EXPERIMENTAL STUDIES OF FLOW SEPARATION AND STALLING ON TWO-DIMENSIONAL AIRFOILS AT LOW SPEEDS

PHASE II

SUPPLEMENT I: STUDIES WITH FOWLER FLAP EXTENDED

SUPPLEMENT II: FLOW STUDIES ON GA(W)-2 & NACA 2412

[GR] (NGR-17-003-021)

Semi-Annual Progress Report

December 1, 1975 to May 30, 1976

(NASA-CR-148085) EXPERIMENTAL STUDIES OF FLOW SEPARATION AND STALLING ON TWO-DIMENSIONAL AIRFOILS AT LOW SPEEDS, PHASE 2. SUPPLEMENT 1: STUDIES WITH FOWLER FLAP EXTENDED. SUPPLEMENT 2: FLOW STUDIES 00/98

N76-74654

Unclas 28095

Submitted to: NASA Langley Research Center

by

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1. Status on Supplement 1: About 16 hours of hot film anemometer surveys were conducted on flap nested and flap 40° configurations. This data will be included in the final report, and examples are included in Figures 1 and 2. Complete report and narrative will be available for NASA reviewers by June 1976.

2. Supplement 2: Extensive flow and anemometer surveys were made during this period on the GA(W)-2 section. The data is being processed at the WSU Computer Center. Preliminary copies of the processed data will be sent to the NASA program monitor during June 1976.

NACA 2412 airfoil has been refurbished and is ready for testing during June-July 1976.

3. A single-channel hot wire anemometer system with linearizer and several hot film probes was procured through Thermo Systems, Inc., and the system was employed to obtain hot film data.

4. Publication: The following papers have been accepted for publication in the AIAA Journal of Aircraft.

(a) H. C. Seetharam & W. H. Wentz, Jr.: Experimental Investigation of Subsonic Turbulent Separated Boundary Layers on an Airfoil. (Full length paper).

(b) H. C. Seetharam, W. H. Wentz, Jr., and J. K. Walker: Measurement of Post-Separated Flow Fields on Airfoils. (As a technical note).

5. <u>Follow-on Research</u>: A proposal has been submitted to extend the present research to include measurements on a thicker airfoil (21%) and slotted flap flows.

