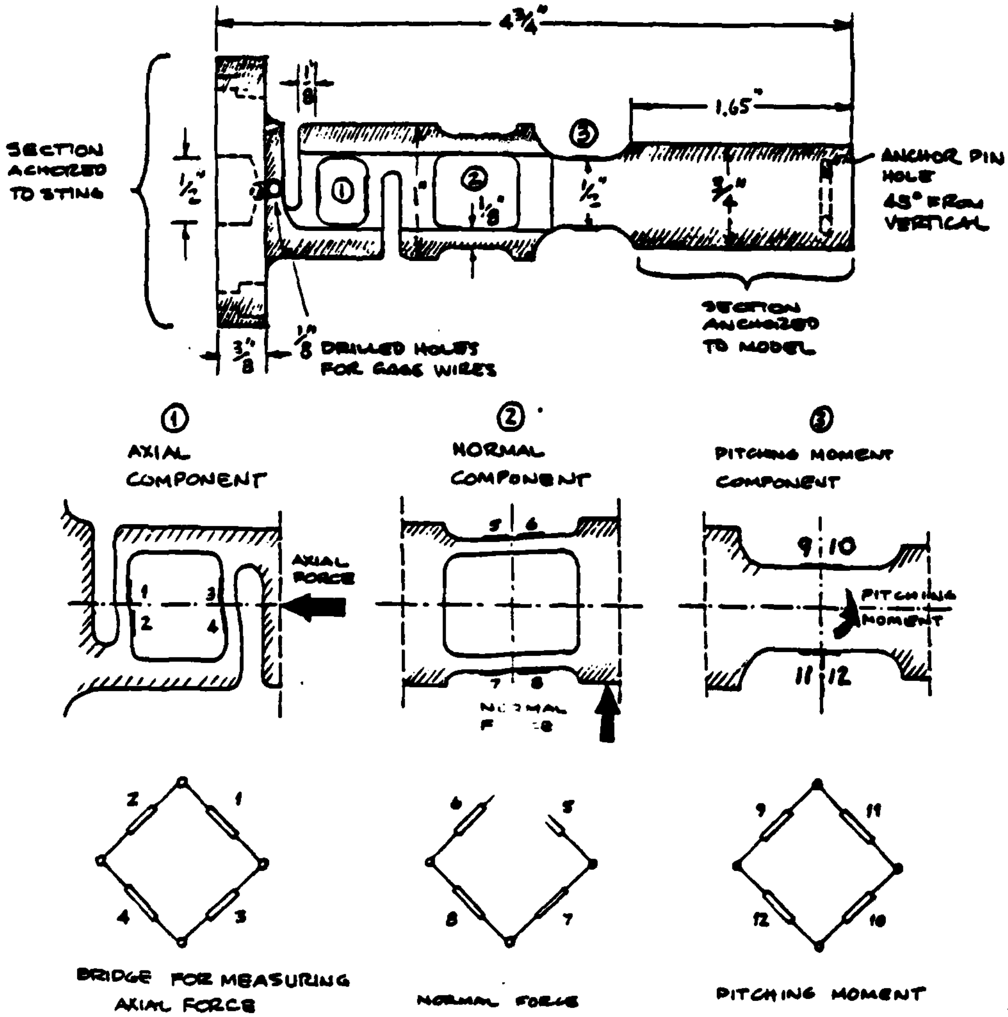


Fig. 6 Bridge Diagram

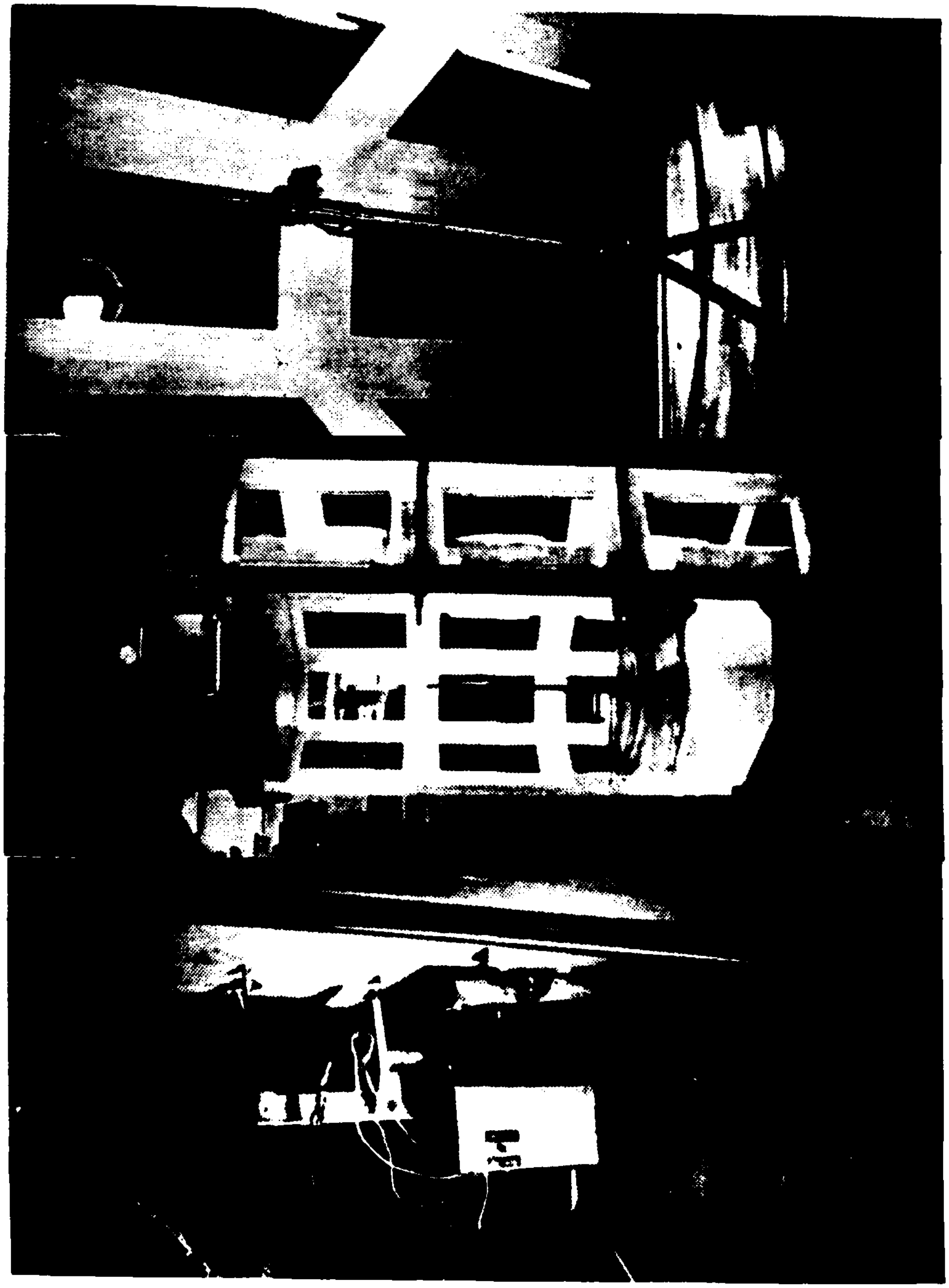


Fig. 7 Support System

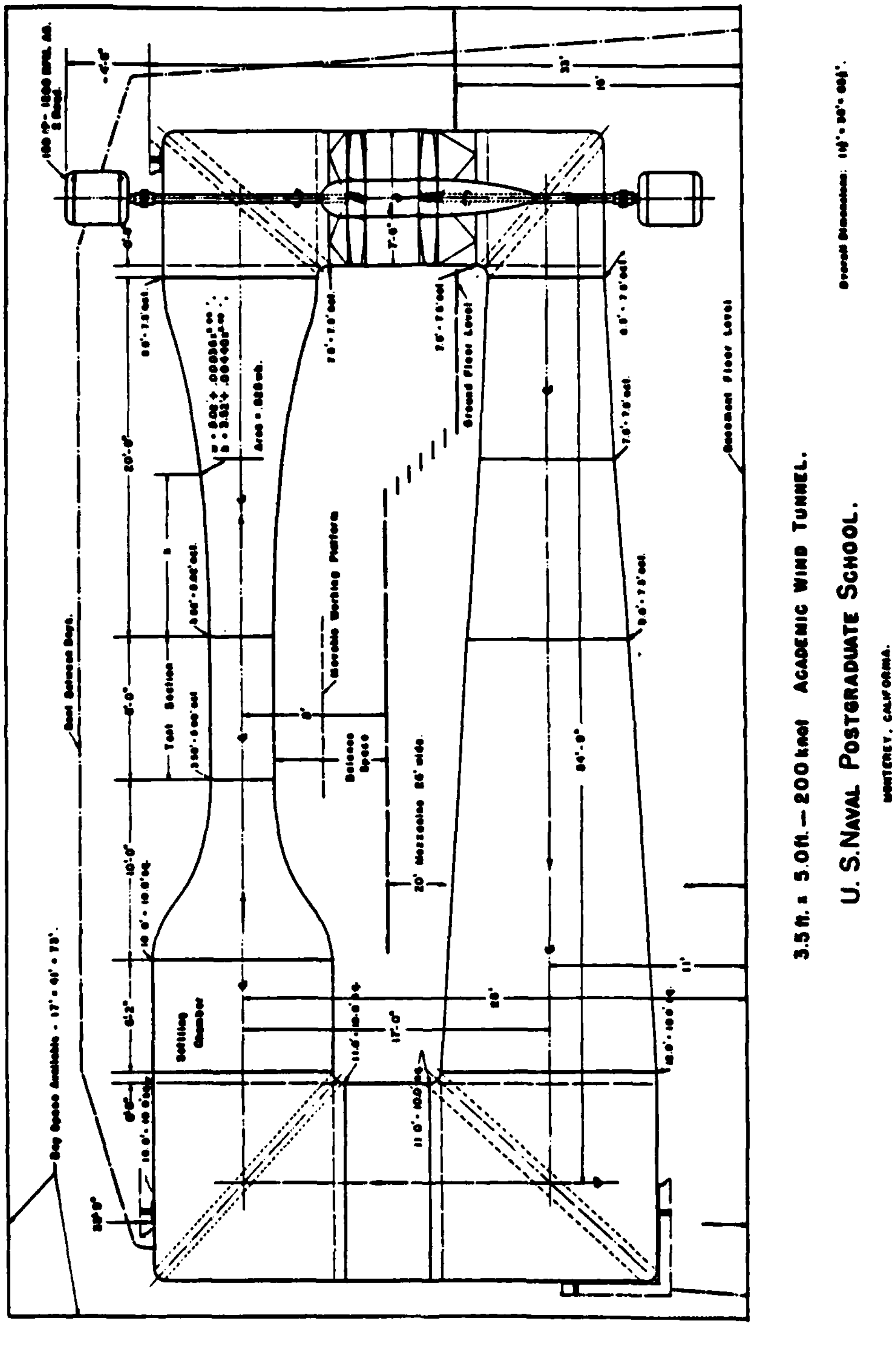


Fig. 7 Wind Tunnel Diagram (Cont'd)

