

A COLOR VIDEO DISPLAY
TECHNIQUE FOR FLOW FIELD SURVEYS

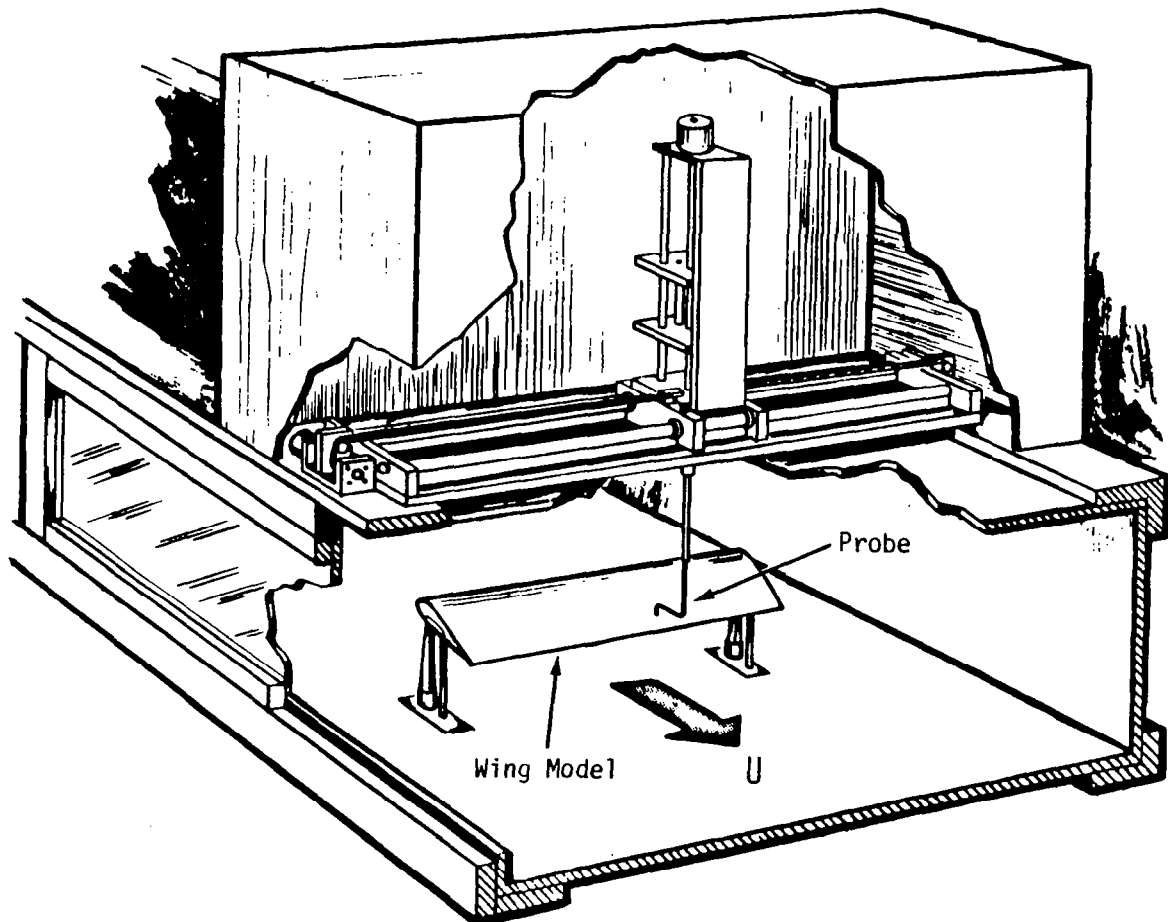
Allen E. Winkelmann
and
Chen P. Tsao

Department of Aerospace Engineering
University of Maryland
College Park, Maryland 20742

