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# LASER VELOCIMETER SURVEY ABOUT A NACA 0012 WING AT LOW ANGLES OF ATTACK

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## SUMMARY

An investigation has been conducted in the Langley V/STOL tunnel with a laser velocimeter to obtain measurements of airflow velocities about a wing at low angles of attack (0.6° and 4.75°). The applicability of the laser velocimeter technique for this purpose in the V/STOL tunnel was demonstrated in this investigation with measurement precision bias calculated at -1.33 percent to 0.91 percent and a random uncertainty calculated at ±0.47 percent. Free-stream measurements were obtained with this device and compared with velocity calculations from pitot-static probe data taken near the laser velocimeter measurement location. The two measurements were in agreement to within 1 percent. Velocity measurement results about the centerline at 0.6° angle of attack were typically those expected. At 4.75°, the velocity measurements indicated that a short laminar separation bubble existed near the leading edge with an oscillating shear layer.

## INTRODUCTION

The laser velocimeter (LV) has a potential of measuring fluid velocities in flow conditions where traditional devices either are incapable of providing measurements or would seriously influence the measurements due to their presence. A fringe-type, two-component LV is being developed for use at the Langley V/STOL tunnel to capitalize on this potential. The most probable early use of this LV system would be the measurement of air velocities in the vicinity of a rotor system on the General Rotor Model System (GRMS) that is used extensively for aerodynamic and acoustic research in the V/STOL tunnel (ref. 1).

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In recent years, several investigators have applied the LV to the problem of measuring helicopter rotor flow fields. (See refs. 2 to 5.) The LV has been applied to velocity measurements within turbine stages of an engine assembly (ref. 6). The examples in references 2 to 6 are indicative of applications where a conventional probe could not survive. The LV is used extensively as a research tool to determine the exhaust characteristics of jets and nozzles (refs. 7 to 9). Quite often a well-defined jet or nozzle has been used as a reference to prove the validity of the LV measurements. Characteristics of turbulent flows have been studied using the LV (refs. 10 and 11), and power-spectral data have been attempted with some success (ref. 12). These latter examples are indicative of applications where a conventional probe's presence would influence the measurement accuracy.

Recently, an LV system was temporarily installed in the 7- by 10-foot tunnel at Langley to measure the flow characteristics over a stalled three-dimensional wing (ref. 13). The system described in the present report was similar to that in reference 13. The system was operated in the backscatter mode to permit a common platform for the transmitting and receiving optics. The tunnel flow was seeded with particles of kerosene smoke with a known particle size distribution output. This was required in order to: (1) increase the number of velocity measurements per unit time to minimize tunnel run duration; and (2) control measurement precision by providing particles with proper density and size characteristics for tracking fidelity.

This investigation was designed to accomplish two objectives: (1) to demonstrate and verify the use of the LV in the V/STOL tunnel; and (2) to obtain two-dimensional velocity measurements about a wing, to be used later for comparison with theoretical techniques.

## SYMBOLS

The axes used for this investigation was presented in figure 1. The units for the physical quantities defined in this paper are in the International System of Units. Most quantities were measured in this system; however, some were measured in the U.S. Customary Units and converted by using factors given in reference 14.

$c$ wing chord, 0.3048 m

$C_i$ number of velocity measurements in $i^{th}$ histogram interval as percent of N

$D_{sv}$ diameter of sample volume, m

DR average data rate in ensemble, measurements/sec

E excess (or kurtosis) of histogram

f signal frequency received from LV, Hz

$L_{sv}$ length of sample volume, m

$L_{fr}$ fringe spacing, m

M free-stream Mach number

N number of velocity measurements in one ensemble

$R_c$ airfoil Reynolds number, based on chord

$S_R$ skewness of histogram

$T_R$ reset time of the high-speed burst counter, sec

U local velocity component, direction described by subscript (see fig. 1)

$U_R$ local total velocity, $\sqrt{U^2 + V^2}$, m/sec

$\pm U$ uncertainty in velocity component (U), m/sec

$U_T$ free-stream velocity determined from pitot-static probe, m/sec

| | |
|---|---|
| $V$ | local velocity component, direction described by subscript (see fig. 1) |
| $V_{fr}$ | velocity of the fringes due to Bragg cell, m/sec |
| $\pm V$ | uncertainty in velocity component (V), m/sec |
| $X_f, Y_f$ | coordinate axis relative to free stream (fig. 1) |
| $X_c, Y_c$ | coordinate axis relative to wing chord (fig. 1) |
| $x_c$ | distance downstream from wing leading edge along chord, m |
| $y_c$ | distance above (and measured on perpendicular to) wing chord, m |
| $\alpha$ | wing angle of attack, deg |
| $\alpha_R$ | local flow angle, $\tan^{-1}\left(\frac{V_f}{U_f}\right)$, deg |
| $\Delta t$ | time between two consecutive velocity measurements, sec |
| $\Delta z$ | distance between beam focus and sample volume, m |
| $\varepsilon$ | error, percent |
| $\theta$ | angle between crossing laser beam components, deg |
| $\lambda$ | laser radiation wave length, m |
| $\sigma$ | standard deviation, m/sec |
| $\pm\sigma$ | uncertainty in calculation of standard deviation, m/sec |

Subscripts:

B data corrected for Bragg bias and velocity bias

e ensemble-average data

f direction indication of parameters U,V,X,Y parallel and perpendicular to free stream (see fig. 1)

i $i^{th}$ measurement in ensemble

L direction indication of velocity components inclined 44.4° above free stream and 45.6° below free stream (see fig. 1)

t time-average data

u data in direction of $U_L$ component

v data in direction of $V_L$ component

## APPARATUS

### Laser Velocimeter - Optical System

A fringe-type LV optics system operating in the backscatter mode was used for these tests. The characteristics of the optics system are provided in table 1. The backscatter mode of operation allowed the use of simplified scanning, vertically and horizontally, without compromizing the optical alignment since the output lens is used for both transmitting the output beams and collecting the scattered light. The system was used to consecutively measure the two components of velocity $\pm 45°$ to a parallel to the test section longitudinal geometric centerline (fig. 1). The LV optics are illustrated in figure 2.

A laser beam is a monochromatic and coherent source of light. The LV uses these source characteristics to develop a fringe pattern. The beam is optically split into two parallel beams, which are focused with a lens to the point where the two beams cross. In the sample volume, at the crossover point, the two light waves interfere constructively and destructively forming a fringe pattern. This is no more than a volume in space which if examined very closely would appear as being a series of alternating light and dark planes, orthogonal to the direction of the velocity measurement and parallel to the optical axis, each with approximately 26 micron size spacing between fringes in the present case.

The spacing between the fringes, as described above, is determined by:

$$L_{fr} = \frac{\lambda}{2 \sin \frac{\theta}{2}} \tag{1}$$

As a micron-sized particle passes through the fringe pattern, light is scattered with an intensity proportional to the incident intensity in the fringe pattern. If a portion of this scattered light is detected by a photomultiplier tube, an electrical signal proportional to the Doppler frequency is generated.

To obtain two components of velocity, $U_L$ and $V_L$, two sets of fringes are formed orthogonal to each other. These two fringe patterns are obtained by focusing three parallel laser beams, instead of two at a point, with each beam located at an apex of an isosceles-right triangle. The resulting fringe patterns are illustrated in figure 3. In reference 13, polarization separation was used to make simultaneous measurements in both components; however, in the present test, the 15 dB cross talk separation was due to the modifications in the optics system to accommodate a Bragg cell system. Thus, the measure of both components were made consecutively.

The investigation described in reference 13 experienced problems in four-fold ambiguity in direction measurement and limited low velocity measurement capability; therefore, a Bragg cell was placed in the beam that is common to both velocity components in the present test. The Bragg cell shifts the frequency of the light beam by a small amount. To obtain maximum resolution in the electronic frequency counter, the effective Bragg shift was chosen to be 5 MHz since the expected signal would be on the order of 2 MHz. This shift sets each fringe pattern in motion at a velocity proportional to a Doppler frequency of 5 MHz ($\approx$132 m/sec). For example, a particle with zero velocity would scatter light with a

Doppler frequency of 5 MHz as the fringes move past the particle. A particle traveling in the direction of the fringe motion would provide a signal frequency less than 5 MHz, conversely a particle moving against the direction of the fringe motion would produce a signal oscillation greater than 5 MHz. Thus, directionality of particle motion through the fringe pattern can be determined. The velocity of the particle is determined from measurement of the frequency of oscillation of the scattered light by:

$$U_L \text{ or } V_L = (f - 5 \text{ MHz}) L_{fr} \tag{2}$$

An Argon-ion continuous wave laser was used in the present LV system. It was operated at about 4 watts output power at a wavelength of $514.5 \times 10^{-9}$ m. The system was installed in the test chamber of the V/STOL tunnel just outside the test section, and the beams were projected through one of the test-section glass windows into the test area. The beam-crossing optics had a focal length of about 3.86 m (sufficient to reach the centerline of the wing) and a collecting solid angle of 0.00108 steradians. The sample volume was 2.29 cm long with a diameter of 0.314 mm. The optical axis was set approximately 3° off orthogonality to the tunnel free stream to provide for unobstructed measurements very near the leading and trailing edge of the wing. The optical system was mounted on a mechanical two-component traversing mechanism to allow movement of the common volume in the $X_f, Y_f$ directions. The overall assembly, including the traverse system, laser, and the optical system, is presented in figure 4.

## Laser Velocimeter - Electronics System

The interface between the optics system and electronics system consisted of two S-20 response photomultiplier tubes, one for each directional component, and signal conditioning electronics. The signal conditioning electronics consisted of line-driving amplifiers attached to the photomultipliers and band-pass filter banks to remove the signal pedestal ("DC bias") and high frequency noise.

The LV electronics system, shown schematically in figure 5, measures the frequency contained in each output signal burst, converts the frequency to velocity, develops velocity histograms, computes the statistical mean velocity and standard deviation of the velocity fluctuations, and stores the raw velocity data, computed data and tunnel parameters on magnetic tape for later, complete, data reduction.