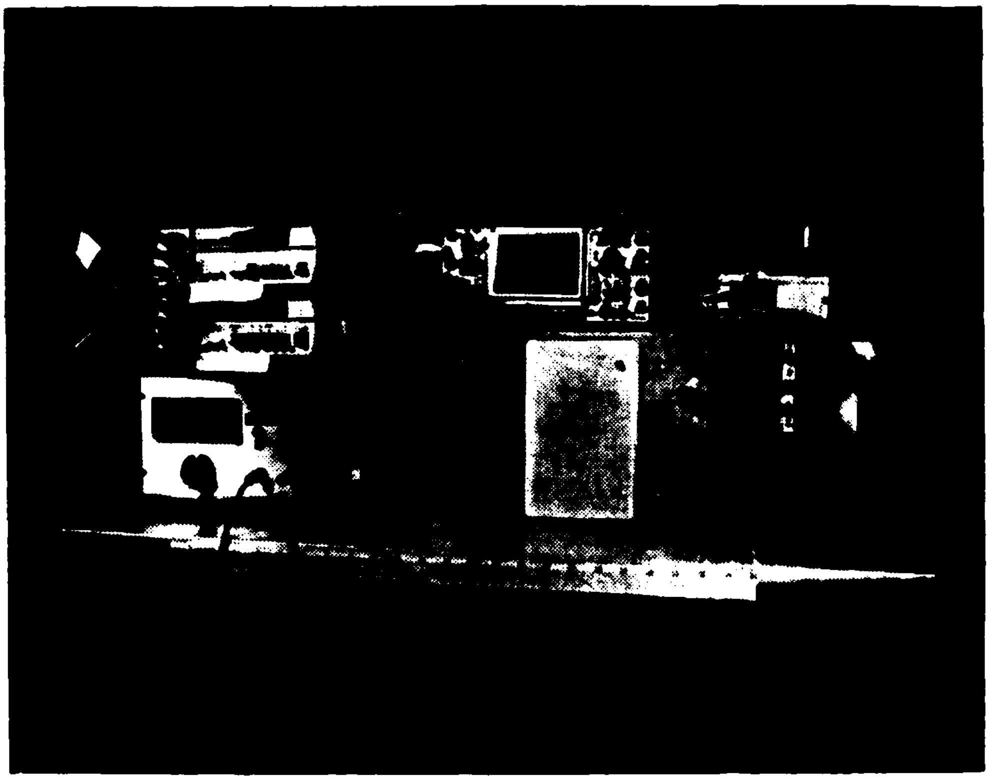


Fig. 8 Test Equipment

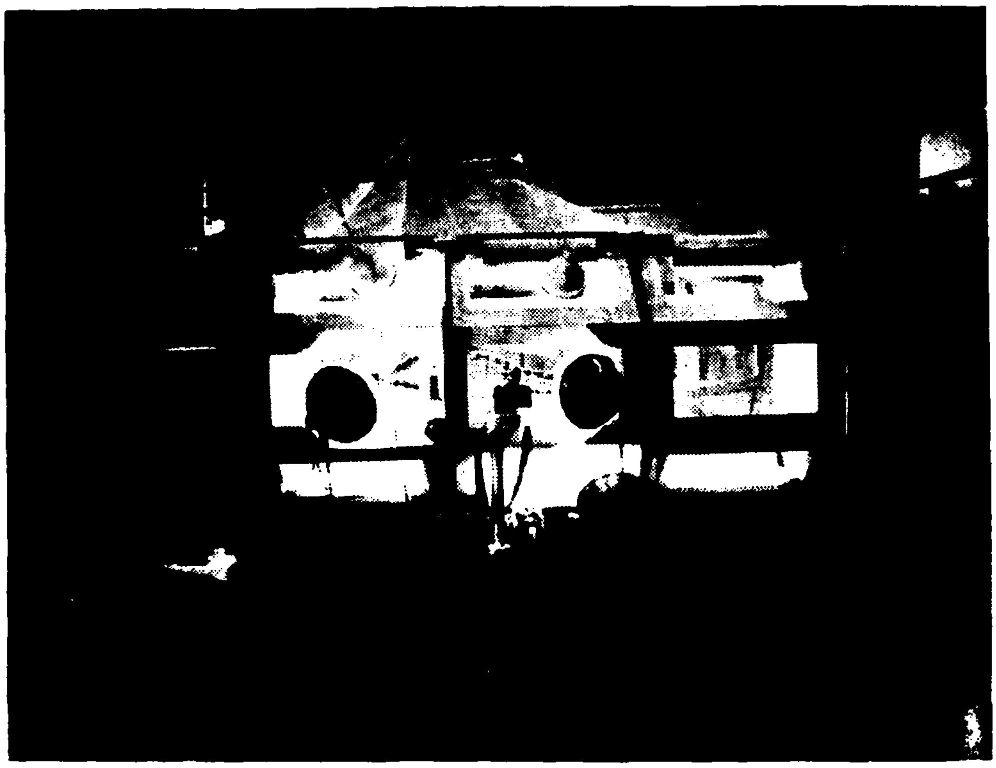


Fig. 9 Camera at Tunnel

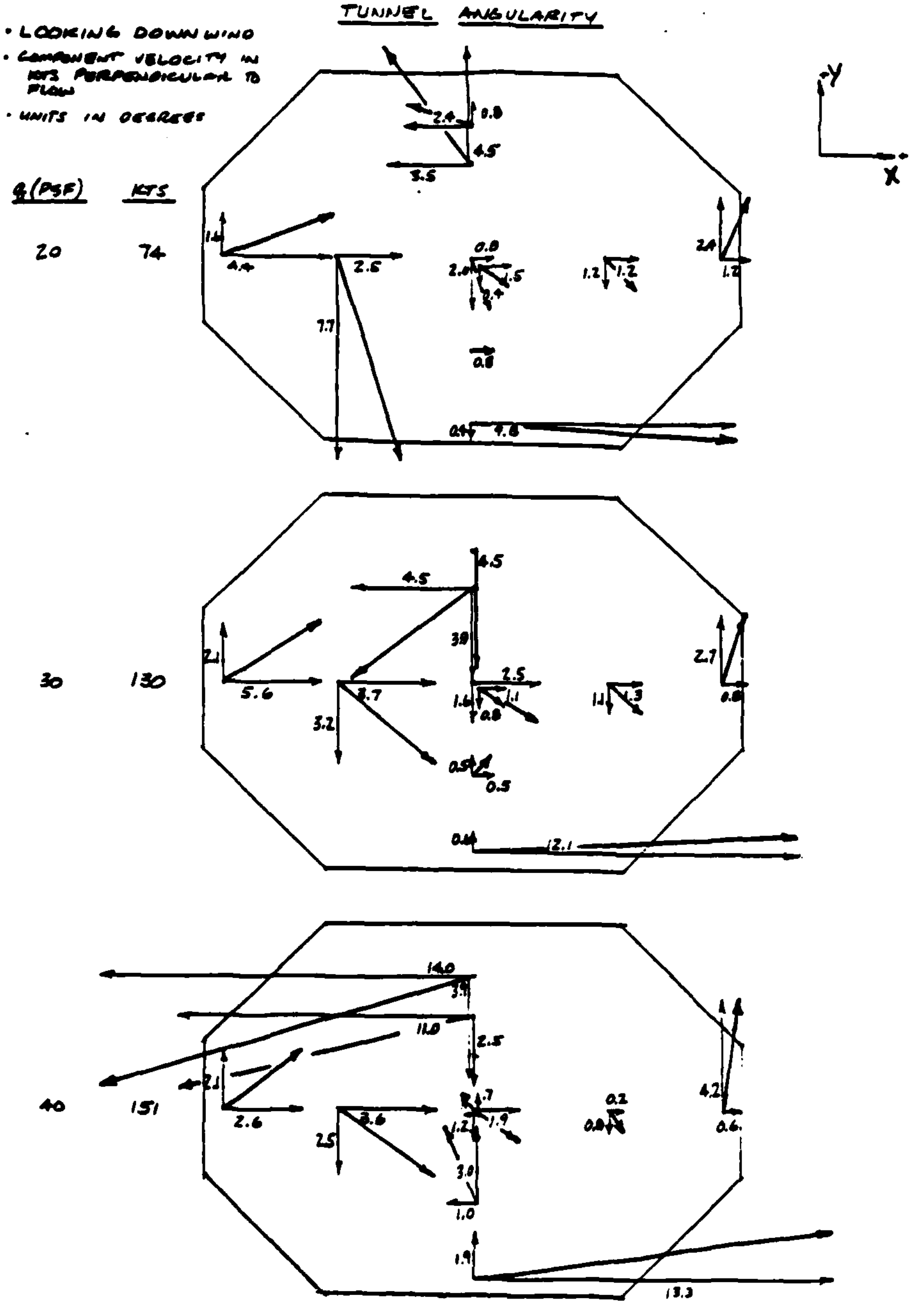

TUNNEL ANGULARITY
• LOOKING DOWNWIND
• COMPONENT VELOCITY IN KTS PERPENDICULAR TO FLOW
• UNITS IN DEGREES
q (PSF)
KTS
20
74
30
130
40
151
Y
X