TRAVERSE DEVICE USED FOR FLOW FIELD SURVEYS
ABOVE AND BEHIND FINITE WING MODELS

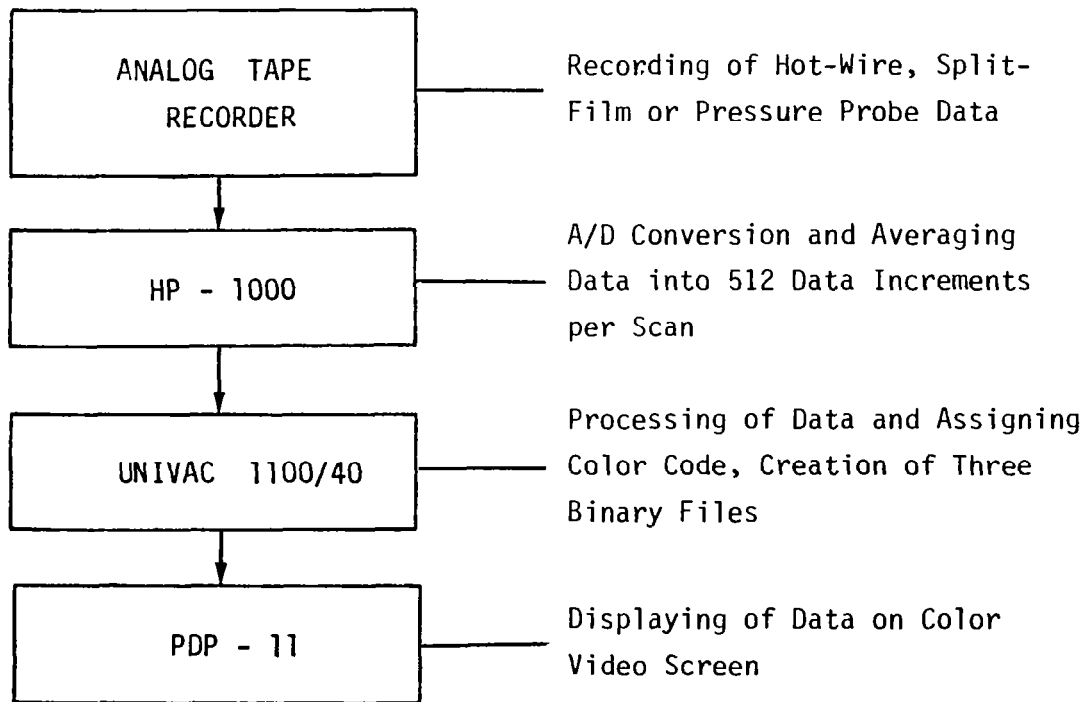
This figure shows a sketch of the traverse device used to obtain flow field survey data above and behind a wing model in the 1.17 x 0.46 m Aerospace Boundary Layer Tunnel at the University of Maryland. The wing model used in this test had an aspect ratio $AR=4.0$ with a 15.24 cm Clark Y-14 airfoil section. The traverse device allowed a probe to be scanned (spanwise) across the flow field generated by the wing. At the end of each scan, a secondary traverse unit was used to increment the probe location vertically. In addition to the hot-wire probe, surveys have also been made with a split-film probe, a Conrad (pitch) probe and a 5-tube probe. In the near future, a single channel laser velocimeter will also be used to scan the flow field generated by the wing.

The X-Y traverse device used in this study provided data in a direct analog to the video raster scan (i.e. in vertically incremented scan lines.) This simplified the computer processing since the data could be handled scan line by scan line. In some applications, such as flow field surveys in transonic or supersonic tunnels, where sting mounting systems are used, traverse devices which scan in circular arcs may be more appropriate. The data from such surveys will require additional computer processing since any given scan may cut across many different video raster lines.



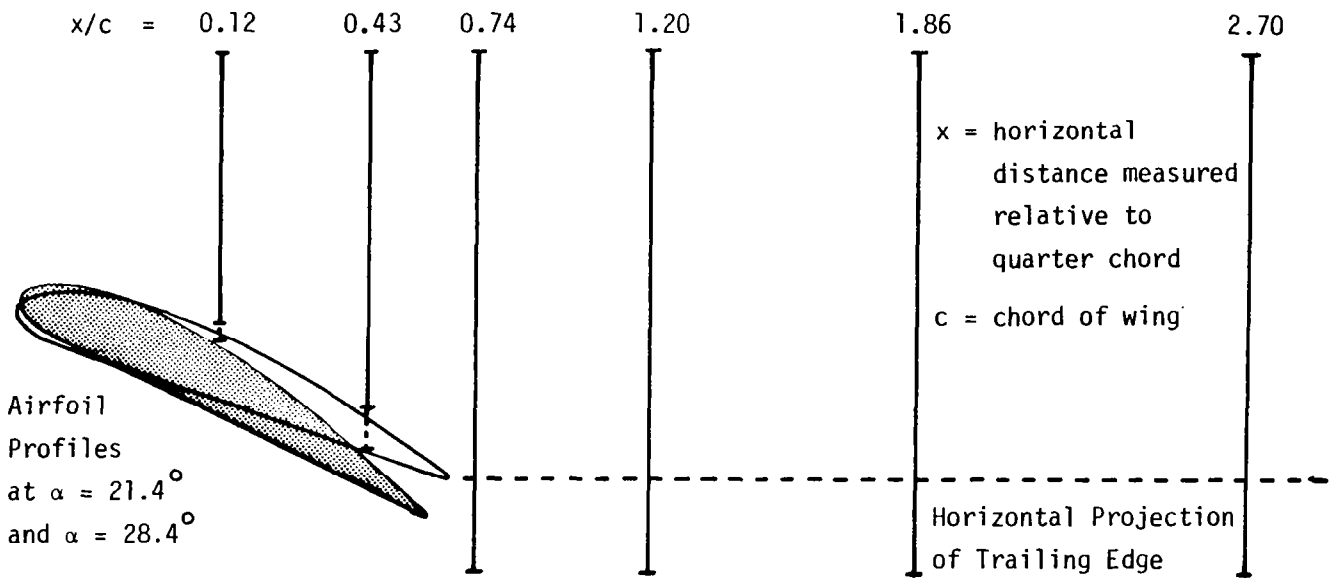
FLOW CHART OF DATA REDUCTION FOR
COLOR VIDEO DISPLAY TECHNIQUE

The data obtained in a flow field survey was initially recorded on analog tape. In addition to the spanwise location and probe transducer output, an on/off signal was recorded on one channel to identify the beginning and end of a scan. The analog tape was processed through the HP-1000 system which did the A/D conversion and averaged the 4000-7000 data points per scan into 512 spatial increments. Additional data processing (including color coding) was completed on the UNIVAC system. For qualitative data such as that obtained by the hot-wire probe, the voltage range from minimum to maximum was divided into 15 to 20 levels or windows and a color was assigned to each level. For qualitative data such as that obtained by the 5-tube probe, each data window or color corresponded to a specific range of flow direction, pressure, etc.. A PDP-11 computer system was finally used to display the data on a color monitor with 512 x 512 pixel resolution.