High-speed burst counter. - The high-speed burst counter is a device designed to measure the period of a high-frequency signal (1 KHz to 100 MHz) contained in a burst of the type received from a LV. An idealized burst received from the LV is illustrated in figure 6(a). The pedestal ("DC bias") is removed by high-pass filters so that the burst is symmetric about 0 volts (fig. 6(b)). A double threshold comparator is used to convert the burst into a digital pulse train (fig. 6(c)). In order for the comparator to work, the signal must cross the positive threshold before crossing 0 volts with a negative slope, and the signal must cross the negative threshold before crossing to 0 volts with a positive slope. Any other combination will not operate the comparator. The first pulse in the digital pulse train is used to clear the counter circuits; the second is used to arm the counters; and the third triggers the counters to begin counting pulses from the 500 MHz reference clock. When the tenth digital pulse occurs, the counters are halted. Thus, each counter now contains the measurement of the period average of 8 signal cycles based on a reference clock of 500 MHz, yielding a period average measurement with a resolution of $2 \times 10^{-9}$ seconds.

Data gathering system. - The data from the two high-speed burst counters is input to the LV buffer interface which stores the velocity data and measures the time between the arrival of each datum and the immediately preceding datum to a resolution of $0.1 \times 10^{-6}$ seconds. The interface is described in greater detail in Appendix A. When either 4096 data points are gathered or 1.0 minute of measurement time elapses, the data gathering process halts and the interface flags the minicomputer which begins the data transfer from the interface to the computer. The raw data are converted to velocity values in the computer and stored, along with the interarrival times, on magnetic tape. The statistical quantities, e.g., mean, standard deviation, skew, etc., are computed on-line and output on-line on the CRT. The total time required for measurement, data transfer, storage, computation and output is less than 2 minutes.

## Tunnel Model

The model used in this investigation was a simple straight wing with revolved tips. It had a span of 2.438 m, a chord of 0.3048 m, and a NACA 0012 airfoil section. Velocity measurements were made within a vertical plane at center span to obtain two-dimensional characteristics. The wing was supported by struts from the floor near the tunnel centerline with no balance measurements taken. The location of the strut mount to the wing was chosen as far outboard as structurally feasible. This provided ample space between struts to minimize flow disturbance at the wing centerline. A photograph of the model with crossing laser beams is presented in figure 7.

Local flow velocities were measured about the wing centerline at two geometric angles of attack, 0° and 4.15°. A pitot-static probe was mounted in the tunnel vertical center plane 2.5 m below and 1 m ahead of the wing leading edge to provide accurate reference of the free-stream tunnel dynamic pressure. A hygrometer was used to obtain wet bulb temperatures; the total temperature was measured in the tunnel settling chamber. Thus, the tunnel air density and velocity could accurately be calculated.

## Tunnel Seeding

Perhaps the foremost problem in achieving LV measurement accuracy is due to seeding-particle lag. In most applications, the distribution of velocities within a gas medium is the main subject of the measurements; however, the LV measures the velocity of seed particles in the gas. In many cases, these velocities are identical; however, in regions of large velocity gradients, such as along a stagnation streamline, the inertia of comparatively larger seed particles does not allow them to immediately adjust to local flow velocity. Care was taken in the present tests to ensure that the seed particles within the flow were small enough to follow the flow with sufficient accuracy. This problem was addressed in the investigation described in reference 13. It was found in those tests that 3-micron size particles responded to the severe velocity gradient (1540 m/sec/m) along the stagnation line of a hemisphere at a Mach number of 0.55. It was determined from laboratory tests and preliminary calculations that with the LV system and at the focal lengths used in the present investigation, the minimum particle size for reasonable signal intensity was of the order of 2 microns. This then put a restriction on the particulate required for practical use of the LV in the V/STOL tunnel 2 to 3 microns.

The V/STOL tunnel standard smoke generator flow-visualization device was modified to yield the appropriate particle size distribution for this test. The distribution was measured by an optical technique similar to that discussed in reference 13 and is presented in figure 8(a). The smoke generator vaporizes liquid kerosene by adding heat and emits a dense white smoke through a nozzle. The nozzle was positioned in the settling chamber of the tunnel to minimize flow disturbance on the model. The nozzle position was critical in that the particulate was only to be applied in the region of the measurement volume. The smoke plume in the test section was observed to be about 0.4 m in diameter. To keep the sample volume from traversing out of the smoke plume, the nozzle was repositioned as necessary. This was done manually which was very time-consuming (required 20 to 60 minutes). Future LV use for similar purposes in the tunnel will require remote positioning of the smoke nozzle to minimize test times.

## DATA ACQUISITION AND REDUCTION

### Laser Velocimeter Data Processing

Statistical quantities. - The LV measures velocity events that are Poisson distributed in time at a location in the flow. During the measurement process, two assumptions are made: first, the particles embedded in the flow are not only randomly dispersed in space but are also randomly dispersed in the velocity field; and secondly, that the measurement sample taken over a finite period of time is a good representation of the stationary condition at the measurement location. The statistical quantities of sample mean, standard deviations (and their statistical uncertainties), skew, and excess are computed. Graphical representation of the velocity probability density functions for each velocity component were made by placing each velocity ensemble in histogram form.

The sample mean was calculated by three different methods: (1) arithmetic mean, (2) arithmetic mean with corrections for velocity bias (ref. 15)and Bragg cell bias, and (3) time averaging (ref. 16). The arithmetic mean assumes that all velocities present in the flow at the measurement point have equal probability of being measured. The computations use the classical nonweighted equation:

$$V_e = \frac{V_i}{N} \tag{3}$$

However, from reference 15, it was found that if the seeding particles are uniformally distributed in the flow, the number of measurements will be weighted toward the higher velocities since more gas (and thus more particles) passes through the sample volume per unit time than at lower velocities. Conversely, when a Bragg cell is used for directionality measurements, as in the present study, the number of measurements will be weighted toward the lower velocities since the particle will cross more of the moving fringes than at higher velocities; for example, a particle at 0 velocity will yield an infinite number of measurements. Therefore, the data must be weighted to account for these biases and then the arithmetic mean calculated:

$$V_B = \frac{\dfrac{10\ L_{fr} + T_r\ V_{fr} + T_r\ V_i}{D_{sv}\ (V_{fr} + V_i)}\ V_i}{\dfrac{10\ L_{fr} + T_r\ V_{fr} + T_r\ V_i}{D_{sv}\ (V_{fr} + V_i)}} \tag{3}$$

From reference 16, it has been suggested that all biases are removed if the data are weighted by the amount of time elapsed between each particle arrival. The restriction of this method is that the mean particle arrival rate must be equal to or greater than the highest flow turbulence frequency that contributes to the energy contained in the overall turbulent power spectra. The method for determining the time weighted average is:

$$V_t = \frac{\dfrac{(V_i + V_{i+1})}{2}\ \Delta t_i}{\Delta t_i} \tag{4}$$

From tables 2 to 4, it may be seen that all three averaging techniques yield similar results when the mean data rate is above about 10 particle arrivals per second. Also, in all cases, the simple mean and the corrected mean for velocity bias and Bragg cell bias yield similar results, which infers that when a Bragg cell is used whose frequency is large compared to the signal frequency, the bias errors are self-cancelling. Thus, the statistical quantities calculated from the test data were determined by using simple moment equations:

$$V_e = \frac{\sum V_i}{N} \qquad (6)$$

$$\sigma = \sqrt{\frac{\sum (V_i - V_e)^2}{N}} \qquad (7)$$

$$S_R = \frac{\sum (V_i - V_e)^3}{N \sigma^3} \qquad (8)$$

$$E = \frac{\frac{\sum (V_i - V_e)^4}{4}}{\left(\frac{\sum (V_i - V_e)^2}{N}\right)^2} - 3.0 \qquad (9)$$

In order to determine the statistical accuracy of the mean and standard deviation obtained from each measurement ensemble, the measurement uncertainties were calculated. From reference 17, the measurement uncertainty in the mean value is expressed for a 95 percent confidence limit as

$$\text{Uncertainty in } V_e = \pm V_e = \frac{\pm 2\sigma}{\sqrt{N}} \qquad (10)$$

where $\sigma$ is the standard deviation of the histogram and N is the number of discrete velocity measurements in the ensemble. That is, the true stationary mean velocity of the flow lies within a radius of uncertainty about the measured mean calculated from the ensemble. Similarly, the measurement uncertainty in the standard deviation for a 95-percent confidence limit is

$$\text{Uncertainty in } \sigma = \pm\sigma = \pm\sigma\sqrt{\frac{2}{N}}\left(1 + \frac{E}{2}\right)^{1/2} \qquad (11)$$

It should be noted that the inclusion of excess in equation 10 allows the measurement uncertainty to be calculated for ensembles with probability densities other than Gaussian.

Since the high-speed burst counters provide data in the form of number of reference clock pulses, the histogram interval width is established. Thus, the histograms are formed by determining the number of occurances of each counter output pattern present in each measurement ensemble. These patterns are converted to velocity and the histograms plotted, either on the CRT for on-line analysis or by plotter off-line.

Instrument precision. The overall measurement precision is obtained by determining the accuracies of all variables in the system which will affect the accuracy of each velocity measurement. From reference 13 these error sources are: cross beam angle measurement, diverging fringes, time jitter, clock synchronization, and quantizing error. The cross beam angle measurement error is a bias error based on the uncertainty in locating the center of each laser beam when the cross beam angle is determined. This error is estimated to be ±1.12 percent in the present study. The diverging fringes, resulting from the focus point of each laser beam being at a different location than the crossover point, yield both a bias error (-0.5 percent in the present test), and a random error (±0.37 percent in the present test). Time jitter is an error resulting from the threshold detector in the high-speed burst counter triggering at different points on the signal burst when the signal amplitude changes as the particle passes through the Gaussian light intensity distribution in the sample volume. However, in the present system, a double threshold technique with zero crossing detection is used which eliminates the time jitter error. The clock synchronization error, time difference between the high-speed burst counter start pulse and the first reference clock pulse that is counted, yields a bias error (0.29 percent in the present test) and a random error (±0.29 percent in the present test). The quantizing error is nonexistent in the present test since the 10 bit digital output from the high-speed burst counter is not truncated, that is, the lowest bit is one clock pulse from the 500 MHz reference clock in the present test. It should be noted that the above calculated errors are percentages of the velocity measurement, but they were calculated at signal frequencies which include the Bragg cell frequency; for example, the errors would be much less if the Bragg cell were removed.