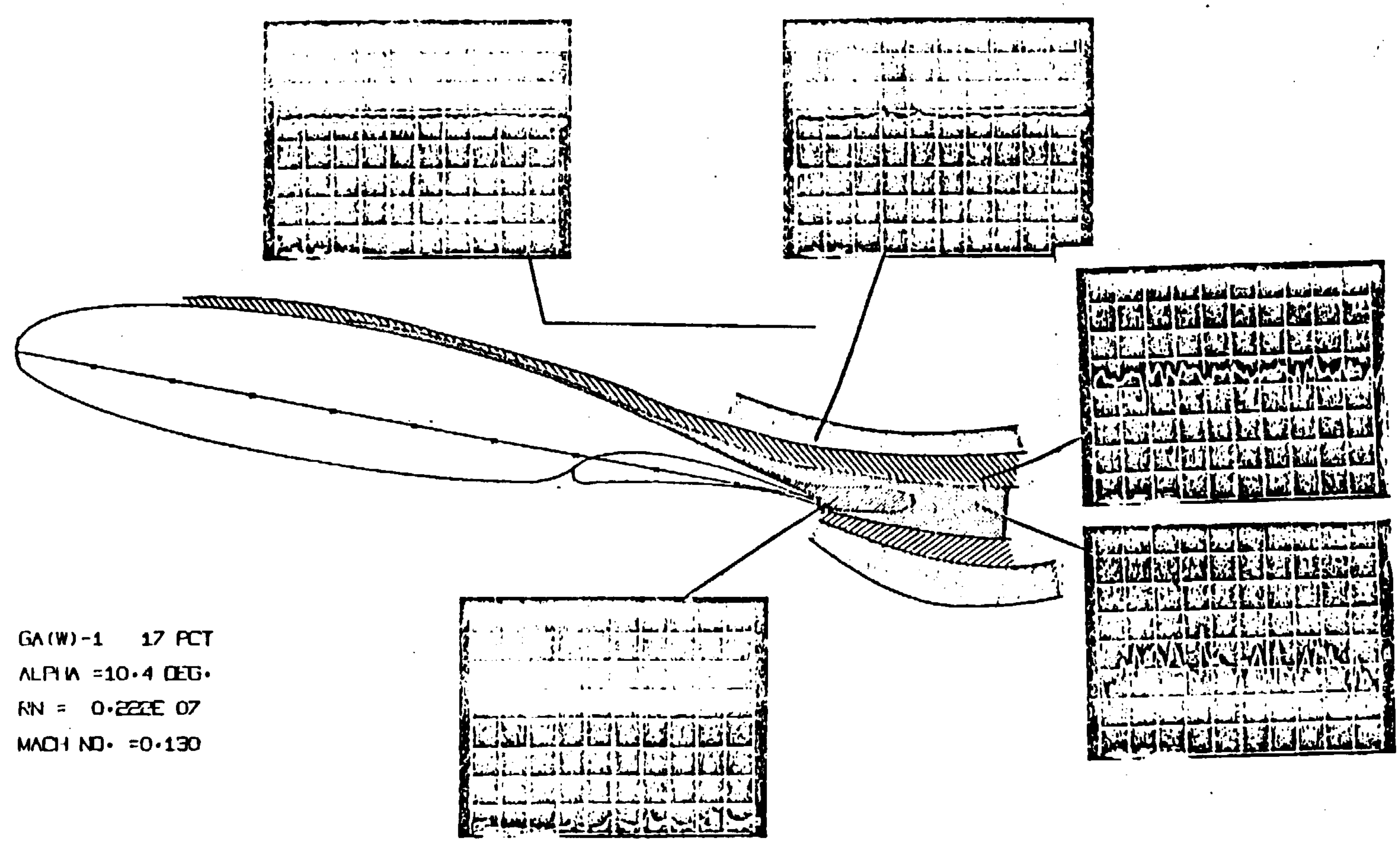

Figure 1. Hot film survey; α = 10.4°

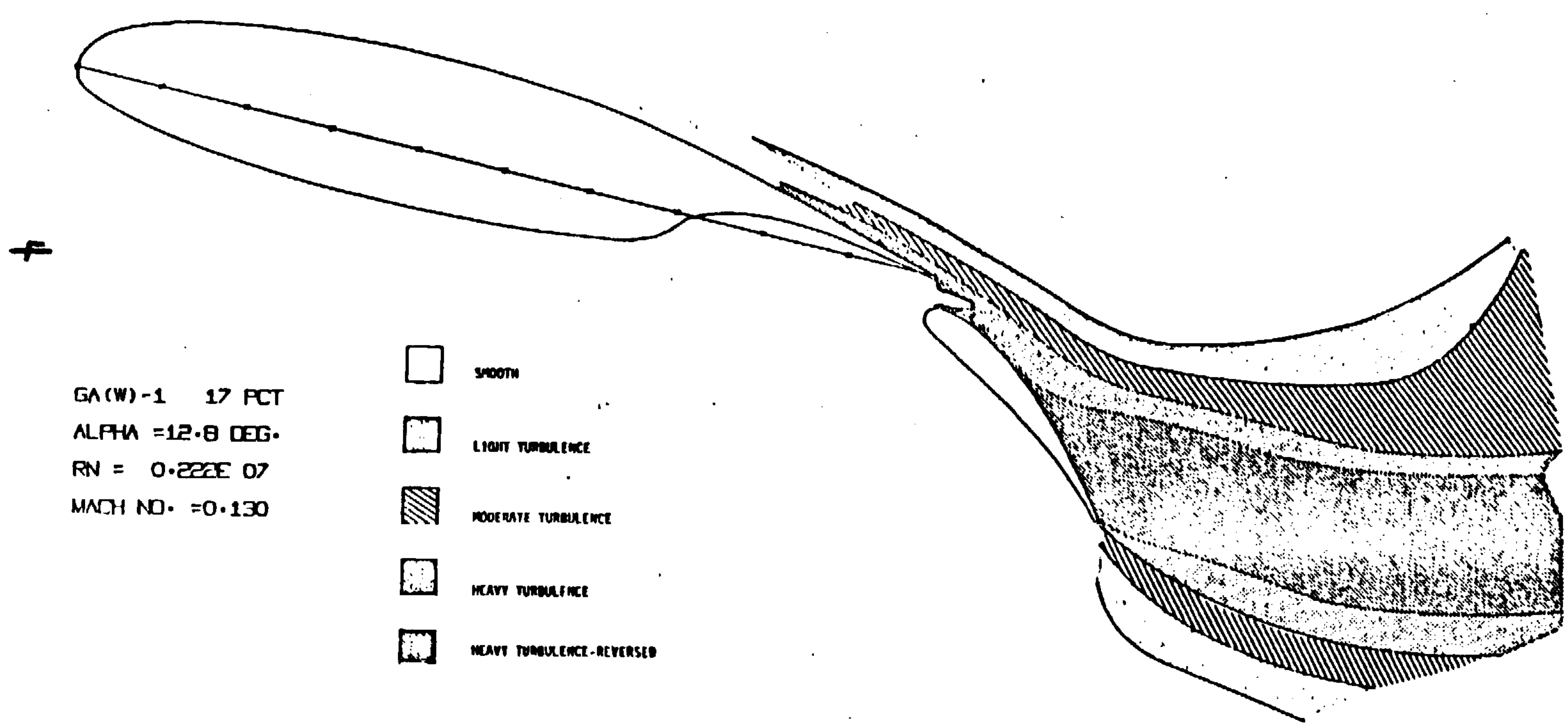

Figure 2. Hot film survey; $\delta\rho = 40°$, $\alpha = 12.8°$

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EXPERIMENTAL STUDIES OF FLOW SEPARATION AND STALLING ON TWO DIMENSIONAL AIRFOILS AT LOW SPEEDS - PHASE I

NGR 17-003-021

Semi Annual Progress Report

1 Jan. 1974 - 30 June 1974

Submitted To: NASA Langley Research Center

By

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(NASA-CR-139754) EXPERIMENTAL STUDIES OF FLOW SEPARATION AND STALLING ON TWO DIMENSIONAL AIRFOILS AT LOW SPEEDS, PHASE 1 Semiannual Progress Report, 1 Jan. - 30 Jun. 1974 (Wichita State Univ.) 17 p

#3.50 N74-75592

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Experimental Studies of Flow Separation and Stalling On Two Dimensional Airfoils at Low Speeds - Phase I

Semi Annual Progress Report - for the period from Jan. 1, 1974 to June 30, 1974.

1. Calibration of the five tube probe: The probe was calibrated through the pitch angle range of ± 45°, under dynamic pressures of 479 and 2874 Newtons/meter^2 (10 & 60 psf) with probe extensions of 254mm and 406mm (10" & 16") in order to explore the effects of dynamic pressure and the support interference on the calibration. No noticeable deviations were observed. Based on the calibration data, polynomial curve fits were employed for subsequent use in the data reduction program (Figs. 1, 2, 3).

   The inputs for the data reduction program are the five pressures, which are fed into the calibration equations to compute EPSILON, the pitch angle (Fig. 1) from which PSFAC & PTFAC (Figs. 2 & 3) and hence the local static, total and dynamic pressures are computed at any location of the probe. The image effect of the probe due to the proximity of the wall is also included as a correction to the pitch angle, EPSILON, for probe positions closer than 17.5mm (0.7") from the surface. Local velocity is then expressed in a non-dimensional form, as the ratio of local to the free stream velocity.

2. Velocity plots:

   a) Five tube probe: Figures 4, 5 & 6 show the velocity plots at angles of attacks of 10°, 14° & 18° respectively. Ten chordwise stations were chosen at each angle of attack, in order to study the behavior of the boundary layer upstream, downstream and at the separation point on the airfoil. Velocity profile measurements were also made at four stations beyond the trailing edge of the airfoil in order to obtain the complete picture of the development of the wake with flow reversal. The closest vertical measurement station from the airfoil surface was 2.54mm (0.1"), in view of the physical dimensions of the five tube probe (Fig. 7).

b) Flat tube probe: Velocities close to the surface were measured employing a flat tube probe (Fig. 7). Total pressure measurements were made at thirteen vertical stations from a distance of about 0.15mm to 5.4mm (.006" to .213"). Surface static pressure reading was used to compute the velocities.

c) Cylindrical tube: At certain downstream chordwise stations, with shallow regions of separation, difficulty was experienced with the flat tube probe, while scanning the reversed flows due to the interference of the probe on the upstream flow. Hence a cylindrical tube (Fig. 7) of .46mm dia.,sealed at one end, and a .3mm hole drilled at a height of about .38mm was used to scan the stations at and downstream of the separation point.

3. Flow visualization: Tuft spoke flow visualization photos (Fig. 8) were taken to obtain qualitative and quantitative information about the depth of the separated regions (α = 9° to 20°). Exploration of the point of separation at the angles of attack of 10°, 14° and 18° was made by surface flow visualization techniques like tuft survey and oil flow patterns. These were found to agree very well with the surface pressure distribution measurements.

The above tests were carried out at a Mach No. of .13 and

Reynolds number of 2×10^6 based on the airfoil chord.

4. Problem areas: A problem has been encountered in measuring the total pressure values at positions very close to the wall (distances less than 1.0mm (.040")). This problem has been discussed with NASA researchers and it appears that differential deflections of the wing and probe under aerodynamic loads may have resulted in probe deflections similar to those reported in NASA TN D-5523. Analysis of this problem is presently underway to determine the source of the discrepancies and appropriate corrections. No other problems have been encountered in carrying out the research.

5. Present Status: The scheduled 60 hours of wind tunnel testing has been completed, The velocity profiles are currently being analyzed to estimate the growth of the boundary layer displacement thickness, local skin friction, and the overall flow pattern. It is anticipated that a preliminary copy of all experimental data for the final report will be available 1 September. Preliminary copy of the narrative will be available approximately 1 October.