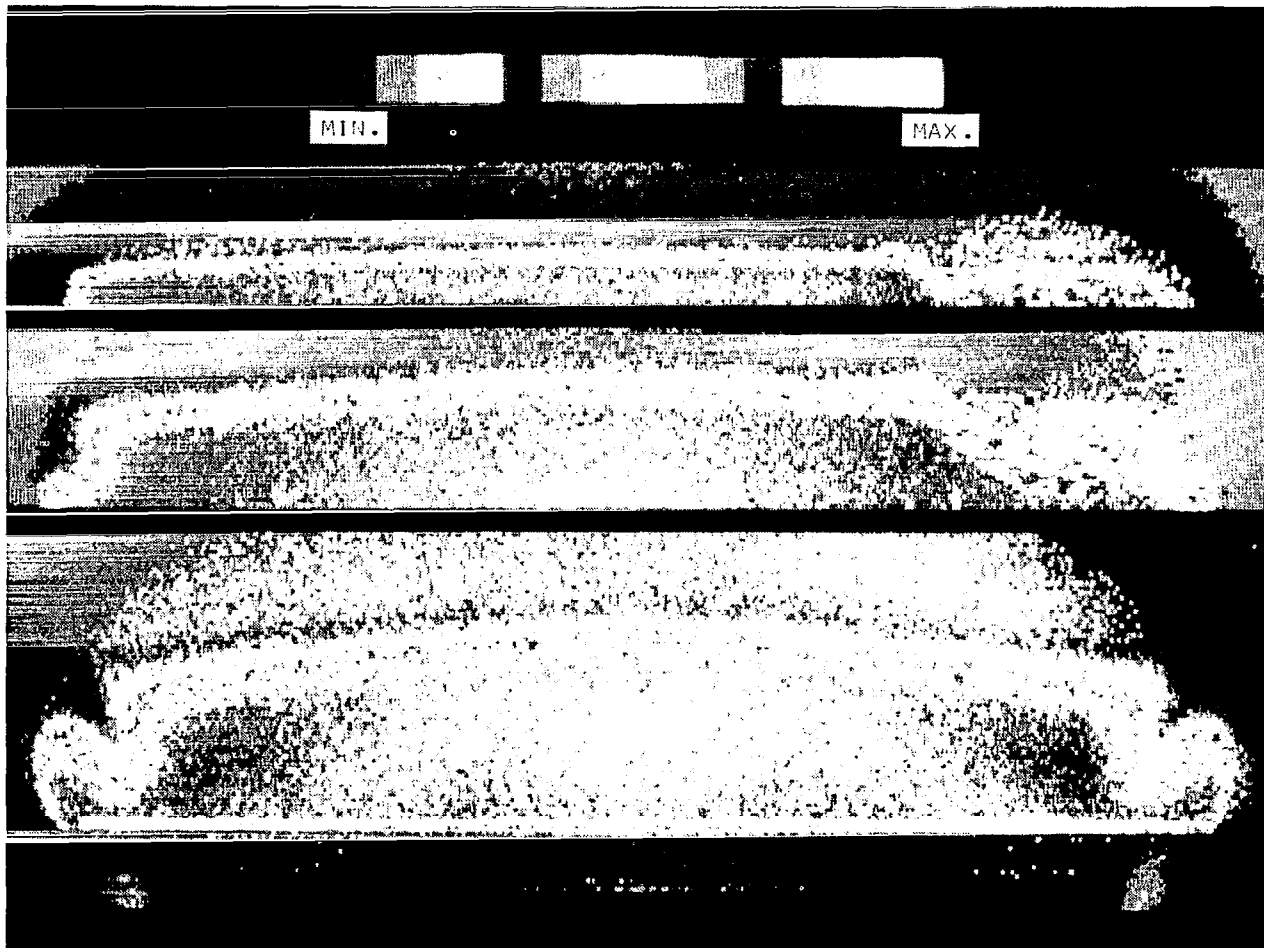
LOCATION OF SPANWISE SURVEY STATIONS ABOVE AND BEHIND WING

Flow field surveys were made at six stations above and behind the wing at two angles of attack. The wing was partially stalled at $\alpha = 21.4^\circ$ and fully stalled at $\alpha = 28.4^\circ$. Surface oil flow studies show the development of a well defined "mushroom" shaped trailing edge stall cell on the wing at $\alpha = 21.4^\circ$. For the fully stalled wing, oil flow studies indicate regions of reversed/recirculating flow over most of the upper surface.