Fig. 10 Swirl

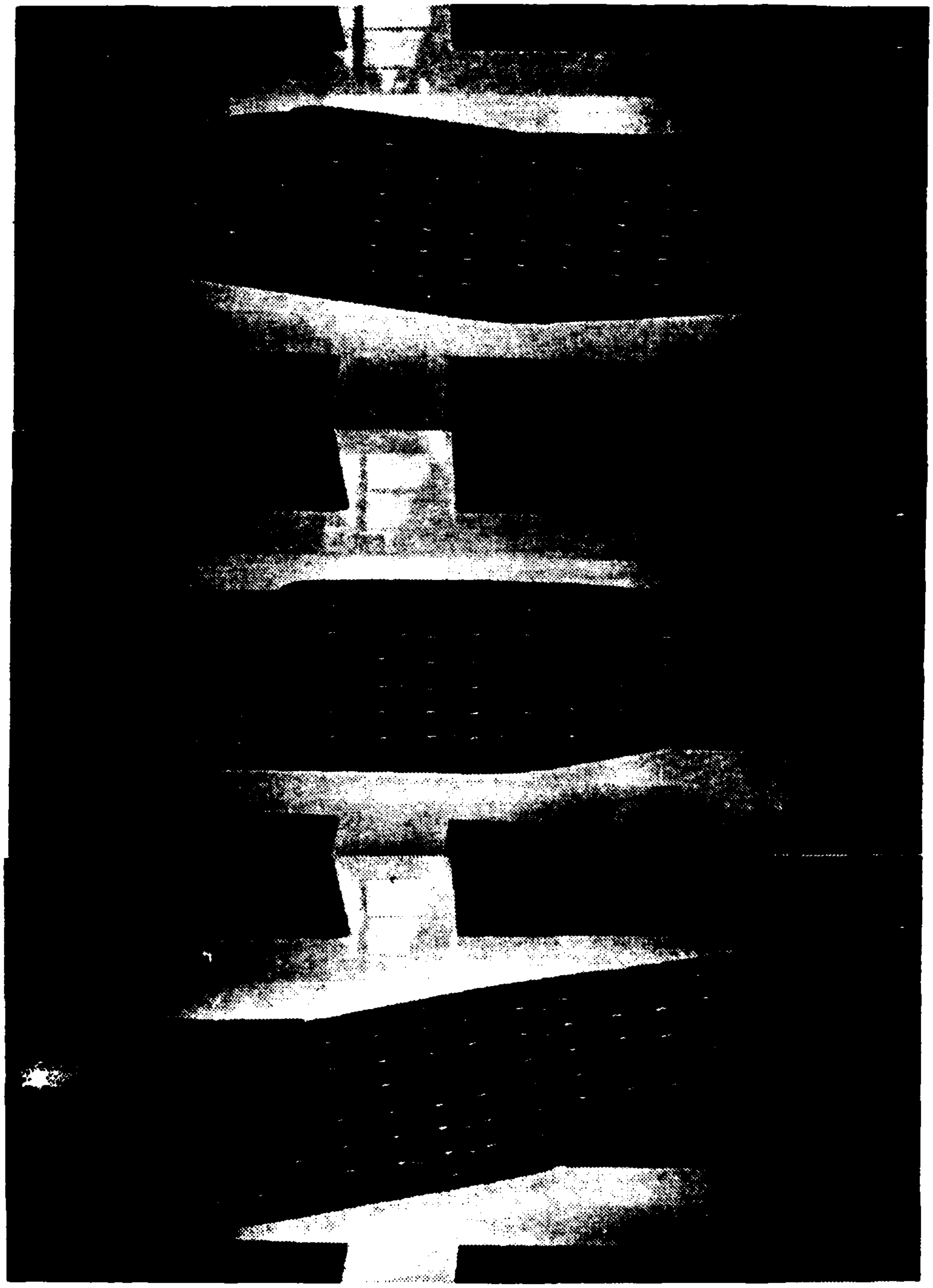


Fig. 11 Attack/High

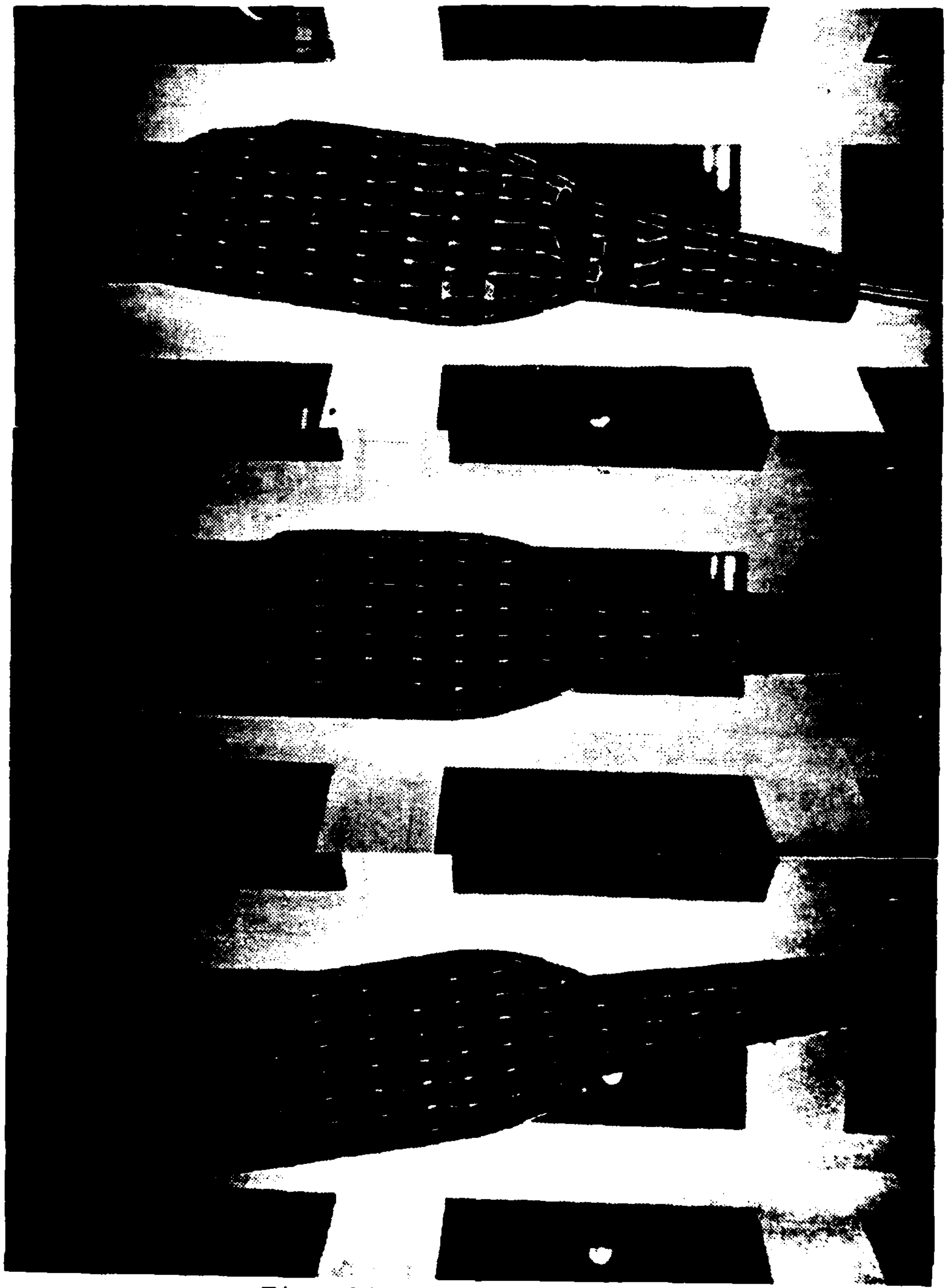


Fig. 12 Attack/Middle

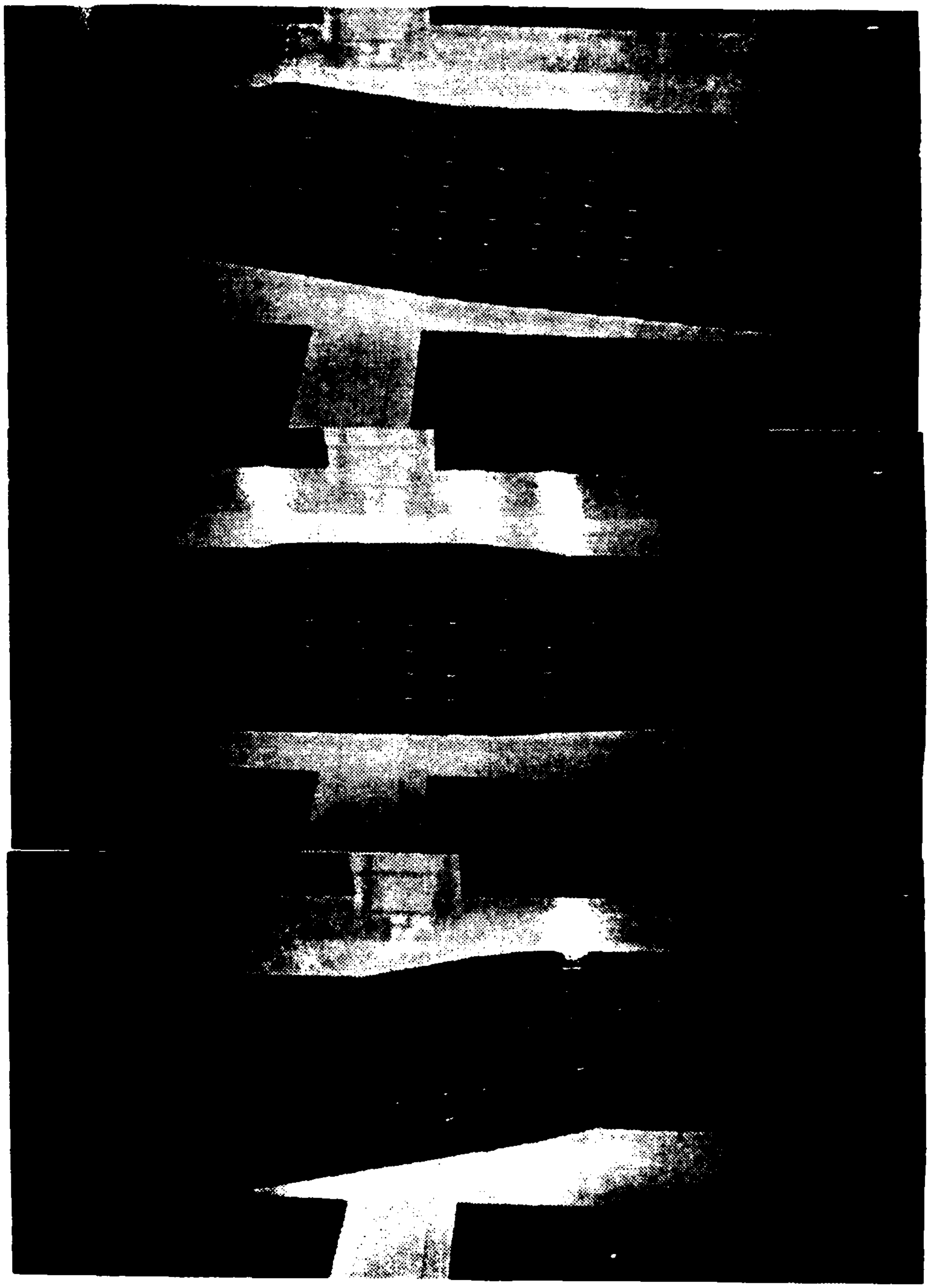


Fig. 13 Attack/Low

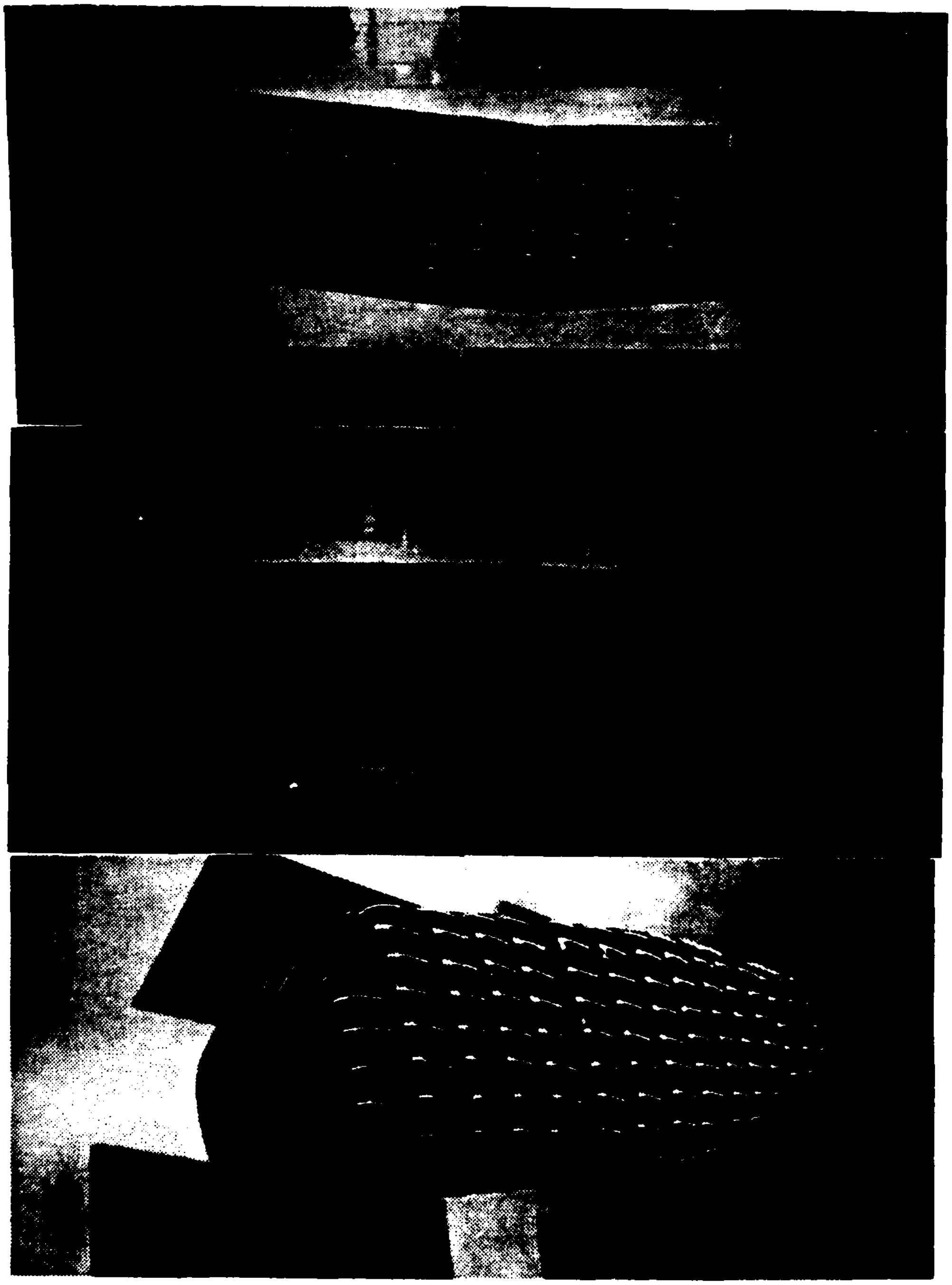


Fig. 14 Blunt/High