The errors mentioned above yield an effective total bias error of -1.33 percent to 0.91 percent calculated by an algebraic sum of the partial bias errors. The total effect of random error was ±0.47 percent uncertainty, which was obtained by the square root of the sum of the squares of the partial random errors described above.

In large velocity gradients, velocity measurement errors may occur if the measurement point is not at the desired location. The two-component, mechanical traversing system for the LV optics had a placement uncertainty of ±1 mm which yield a worst case (based on the measured velocity flow field) uncertainty of 1.6 percent.

Particle lag. - Since the LV measures particle velocities and not the gas velocity, the final measurement accuracy is dependent on the ability of the particle to faithfully follow the flow. The size distribution of the seed particle was measured using an optical particle size analyzer placed in the test section so as to capture particles from the generator which yielded acceptable LV signals. The resulting distribution is shown in figure 8(a). The particle size necessary from the LV to obtain valid measurements was determined using the computer simulation of the LV developed by Meyers (ref. 18). The probability of a successful measurement is based on the signal level calculated for a given particle size. The effective sample volume size that would yield a successful measurement was calculated and compared to the sample volume size based on the $1/e^2$ power level. For example, if a particle of a certain size whose path is tangent to the $1/e^2$ power circle, and it yielded a successful measurement, that particle size is given a weight of unity. Any particle size that would result in a measure beyond or less than $1/e^2$ is weighted greater than or less than unity, respectively. The probability of a successfull measurement, as a function of particle size is shown in figure 8(b). Thus, the overall measurement probability for this test was found (fig. 8(c)). As mentioned previously, from reference 13 it was determined that a 3-micron particle traveling at Mach 0.55 free stream would faithfully follow a velocity gradient of 1540 m/sec per m. Since this velocity gradient is far greater than any experienced in these tests, it is concluded that the velocity measurements obtained are a true representation of the gas velocity flow field.

## TEST AND PROCEDURES

This investigation was conducted in the Langley V/STOL tunnel at a nominal free-stream Mach number of 0.15. The Reynolds number, based on the wing chord length was approximately $1 \times 10^6$. Preliminary free-stream measurements were made with the tunnel clear except for the pitot-static probe used as a reference. These measurements were made in the vicinity where the model would be positioned later. The wing was installed at two geometric angles of attack, 0° and 4.15°.

The scan capability of this particular preliminary LV system was not sufficient to survey above, ahead of, and behind the wing without moving either the wing or LV system platform. There was no survey behind the wing in the $\alpha = 0°$ case. With the wing at 4.15° angle of attack, a complete survey was made. To obtain the measurements behind the trailing edge, the model was moved forward and raised inside the test section with very little change to the LV system platform.

To obtain measurements very near the leading and trailing edges of the model, the optical centerline was inclined off perpendicular to the tunnel vertical center plane such that the laser beam component nearest the leading (or trailing) edge was aligned with the edge. Thus, in these cases, the angle of inclination of the optical centerline was approximately 3°.

At each angle of attack, a series of runs was made by beginning at the uppermost limit of traverse capability at a desired $x_c$ location. The scan was accomplished by making measurements at locations along a line perpendicular to the wing chord line. Runs were taken increasingly closer to the wing surface until blockage by the wing precluded further measurements, or the lower limit of the traverse was reached.

The measurements were obtained as indicated previously and raw data converted to velocity values and stored on magnetic tape for later data reduction. The on-line capability of the computer system was invaluable in the immediate assessment of the acceptability of each data ensemble as it was obtained.

## PRESENTATION OF RESULTS

As mentioned previously, all of the velocity measurements at each measurement location were first reduced to histogram form. These histograms are presented in Appendix B with a figure list and a short discussion of interpretation. Statistical analysis of the data was performed as described previously, and the results are presented in tabulated form. The free-stream data are presented in table 2, data for the wing at two angles of attack are presented in tables 3 and 4.

The statistical characteristics of the data presented in tables 3 and 4 are plotted as a function of vertical height above the wing chord in figures 9 to 39. To summarize some of the statistical characteristics, contour plots were generated using spline-fit routines between data points. They are local total velocity and local flow angle presented as contours of constant values about the wing. These are presented in figures 40 to 47.

## DISCUSSSION

### Free-Stream Data

The data acquired in the free stream are presented in table 2(a). Analysis of these data indicated that, at the Mach number used for this test, the flow angularity in the tunnel at the model position was, on the average, 0.6° (inclined above the tunnel centerline). The $U_{f_e}$ and $V_{f_e}$ velocities listed in table 2 are, therefore, referenced to free stream rather than tunnel centerline. The velocity computed from measurements by the pitot-static probe $U_T$ was used to nondimensionalize these velocity components. The ratio provides a means of determining the error in measurement between this device and the LV. The variation of $U_{R_e}/U_T$ can be accepted as reasonable instrument error as compared to the previously determined LV instrument error.

The standard deviation, , can be considered as a measure of the unsteadiness of the flow. For the first five runs, the Mach number was 0.15. The average ratio $\sigma_u/U_T$ and $\sigma_v/U_T$ is 3.4 percent and 2.5 percent, respectively. For runs 6 and 7, the Mach number was 0.37 with average ratio $\sigma_u/U_T$ and $\sigma_v/U_T$ of 3.5 percent and 2.9 percent, respectively.

### Basic Velocity Data - Wing at $\alpha$ = 4.75° and 0.6°

The wing was installed at 4.15° and 0°, referenced to the tunnel centerline. With the tunnel flow angularity of 0.6, the effective angles of attack were 4.75° and 0.6°; therefore, all analyses were conducted with these values.

The statistical characteristics of the velocity data are presented in figures 9 to 27 for the wing at $\alpha$ = 4.75° and figures 28 to 39 for the wing at

$\alpha = 0.6°$. Each figure represents a scan along a perpendicular to the wing chord. Total velocity and local flow angle plots are consistent and reasonable. The wake defect is evident in the trailing-edge scans in both velocity and local flow angle (figs. 25 to 27). The $^{U}L_e$ and $^{V}L_e$ component measurements are as expected, except near the surface (at $\alpha = 4.75°$) near the leading edge (figs. 12 to 16). Near the surface, the $^{U}L_e$ component decreases rapidly as the measurement approaches the surface, with a corresponding increase in the $^{V}L_e$ component. For most of the data, standard deviation, skew, and excess, indicate gradual changes as the surface is approached. Away from the surface, the small values of standard deviation and negative values of excess indicate a flow that is relatively steady and contains fewer larger fluctuations from the mean velocity than the traditional Gaussian model of turbulence (for which the excess is zero). The skew differs little from zero (note the expanded scale). The skewness of the histogram (as discussed in Appendix C) provides a measure of flow angle variation and velocity variation. Large values of excess (fig. 12) can be attributed to the double peaks (see App. B, $\alpha = 4.75°$, runs 51 and 52). However, near the surface, these values change drastically. This behavior of the velocity field in this area suggest drastic change in the field as though the sample volume passed through a shear layer.

The characteristics of the flow field can be seen in the histograms in Appendix B. The cases for the proposed traverse through a shear layer are presented in figures B-5 to B-7. Notice that in runs 50, 63, 67, and 78, the shape of the histogram alters from the data point just above, runs 49, 62, 66, and 77, respectively. Each histogram seems to split into a double-peaked histogram at this point. This indicates that there are two predominant velocity values. The flow experiences an oscillation between the two values, sometimes with greater tendency to be at or near one value than the other, but spends little time between the two general values. Notice figure B-5, runs 51 and 52. The $^{V}L_e$ component indicates that, at the position for run 51, the flow experiences the lower velocity value most of the time; however, at the position for run 52, the flow experiences the higher velocity value most of the time. The positions, as listed in table 3(b), are only 0.007 chords apart (2.1 mm). These points, therefore, must be on opposite sides of the proposed shear layer. The most likely explanation of this is that the shear layer is oscillating to provide the double peaks. It is suggested that this is very near the location of the start of the shear layer. The double peaks are also evident in runs 63, 64, 67, 68, 78 and 79. For the latter run numbers, the double-peaked histograms are broader, and the tendency to favor one velocity over the other is not as evident. The broad histograms are indicative of flow situations with large flow unsteadiness. The double-peaked histograms indicate flow unsteadiness with oscillating velocity fields. If the shear layer was steady, the inner region separated field would be of much lower velocity than the outer. The most probable explanation of these two facts is that the double-peaked histograms were obtained at the region of the shear layer of a laminar separation bubble. This shear layer was oscillatory and possibly a thin vortex sheet was formed between the undisturbed region and separated region. It is postulated that this sheet was the cause of the double peaks.

The broadening of the double-peak histograms for runs 78 and 79 indicate that the separation bubble shear layer has experienced a transition to turbulent flow characteristics, and it is suspected that the flow had reattached further downstream.

A similar situation was reported in reference 19. A NACA 0010 (modified) airfoil was tested to determine its characteristics when laminar separation was developed. Reference 19 report that at a Reynolds number of $1.5 \times 10^6$ at 4.75° angle of attack, the NACA 0010 (modified) should have a laminar separation at approximately $x_c/c = 0.02$. The flow should transition from laminar to turbulent at $x_c/c = 0.05$ and should reattach at about $x_c/c = 0.05$.

The laminar separation bubble measured in this investigation began at about $x_c/c = 0.01$, with evidence of its existence reaching to $x_c/c = 0.09$. Realizing that this investigation was conducted with a NACA 0012 airfoil at Reynolds number = $1 \times 10^6$, it seems entirely possible that the phenomena observed was a laminar separation bubble.

As described in appendix B, a skewed histogram indicates a fluctuation in flow angle and velocity. The histograms of the measurements leading up to the double-peaked histograms were skewed, thus the flow at this location was experiencing variation in velocity and angle. The position of the laminar separation point, as measured in reference 19, is highly sensitive to slight wing angle-of-attack changes; therefore, it is possible that the separation point was moving with the tunnel flow angle oscillation. This unsteadiness in separation point would result in unsteadiness in the shear layer of the separation and trigger an undulating shear layer; thus the double histograms with increasing total velocity as the sample volume is traversed downward into the bubble.