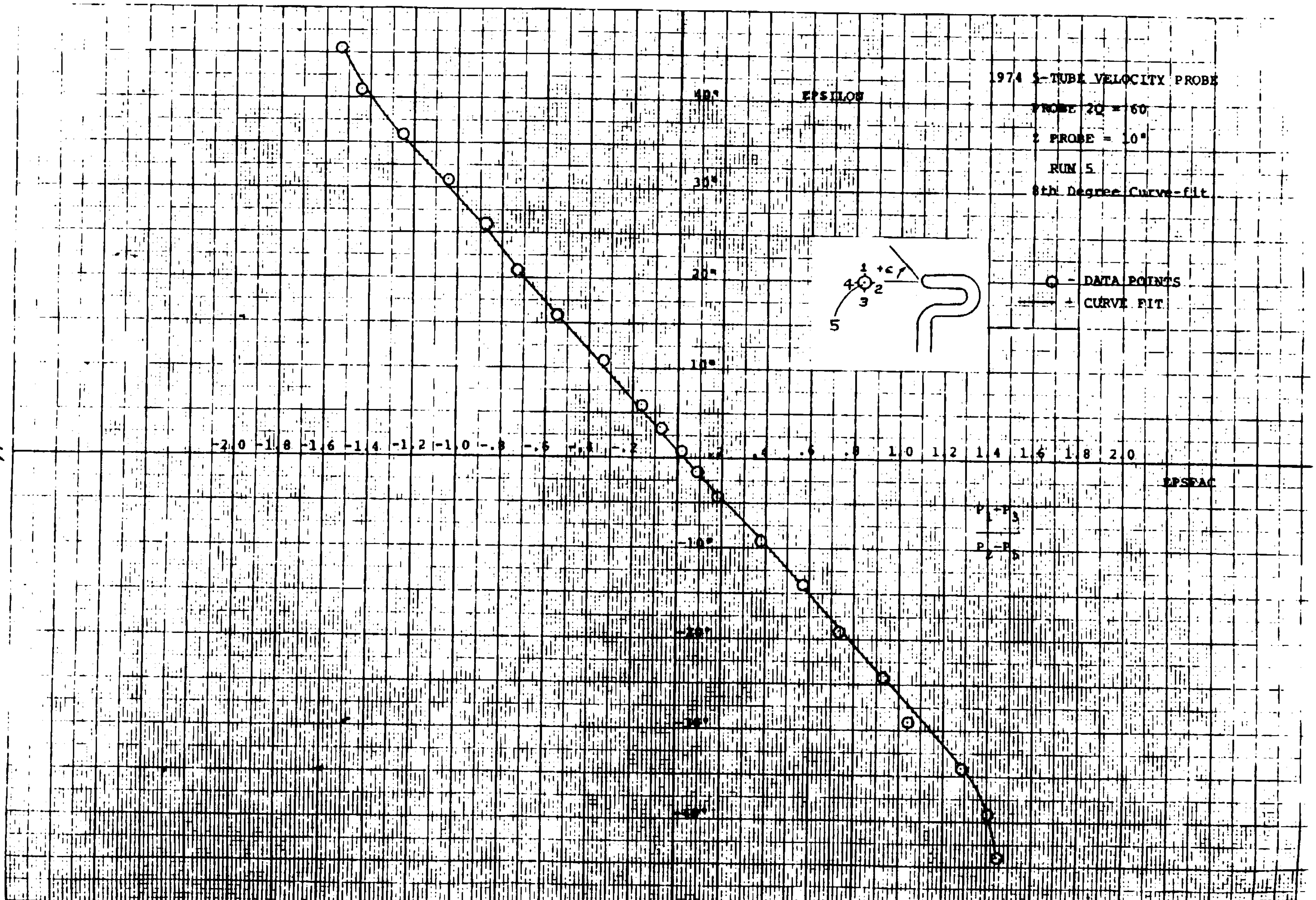

1974 S-TUBE VELOCITY PROBE
PROBE 2Ω = 60
∠ PROBE = 10°
RUN 5
8th Degree Curve-fit
○ - DATA POINTS
— - CURVE FIT
EPSILON
EPSFAC
40°
30°
20°
10°
-10°
-20°
-30°
-40°
-2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -.8 -.6 -.4 -.2 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0
$\frac{P_1 - P_3}{P_2 - P_5}$
1
2
3
4
5
+ε
Walber 1-31-74

Fig. 1

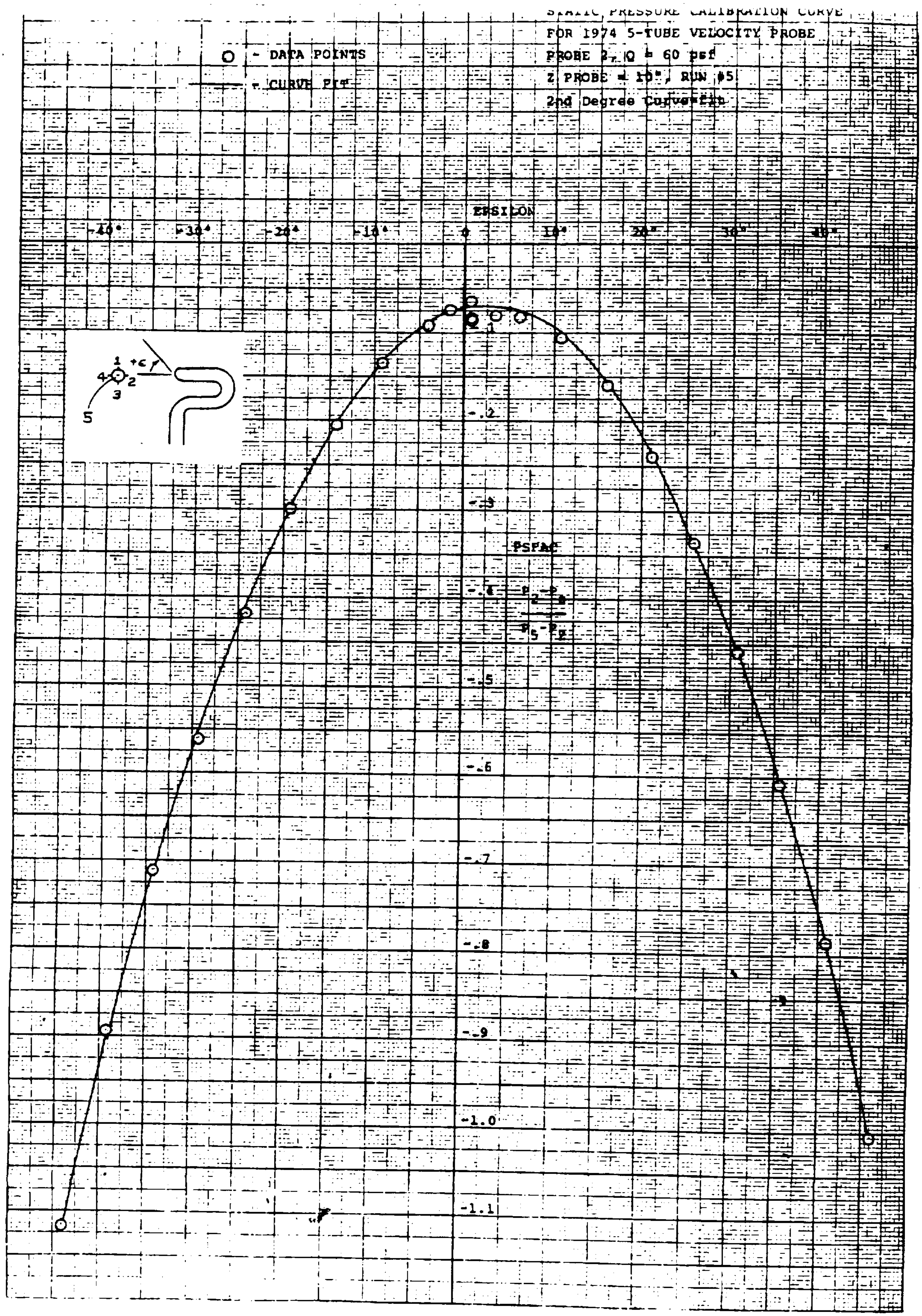

STATIC PRESSURE CALIBRATION CURVE
FOR 1974 5-TUBE VELOCITY PROBE
PROBE 2, Q = 60 psf
2nd Degree Curve Fit
O - DATA POINTS
— CURVE FIT
EPSILON
-40°
-30°
-20°
-10°
0
10°
20°
30°
40°
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
PSFAC
1
2
3
4
5