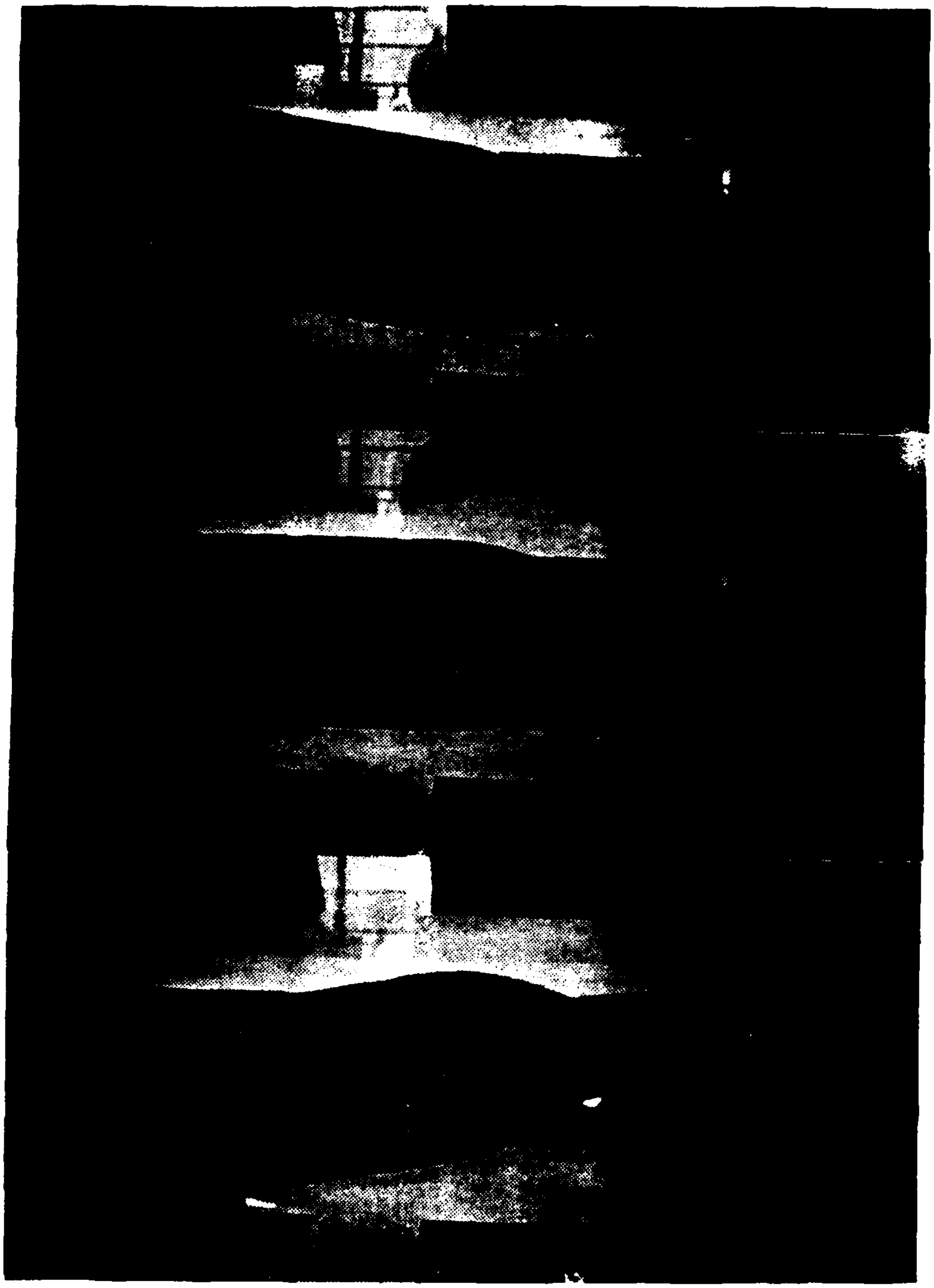


Fig. 15 Blunt/Middle

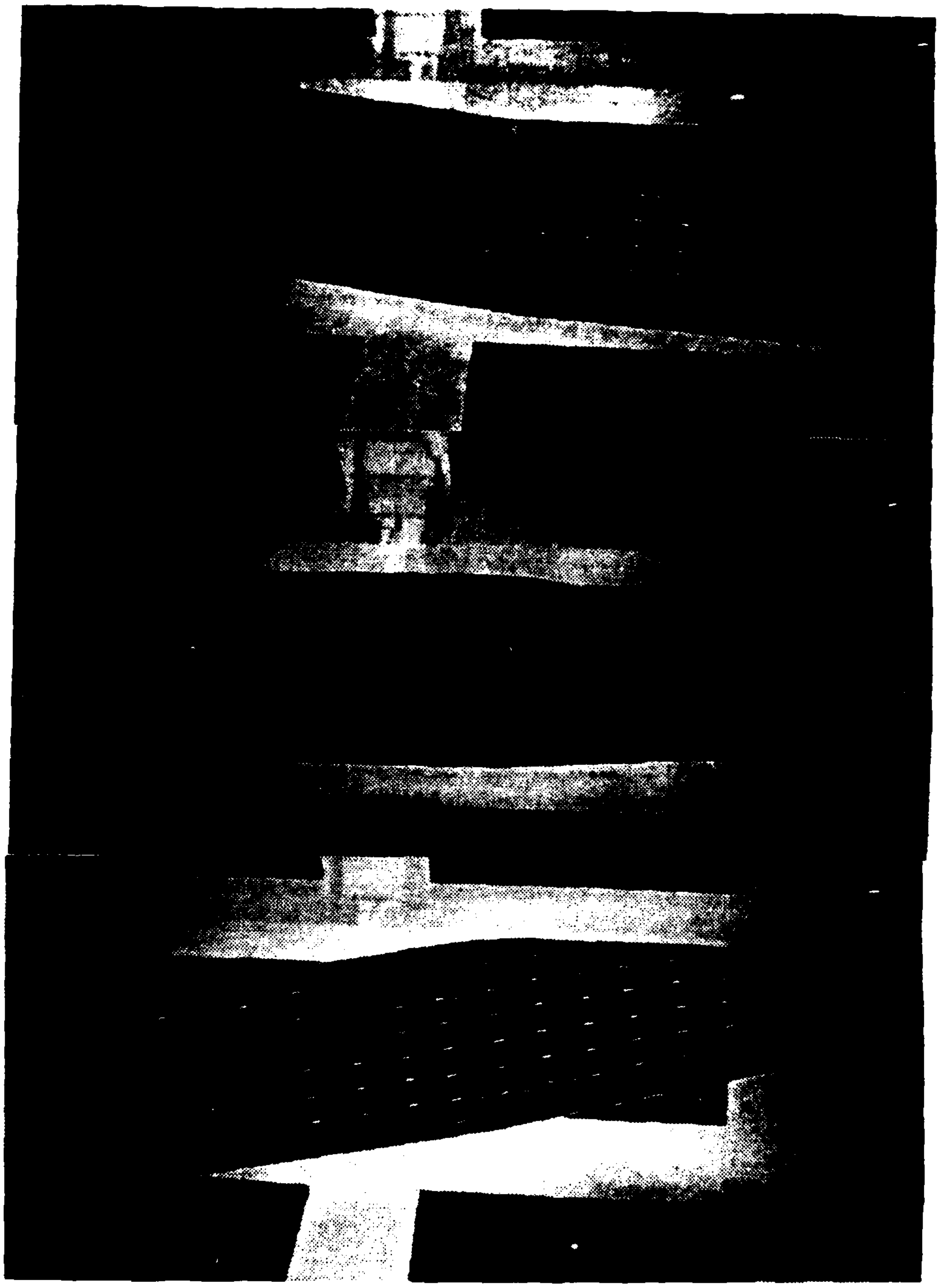


Fig. 16 Blunt/Low

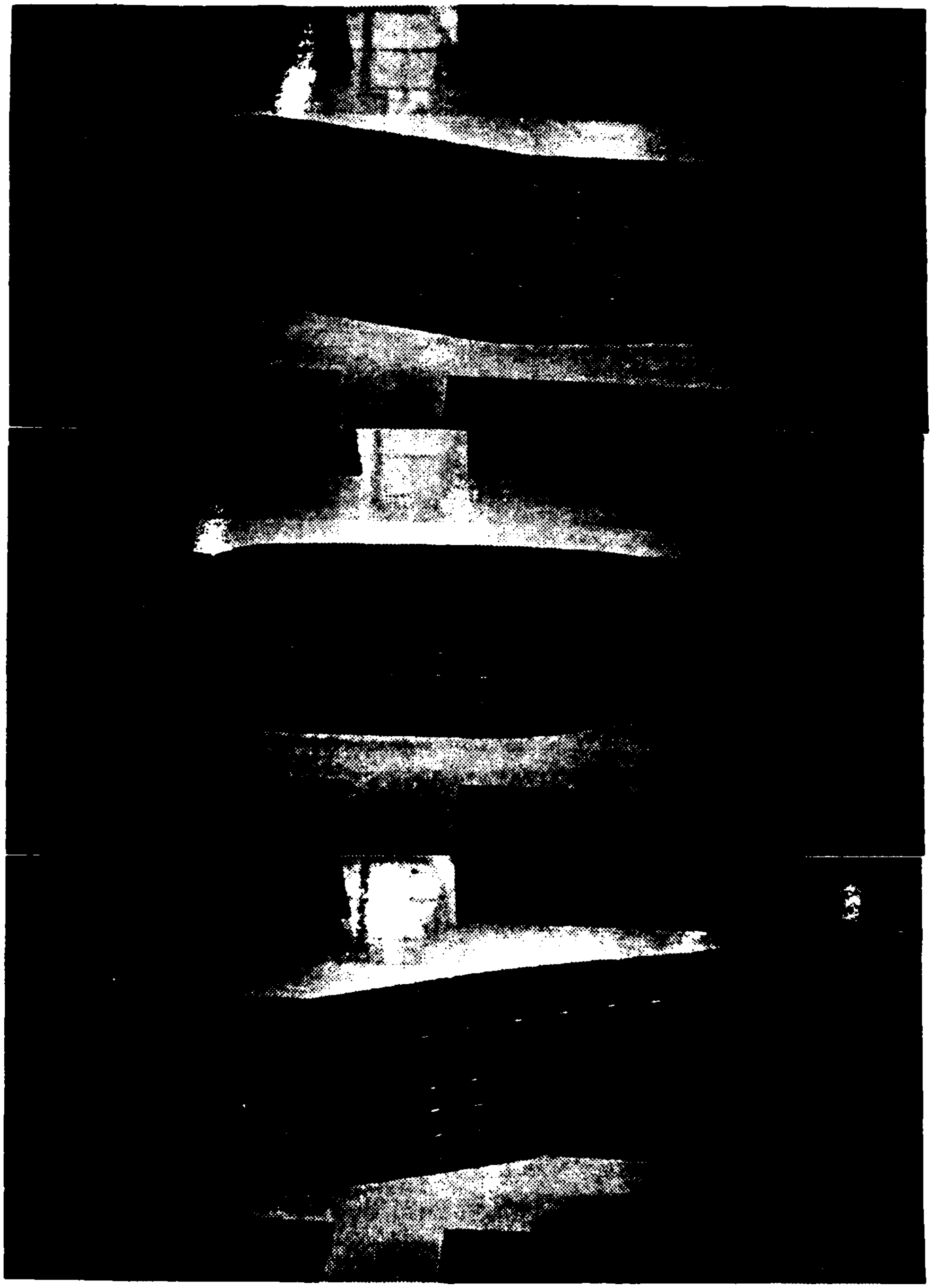


Fig. 17 Smooth/High

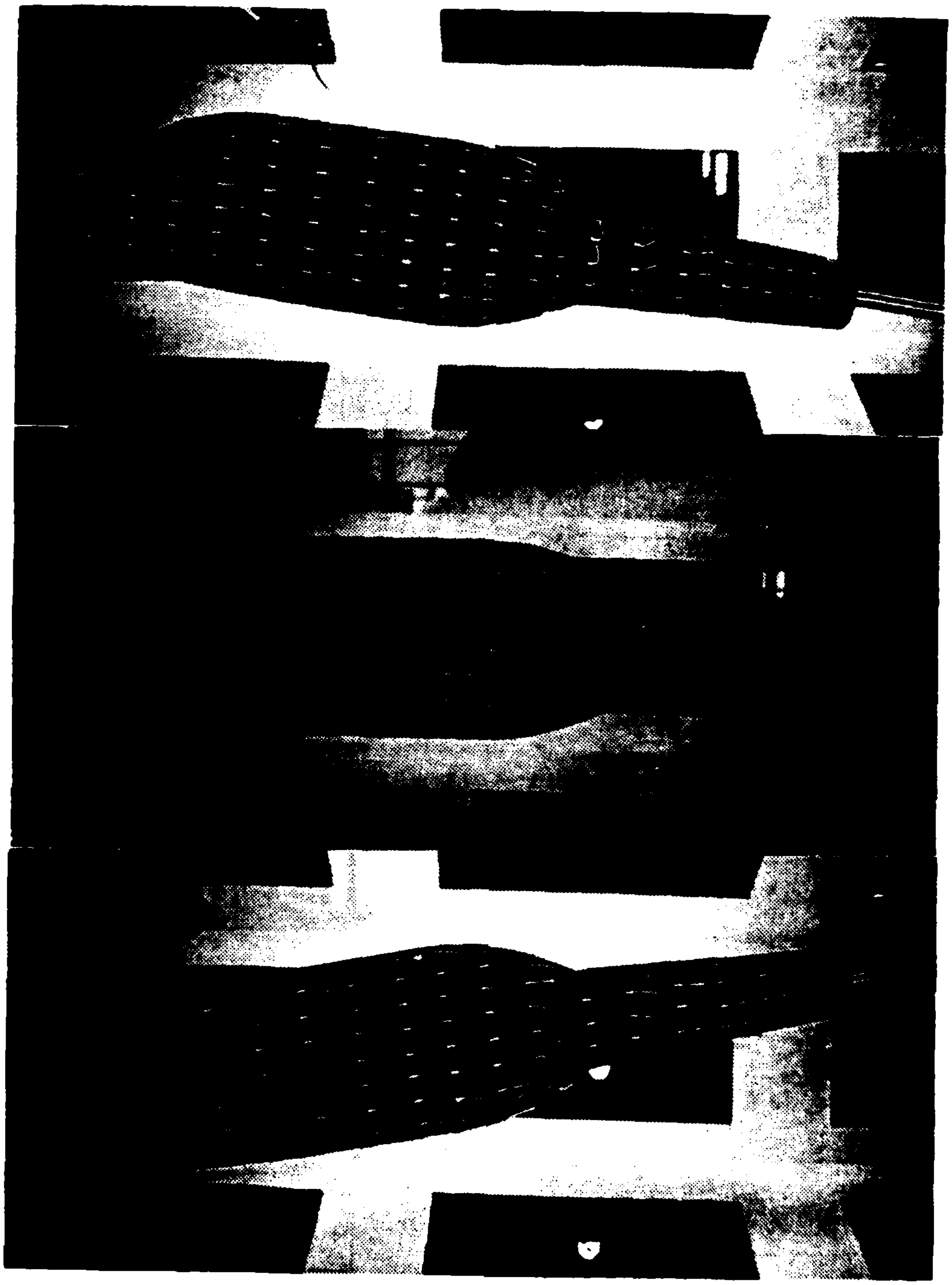


Fig. 18 Smooth/Middle