The trailing-edge scans show expected results: (1) wake defect behind the trailing edge; (2) flow angle change through the wake; (3) large unsteadiness in the wake. The data for the wing at $\alpha = 0.6°$ indicate that the flow is smooth and can be easily predicted by theories such as that reported in reference 20.

## Statistical Characteristics Summarized

In an attempt to summarize the statistical characteristics of the flow field, composites were developed which describe the flow situation over the wing wing as measured.

Total velocity vectors, streamlines, contours of constant local flow angle, and contours of constant $U_{R_e}/U_T$ were computed and plotted. These are presented in figures 40 to 43 for the wing at $\alpha = 4.75°$ and in figures 44 to 47 for the wing at $\alpha = 0.6°$.

At $\alpha = 4.75°$, the velocity vectors near the region of the laminar separation bubble are clearly affected by the calculation of mean velocity from a double-peaked histogram. This fact in turn affects the spline fit of the survey flow angle map in an attempt to compute streamlines (a path a particle would take in the flow). The local flow angle is maximum (25°) at the expected location (near the nose), and approaches the upper surface local angle at the trailing edge. The velocity decreases along the stagnation line is evident at the leading edge in the contours of constant $U_{R_e}/U_T$ plot. The wake region is evident with approximately 70 percent of the free-stream velocity. It is interesting to note in these figures that the presence of the wing was obvious ahead of it as far as the scans were made. This is evident in all of the plots.

At $\alpha = 0.6°$, the velocity vectors are classic, exactly what would be expected for the flow about this airfoil. The streamlines are well-defined and exhibit no obvious inconsistencies. The plot of constant $U_{R_e}/U_T$ indicates the velocity decrease along the stagnation line. Local flow angles are smoothly varying with maximum value (17°) at the nose upper surface.

## CONCLUDING REMARKS

A LV survey about a NACA 0012 wing installed in the Langley V/STOL tunnel has been conducted to accomplish two objectives: (1) demonstrate the applicability of the LV in the V/STOL tunnel; and (2) to obtain two-dimensional velocity measurements to be used later for comparison with theoretical techniques.

The results of this investigation indicated that the LV is a viable tool in fluid flow research with measurement precision calculated to be -1.33 percent to 0.91 percent bias uncertainty and ±0.47 percent random uncertainty in this investigation.

The histogram is one means of analyzing the result of LV measurements and provide invaluable insight into the character of the flow.

Free-stream measurement comparison with calculations from a pitot-static probe measurements agree to within 1 percent.

The data for the wing at $\alpha$ = 4.75° indicated that a laminar separation bubble probably existed with a thin oscillating shear layer. The data for the wing at $\alpha$ = 0.6° indicated that the flow is smooth and can be easily predicted by existing theories.

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Table 1

| | |
|---|---|
| Laser Wavelength | 514.5 nm |
| Input Lens Focal Length | 3.8649 m |
| Cross Beam Angle | 1.1139 deg |
| Transmission Coefficient | |
| Beam A | 0.15 |
| Beam B | 0.16 |
| Beam C | 0.12 |
| Input Laser Power | 4.0 W |
| Diameter of Laser Beam at Input Lens | 0.0081 m |
| Receiving Lens Focal Length | 3.8649 m |
| Rotation Angle of Receiver | |
| Horizontal | 180.0 deg |
| Vertical | 0.0 deg |
| Effective Receiving Lens Diameter | 0.127 m |
| Transmission Coefficient, Receiver | 0.42 |
| Bragg Frequency | 5.0 MHz |
| Photomultiplier Quantum Efficiency | 0.14 |
| Photomultiplier Gain | 60000 |
| Counter Threshold Voltage | 0.015 V |
| Low Pass Filter Cutoff | 8.0 MHz |
| High Pass Filter Cutoff | 0.5 MHz |
| Counter Count Comparison Accuracy | 0.02 |
| System Gain | -4.0 dB |

Table 2-A (freestream)

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $U_{L_B}$ m/sec | $V_{L_B}$ m/sec | $U_{L_t}$ m/sec | $V_{L_t}$ m/sec | $S_{R_u}$ | $S_{R_v}$ | $E_u$ | $E_v$ | $N_u$ | $N_v$ | $DR_u$ $sec^{-1}$ | $DR_v$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.7 | .0 | 35.8 | .0 | 36.7 | 35.9 | 36.7 | 35.8 | .15 | .03 | -.2 | .1 | 2347 | 2397 | 39 | 40 | 9:45 | 147 |
| 2 | 36.9 | .0 | 36.1 | .0 | 36.9 | 36.1 | 36.9 | 36.0 | .06 | .01 | .3 | .0 | 3064 | 2302 | 51 | 33 | 9:43 | 147 |
| 3 | 36.8 | .0 | 36.0 | .0 | 36.8 | 36.0 | 36.9 | 35.9 | -.15 | -.20 | .1 | .3 | 3025 | 2353 | 50 | 39 | 9:39 | 147 |
| 4 | 36.7 | .0 | 36.0 | .0 | 36.7 | 36.0 | 36.7 | 36.1 | .01 | -.07 | .3 | .4 | 3054 | 2439 | 51 | 41 | 9:41 | 147 |
| 5 | 36.7 | .0 | 36.0 | .0 | 36.8 | 36.1 | 36.4 | 36.0 | .22 | .22 | .3 | .2 | 2252 | 565 | 38 | 19 | 9:48 | 147 |
| 6 | 65.6 | .1 | 63.2 | .1 | 65.9 | 63.8 | 66.2 | 60.9 | .55 | .18 | 3.6 | 18.0 | 3973 | 3787 | 169 | 63 | 10:24 | 147 |
| 7 | 66.0 | .0 | 63.9 | .0 | 66.4 | 64.4 | 66.8 | 62.9 | .41 | -.20 | 1.6 | 11.1 | 4023 | 3113 | 166 | 52 | 10:26 | 147 |

Table 2-B (freestream)

| Run | $\frac{x_c^*}{c}$ | $\frac{y_c^*}{c}$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $\frac{U_{f_e}}{U_T}$ | $\frac{V_{f_e}}{U_T}$ | $\frac{U_{R_e}}{U_T}$ | $\alpha_{R_e}$ deg | $\frac{U_{f_B}}{U_T}$ | $\frac{V_{f_B}}{U_T}$ | $\frac{U_{R_B}}{U_T}$ | $\alpha_{R_B}$ deg | $\frac{U_{f_t}}{U_T}$ | $\frac{V_{f_t}}{U_T}$ | $\frac{U_{R_f}}{U_T}$ | $\alpha_{R_t}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .590 | .110 | 1.2 | .0 | .9 | .0 | 1.00 | .00 | 1.00 | .1 | 1.00 | .00 | 1.00 | .1 | 1.00 | .00 | 1.00 | .1 |
| 2 | .594 | .047 | 1.3 | .0 | .9 | .0 | 1.01 | .00 | 1.01 | .0 | 1.01 | .00 | 1.01 | .0 | 1.01 | .00 | 1.01 | .1 |
| 3 | .602 | -.066 | 1.3 | .0 | .9 | .0 | 1.01 | -.00 | 1.01 | -.0 | 1.01 | .00 | 1.01 | .0 | 1.00 | .00 | 1.00 | .2 |
| 4 | .603 | -.075 | 1.3 | .0 | .9 | .0 | 1.00 | -.00 | 1.00 | -.0 | 1.00 | -.00 | 1.00 | -.0 | 1.01 | -.00 | 1.01 | -.1 |
| 5 | .607 | -.137 | 1.3 | .0 | .9 | .0 | 1.01 | -.00 | 1.01 | -.1 | 1.01 | -.00 | 1.01 | -.0 | 1.00 | -.00 | 1.00 | -.3 |
| 6 | .600 | -.035 | 3.4 | .1 | 3.3 | .1 | 1.00 | .01 | 1.00 | .4 | 1.01 | .01 | 1.01 | .3 | .99 | .03 | .99 | 1.8 |
| 7 | .600 | -.035 | 3.1 | .0 | 2.0 | .1 | 1.01 | .01 | 1.01 | .3 | 1.02 | .00 | 1.02 | .3 | 1.01 | .02 | 1.01 | 1.1 |

* referenced to location of wing at $\alpha = 4.75^0$.

Table 3-A ($\alpha = 4.75^0$)