HOT-WIRE DATA AT FIRST THREE SURVEY
STATIONS ON FULLY STALLED WING

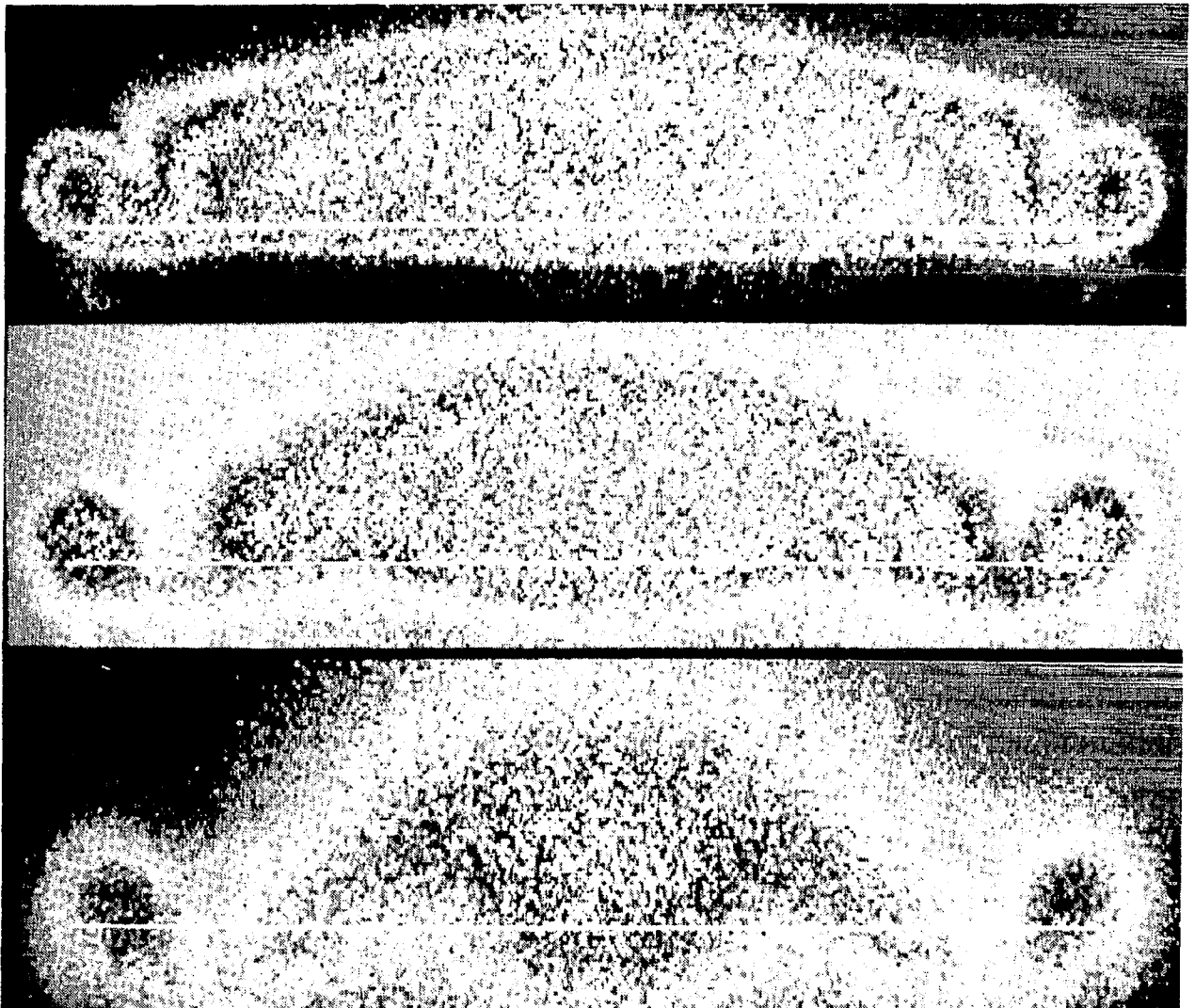
This photograph shows the hot-wire data (dc output) obtained at the first three stations on the fully stalled wing ($\alpha = 28.4^\circ$, $x/c = 0.12$, 0.43 , 0.74). The view of the data plane is from behind the wing--i.e. as if the viewer were in the diffuser. The white line in the bottom data image is the horizontal projection of the trailing edge of the wing. The separated wake region is characterized by shades of red and yellow indicating the minimum hot-wire output. This data display is highly qualitative since the hot-wire probe is sensitive to changes in flow speed and/or flow angle. The formation of a rather diffuse tip vortex can be seen in the bottom data image. Wake blockage above the separated region appears as shades of pink (maximum output). The wake flow from the mounting struts can be seen near each wing tip in the bottom data image. In some sense, this data display can be considered as a form of flow visualization.