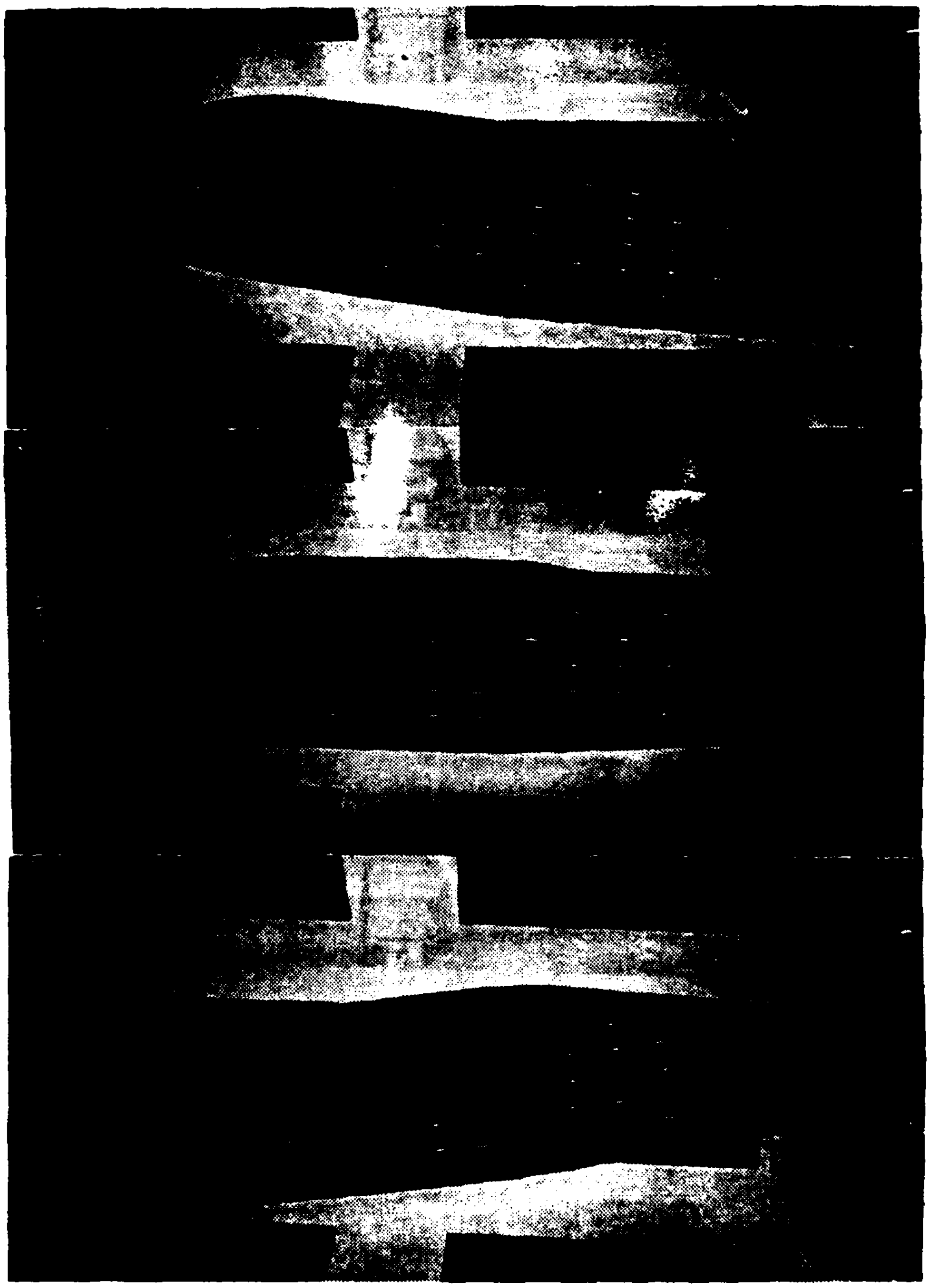


Fig. 19 Smooth/Low

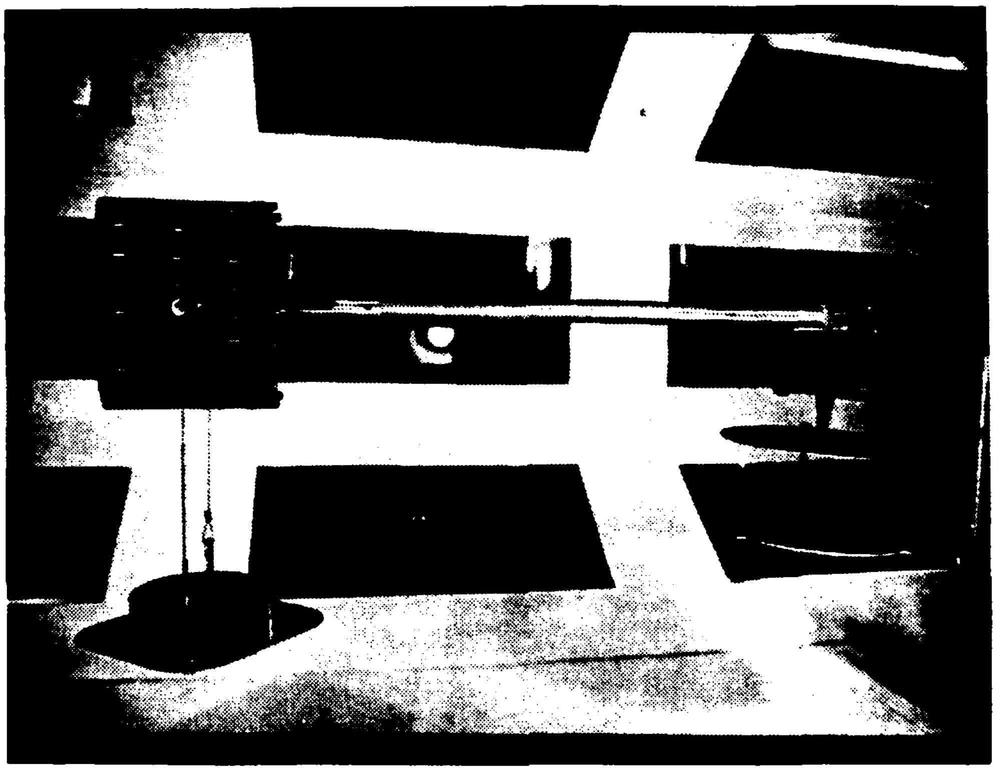


Fig. 20 Test Calibration Rigging

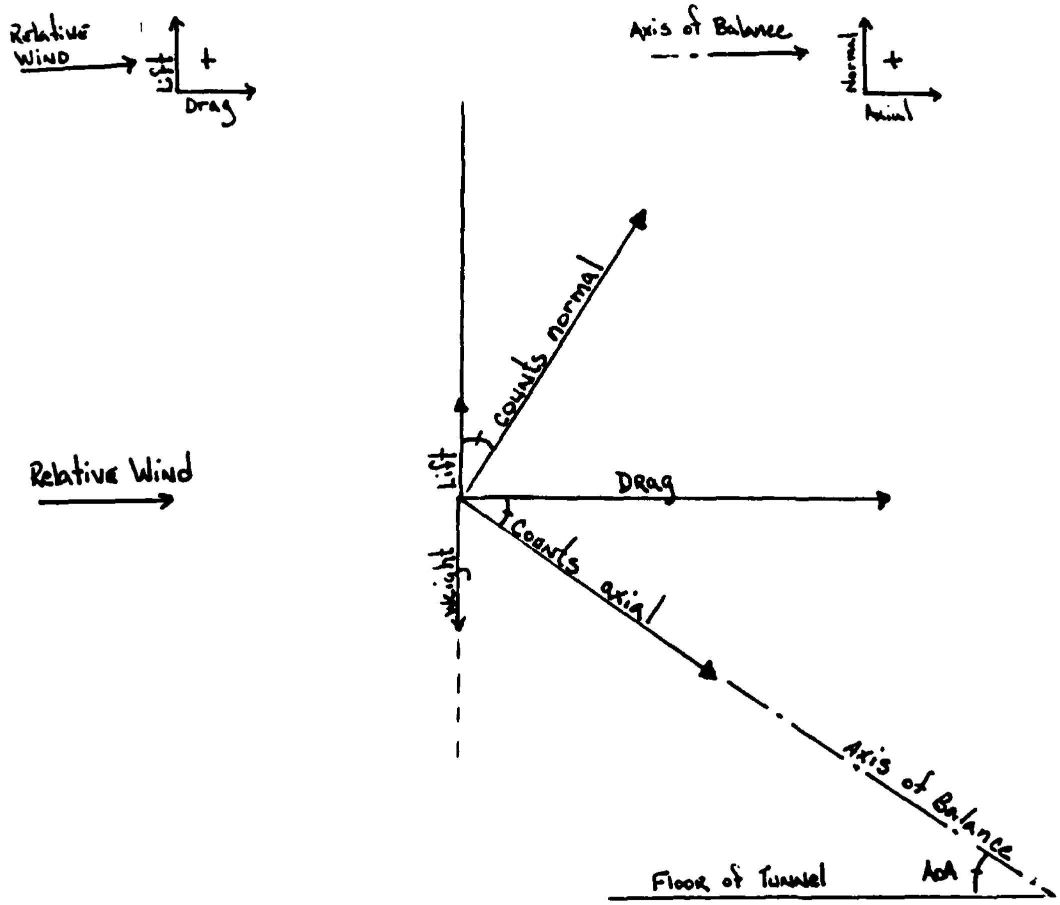


Fig. 21 Diagram of Forces

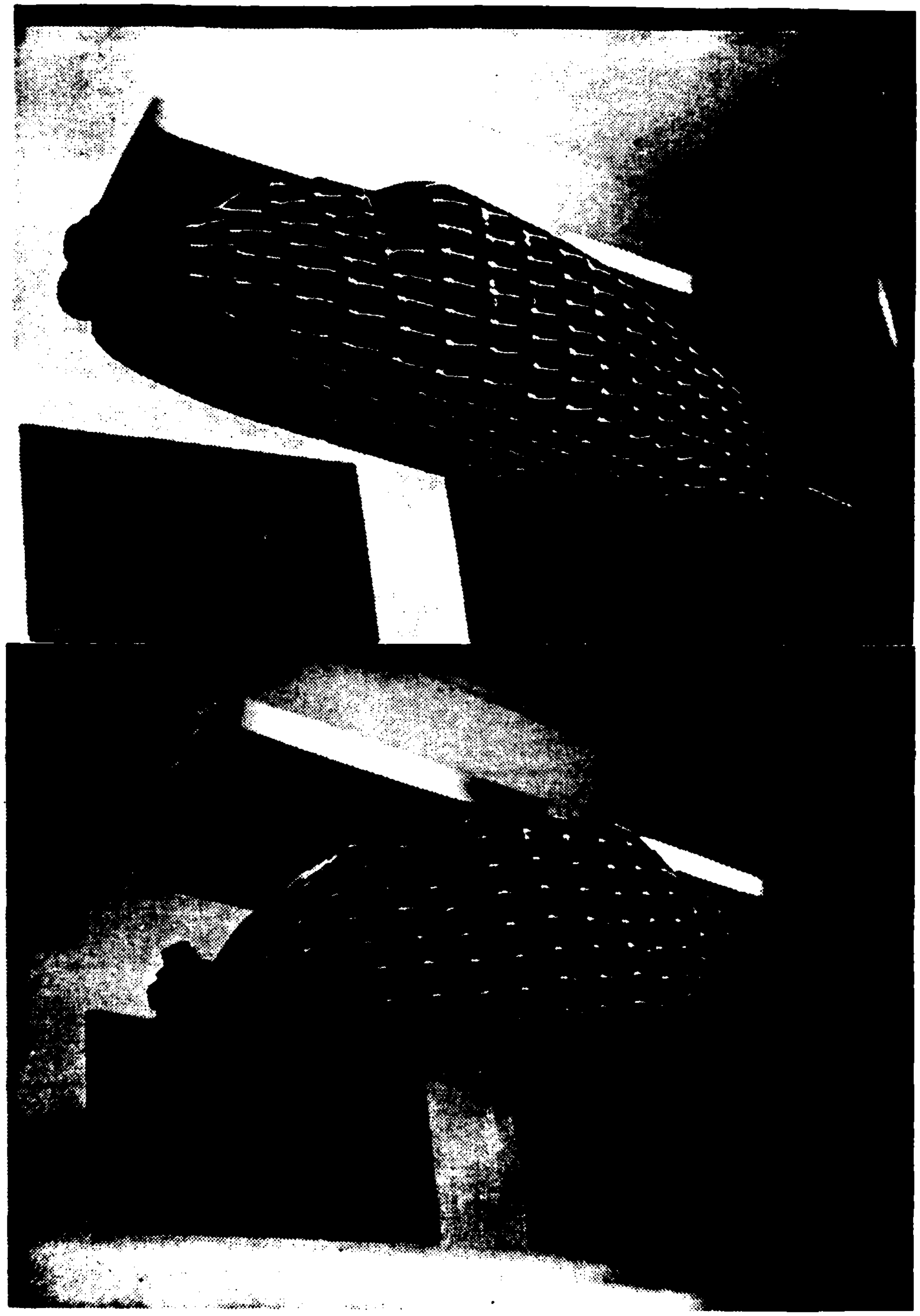
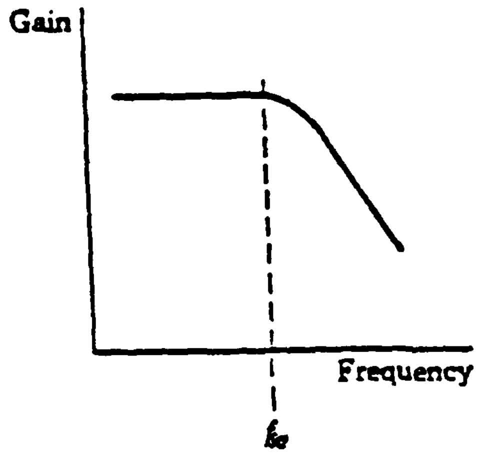