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $U_{L_B}$ m/sec | $V_{L_B}$ m/sec | $U_{L_t}$ m/sec | $V_{L_t}$ m/sec | $S_{R_U}$ | $S_{R_V}$ | $E_U$ | $E_V$ | $N_U$ | $N_V$ | $DR_U$ $sec^{-1}$ | $DR_V$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 41.2 | .1 | 35.2 | .1 | 41.2 | 35.1 | 41.5 | 35.1 | -.26 | .03 | -.6 | .2 | 165 | 225 | 3 | 4 | 17:32 | 133 |
| 2 | 41.7 | .0 | 34.6 | .0 | 41.7 | 34.5 | 41.9 | 34.3 | -.54 | .20 | .2 | .8 | 1008 | 1072 | 17 | 18 | 17:34 | 133 |
| 3 | 41.7 | .0 | 34.3 | .0 | 41.7 | 34.2 | 41.8 | 34.2 | -.21 | .25 | .1 | .1 | 1195 | 1811 | 20 | 30 | 17:35 | 133 |
| 4 | 41.8 | .0 | 33.5 | .0 | 41.8 | 33.4 | 42.0 | 33.3 | -.39 | .46 | -.0 | .6 | 1332 | 1329 | 22 | 22 | 17:37 | 133 |
| 5 | 41.2 | .0 | 32.8 | .0 | 41.2 | 32.7 | 41.4 | 32.6 | -.27 | .45 | .1 | .4 | 1489 | 1759 | 25 | 29 | 17:38 | 133 |
| 6 | 40.7 | .0 | 32.1 | .0 | 40.7 | 32.0 | 40.8 | 32.0 | -.24 | .35 | -.1 | .2 | 2087 | 3398 | 35 | 57 | 17:40 | 133 |
| 7 | 39.8 | .0 | 31.8 | .0 | 39.9 | 31.7 | 40.0 | 31.5 | -.16 | .49 | .2 | .4 | 2323 | 2066 | 39 | 34 | 17:42 | 133 |
| 8 | 39.2 | .0 | 31.5 | .0 | 39.2 | 31.5 | 39.3 | 31.4 | .04 | .47 | .2 | .4 | 1289 | 1567 | 21 | 26 | 17:43 | 133 |
| 9 | 38.8 | .0 | 31.5 | .0 | 38.8 | 31.4 | 38.7 | 31.0 | .05 | .45 | .1 | .3 | 2167 | 1894 | 36 | 32 | 17:45 | 133 |
| 10 | 38.2 | .0 | 31.5 | .0 | 38.2 | 31.4 | 38.2 | 30.9 | .15 | .40 | .4 | .2 | 2170 | 1696 | 36 | 28 | 17:46 | 133 |
| 11 | 37.8 | .0 | 31.8 | .0 | 37.8 | 31.7 | 37.8 | 31.6 | .15 | .54 | .4 | .4 | 1312 | 1407 | 22 | 23 | 17:48 | 133 |
| 12 | 43.1 | .1 | 35.6 | .1 | 43.1 | 35.5 | 43.2 | 35.5 | -.41 | -.10 | .1 | .3 | 254 | 331 | 4 | 6 | 17:52 | 133 |
| 13 | 43.4 | .1 | 34.9 | .1 | 43.5 | 34.9 | 43.6 | 34.6 | -.61 | -.01 | .0 | -.2 | 262 | 205 | 4 | 3 | 17:53 | 133 |
| 14 | 43.9 | .1 | 34.1 | .1 | 44.0 | 34.1 | 44.0 | 34.1 | -.74 | .19 | 1.5 | .1 | 474 | 379 | 8 | 6 | 17:55 | 133 |
| 15 | 44.1 | .0 | 33.2 | .0 | 44.2 | 33.1 | 44.2 | 33.0 | -.41 | .24 | .0 | .7 | 1651 | 909 | 28 | 15 | 17:56 | 133 |
| 16 | 43.8 | .0 | 31.7 | .0 | 43.8 | 31.7 | 44.0 | 31.6 | -.27 | .16 | -.3 | -.1 | 1361 | 1169 | 23 | 19 | 17:58 | 133 |
| 17 | 43.1 | .0 | 29.8 | .0 | 43.1 | 29.8 | 43.4 | 29.7 | -.30 | .84 | -.3 | .7 | 1315 | 1444 | 22 | 24 | 17:59 | 133 |
| 18 | 42.2 | .0 | 28.7 | .1 | 42.2 | 28.5 | 42.3 | 28.6 | -.24 | .64 | -.1 | .6 | 1242 | 1060 | 21 | 18 | 18: 1 | 133 |
| 19 | 41.0 | .0 | 28.1 | .1 | 41.0 | 28.1 | 41.1 | 28.1 | -.24 | .52 | -.0 | -.2 | 1055 | 989 | 18 | 16 | 18: 2 | 133 |
| 20 | 39.8 | .0 | 27.8 | .1 | 39.8 | 27.7 | 39.9 | 27.7 | -.07 | .71 | -.2 | .4 | 1239 | 874 | 21 | 15 | 18: 3 | 133 |
| 21 | 38.5 | .0 | 30.1 | .1 | 38.6 | 30.2 | 38.6 | 29.9 | .10 | .21 | .2 | -.5 | 2877 | 1877 | 48 | 31 | 18:58 | 133 |
| 22 | 38.1 | .0 | 30.4 | .1 | 38.1 | 30.4 | 38.1 | 29.9 | .04 | .08 | .1 | -.7 | 1703 | 1485 | 28 | 25 | 19: 0 | 133 |
| 23 | 37.7 | .0 | 31.2 | .1 | 37.7 | 31.2 | 37.6 | 29.9 | .13 | -.03 | -.1 | -.9 | 980 | 1209 | 16 | 20 | 19: 2 | 133 |
| 24 | 37.2 | .0 | 30.9 | .1 | 37.1 | 30.9 | 37.2 | 30.1 | .25 | .09 | -.2 | -.5 | 1192 | 1221 | 20 | 20 | 19: 4 | 133 |
| 25 | 36.8 | .0 | 31.0 | .1 | 36.8 | 31.0 | 36.8 | 30.3 | .35 | .21 | -.0 | -.4 | 1814 | 1762 | 30 | 29 | 19: 6 | 133 |
| 26 | 42.0 | .1 | 35.7 | .1 | 42.2 | 35.7 | 42.0 | 35.7 | -.03 | .05 | -.1 | .6 | 763 | 954 | 13 | 16 | 19:10 | 133 |
| 27 | 43.2 | .1 | 35.1 | .0 | 43.3 | 35.2 | 43.5 | 35.1 | -.51 | .31 | .2 | 1.1 | 1489 | 1544 | 25 | 26 | 19:12 | 133 |
| 28 | 43.4 | .1 | 34.2 | .0 | 43.6 | 34.2 | 43.9 | 34.1 | -.49 | .15 | -.0 | 1.2 | 1993 | 2562 | 33 | 43 | 19:13 | 133 |
| 29 | 45.5 | .0 | 33.0 | .0 | 45.6 | 32.9 | 45.7 | 33.0 | -.59 | .19 | .2 | .4 | 4073 | 4076 | 161 | 200 | 19:16 | 133 |
| 30 | 45.9 | .0 | 32.1 | .0 | 45.9 | 32.1 | 46.1 | 31.9 | -.48 | .50 | .0 | 1.1 | 4066 | 4081 | 168 | 208 | 19:17 | 133 |
| 31 | 46.4 | .0 | 29.6 | .0 | 46.4 | 29.5 | 46.5 | 29.4 | -.40 | .32 | .1 | .3 | 4076 | 4044 | 209 | 240 | 19:19 | 133 |
| 32 | 46.2 | .0 | 27.5 | .0 | 46.2 | 27.4 | 46.4 | 27.3 | -.43 | .51 | -.1 | .4 | 4087 | 4055 | 182 | 254 | 19:21 | 133 |
| 33 | 45.2 | .0 | 25.7 | .0 | 45.2 | 25.6 | 45.3 | 25.3 | -.35 | .66 | -.1 | .3 | 4078 | 4044 | 162 | 185 | 19:23 | 133 |
| 34 | 43.4 | .0 | 23.1 | .0 | 43.4 | 22.9 | 43.5 | 22.8 | -.20 | .81 | -.2 | .5 | 4091 | 4033 | 150 | 164 | 19:25 | 133 |
| 35 | 41.7 | .0 | 21.9 | .0 | 41.7 | 21.6 | 41.8 | 20.6 | -.08 | .60 | -.2 | .3 | 3815 | 3381 | 64 | 56 | 19:27 | 133 |
| 36 | 40.0 | .0 | 23.0 | .1 | 40.0 | 22.7 | 40.2 | 22.5 | -.17 | .90 | -.2 | .7 | 781 | 715 | 13 | 12 | 19:29 | 133 |
| 37 | 38.1 | .1 | 24.3 | .3 | 38.1 | 24.2 | 38.1 | 24.5 | .18 | .82 | .5 | -.4 | 107 | 159 | 2 | 3 | 19:32 | 133 |
| 38 | 37.0 | .1 | 23.8 | .3 | 37.0 | 23.7 | 37.1 | 23.6 | .55 | 1.20 | -.7 | 1.0 | 58 | 174 | 1 | 3 | 19:35 | 133 |
| 39 | 35.7 | .1 | 24.6 | .2 | 35.7 | 24.3 | 35.6 | 23.9 | .50 | .72 | -.3 | .6 | 192 | 156 | 3 | 3 | 19:39 | 133 |
| 40 | 34.9 | .2 | 25.9 | .4 | 34.9 | 25.7 | 34.8 | 26.1 | .26 | .56 | -.7 | -.2 | 72 | 51 | 1 | 1 | 19:43 | 133 |
| 41 | 34.4 | .2 | 26.0 | .2 | 34.4 | 25.8 | 34.3 | 25.2 | .45 | 1.11 | -.5 | .9 | 105 | 280 | 2 | 5 | 19:46 | 133 |
| 42 | 28.9 | .3 | 24.4 | .3 | 28.9 | 24.1 | 28.9 | 24.0 | .67 | .64 | .4 | .2 | 24 | 58 | 0 | 1 | 19:49 | 133 |
| 43 | 43.9 | .0 | 36.4 | .0 | 43.9 | 36.4 | 44.0 | 36.6 | -.36 | -.11 | .1 | .0 | 4060 | 4010 | 153 | 154 | 20:25 | 133 |
| 44 | 44.8 | .0 | 35.7 | .0 | 44.9 | 35.7 | 45.0 | 35.8 | -.32 | -.03 | -.1 | .1 | 3743 | 2251 | 62 | 38 | 20:27 | 133 |
| 45 | 45.6 | .0 | 34.8 | .0 | 45.6 | 34.8 | 46.3 | 34.9 | -.46 | -.08 | .2 | .4 | 4053 | 4085 | 159 | 183 | 20:29 | 133 |
| 46 | 46.0 | .0 | 33.6 | .0 | 46.0 | 33.5 | 46.4 | 33.5 | -.63 | -.02 | -.1 | .5 | 4074 | 4078 | 139 | 160 | 20:31 | 133 |
| 47 | 47.5 | .0 | 31.4 | .0 | 47.5 | 31.4 | 48.1 | 31.4 | -.39 | .27 | -.4 | .4 | 4076 | 4075 | 153 | 150 | 20:34 | 133 |
| 48 | 49.8 | .1 | 27.2 | .0 | 49.7 | 27.1 | 50.3 | 27.3 | -.34 | .53 | -.3 | .8 | 4083 | 3780 | 127 | 63 | 20:36 | 133 |
| 49 | 51.2 | .1 | 21.7 | .0 | 51.2 | 21.6 | 52.0 | 21.5 | -.14 | .41 | -.6 | .4 | 3456 | 1967 | 58 | 33 | 20:53 | 133 |
| 50 | 49.4 | .1 | 17.5 | .1 | 49.4 | 17.2 | 49.9 | 16.1 | .11 | 1.65 | .2 | 2.3 | 2755 | 1190 | 46 | 20 | 20:39 | 133 |
| 51 | 48.4 | .1 | 18.0 | .3 | 48.4 | 17.3 | 48.9 | 17.4 | .44 | 1.80 | .5 | 4.9 | 934 | 206 | 16 | 3 | 20:51 | 133 |
| 52 | 45.7 | .3 | 26.3 | .5 | 45.6 | 26.1 | 46.4 | 21.6 | -1.05 | -1.93 | .1 | 2.3 | 163 | 113 | 3 | 2 | 20:42 | 133 |
| 53 | 27.2 | .1 | 26.3 | .1 | 27.2 | 26.1 | 24.1 | 25.7 | .32 | 1.17 | .1 | 1.9 | 542 | 849 | 9 | 14 | 20:47 | 133 |
| 54 | 44.5 | .0 | 37.4 | .0 | 44.6 | 37.4 | 44.8 | 37.6 | -.37 | -.04 | .5 | .2 | 2135 | 1535 | 36 | 26 | 20:56 | 133 |
| 55 | 45.0 | .0 | 37.2 | .0 | 45.0 | 37.2 | 45.1 | 37.3 | -.23 | -.21 | .3 | .1 | 2129 | 1250 | 35 | 21 | 20:57 | 133 |
| 56 | 46.0 | .0 | 37.0 | .1 | 46.1 | 37.0 | 46.2 | 37.2 | -.44 | -.32 | .7 | .1 | 955 | 624 | 16 | 10 | 20:59 | 133 |
| 57 | 47.2 | .0 | 35.9 | .0 | 47.3 | 35.9 | 47.4 | 36.1 | -.57 | -.14 | .3 | -.1 | 4037 | 4082 | 186 | 167 | 21: 1 | 133 |
| 58 | 48.0 | .0 | 35.2 | .0 | 48.1 | 35.2 | 48.5 | 35.4 | -.66 | -.23 | .1 | -.1 | 1017 | 4007 | 143 | 153 | 21: 3 | 133 |
| 59 | 50.0 | .0 | 34.3 | .0 | 50.1 | 34.3 | 50.4 | 34.1 | -.59 | -.15 | -.1 | -.3 | 4053 | 3514 | 126 | 59 | 21: 4 | 133 |
| 60 | 52.8 | .0 | 32.3 | .0 | 52.9 | 32.3 | 53.4 | 32.6 | -.52 | .07 | -.2 | -.4 | 4045 | 3028 | 127 | 50 | 21: 6 | 133 |