FIG. 2

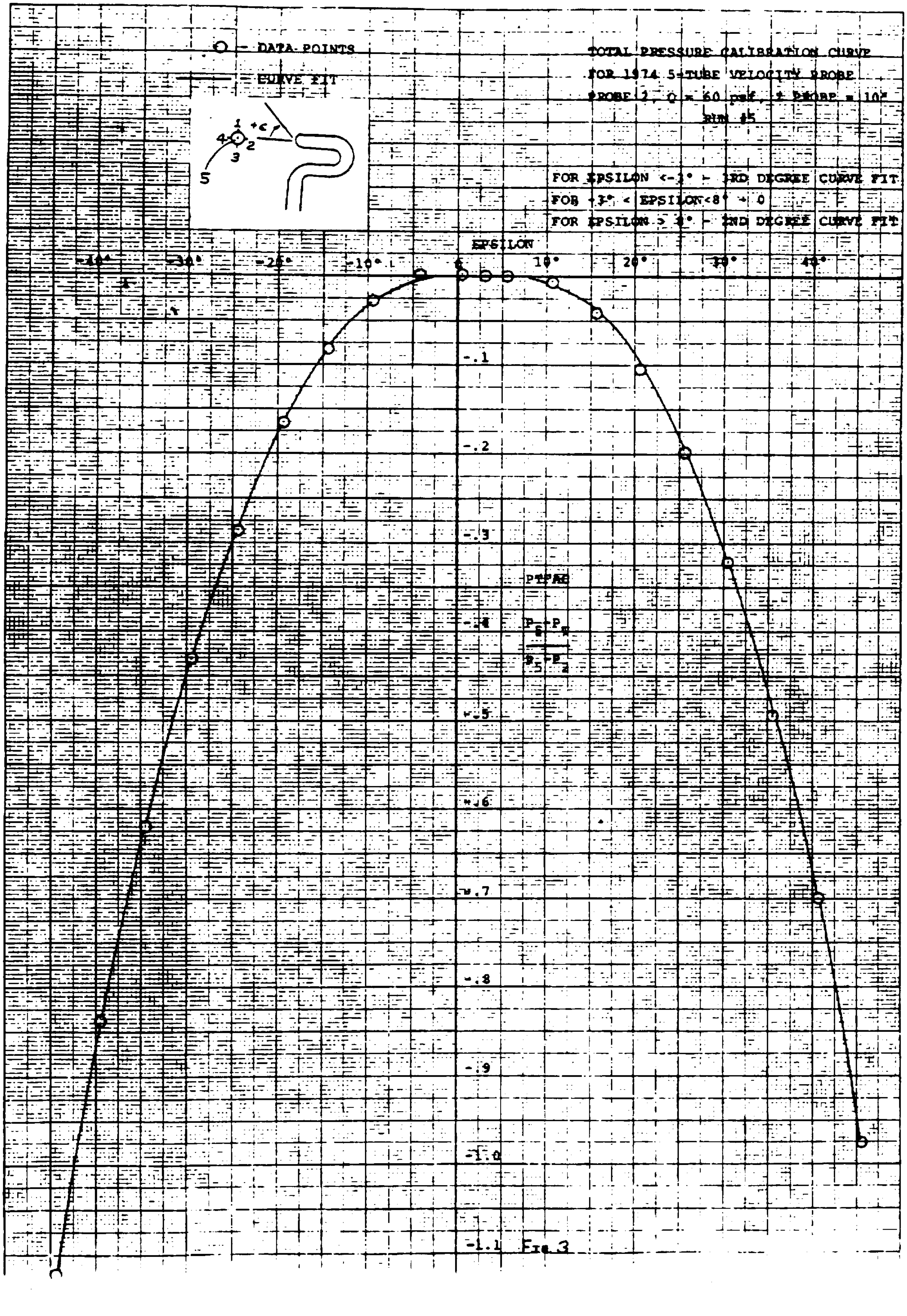

○ - DATA POINTS
—— = CURVE FIT
TOTAL PRESSURE CALIBRATION CURVE
FOR 1974 5-TUBE VELOCITY PROBE
RUN #5
1
2
3
4
5
+ε
FOR EPSILON <-3° - 3RD DEGREE CURVE FIT
FOR -3° < EPSILON < 8° → 0
FOR EPSILON > 8° - 2ND DEGREE CURVE FIT
EPSILON
-40°
-30°
-20°
-10°
0
10°
20°
30°
40°
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
PTPRE

Fig. 3

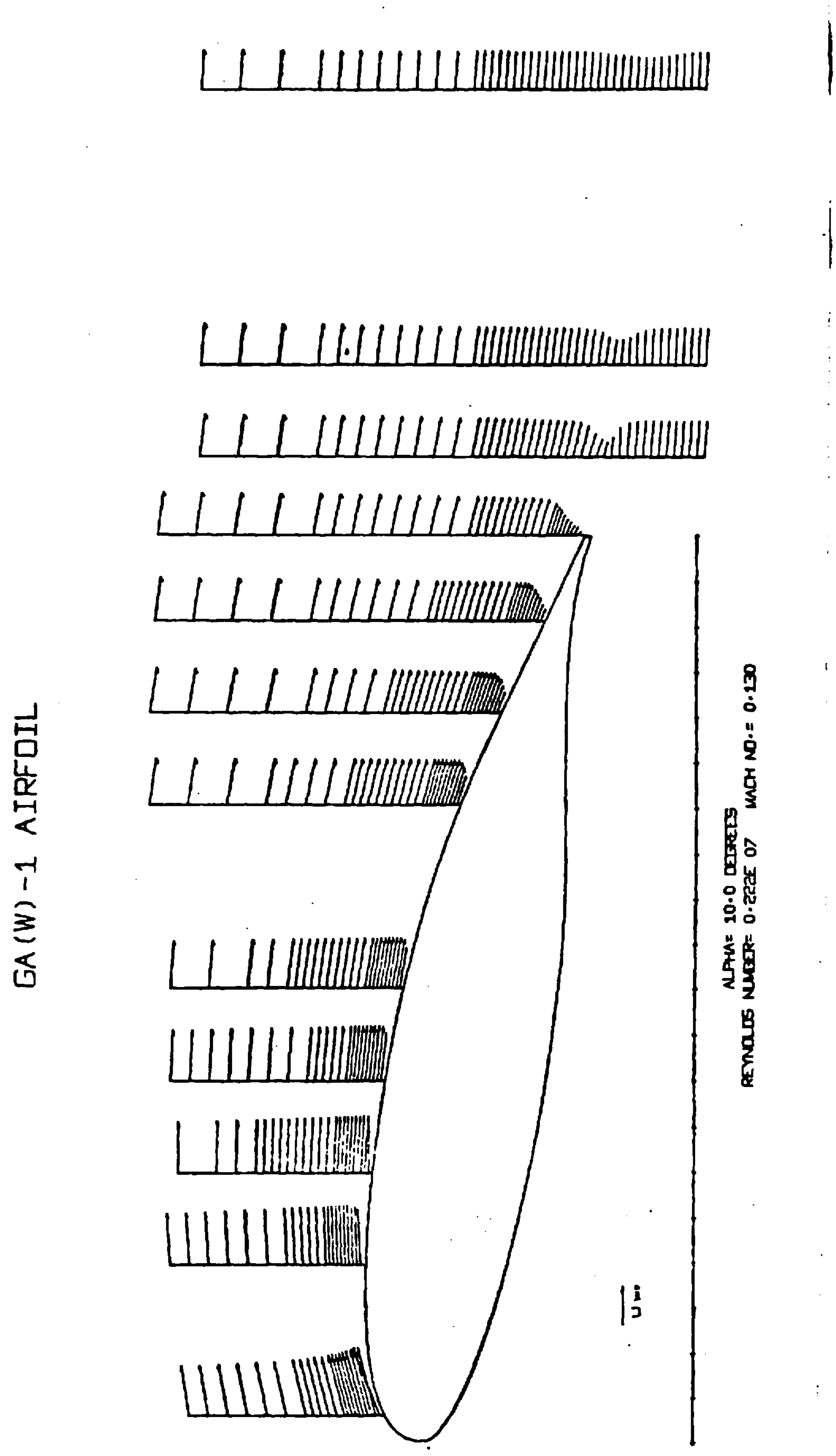
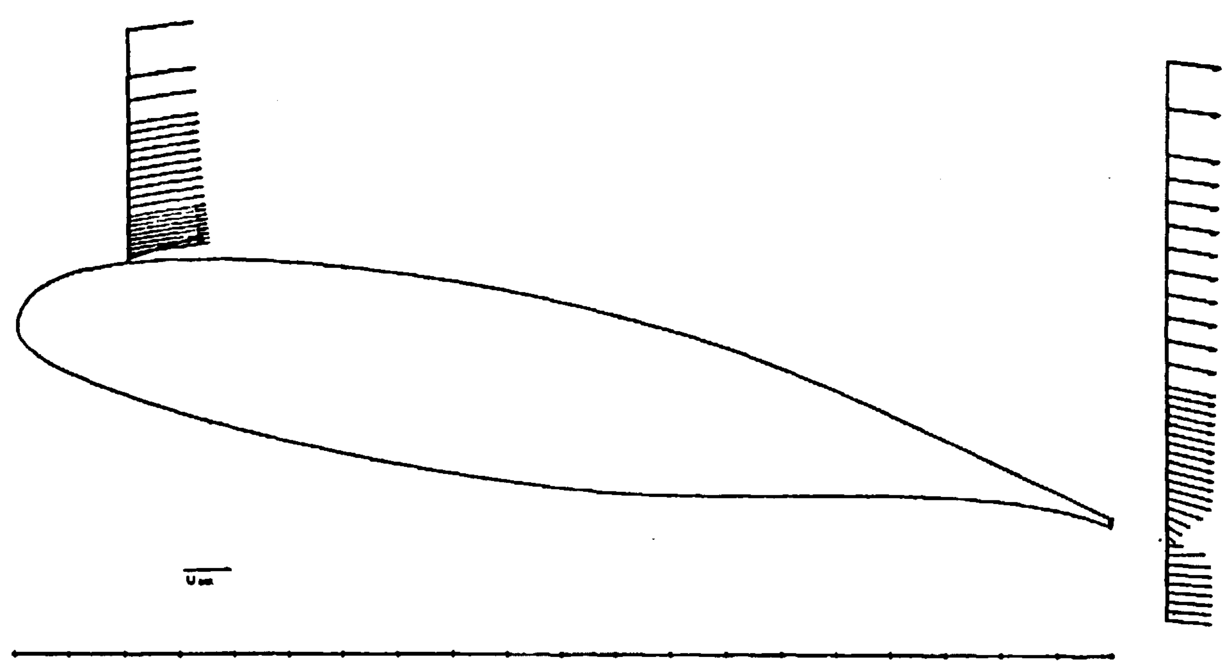