Fig. 22 Attack Nose at Different Aspect Angles

Low Pass Filter & Signal Conditioner



note: f_{sc} was .5 hertz
on the Signal for

Signal Conditioner Low Pass
Filter

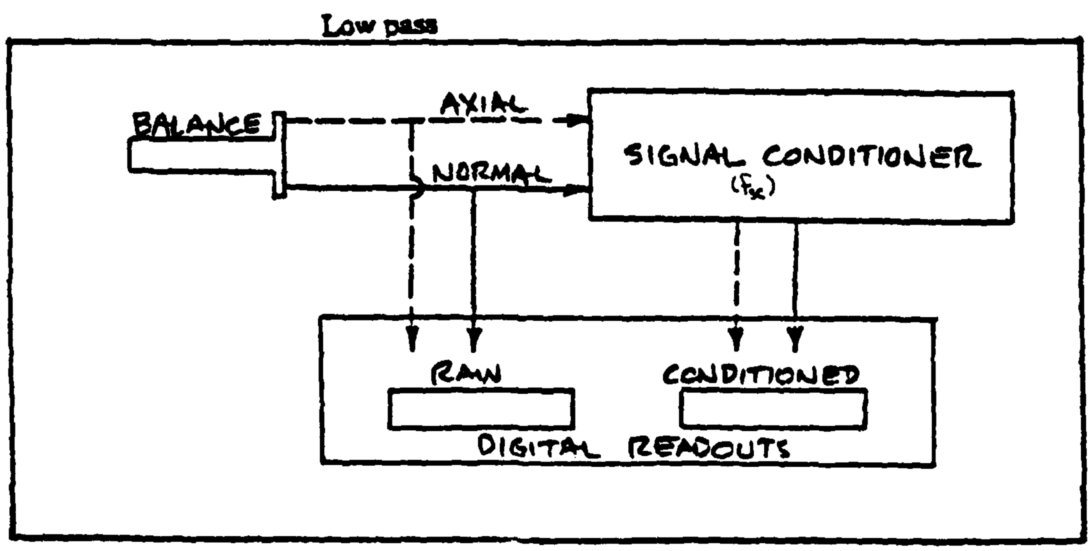


Fig. 23 Low Pass Filter & Signal Conditioner

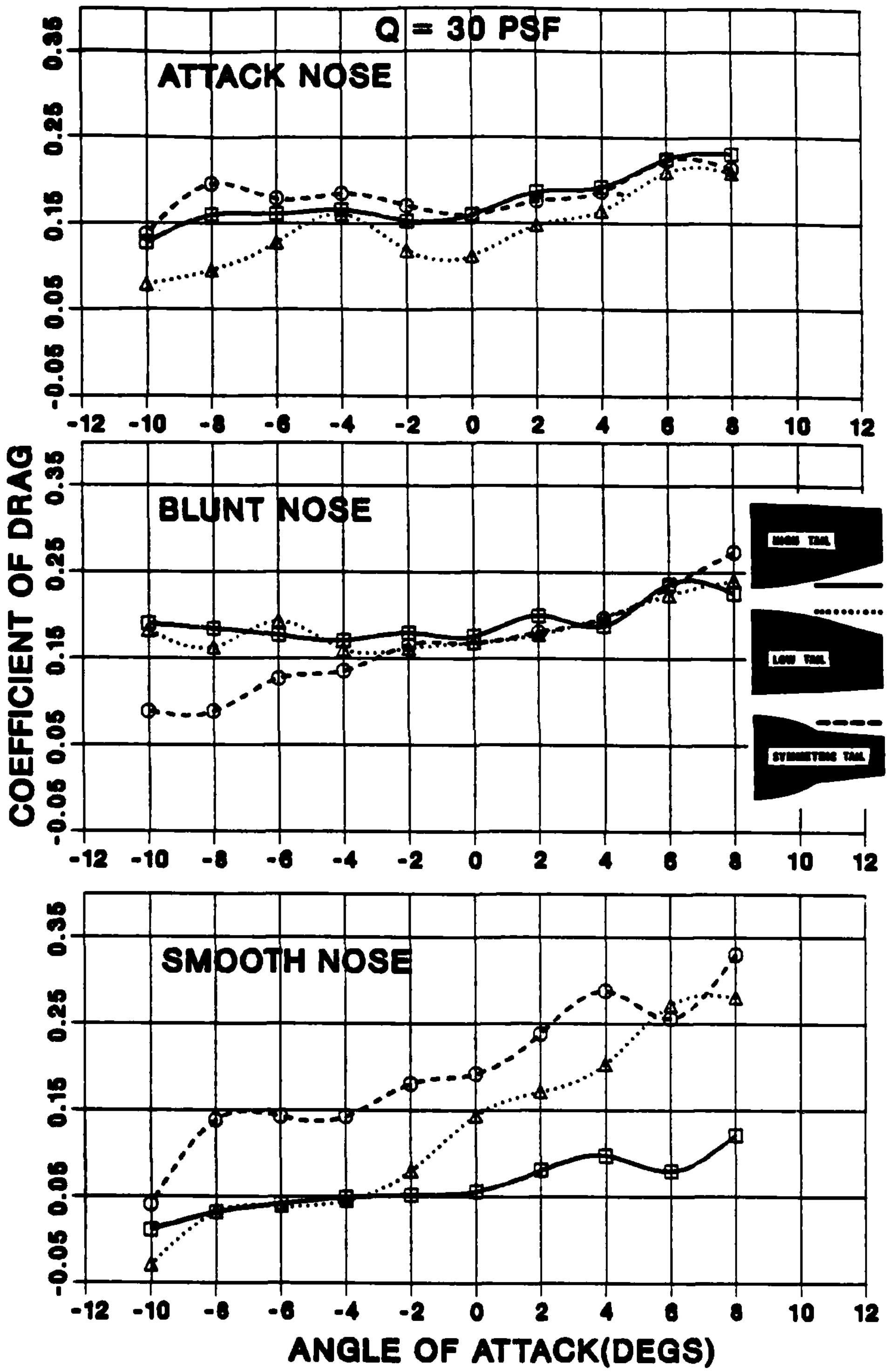


Fig. 24 CD vs AOA

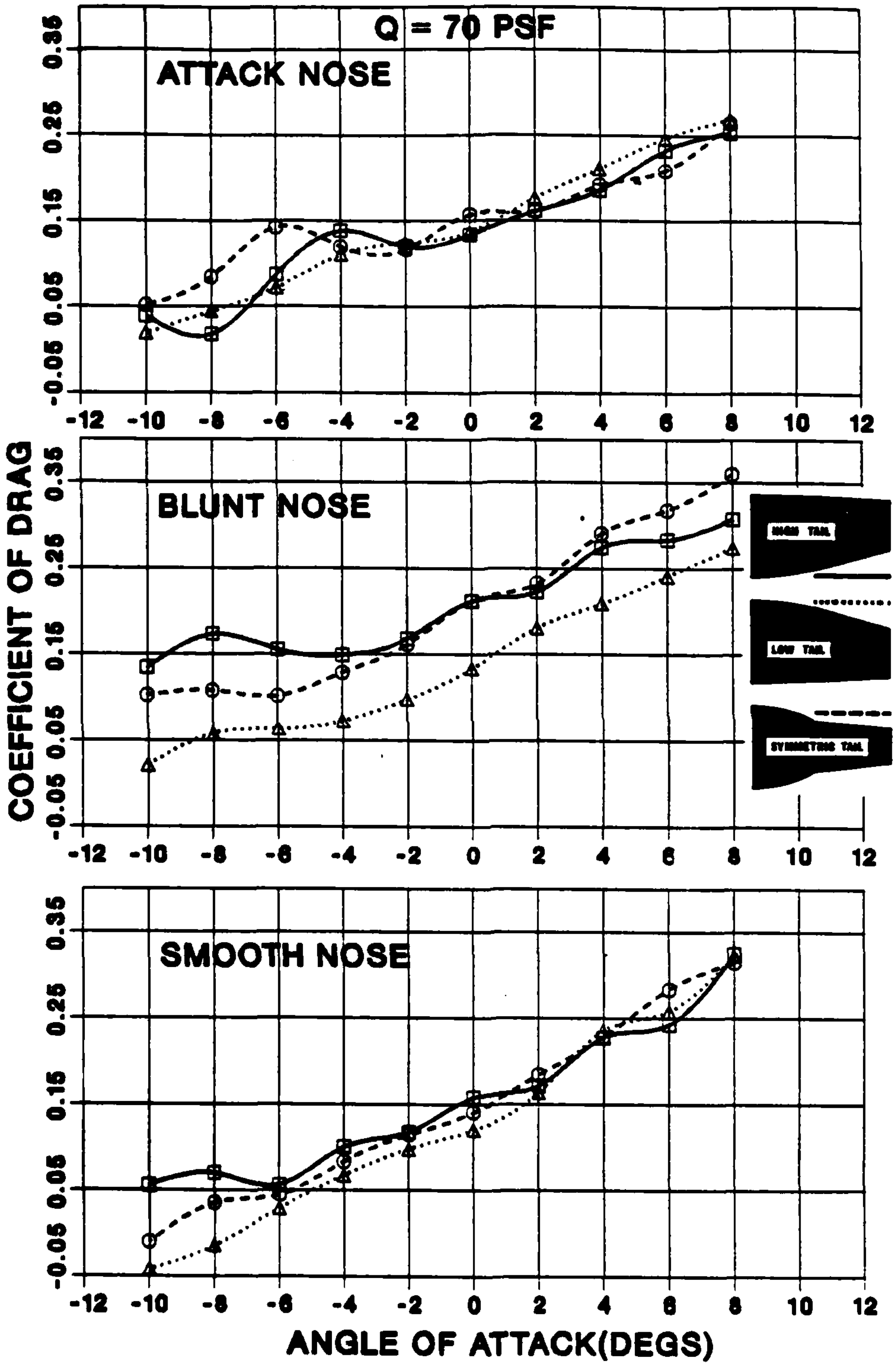


Fig. 25 CD vs AOA

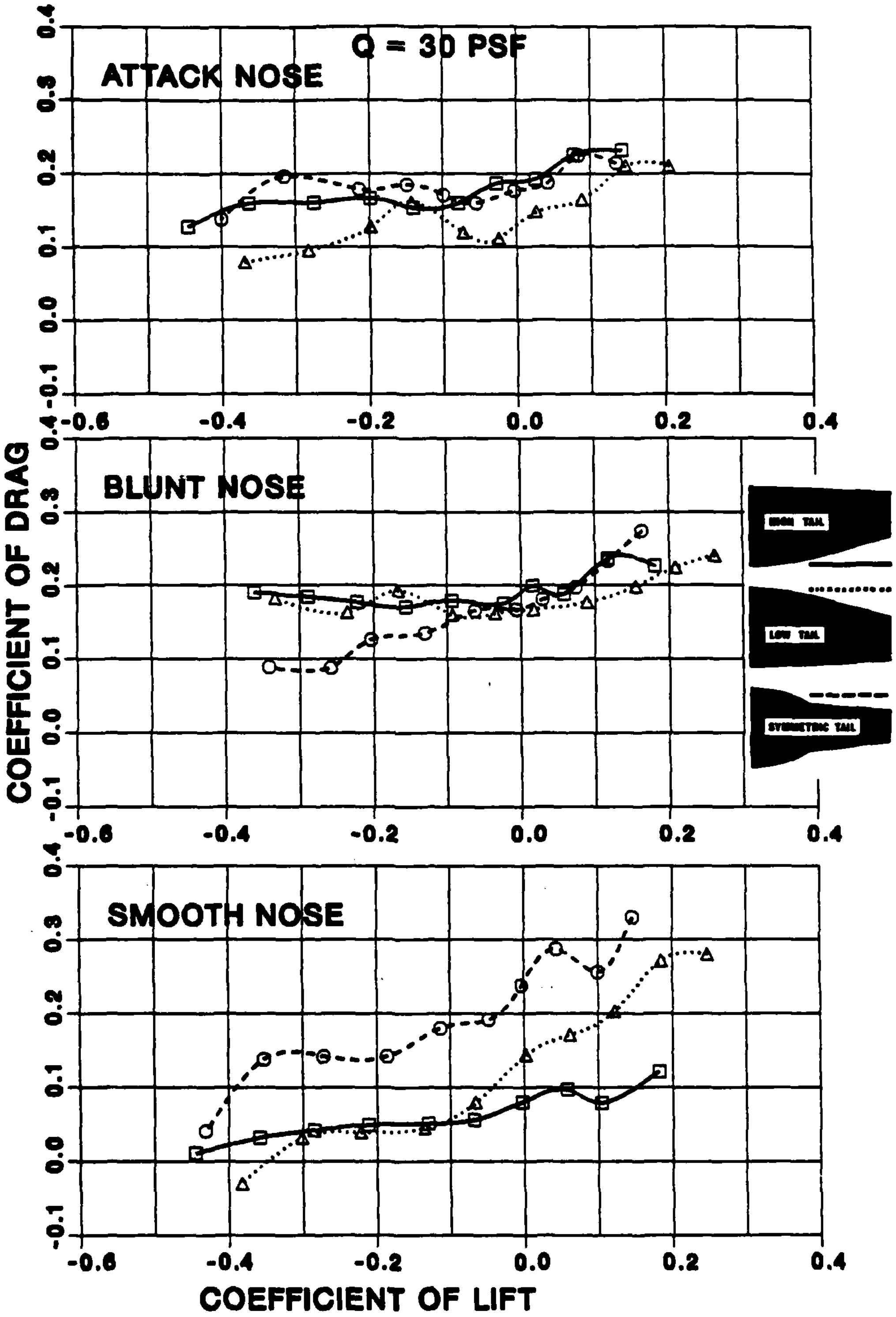


Fig. 26 CD vs CL

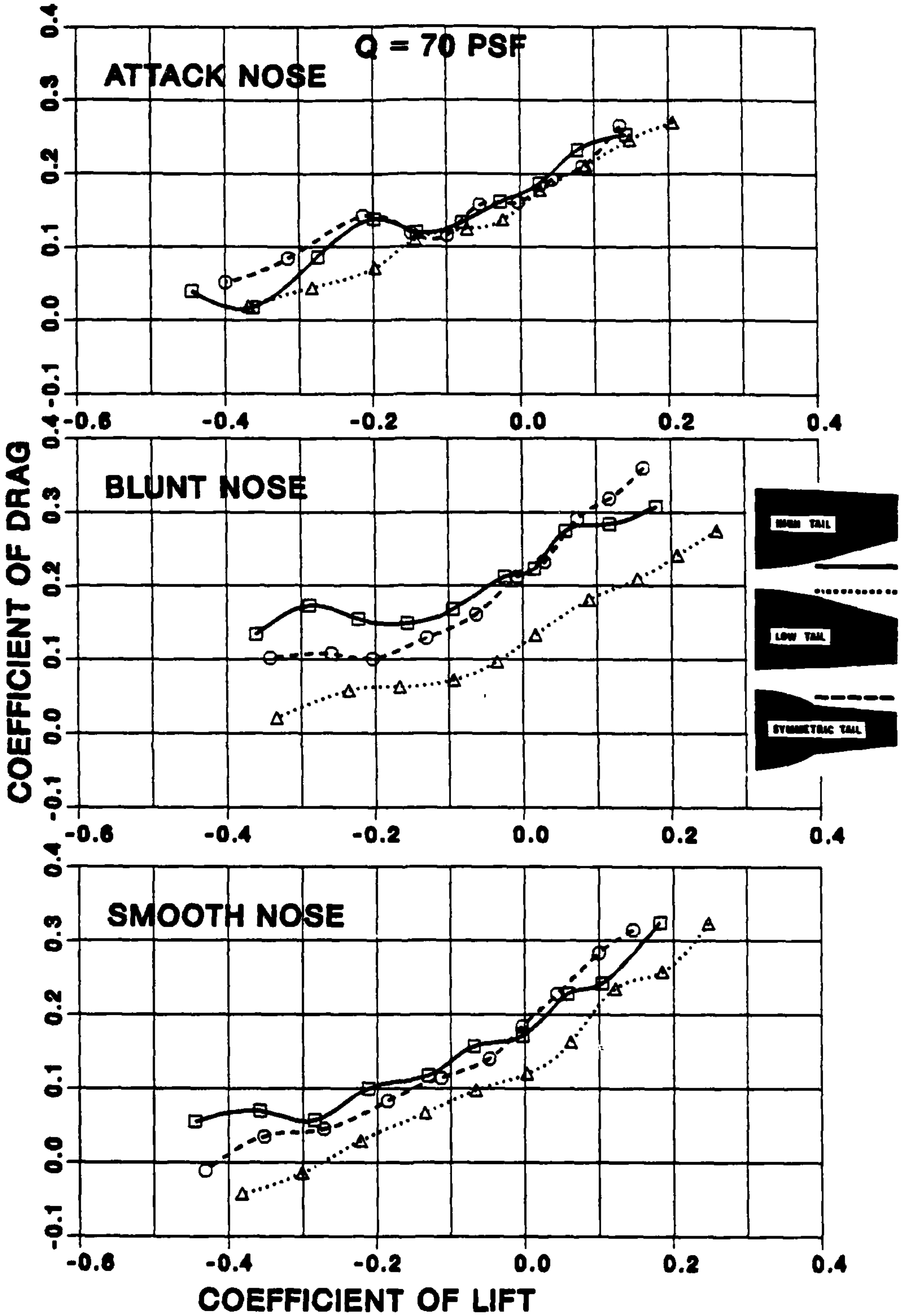


Fig. 27 CD vs CL

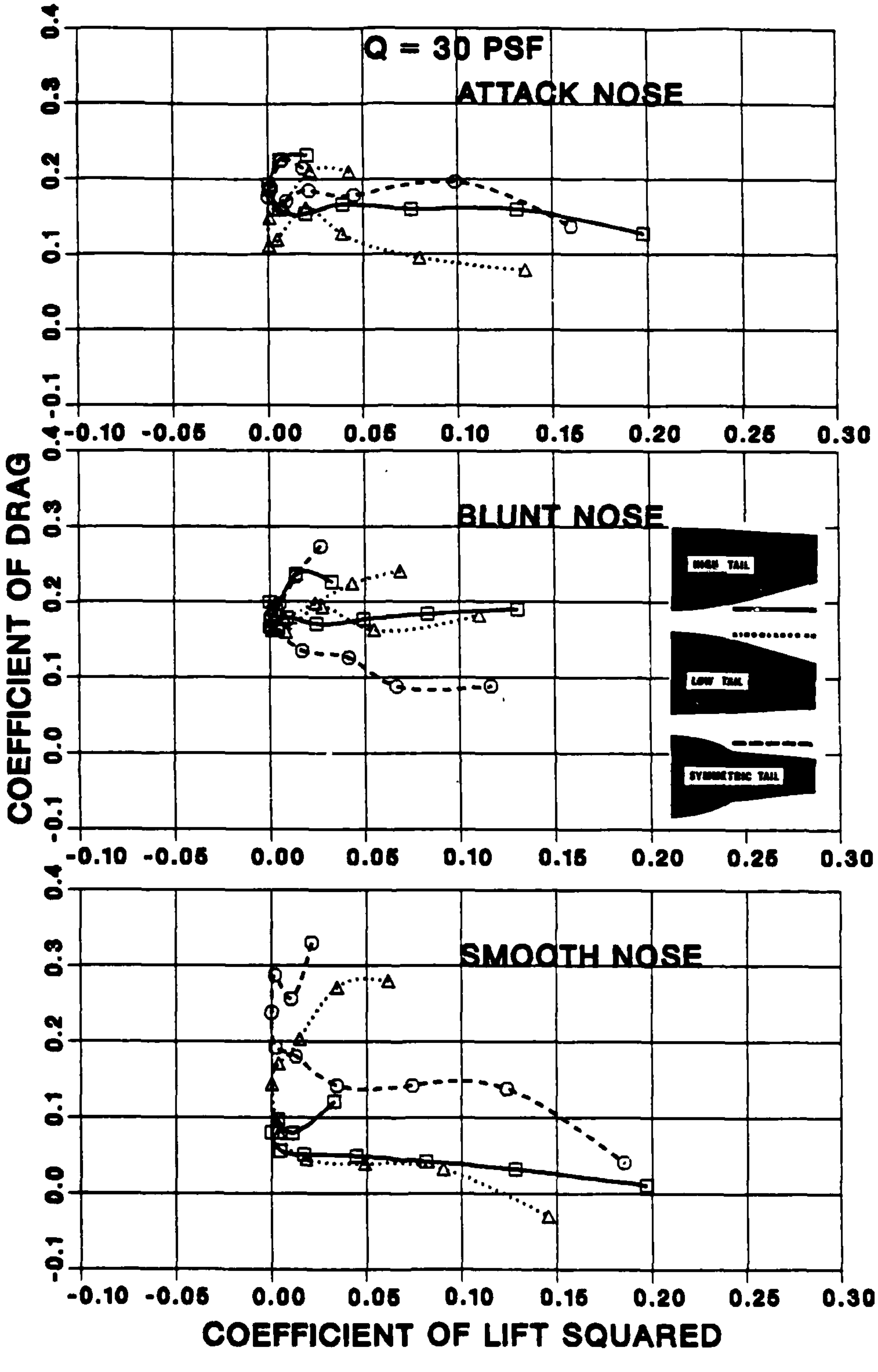
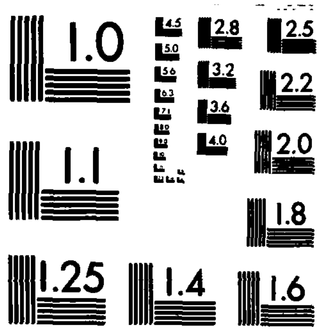


Fig. 28 CD vs CL^2

AD-A155 489 WIND TUNNEL DRAG EVALUATIONS OF HELICOPTER NOSE SECTIONS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA R S MAIR MAR 85 2/2