Table 3-A. - Continued.

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $U_{L_B}$ m/sec | $V_{L_B}$ m/sec | $U_{L_t}$ m/sec | $V_{L_t}$ m/sec | $S_{R_u}$ | $S_{R_v}$ | $E_u$ | $E_v$ | $N_u$ | $N_v$ | $DR_u$ $sec^{-1}$ | $DR_v$ $sec^{-1}$ | Time | Julian -day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 56.2 | .1 | 30.4 | .0 | 56.3 | 30.3 | 56.7 | 30.6 | -.61 | .43 | -.2 | -.3 | 3861 | 2843 | 64 | 47 | 21: 7 | 133 |
| 62 | 62.0 | .1 | 25.9 | .0 | 62.2 | 25.8 | 62.4 | 26.0 | -.67 | .84 | .3 | .6 | 2605 | 4041 | 43 | 125 | 21: 9 | 133 |
| 63 | 63.8 | .1 | 21.9 | .1 | 64.0 | 21.3 | 64.4 | 22.6 | -.15 | 1.68 | .3 | 3.4 | 2041 | 2352 | 34 | 39 | 21:14 | 133 |
| 64 | 63.6 | .1 | 22.0 | .1 | 64.2 | 21.6 | 64.2 | 22.3 | -.25 | 1.80 | .8 | 3.1 | 1792 | 2562 | 30 | 43 | 21:15 | 133 |
| 65 | 52.0 | 1.1 | 27.0 | .4 | 51.7 | 27.0 | 52.5 | 23.7 | .26 | .16 | -1.0 | -.9 | 58 | 159 | 1 | 3 | 21:12 | 133 |
| 66 | 57.2 | .1 | 29.6 | .0 | 57.3 | 29.6 | 58.0 | 29.9 | -.82 | .53 | -.0 | .1 | 4045 | 3984 | 108 | 135 | 14:47 | 136 |
| 67 | 53.2 | .1 | 24.8 | .1 | 53.0 | 24.7 | 54.5 | 24.6 | -.47 | .99 | -.5 | .5 | 4093 | 4049 | 111 | 143 | 14:39 | 136 |
| 68 | 54.7 | .1 | 21.1 | .1 | 54.5 | 21.2 | 56.3 | 20.8 | -.36 | .93 | -.4 | 1.2 | 3585 | 3752 | 60 | 63 | 14:41 | 136 |
| 69 | 56.1 | .3 | 17.4 | .3 | 55.7 | 16.9 | 57.7 | 15.7 | -.68 | .45 | -1.0 | -1.4 | 1073 | 1249 | 18 | 21 | 14:43 | 136 |
| 70 | 43.5 | .0 | 37.2 | .1 | 43.6 | 37.2 | 43.8 | 37.3 | -.47 | -.00 | .8 | -.0 | 699 | 840 | 12 | 14 | 10:17 | 136 |
| 71 | 43.6 | .0 | 37.0 | .0 | 43.6 | 37.0 | 43.6 | 37.2 | -.61 | -.22 | .4 | -.1 | 2670 | 3573 | 44 | 60 | 10:18 | 136 |
| 72 | 45.4 | .0 | 36.9 | .0 | 45.4 | 36.9 | 45.5 | 37.1 | -.44 | -.29 | .3 | -.1 | 4044 | 4075 | 152 | 151 | 10:20 | 136 |
| 73 | 47.1 | .0 | 36.7 | .0 | 47.2 | 36.7 | 47.3 | 37.1 | -.39 | -.23 | .3 | -.3 | 4034 | 4084 | 181 | 158 | 10:22 | 136 |
| 74 | 49.9 | .0 | 37.0 | .0 | 50.0 | 37.0 | 50.1 | 37.3 | -.50 | -.27 | .6 | -.3 | 4035 | 4067 | 202 | 177 | 10:24 | 136 |
| 75 | 51.5 | .0 | 37.0 | .0 | 51.6 | 37.1 | 51.7 | 37.4 | -.61 | -.25 | .9 | -.4 | 4029 | 4084 | 224 | 151 | 10:26 | 136 |
| 76 | 53.8 | .0 | 37.4 | .0 | 53.9 | 37.4 | 53.9 | 37.8 | -.62 | -.30 | 1.6 | -.4 | 4050 | 4089 | 149 | 136 | 10:28 | 136 |
| 77 | 57.0 | .0 | 36.8 | .1 | 57.2 | 36.8 | 57.1 | 37.2 | -.07 | -.36 | .6 | -.7 | 4032 | 3794 | 128 | 63 | 10:29 | 136 |
| 78 | 58.2 | .1 | 35.6 | .9 | 58.7 | 35.4 | 58.5 | 36.6 | -1.79 | .09 | 7.9 | -1.6 | 470 | 55 | 8 | 1 | 10:35 | 136 |
| 79 | 54.0 | .6 | 26.8 | 3.5 | 53.8 | 26.0 | 55.3 | 30.1 | -.66 | -2.36 | -1.2 | 4.2 | 115 | 10 | 2 | 0 | 10:34 | 136 |
| 80 | 61.1 | .1 | 28.2 | .1 | 61.7 | 28.1 | 62.0 | 28.5 | -.32 | .65 | 3.1 | .3 | 3996 | 4078 | 136 | 157 | 14:49 | 136 |
| 81 | 50.3 | .6 | 29.6 | .2 | 50.0 | 29.5 | 50.9 | 28.6 | .67 | -.42 | -.7 | -.1 | 209 | 261 | 3 | 4 | 14:52 | 136 |
| 82 | 44.6 | .5 | 30.1 | .8 | 44.6 | 30.1 | 45.4 | 31.0 | .90 | -1.27 | .1 | 1.3 | 52 | 21 | 1 | 0 | 14:56 | 136 |
| 83 | 43.0 | .1 | 36.8 | .1 | 43.0 | 36.8 | 43.3 | 36.9 | -.33 | -.46 | .1 | .6 | 357 | 343 | 6 | 6 | 10:15 | 136 |
| 84 | 43.4 | .0 | 38.7 | .0 | 43.5 | 38.7 | 43.3 | 38.8 | -.20 | -.22 | .5 | -.0 | 1491 | 1288 | 25 | 21 | 10:38 | 136 |
| 85 | 44.5 | .0 | 38.7 | .1 | 44.6 | 38.7 | 44.6 | 39.1 | -.04 | -.37 | .1 | .2 | 1576 | 1165 | 26 | 19 | 10:40 | 136 |
| 86 | 45.7 | .0 | 38.9 | .1 | 45.8 | 7.7 | 46.1 | 39.8 | .05 | -.58 | .2 | -.3 | 988 | 224 | 16 | 4 | 10:41 | 136 |
| 87 | 46.9 | .0 | 38.0 | .0 | 47.0 | 38.0 | 47.1 | 38.5 | -.26 | -.10 | .3 | -.6 | 4050 | 4092 | 231 | 191 | 10:43 | 136 |
| 88 | 49.0 | .0 | 38.3 | .0 | 49.2 | 38.4 | 49.2 | 38.8 | -.75 | .02 | 1.4 | -.8 | 4022 | 4083 | 184 | 167 | 10:45 | 136 |
| 89 | 50.1 | .0 | 38.9 | .1 | 50.3 | 39.0 | 50.5 | 39.3 | -.65 | -.10 | 1.4 | -.8 | 3991 | 3714 | 154 | 62 | 10:46 | 136 |