L-82-5680

HOT-WIRE DATA AT LAST THREE STATIONS
BEHIND FULLY STALLED WING

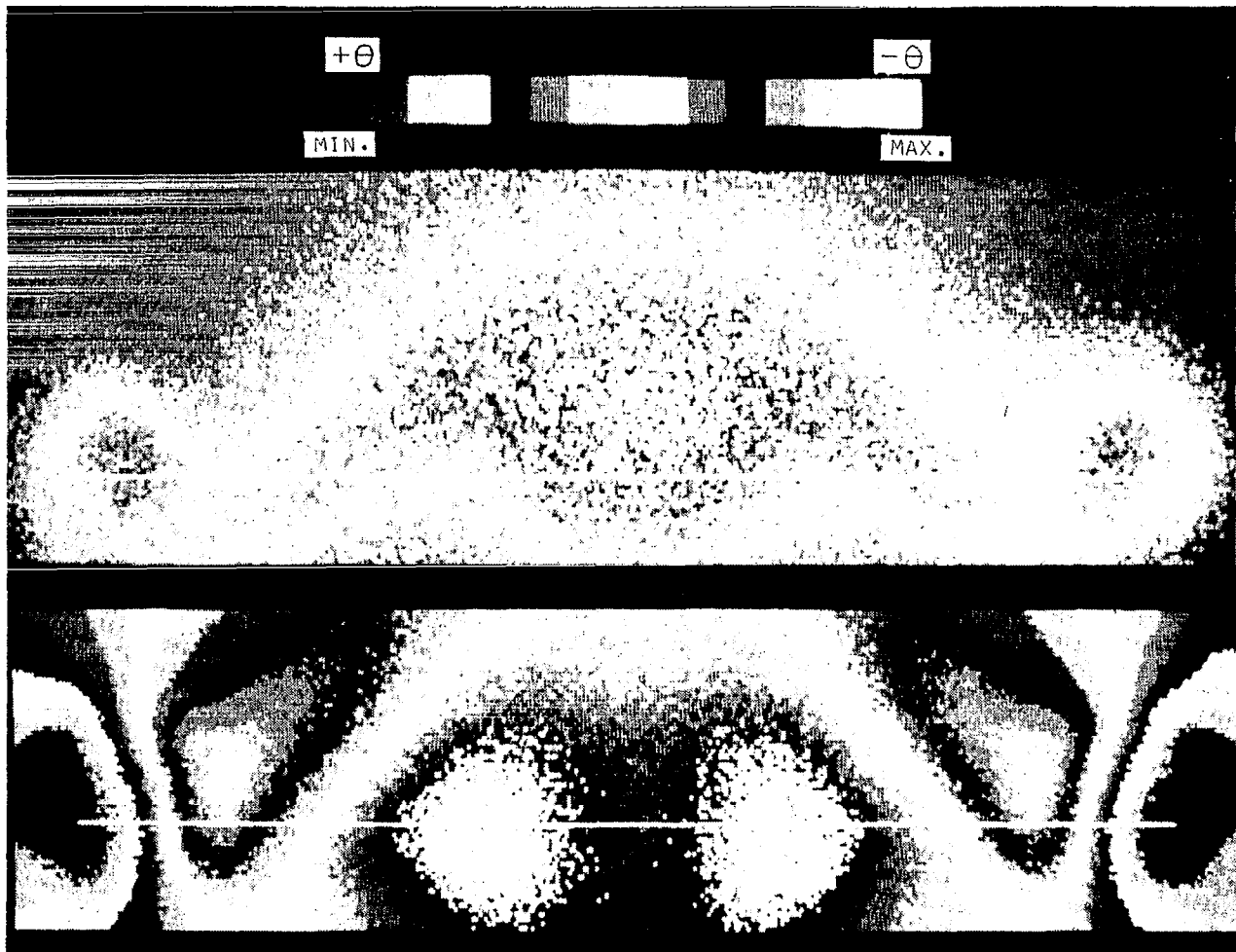
The hot-wire data at the last three stations on the fully stalled wing ($\alpha = 28.4^\circ$, $x/c = 1.20, 1.86, 2.70$) indicates the gradual dissipation of the separated wake region. The diffuse structure of the tip vortices may be an indication of a vortex "bursting" phenomenon.



L-82-5681

HOT-WIRE AND PITCH PROBE DATA AT
X/C = 2.70 BEHIND FULLY STALLED WING

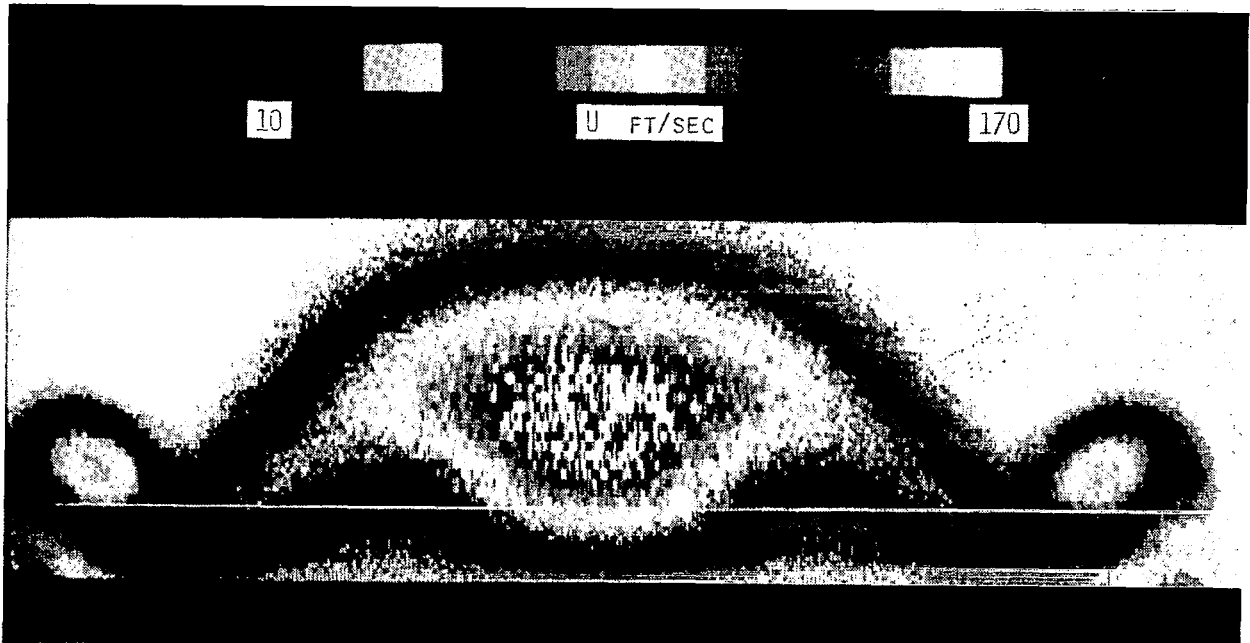
The hot-wire data and pitch probe data at the last survey station for the fully stalled wing are shown here for comparison. The tip vortex structure is very clearly shown by the pitch probe output. Shades of red and yellow outboard of the wing tips indicate a strong upward (+ θ) flow. Just inboard of the tips, shades of pink indicate a strong downward (- θ) flow. Because the pitch probe is also affected by cross flow, the data display from this probe is considered qualitative.