GA(W)-1 AIRFOIL
ALPHA= 10.0 DEGREES
REYNOLDS NUMBER= 0.222E 07 MACH NO.= 0.130

Fig. 4

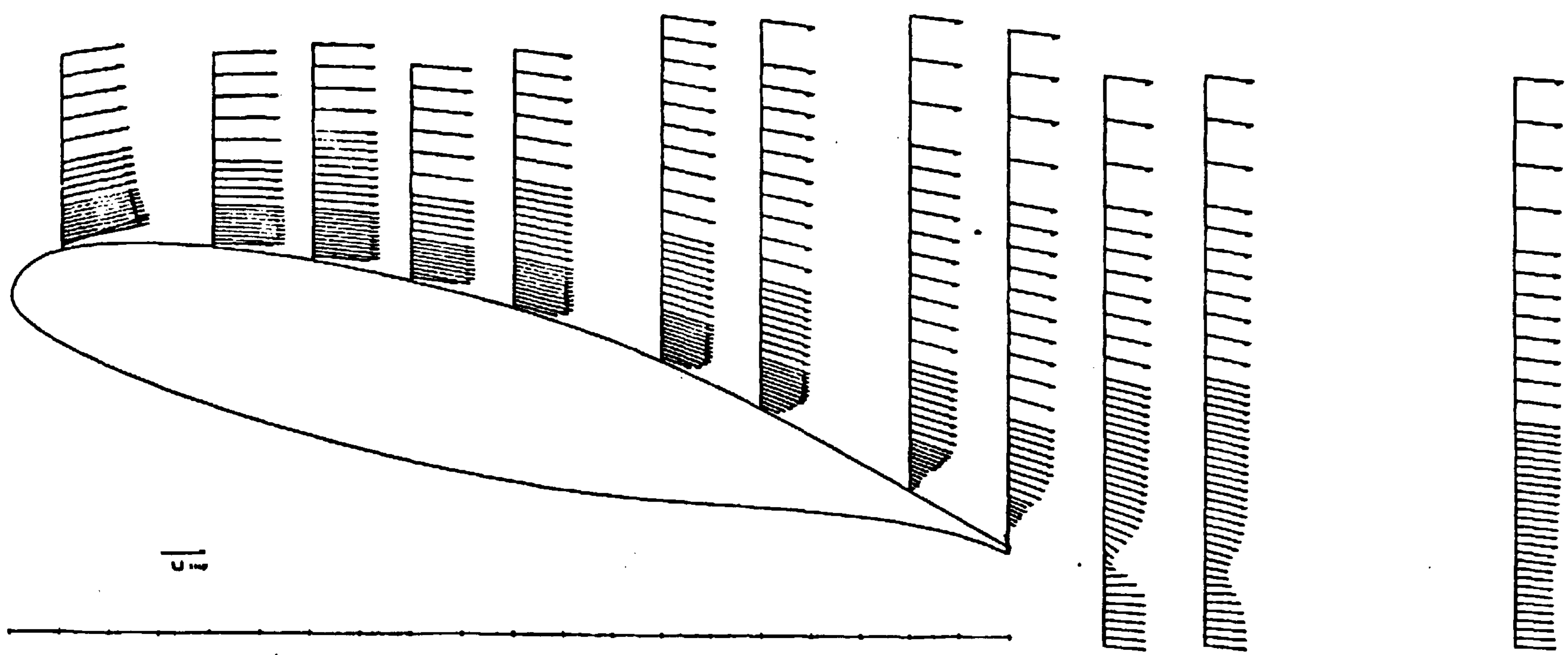
GA(W)-1 AIRFOIL



ALPHA= 10.0 DEGREES
REYNOLDS NUMBER= 0.222E 07   MACH NO.= 0.130

Fig. 4

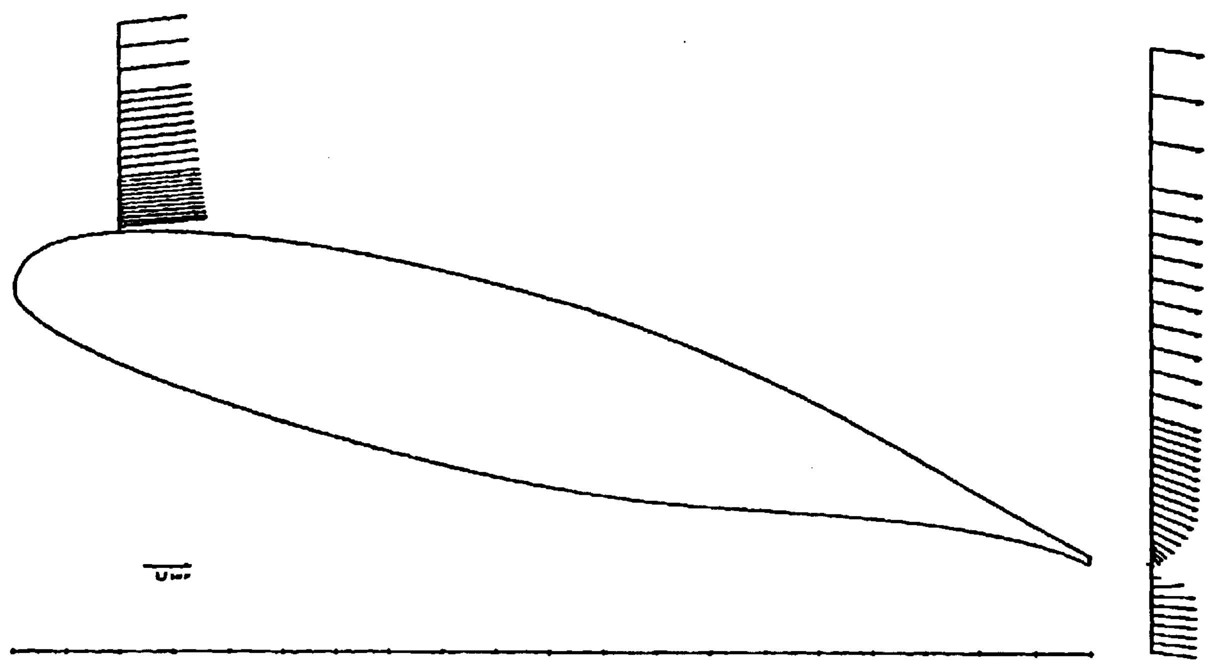