| 90 | 52.0 | .0 | 39.3 | .1 | 52.2 | 39.5 | 52.2 | 39.6 | -.58 | -.19 | 1.3 | -.7 | 4000 | 3258 | 134 | 54 | 10:48 | 136 |
| 91 | 55.1 | .0 | 38.5 | .1 | 55.4 | 38.4 | 55.3 | 39.1 | -.60 | .14 | 1.2 | -1.2 | 3995 | 3844 | 140 | 64 | 10:50 | 136 |
| 92 | 44.1 | .0 | 38.3 | .0 | 44.2 | 38.3 | 44.2 | 38.6 | -.42 | .00 | .6 | -.2 | 3671 | 4085 | 65 | 169 | 10:58 | 136 |
| 93 | 45.3 | .0 | 38.1 | .0 | 45.4 | 38.2 | 45.5 | 38.3 | -.63 | .09 | 1.3 | -.5 | 4080 | 2988 | 125 | 50 | 10:59 | 136 |
| 94 | 46.6 | .0 | 39.0 | .0 | 46.6 | 39.0 | 46.7 | 39.5 | -.40 | -.07 | .9 | -.6 | 4069 | 3828 | 139 | 64 | 11: 1 | 136 |
| 95 | 48.2 | .0 | 40.4 | .0 | 48.3 | 40.5 | 48.4 | 40.8 | -.21 | -.27 | .8 | -.6 | 4034 | 4081 | 136 | 144 | 11: 3 | 136 |
| 96 | 48.7 | .0 | 41.5 | .1 | 48.8 | 41.5 | 48.9 | 41.9 | -.84 | -.53 | 1.4 | -.6 | 4045 | 4085 | 150 | 180 | 12:31 | 136 |
| 97 | 50.5 | .0 | 43.8 | .0 | 50.5 | 43.9 | 50.4 | 43.9 | .42 | -.64 | -.0 | .9 | 4067 | 3441 | 219 | 57 | 12:33 | 136 |
| 98 | 52.7 | .0 | 36.5 | .1 | 52.8 | 36.6 | 52.7 | 36.8 | -.29 | 1.20 | .3 | 1.1 | 4026 | 669 | 129 | 11 | 12:41 | 136 |
| 99 | 42.4 | .0 | 41.0 | .0 | 42.5 | 41.1 | 42.5 | 41.6 | .32 | -.22 | .4 | .2 | 2544 | 4001 | 42 | 171 | 12:43 | 136 |
| 100 | 42.8 | .0 | 41.7 | .0 | 42.9 | 41.7 | 42.8 | 41.9 | .47 | -.43 | .1 | .2 | 4082 | 4087 | 119 | 171 | 12:45 | 136 |
| 101 | 43.6 | .0 | 42.3 | .0 | 43.6 | 42.3 | 43.5 | 42.7 | .24 | -.46 | -.3 | -.1 | 3056 | 3560 | 51 | 59 | 12:47 | 136 |
| 102 | 43.7 | .0 | 43.6 | .0 | 43.7 | 43.7 | 43.6 | 43.9 | .47 | -.70 | -.0 | .4 | 4086 | 4083 | 124 | 163 | 12:48 | 136 |
| 103 | 44.2 | .0 | 44.4 | .0 | 44.2 | 44.4 | 44.1 | 44.9 | .52 | -.54 | -.1 | -.0 | 2780 | 2903 | 46 | 43 | 12:50 | 136 |
| 104 | 44.8 | .0 | 44.3 | .1 | 44.7 | 44.4 | 44.5 | 44.6 | .54 | -.36 | -.3 | -.4 | 2059 | 1967 | 34 | 33 | 12:52 | 136 |
| 105 | 40.4 | .0 | 43.1 | .1 | 40.3 | 43.2 | 40.2 | 43.2 | .48 | -.63 | -.1 | 2.5 | 1340 | 973 | 22 | 16 | 12:56 | 136 |
| 106 | 40.7 | .1 | 42.6 | .0 | 41.2 | 42.7 | 41.0 | 43.2 | 1.25 | -.36 | .7 | -.2 | 166 | 3160 | 3 | 53 | 12:58 | 136 |
| 107 | 40.4 | .0 | 42.3 | .0 | 40.5 | 42.5 | 40.2 | 43.1 | .81 | -.30 | .5 | -.2 | 4079 | 3305 | 124 | 55 | 13: 2 | 136 |
| 108 | 41.1 | .0 | 43.1 | .0 | 41.1 | 43.3 | 40.3 | 43.3 | .53 | -.30 | -.0 | -.1 | 3990 | 3960 | 113 | 64 | 13: 5 | 136 |
| 109 | 42.1 | .0 | 43.5 | .1 | 42.1 | 43.6 | 41.9 | 43.9 | .15 | -.22 | -.3 | -.1 | 3193 | 2822 | 53 | 47 | 13: 6 | 136 |
| 110 | 43.0 | .0 | 44.6 | .1 | 43.0 | 44.7 | 42.6 | 45.2 | .16 | -.22 | -.7 | .0 | 2001 | 2372 | 47 | 40 | 13: 9 | 136 |
| 111 | 41.0 | .0 | 43.8 | .0 | 41.0 | 43.9 | 40.9 | [illegible] | .51 | -.70 | .0 | -.1 | 1063 | 3077 | 133 | 51 | 13: 9 | 143 |
| 112 | 40.5 | .0 | 46.1 | .0 | 40.5 | 46.3 | 40.6 | 46.2 | .12 | -.01 | -.1 | .4 | 1552 | 963 | 26 | 16 | 13:10 | 143 |
| 113 | 37.9 | .0 | 43.4 | .0 | 37.9 | 43.4 | 37.8 | 43.1 | .59 | -.57 | .1 | 1.4 | 4071 | 4037 | 158 | 165 | 13:16 | 136 |
| 114 | 38.7 | .0 | 43.6 | .0 | 38.7 | 43.6 | 38.3 | 43.6 | .44 | -.49 | -.1 | 1.2 | 4077 | 3928 | 135 | 148 | 13:18 | 136 |
| 115 | 38.5 | .0 | 43.9 | .0 | 38.5 | 43.9 | [illegible] | 43.5 | .23 | -.42 | -.5 | 1.0 | 1734 | 4075 | 29 | 173 | 13:20 | 136 |
| 116 | 39.5 | .0 | 44.2 | .1 | 39.6 | 14.2 | 39.5 | 44.1 | .40 | -.41 | .0 | .5 | 1567 | [illegible] | 20 | 13 | 13:22 | 136 |
| 117 | 38.5 | .0 | 43.8 | .0 | 38.5 | 43.9 | 38.1 | 44.3 | .65 | -.74 | -.1 | 1.1 | [illegible] | 4077 | 136 | 153 | 13:58 | 136 |
| 118 | 37.7 | .0 | 44.4 | .0 | 37.7 | 44.5 | 37.4 | 44.7 | 1.16 | -1.05 | .0 | 2.1 | 3695 | 3750 | 62 | 62 | 14: 0 | 136 |
| 119 | 37.3 | .0 | 44.7 | .0 | 37.2 | 44.8 | 37.0 | 45.2 | [illegible] | -1.16 | 1.3 | 1.3 | 4059 | 4082 | 110 | 151 | 14: 2 | 136 |
| 120 | 38.0 | .0 | 44.4 | .0 | 38.0 | 44.5 | 37.4 | 45.2 | .97 | -.67 | -.1 | .5 | 3754 | 4084 | 63 | 165 | 14: 4 | 136 |

Table 3-A. - Continued.