L-82-5682

MAGNITUDE OF VELOCITY FROM 5-TUBE SURVEY
AT $x/c = 2.70$ BEHIND FULLY STALLED WING

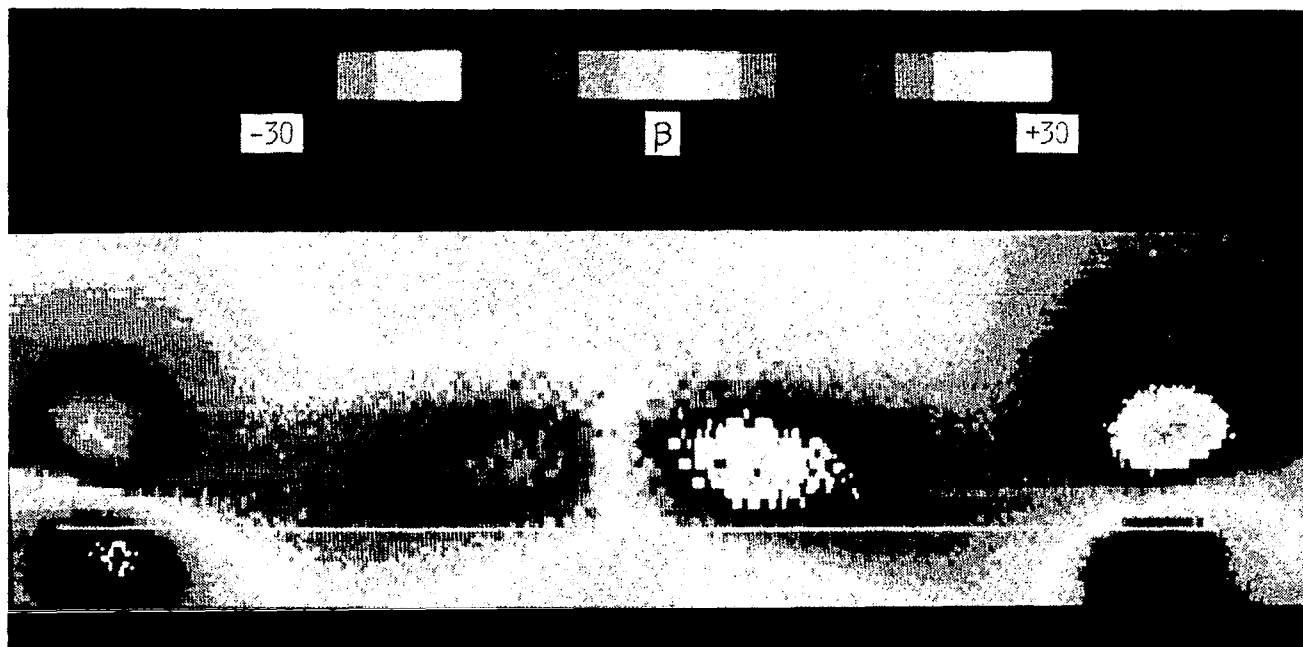
This photograph shows the magnitude of velocity obtained at the last survey station on the fully stalled wing ($\alpha = 28.4^\circ$, $x/c = 2.70$) using a scanning 5-tube probe. Each color covers a speed range of 8 ft/sec. The lowest speeds in shades of reds and yellows occur in the center of the wake region. It is interesting to note that the core of the tip vortex is relatively slow ($U \approx 90$ ft/sec). A similarity between this data display and the hot-wire data shown in the previous photograph is apparent.