GA(W)-1 AIRFOIL



ALPHA= 14.0 DEGREES
REYNOLDS NUMBER= 0.222E 07 MACH NO.= 0.130

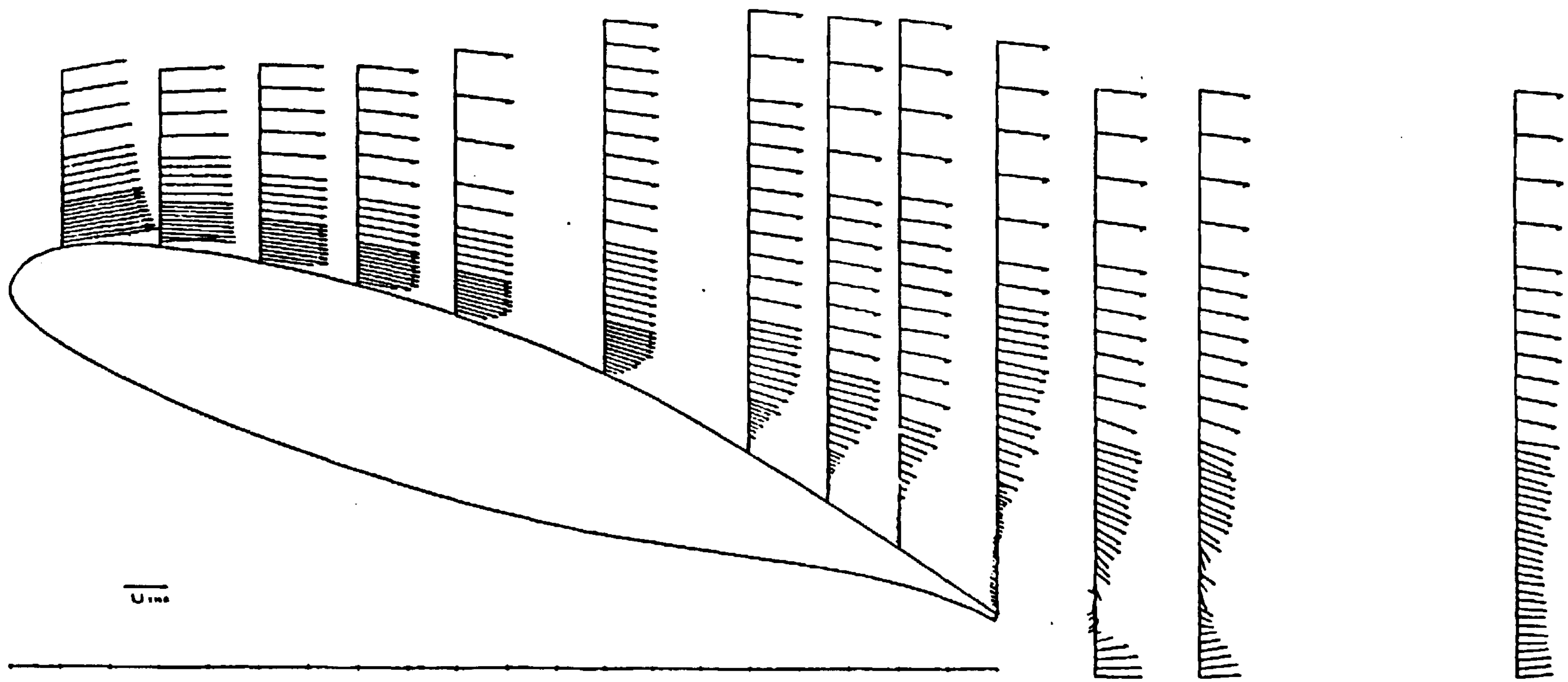
Fig. 5

GA(W)-1 AIRFOIL



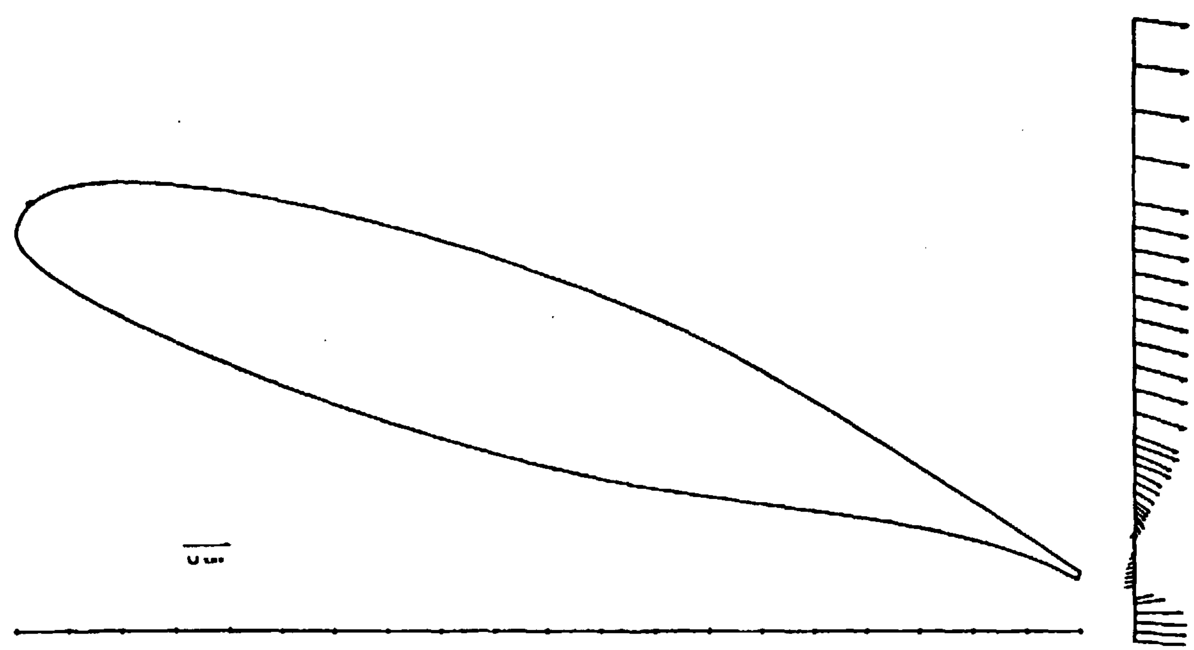
ALPHA= 14.0 DEGREES
REYNOLDS NUMBER= 0.222E 07   MACH NO.= 0.130

