TRANSONIC APPLICATIONS OF THE WAKE IMAGING SYSTEM

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A rapid flow field survey method, known as the Wake Imaging System (WIS), originally developed for low speed wind tunnel operation, is being extended to transonic wind tunnel applications. The greatest difficulty in performing these flow field surveys at high dynamic pressures in transonic wind tunnels is the development of a relatively unobtrusive probe traversing system. The unique features of the WIS permits great flexibility in selecting a flow field traversing system.

Figure 1 shows a typical WIS data image from the Boeing 5 x 8 foot low speed wind tunnel. This photograph is the only form of the flow field data and is produced directly as a time-exposure photograph of a traversing colored signal light attached adjacent to the sensing probe. As the sensor, in this case a total pressure pickup, is traversed through the flow field, its output voltage goes to a level detector circuit which causes the signal light to turn on various colors in certain, preset pressure ranges. As the sensor and signal light sweep through the flow field, the light blinks on and off with different colors corresponding to the local total pressure level. A camera located in the wind tunnel, focused on the survey plane, records the trajectory of the signal light as colored streaks which merge into the total pressure isobars seen here. The results can be available immediately at the conclusion of a run in the form of color Polaroid photographs without any additional data manipulation.

The great advantage of the WIS, besides the simplicity and low cost of the data acquisition system, is that the probe position data are recorded as an optical image of the actual sensor and thus are unaffected by the inevitable deflections of the probe support. This permits traversing systems which are deliberately flexible and have unusual motions.

The traversing system developed for low speed tunnels has the sensor supported on the end of a high aspect ratio strut extending perpendicular to the flow, inserted through a small hole in the test section ceiling. The type of motion used is polar coordinate, with the center of azimuthal travel at the tunnel boundary.

The first transonic application of the WIS at Boeing uses, as one of the two degrees of motion, the main model support strut, which moves vertically. The second degree of motion is provided by a linear traverse drive rigged to move perpendicular to the main strut motion (or horizontally). This drive has 25 inches of travel and a traverse rate of 5 inches per second. The system can survey a 2-D plane, perpendicular to the flow, with rectangular motion. It is limited to surveying models not mounted on the sting, such as floor mounted or external balance plate mounted models.

Since this system is relatively stiff and because we were not ready to install a camera in the tunnel, the position readout is by conventional electrical potentiometers. The data acquisition procedure uses an analog X-Y plotter driven by the two position potentiometers with the signal light mounted on the plotter pen arm. The plotter is placed inside a box and a camera located directly over it to take the time exposure photograph.

Figure 2 shows the system installed in the Ames 11-Foot Transonic Wind Tunnel behind a floor mounted half-span model of the 747. Notice the vortex generators attached to the wing surface. Figure 3 shows several typical data images from this installation and illustrates the type of details that can be resolved by the system. Keep in mind that these images are available on-line in the form of a Polaroid print after a ten-minute run.

Figure 4 shows WIS images acquired in the Boeing Transonic Wind Tunnel of the outboard nacelle flow field on the 747 with and without a wing-strut intersection fairing. The ability to resolve these local flow field details greatly enhances the ability to understand the aerodynamic effects of small configuration changes that way not be discernable in the overall model forces.

This particular traversing drive is far from optimum for this experiment. We are presently developing an all new 2-D traversing system utilizing a combination of linear and rotary motion as shown in Figures 5 and 6. This new traverser is called the Wide Area Rapid Traverser, or WART. It will use a slow moving, rigid, linear-traversing strut from the tunnel wall with a fast moving rotating strut on the end. The rotating strut relys on a self-trimming mechanism to automatically rotate its incidence angle to produce zero root bending moment on the strut as the rotational traverse motion carries it through the model flow field.

We are also developing a digital data acquisition and display system to replace the time exposure camera. An opto-electronic position sensor located inside the tunnel will produce electrical signals from a continuously illuminated light on the tip of the survey strut. The position signals and pressure transducer output will be connected to signal conditioners and a fast analog-to-digital converter and stored in a color graphics buffer. The color video display will show the traversing probe location in real time and so can aid in controlling the traverse motion. The completed image can be stored on a floppy disk and can be accessed for further analysis.