L-82-5683

YAW ANGLE FROM 5-TUBE SURVEY AT X/C = 2.70
BEHIND FULLY STALLED WING

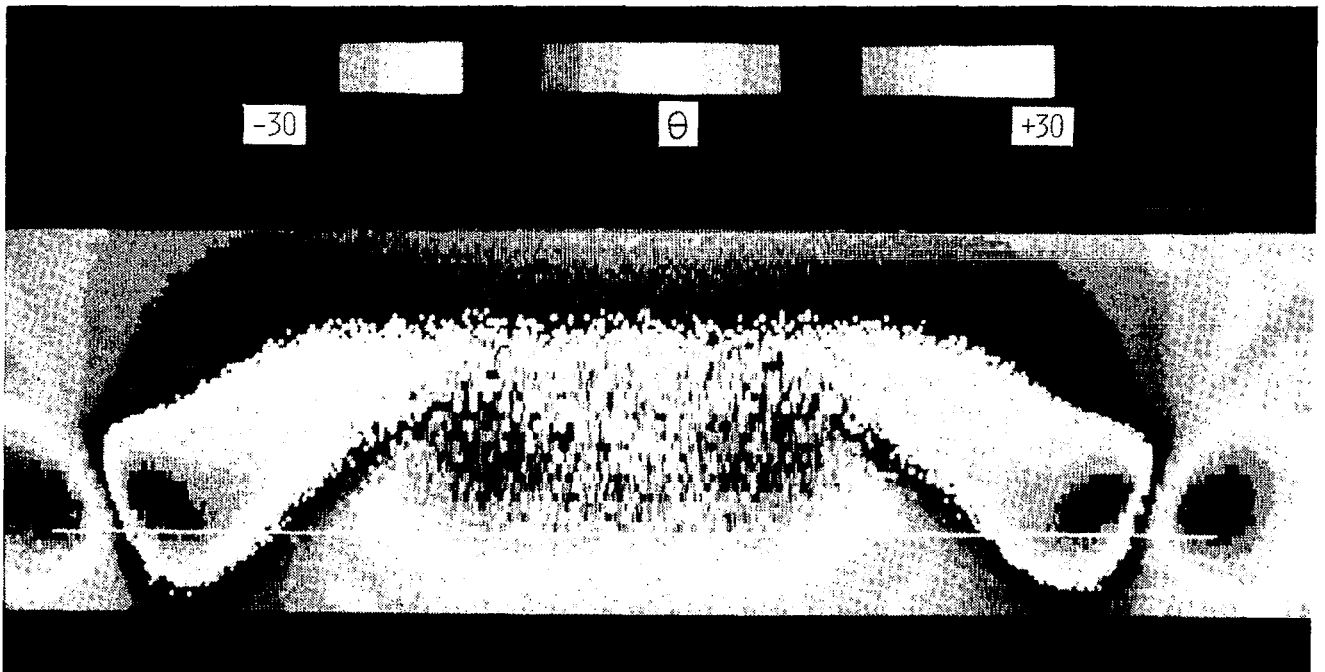
In this data display, flow to the right ($+\beta$) is indicated in shades of blues and pinks, where each shade of color is an increment of 3° . Flow to the left ($-\beta$) is in shades of greens and yellows. The inward (vortex) flow above the wing tips is clearly indicated in this display. The two regions of pink and yellow to either side of the center also indicate an inward flow.



L-82-5684

PITCH ANGLE FROM 5-TUBE SURVEY AT $X/C = 2.70$
BEHIND FULLY STALLED WING

This photograph looks quite similar to the pitch probe data shown on a previous page. The color code has been reversed so that shades of yellow and green indicate downward ($-\theta$) flow and shades of blue and pink indicate upward flow ($+\theta$). As before, the pitch data very clearly shows the tip vortices.

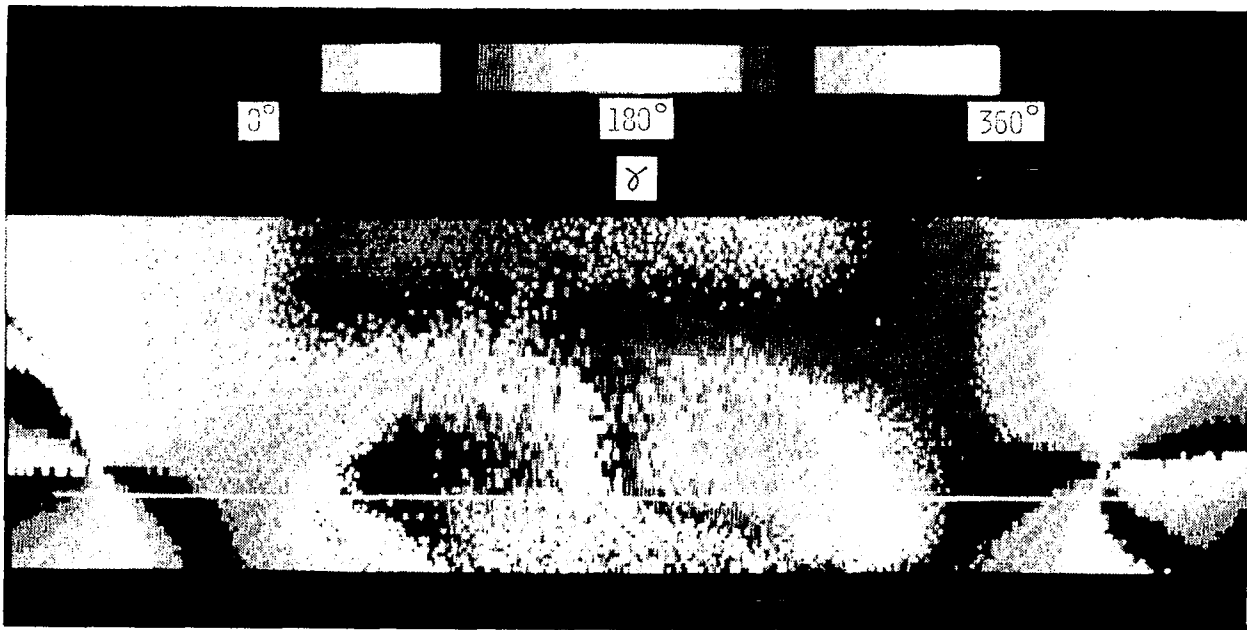


L-82-5685

CROSS-FLOW DIRECTION FROM 5-TUBE SURVEY AT
X/C = 2.70 BEHIND FULLY STALLED WING

This display shows the cross-flow direction γ at the $x/c = 2.70$ station of the fully stalled wing. Each color represents a flow angle increment of 18° . For example, any region showing the darkest shade of red is flow going off to the right side between $\gamma = 0^\circ$ (horizontally to the right) and $\gamma = 18^\circ$ (γ measured positive in the CCW direction). The border between the darkest shade of red and white is flow going horizontally to the right ($\gamma = 0^\circ$). The next lighter shade of red is for flow going to the upper right corner at flow angles γ between 18° and 36° to the horizon. In a similar manner, the subsequent colors are for flows (in 18° increments) going off in other pie shaped sectors. Obviously a circular pie sectored color chart would be appropriate here. The circular flow field generated by the tip vortices is very clearly shown in this display.