GA(W)-1 AIRFOIL



ALPHA= 18.0 DEGREES
REYNOLDS NUMBER= 0.222E 07 MACH NO.= 0.130

GA(W)-1 AIRFOIL



ALPHA= 18.0 DEGREES
REYNOLDS NUMBER= 0.222E 07   MACH NO.= 0.130

Fig. 6

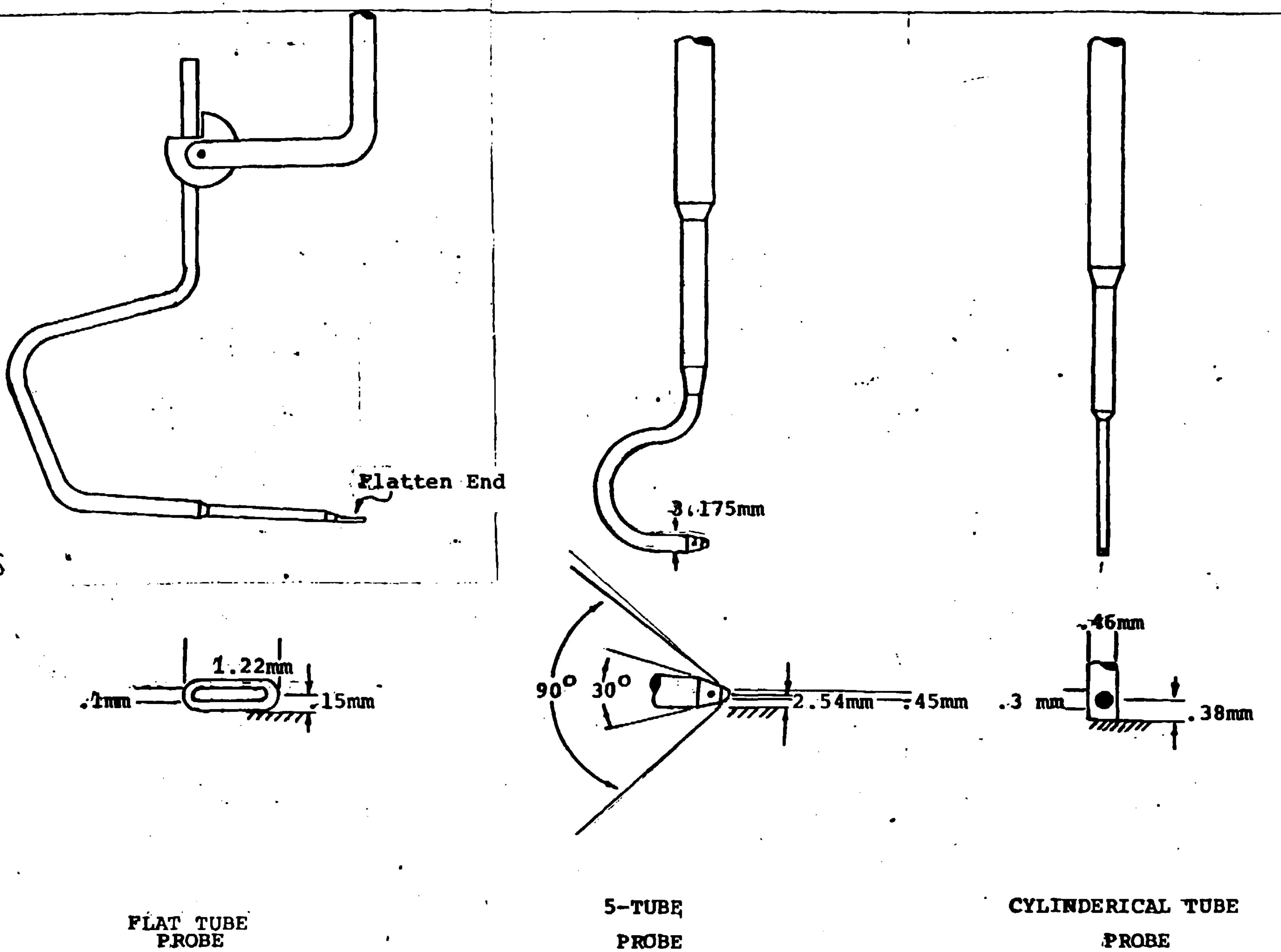
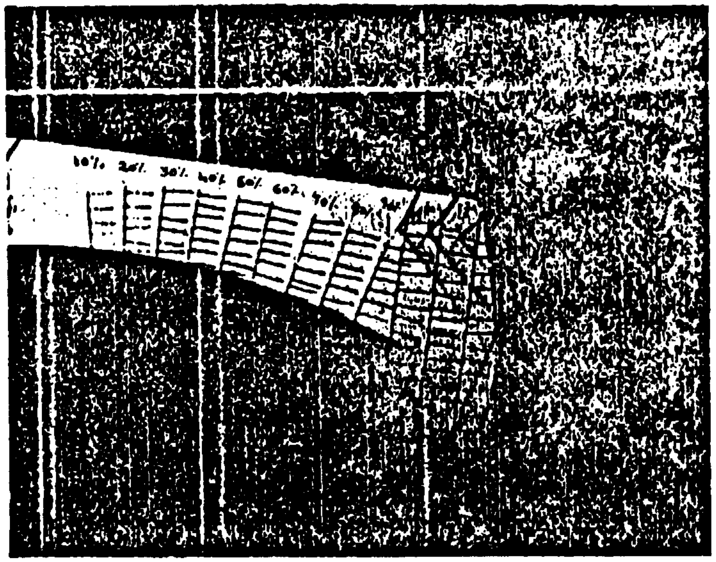
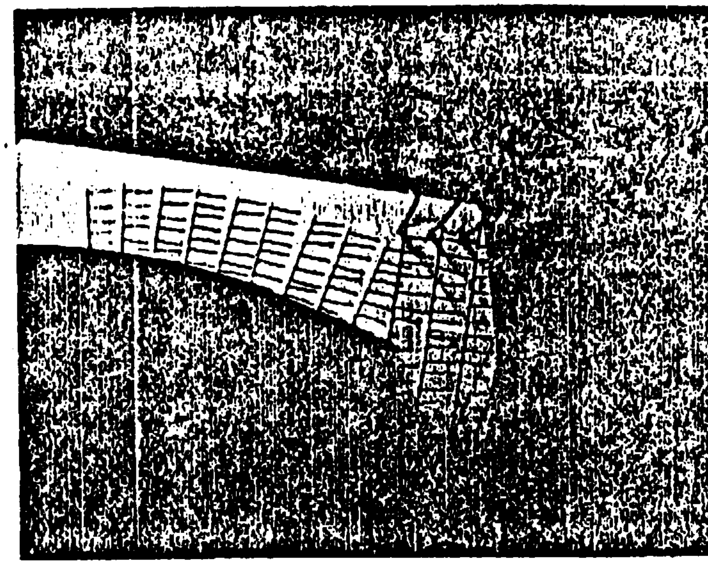

Flatten End
3.175mm
1.22mm
.1mm
.15mm
90°
30°
2.54mm
.45mm
.46mm
.3 mm
.38mm
FLAT TUBE PROBE
5-TUBE PROBE
CYLINDERICAL TUBE PROBE

Figure 7

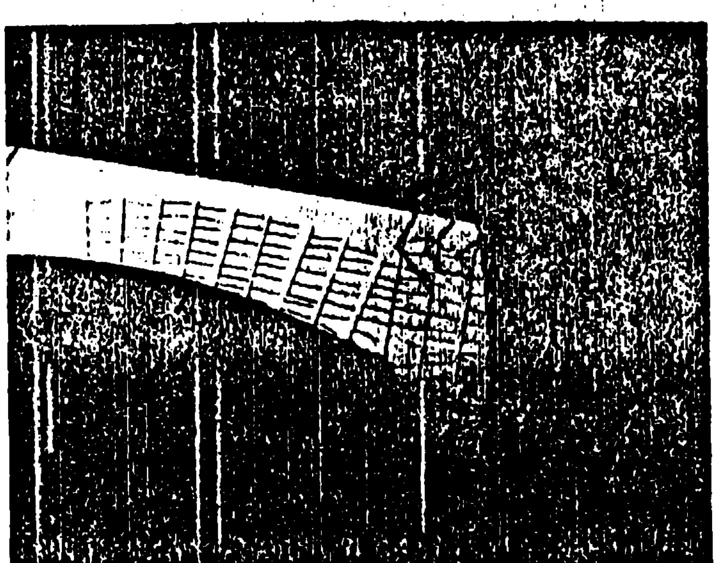
Fig 8: Tuft Spoke Flow Visualization $\alpha = 9° - 12°$ (Contd)