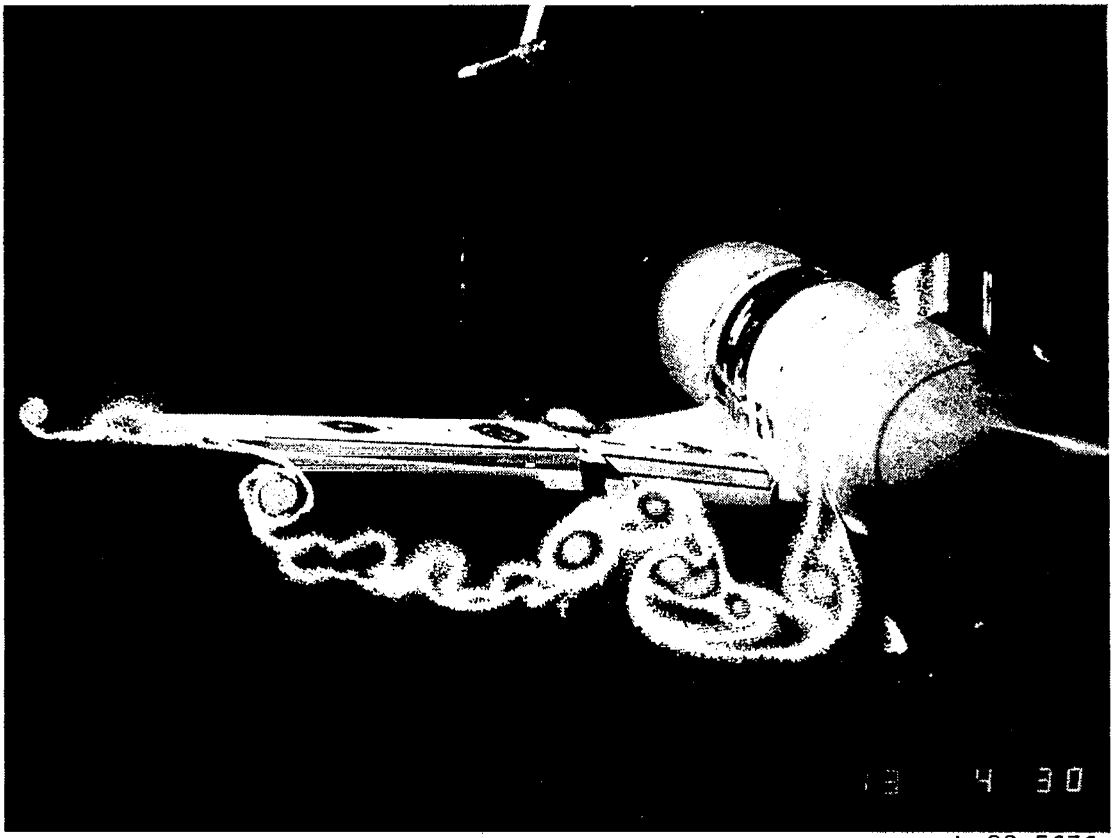

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Figure 1.- Typical WIS data image from 5 X 8 foot low speed wind tunnel.