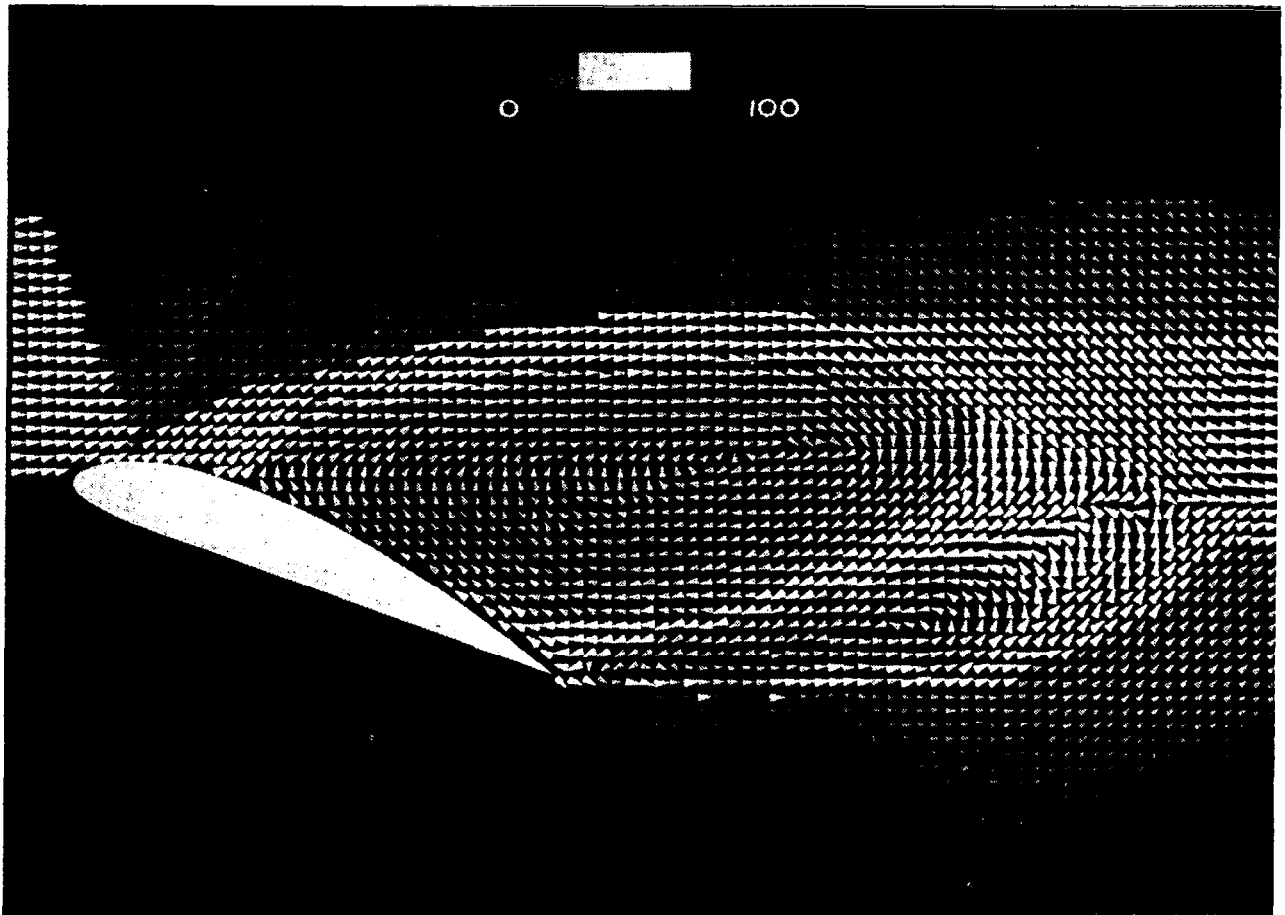
In addition to the data from the 5-tube probe shown in the above photographs, further data processing has been completed to show the total and static pressure fields. Further details of the technique presented here are given in AIAA Paper No. 82-0611.



L-82-5686

FUTURE DEVELOPMENTS FOR COLOR VIDEO
DISPLAY OF FLOW FIELD SURVEY DATA

With future advances in the resolution of computer driven color video monitors, someday a data display such as shown above may be possible. In this highly idealized artist's conception, color is used to indicate magnitude while the deltas show flow direction. Perhaps someday a wind tunnel operator will sit in the control room watching a large projection video monitor on which a view of the model has been dubbed in, and shimmering behind the model will be a real time data display being constantly updated with a rapidly scanning laser velocimeter. When the operator changes the model to a different angle of attack, the data image will gradually change to show the new flow field geometry.



L-82-5687