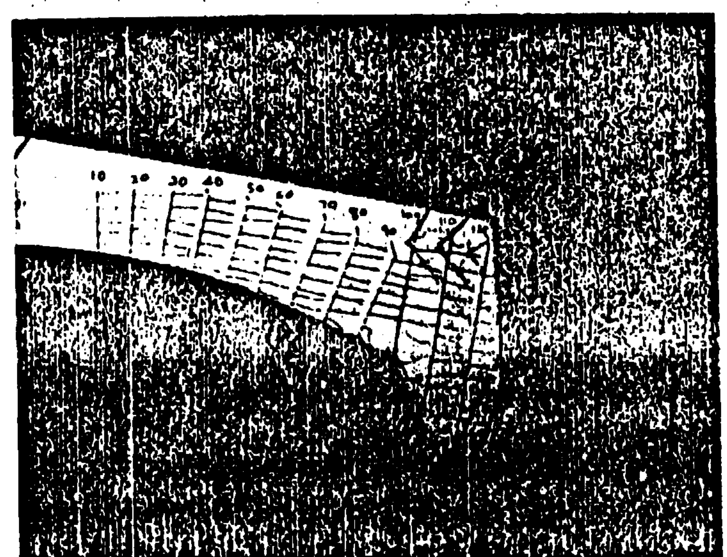
$\alpha = 9°$



$\alpha = 10°$

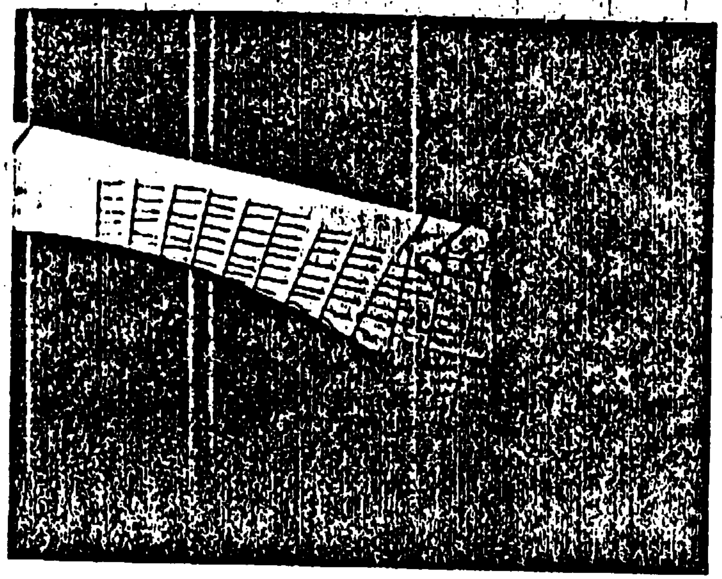


$\alpha = 11°$

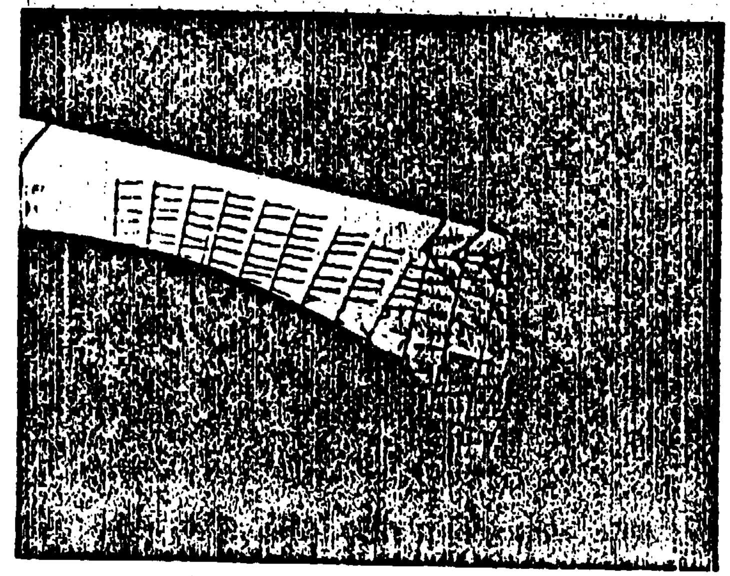


$\alpha = 12°$

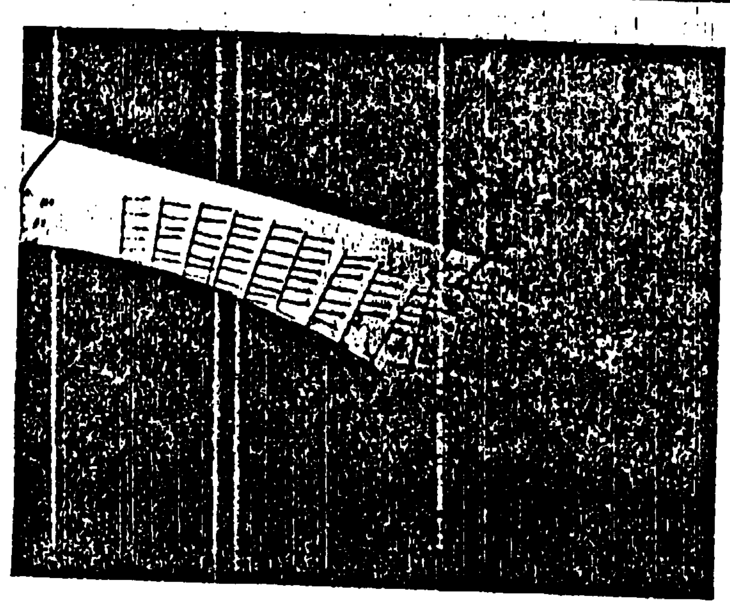
Fig 8: TUFT SPOKE FLOW visualization $\alpha = 13°$ to $16°$ (Contd)



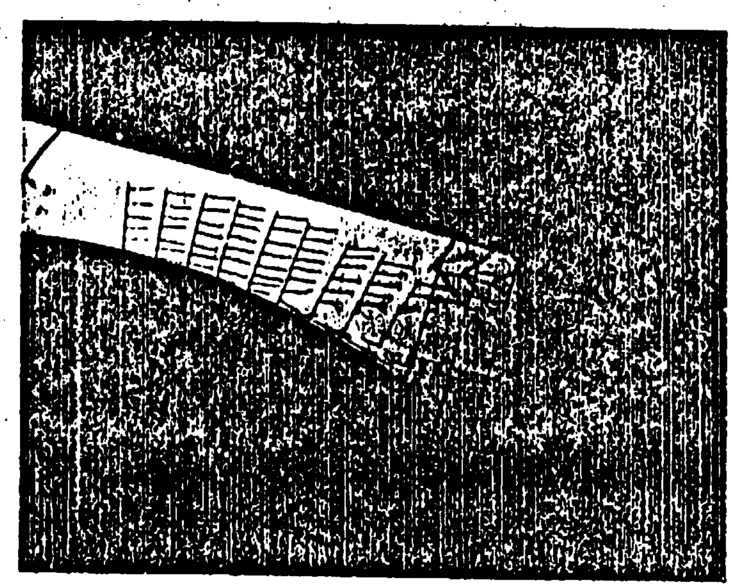
$\alpha = 13°$



$\alpha = 14°$ PRE STALL

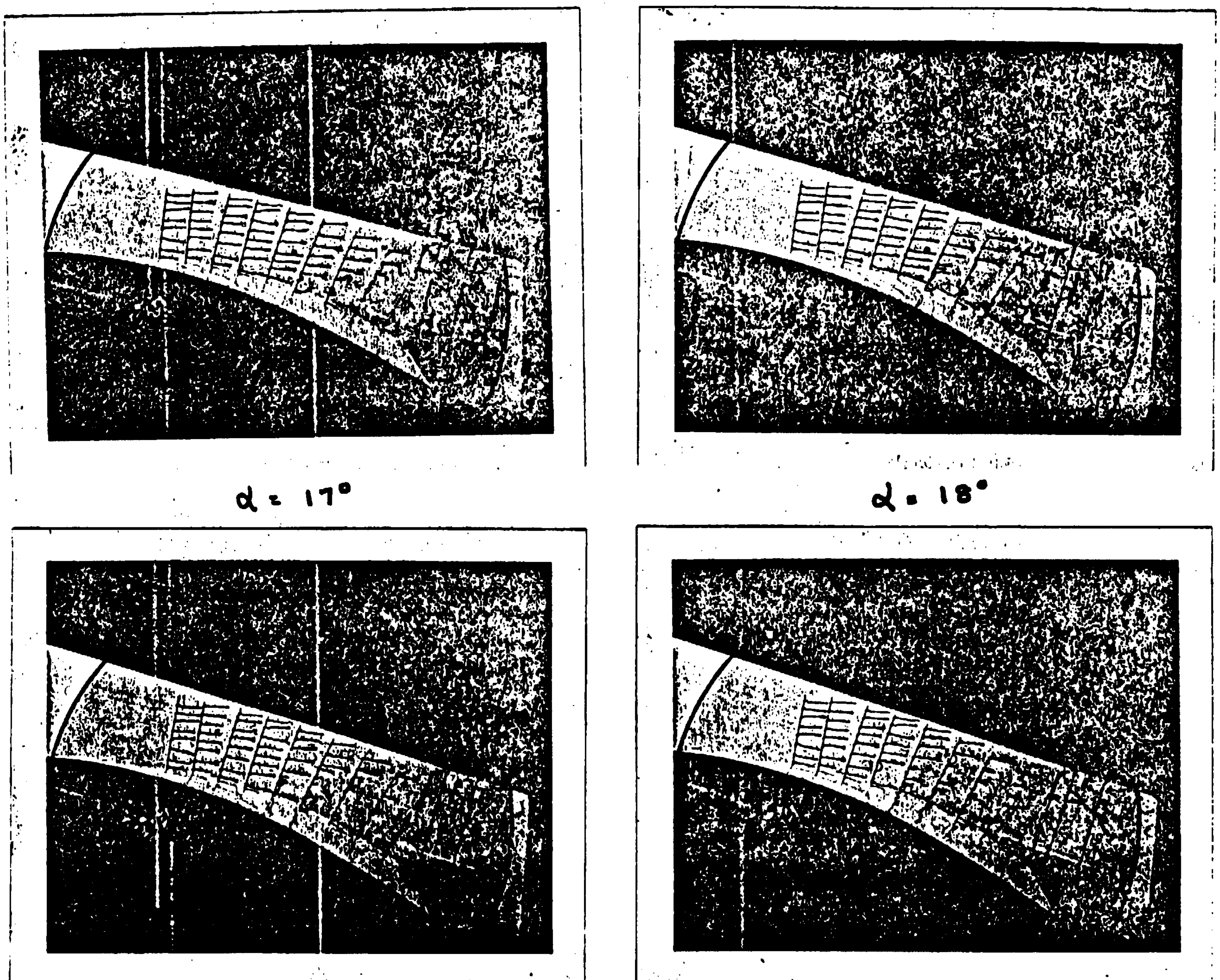


$\alpha = 15°$ STALL



$\alpha = 16°$; POST STALL

Fig 8: Tuft Spoke flow Visualization α = 17° to 20° (Concluded)



α = 17° α = 18°

α = 19° α = 20°