UNCLASSIFIED F/G 14/2 NL

END



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

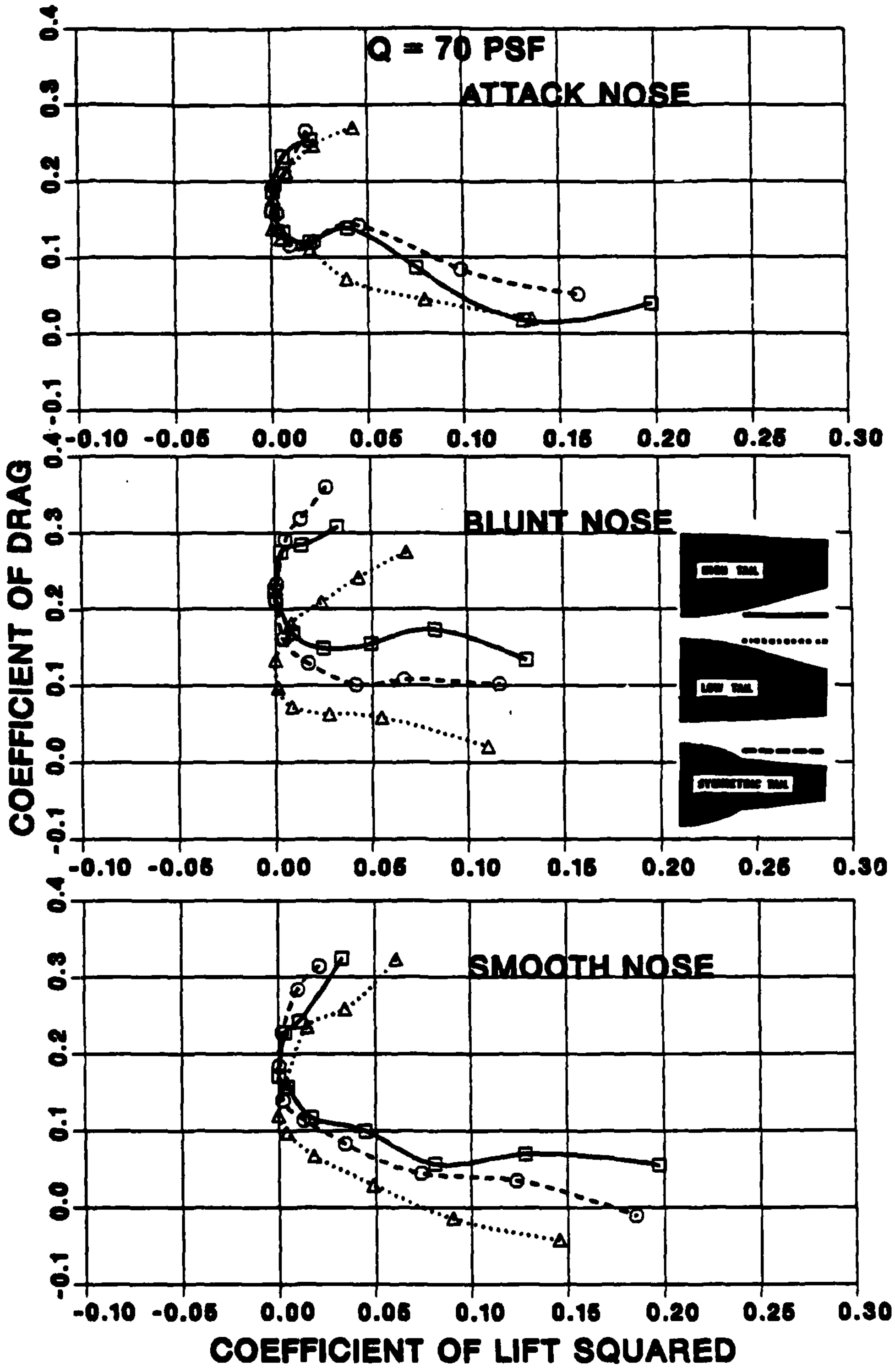


Fig. 29 CD vs CL^2

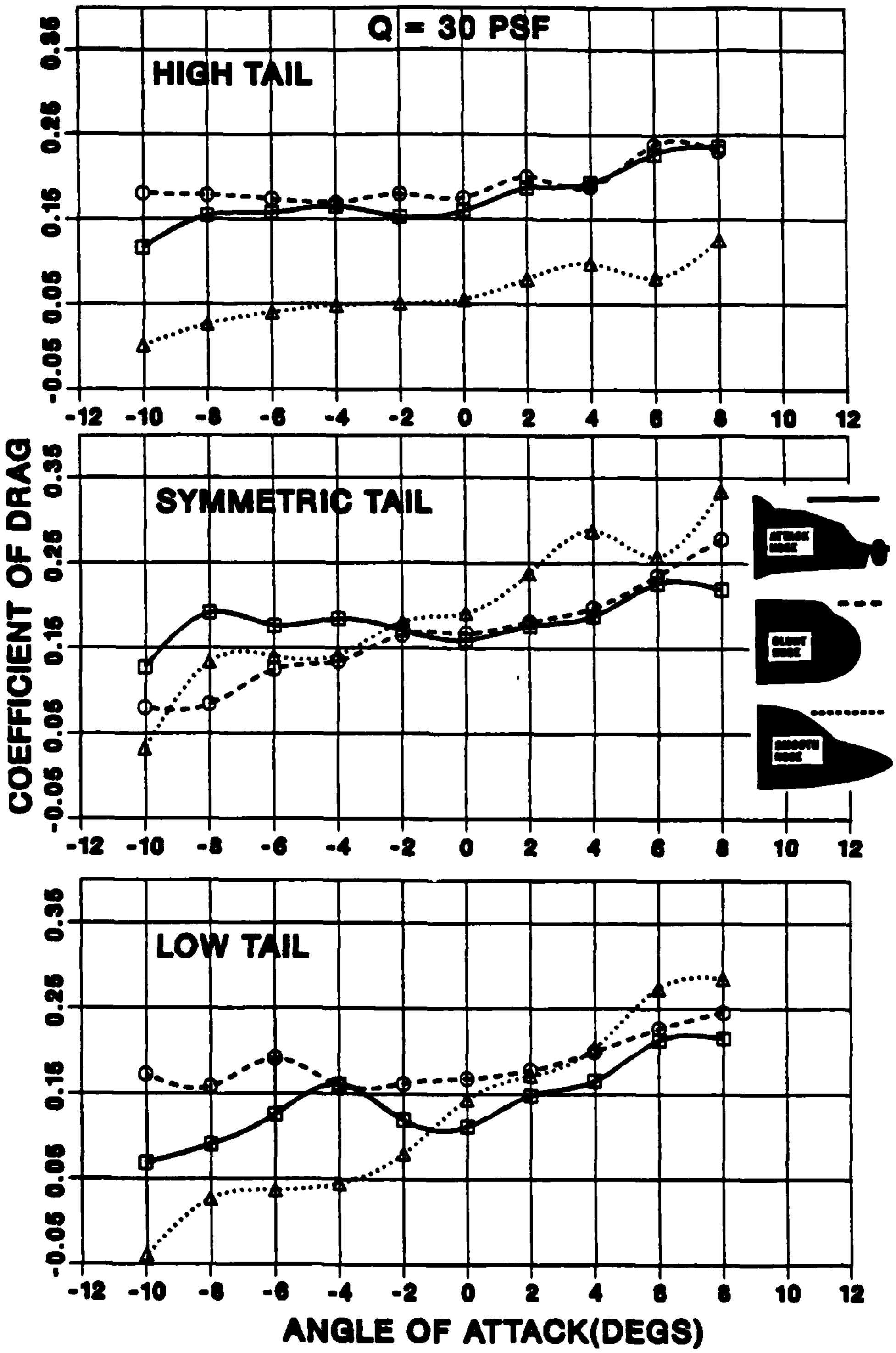


Fig. 30 CD vs AOA

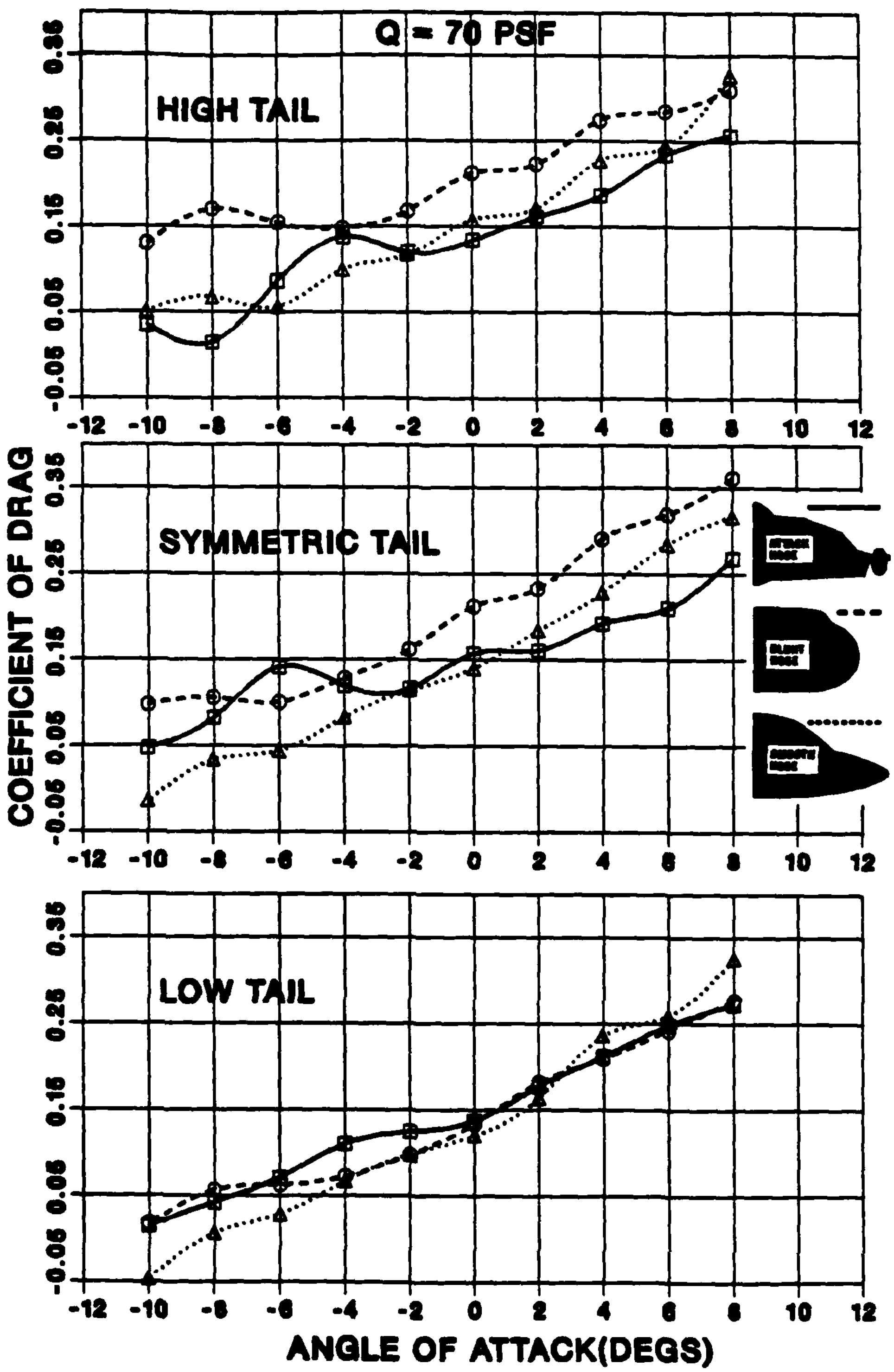


Fig. 31 CD vs AOA

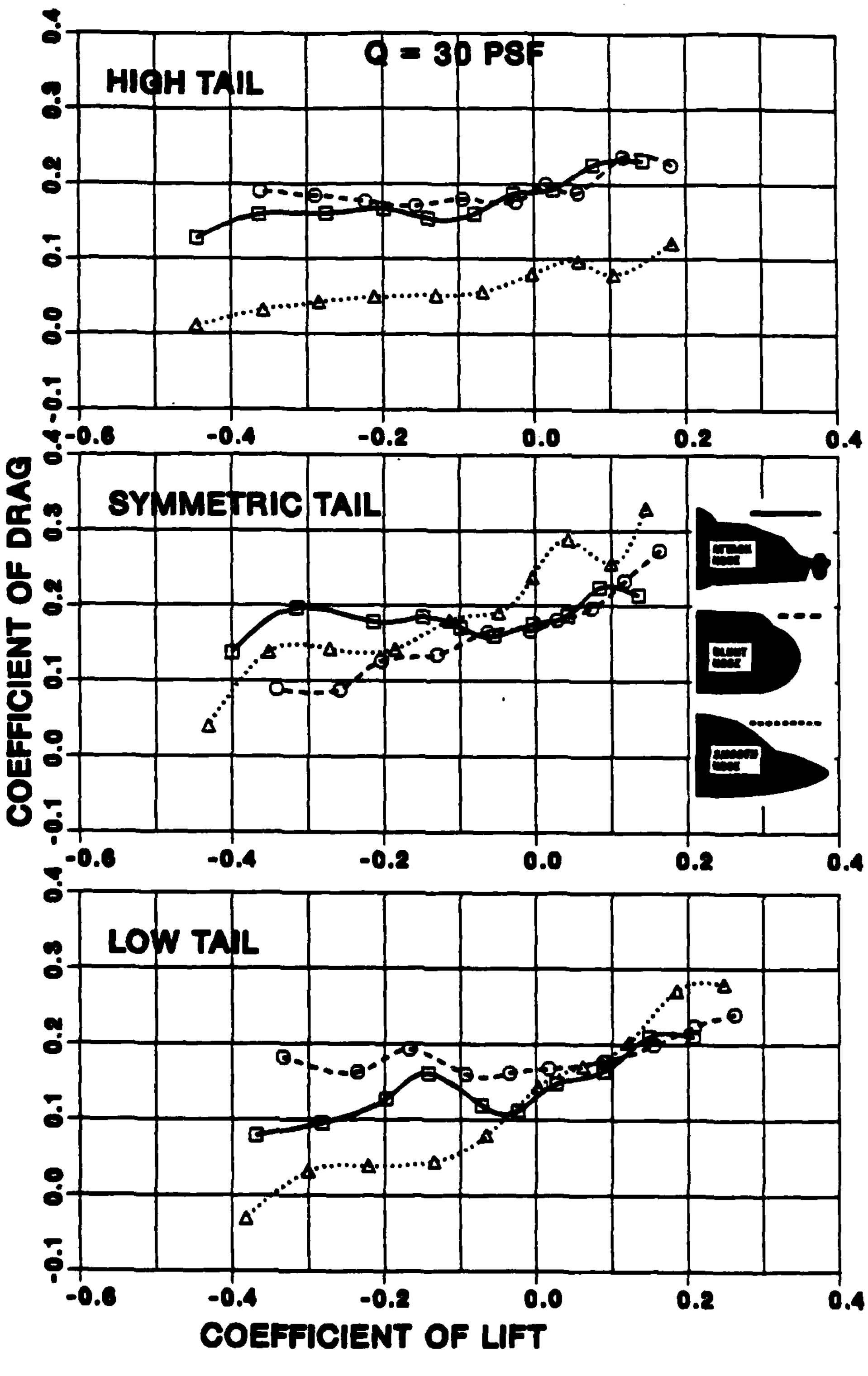


Fig. 32 CD vs CL

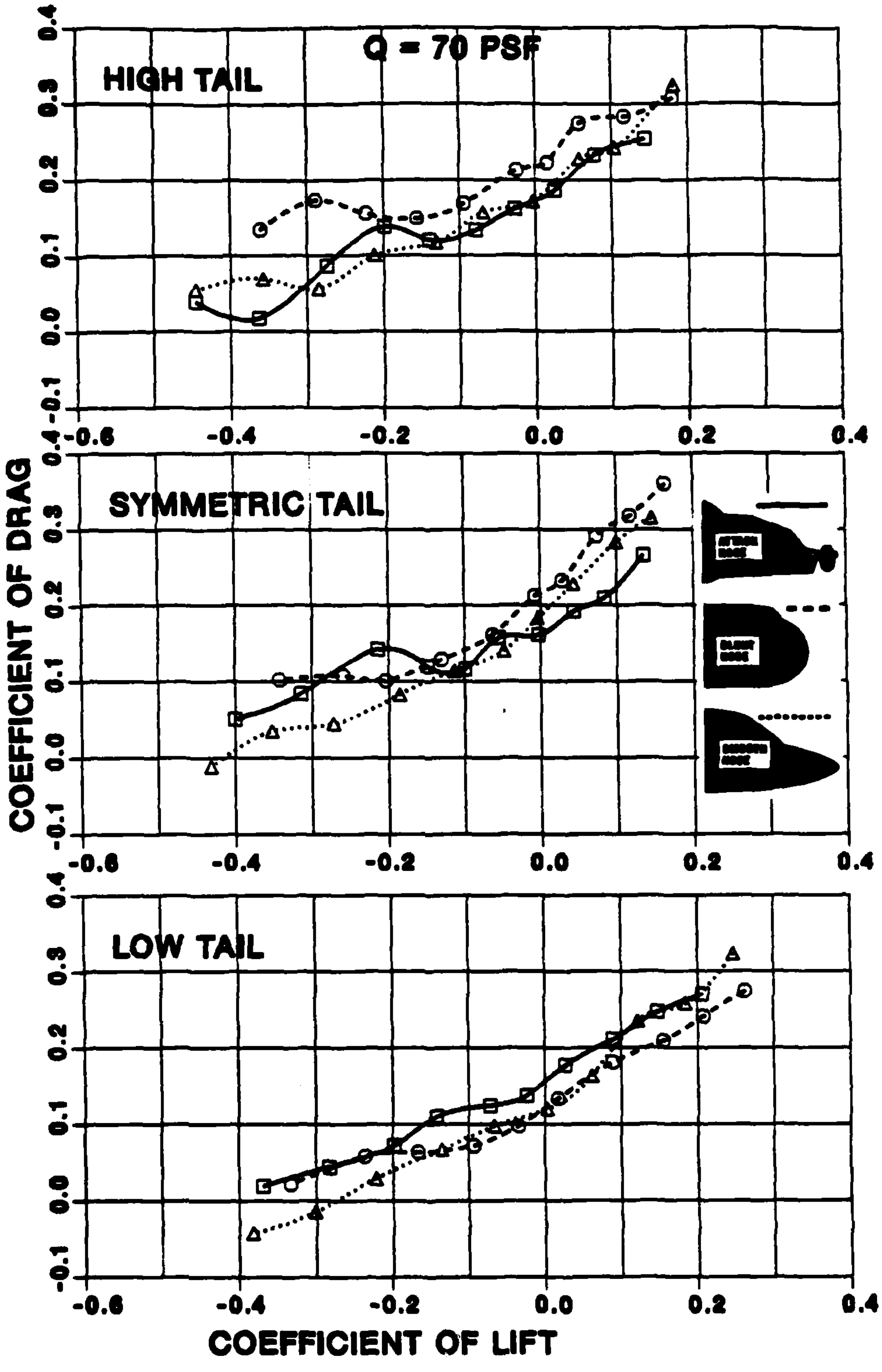


Fig. 33 CD vs CL