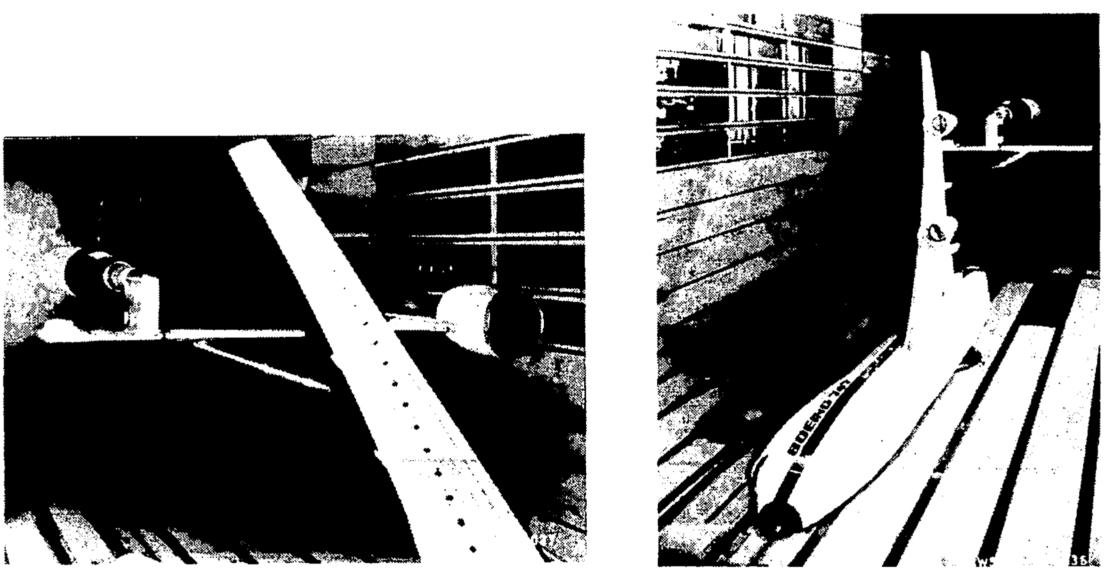

Figure 2.- Existing transonic WIS installed in Ames 11-Foot Transonic Wind Tunnel.

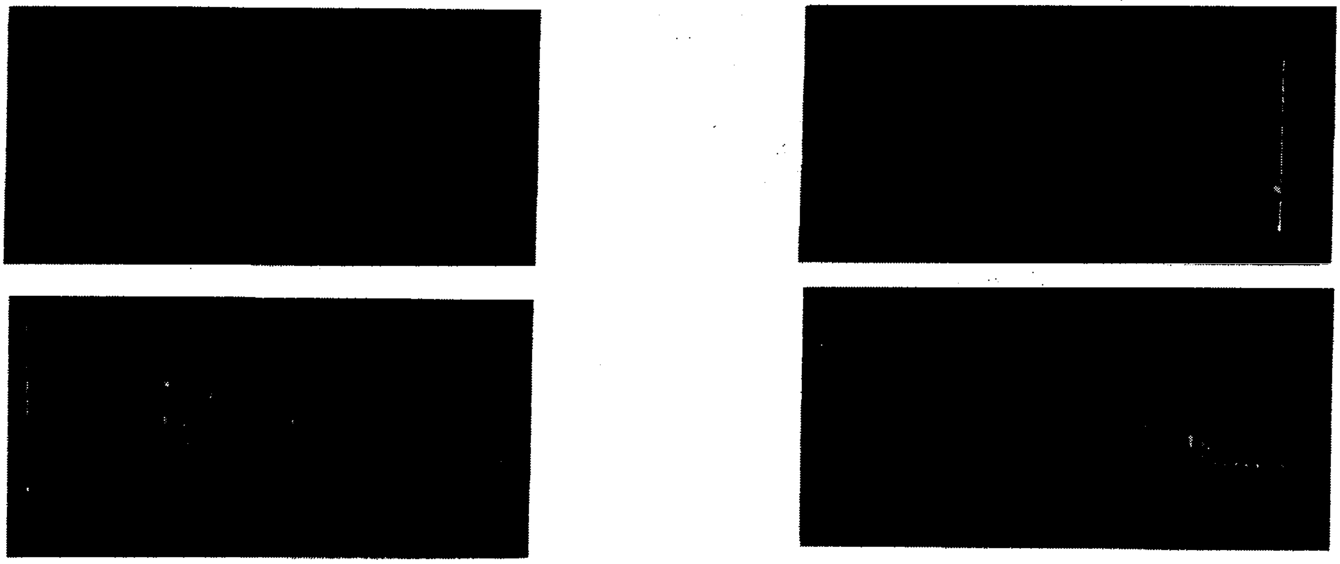

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Figure 3.- WIS survey results.

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Figure 4.- Effect of intersection fairing on 747 from WIS survey.