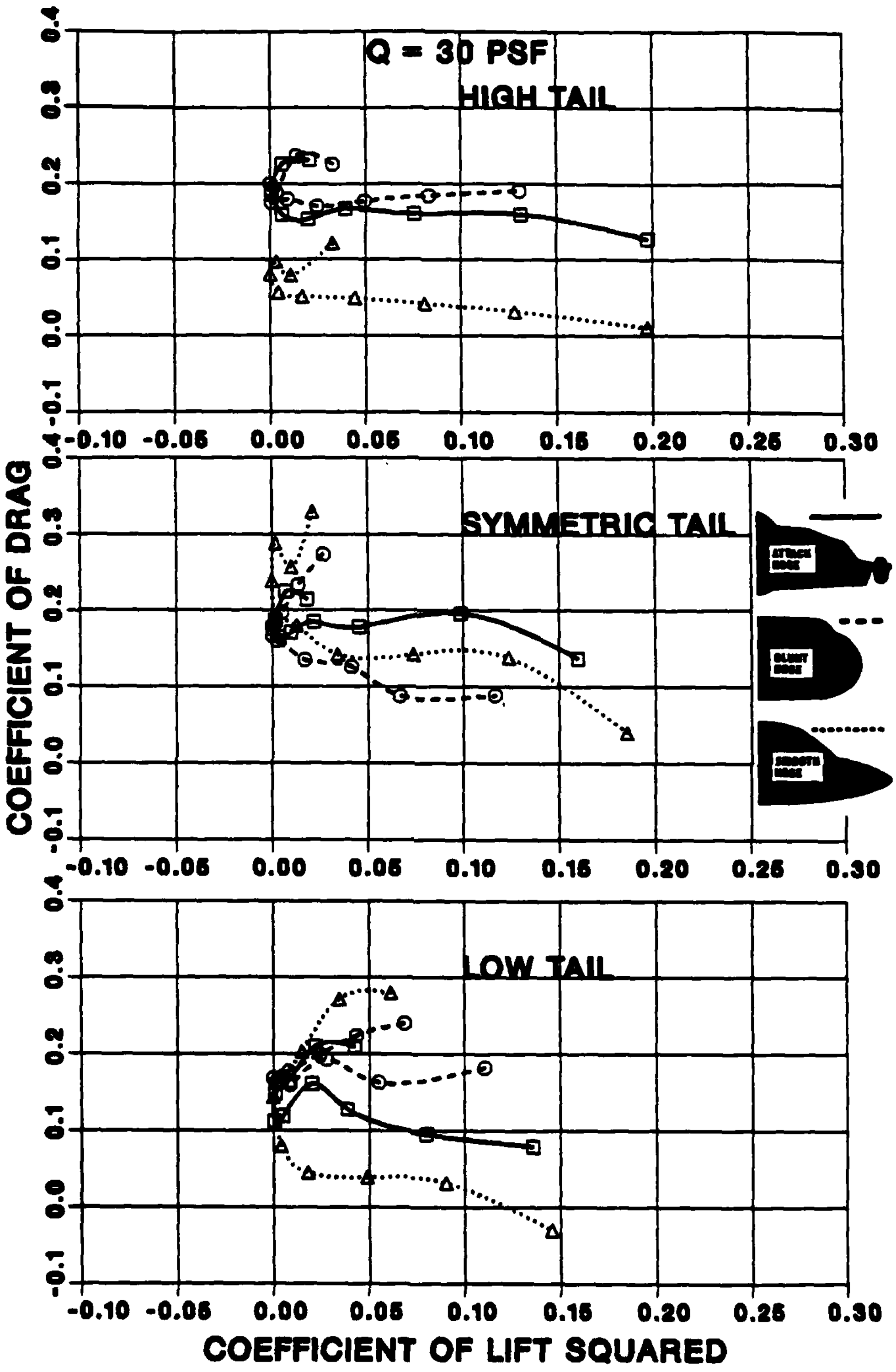


Fig. 34 CD vs CL^2

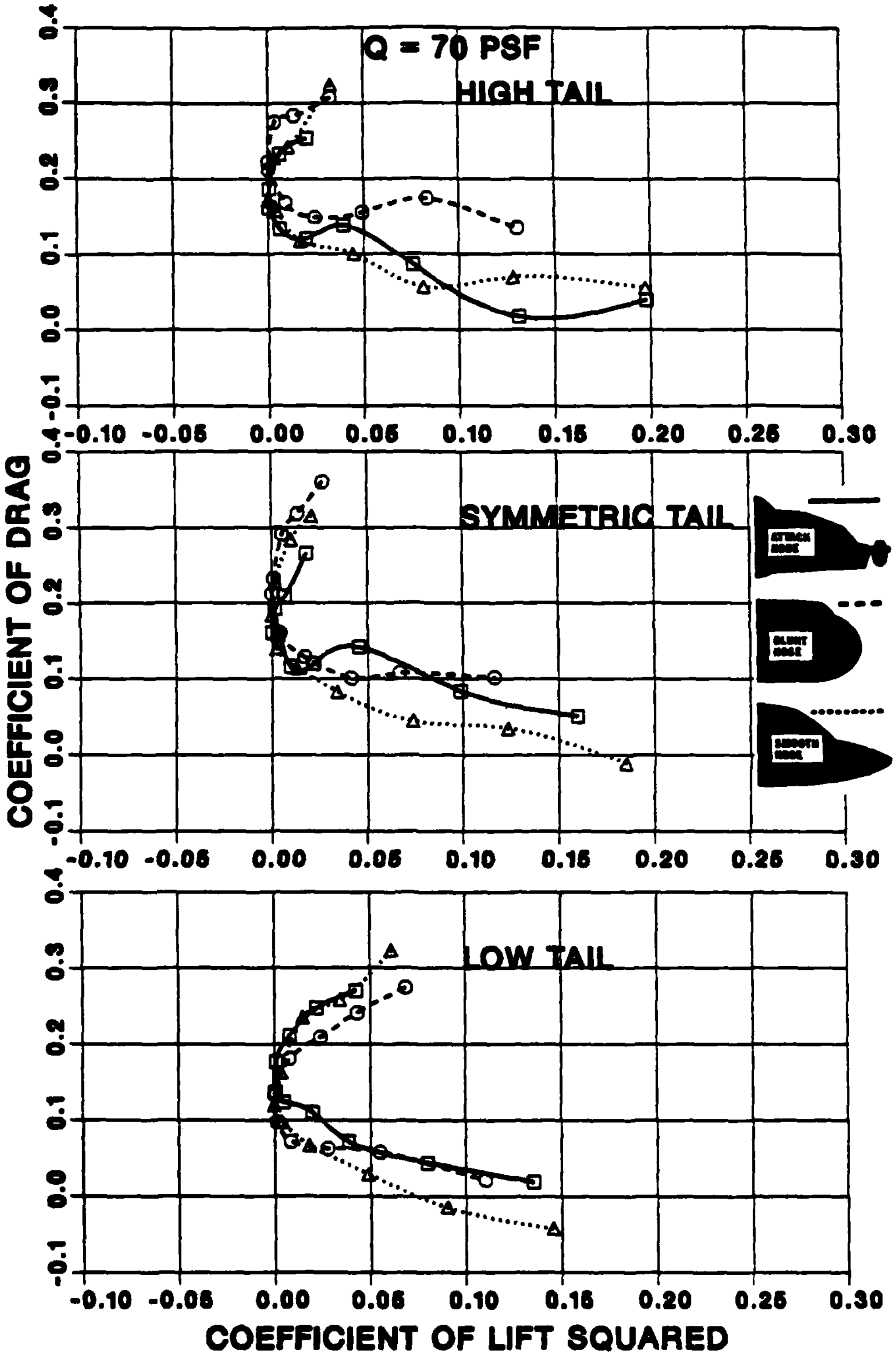


Fig. 35 CD vs CL^2

BALANCE CALIBRATION
INTERACTION (PERCENT)

HOW AXIAL LOADING AFFECTS NORMAL COMPONENT

HOW NORMAL LOADING AFFECTS AXIAL COMPONENT

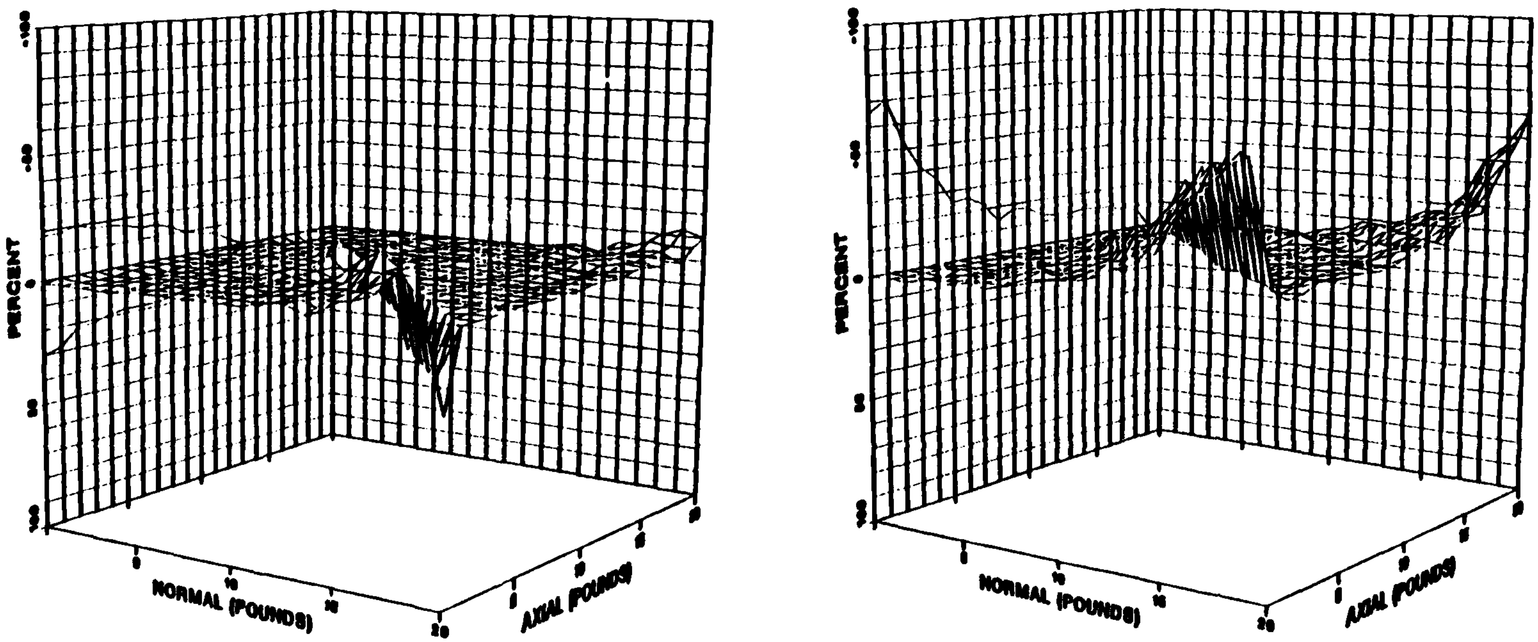


Fig. 36 Balance Calibration

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