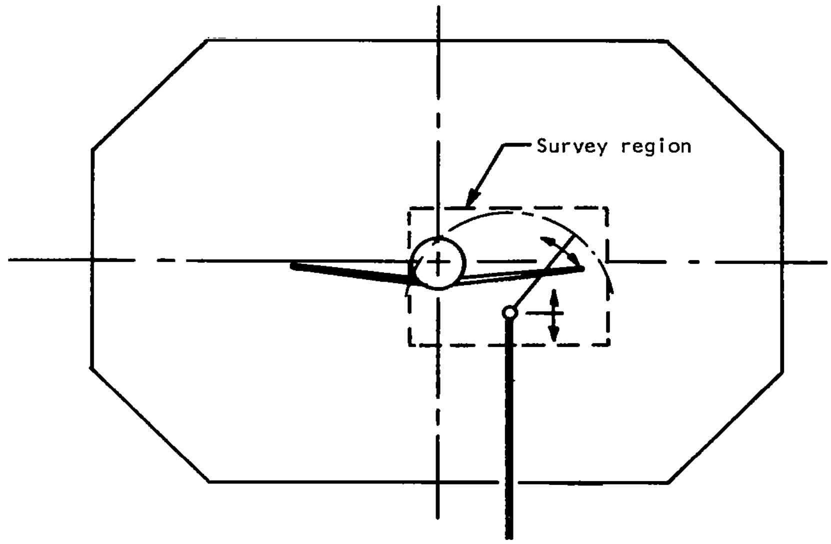

Figure 5.- Two-dimensional motion for wide area rapid traverser.

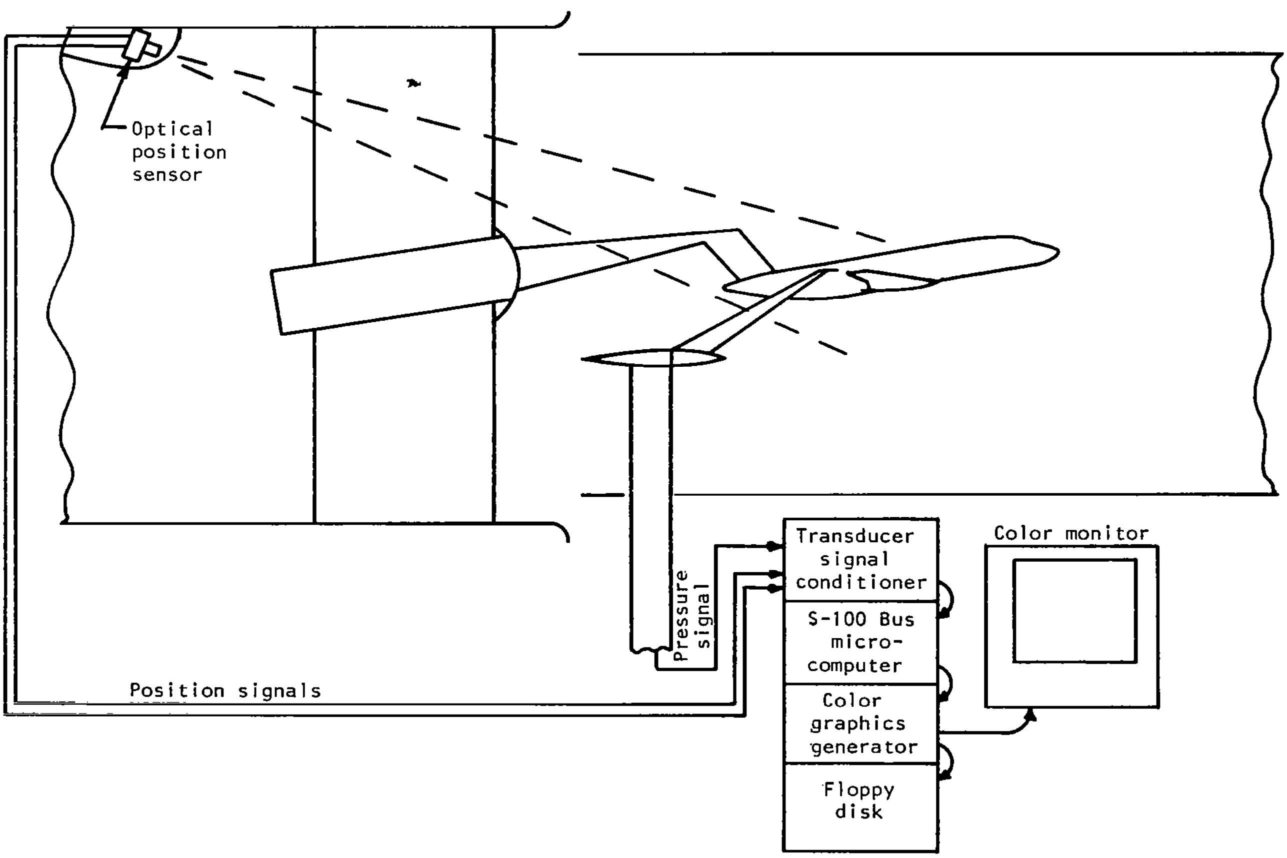

Figure 6.- Transonic wake imaging system - real time acquisition and display.