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $U_{L_B}$ m/sec | $V_{L_B}$ m/sec | $U_{L_t}$ m/sec | $V_{L_t}$ m/sec | $S_{R_u}$ | $S_{R_v}$ | $E_u$ | $E_v$ | $N_u$ | $N_v$ | $DR_u$ $sec^{-1}$ | $DR_v$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | 38.1 | .1 | 45.1 | .1 | 38.1 | 45.2 | 37.9 | 45.4 | .66 | -1.34 | -.5 | 2.0 | 1635 | 2474 | 27 | 41 | 14: 6 | 136 |
| 122 | 37.6 | .0 | 44.9 | .0 | 37.6 | 45.0 | 37.5 | 45.0 | .58 | -.06 | .2 | .9 | 4070 | 3703 | 174 | 62 | 13:21 | 143 |
| 123 | 36.9 | .0 | 45.4 | .0 | 36.9 | 45.4 | 36.7 | 45.5 | .38 | .10 | .1 | -.1 | 2158 | 795 | 36 | 13 | 13:23 | 143 |
| 124 | 36.2 | .1 | 45.8 | .1 | 36.2 | 45.8 | 36.2 | 45.9 | .05 | .10 | -.1 | -.0 | 248 | 102 | 4 | 2 | 13:25 | 143 |
| 125 | 37.1 | .0 | 42.9 | .0 | 37.3 | 43.0 | 36.9 | 43.1 | .53 | .04 | -.3 | 1.0 | 1919 | 2269 | 32 | 38 | 14:13 | 136 |
| 126 | 36.3 | .0 | 43.2 | .0 | 36.4 | 43.3 | 36.2 | 43.3 | .87 | .17 | .8 | 1.6 | 4073 | 4080 | 152 | 168 | 14:14 | 136 |
| 127 | 37.9 | .1 | 42.6 | .1 | 37.9 | 42.7 | 37.8 | 42.4 | .31 | -.06 | -.1 | .5 | 916 | 752 | 15 | 13 | 14:16 | 136 |
| 128 | 36.2 | .0 | 42.9 | .0 | 36.4 | 43.3 | 35.9 | 43.4 | .75 | .30 | -.0 | 2.0 | 2737 | 3305 | 46 | 55 | 14:19 | 136 |
| 129 | 35.8 | .0 | 43.2 | .0 | 35.9 | 43.5 | 35.2 | 43.5 | .91 | -.36 | .3 | 2.3 | 4073 | 3990 | 120 | 152 | 14:21 | 136 |
| 130 | 35.7 | .0 | 43.9 | .0 | 35.7 | 44.0 | 35.2 | 43.8 | .91 | -.20 | .2 | 1.6 | 4076 | 4076 | 123 | 181 | 14:23 | 136 |
| 131 | 35.8 | .0 | 43.9 | .0 | 35.8 | 44.2 | 35.1 | 44.0 | .73 | .12 | -.1 | 2.1 | 4073 | 4071 | 126 | 172 | 14:25 | 136 |
| 132 | 35.9 | .0 | 44.7 | .0 | 35.9 | 44.8 | 35.3 | 44.5 | .59 | -.14 | -.6 | 2.3 | 3979 | 4075 | 120 | 160 | 14:27 | 136 |
| 133 | 34.8 | .1 | 45.2 | .0 | 34.7 | 45.2 | 34.7 | 45.1 | .34 | .41 | -.2 | .7 | 1018 | 1937 | 17 | 32 | 14:29 | 136 |
| 134 | 35.6 | .0 | 43.8 | .0 | 35.8 | 43.9 | 35.5 | 43.8 | .33 | .09 | .0 | .3 | 4065 | 4069 | 167 | 129 | 13:28 | 143 |
| 135 | 34.8 | .0 | 44.1 | .0 | 34.8 | 44.0 | 34.7 | 44.0 | .19 | .15 | -.0 | .0 | 3738 | 3076 | 62 | 51 | 13:30 | 143 |
| 136 | 33.9 | .0 | 44.4 | .0 | 33.9 | 44.4 | 33.8 | 44.4 | .19 | .11 | .0 | -.1 | 1879 | 2146 | 31 | 36 | 13:32 | 143 |
| 137 | 33.3 | .0 | 44.5 | .0 | 33.3 | 44.5 | 33.1 | 44.5 | .08 | -.12 | -.1 | -.2 | 1295 | 1711 | 22 | 29 | 13:33 | 143 |
| 138 | 33.7 | .0 | 41.2 | .0 | 33.8 | 41.2 | 33.3 | 41.1 | .84 | .38 | 1.0 | .1 | 4063 | 3609 | 170 | 60 | 13:36 | 143 |
| 139 | 33.0 | .0 | 41.9 | .0 | 33.0 | 41.9 | 33.0 | 41.8 | .50 | .08 | .3 | -.4 | 3139 | 1746 | 52 | 29 | 13:38 | 143 |
| 140 | 31.6 | .0 | 40.8 | .0 | 31.5 | 40.8 | 31.6 | 40.8 | .04 | .24 | .2 | -.1 | 3633 | 3136 | 61 | 52 | 13:40 | 143 |
| 141 | 30.8 | .0 | 40.8 | .0 | 30.8 | 40.8 | 30.7 | 40.7 | .04 | .14 | -.0 | -.0 | 2394 | 3810 | 40 | 63 | 13:42 | 143 |
| 142 | 30.2 | .0 | 40.7 | .0 | 30.2 | 40.7 | 30.3 | 40.7 | -.10 | .05 | .1 | -.2 | 1075 | 1423 | 18 | 24 | 13:44 | 143 |
| 143 | 34.3 | .1 | 31.5 | .1 | 34.4 | 31.5 | 34.5 | 31.4 | .04 | .12 | -.1 | -.2 | 636 | 369 | 11 | 6 | 8:52 | 144 |
| 144 | 35.3 | .0 | 32.8 | .0 | 35.3 | 32.8 | 35.3 | 32.8 | .06 | .11 | .0 | .2 | 4079 | 2670 | 177 | 44 | 8:53 | 144 |
| 145 | 35.3 | .0 | 33.3 | .0 | 35.3 | 33.3 | 35.3 | 33.3 | -.02 | .38 | .3 | .3 | 4064 | 2429 | 168 | 40 | 8:55 | 144 |
| 146 | 35.3 | .0 | 33.6 | .0 | 35.3 | 33.6 | 35.2 | 33.5 | .09 | .29 | .4 | .4 | 4080 | 3178 | 150 | 53 | 8:56 | 144 |
| 147 | 35.3 | .0 | 34.0 | .0 | 35.3 | 33.9 | 35.5 | 33.9 | .07 | .22 | .2 | .4 | 3186 | 2054 | 53 | 34 | 8:59 | 144 |
| 148 | 35.2 | .0 | 34.2 | .0 | 35.3 | 34.2 | 35.2 | 34.2 | .14 | .41 | .6 | .8 | 2322 | 1768 | 39 | 29 | 9: 1 | 144 |
| 149 | 33.1 | .0 | 40.0 | .0 | 33.1 | 39.9 | 33.1 | 39.8 | .68 | .42 | 1.2 | .2 | 4065 | 4059 | 350 | 267 | 14: 7 | 143 |
| 150 | 33.5 | .1 | 41.1 | .1 | 33.4 | 41.1 | 33.7 | 40.9 | .05 | .17 | -.3 | -.5 | 386 | 1027 | 6 | 17 | 14: 9 | 143 |
| 151 | 31.7 | .1 | 39.6 | .0 | 31.7 | 39.5 | 31.9 | 39.7 | .21 | .42 | -.1 | .0 | 380 | 913 | 6 | 15 | 14:26 | 143 |
| 152 | 30.9 | .0 | 38.7 | .0 | 30.8 | 38.7 | 30.6 | 38.7 | .04 | .10 | -.1 | -.1 | 2618 | 2187 | 44 | 36 | 14:28 | 143 |
| 153 | 30.3 | .0 | 38.1 | .0 | 30.3 | 38.1 | 30.2 | 38.1 | -.00 | -.06 | .0 | -.2 | 2616 | 961 | 44 | 16 | 14:29 | 143 |
| 154 | 32.2 | .4 | 28.7 | .3 | 32.3 | 28.7 | 32.4 | 14.3 | -.83 | .16 | 1.0 | -.6 | 76 | 43 | 1 | 1 | 14:37 | 143 |
| 155 | 34.2 | .1 | 32.3 | .1 | 34.3 | 32.3 | 34.1 | 32.4 | .05 | -.09 | .1 | -.3 | 450 | 202 | 7 | 3 | 14:38 | 143 |
| 156 | 35.0 | .1 | 32.7 | .0 | 35.0 | 32.7 | 34.9 | 32.8 | .26 | -.07 | .4 | .1 | 538 | 986 | 9 | 16 | 14:40 | 143 |
| 157 | 35.4 | .0 | 33.3 | .0 | 35.4 | 33.3 | 35.4 | 33.2 | .03 | .08 | .1 | .3 | 3757 | 3064 | 63 | 51 | 14:41 | 143 |
| 158 | 35.6 | .0 | 33.9 | .0 | 35.7 | 33.9 | 35.5 | 33.8 | .30 | .54 | .8 | .6 | 4064 | 4058 | 159 | 137 | 14:42 | 143 |
| 159 | 35.6 | .0 | 34.4 | .0 | 35.8 | 34.3 | 35.5 | 34.2 | .43 | .54 | .8 | .5 | 3662 | 3621 | 61 | 60 | 14:44 | 143 |
| 160 | 35.5 | .0 | 34.6 | .0 | 35.7 | 34.6 | 35.0 | 34.5 | .44 | .50 | 1.0 | .7 | 4079 | 3490 | 140 | 58 | 14:46 | 143 |
| 161 | 35.6 | .0 | 34.8 | .0 | 35.7 | 34.8 | 35.6 | 34.8 | .42 | .60 | 1.1 | 1.5 | 4081 | 4084 | 152 | 125 | 14:47 | 143 |
| 162 | 35.8 | .0 | 35.1 | .0 | 35.8 | 35.1 | 35.7 | 35.1 | .11 | .32 | .4 | .5 | 3710 | 1966 | 62 | 33 | 14:49 | 143 |
| 163 | 35.1 | .0 | 34.6 | .0 | 35.1 | 34.6 | 34.9 | 34.6 | .08 | .12 | .7 | .3 | 4080 | 4069 | 258 | 152 | 8:44 | 144 |
| 164 | 33.4 | .1 | 39.7 | .0 | 33.7 | 39.8 | 32.6 | 39.6 | 1.23 | .39 | 1.4 | -.4 | 1977 | 2178 | 33 | 36 | 9:23 | 144 |
| 165 | 32.7 | .1 | 39.6 | .1 | 32.6 | 39.6 | 32.6 | 39.6 | .27 | .14 | .4 | -.5 | 373 | 362 | 6 | 14 | 9:24 | 144 |
| 166 | 31.5 | .0 | 37.7 | .0 | 31.5 | 37.7 | 31.6 | 37.8 | -.07 | .17 | .1 | .1 | 4075 | 4055 | 207 | 274 | 9:26 | 144 |
| 167 | 31.1 | .0 | 36.7 | .0 | 31.1 | 36.7 | 31.1 | 36.8 | -.01 | .07 | -.1 | -.0 | 4079 | 2452 | 143 | 41 | 9:28 | 144 |
| 168 | 31.4 | .0 | 36.2 | .0 | 31.4 | 36.1 | 31.3 | 36.2 | .07 | -.06 | -.1 | -.2 | 853 | 995 | 14 | 17 | 9:29 | 144 |
| 169 | 30.8 | .1 | 34.9 | .2 | 30.8 | 35.0 | 31.0 | 35.2 | -.04 | -1.17 | .2 | 2.1 | 94 | 63 | 2 | 1 | 9:30 | 144 |
| 170 | 28.2 | .2 | 34.0 | .4 | 28.2 | 34.0 | 28.1 | 34.1 | -.35 | -1.16 | .1 | .9 | 70 | 35 | 1 | 1 | 9:37 | 144 |
| 171 | 25.4 | .3 | 33.2 | .6 | 25.3 | 33.2 | 25.3 | 33.0 | -.46 | -.35 | .9 | -.4 | 36 | 13 | 1 | 0 | 9:39 | 144 |
| 172 | 23.9 | .7 | 22.2 | .6 | 23.3 | 22.2 | 24.3 | 22.4 | .55 | .30 | -.7 | -.6 | 45 | 29 | 1 | 0 | 9:40 | 144 |
| 173 | 25.6 | .6 | 22.1 | .3 | 25.9 | 22.0 | 26.6 | 22.1 | .25 | -.36 | -1.0 | -.3 | 92 | 73 | 2 | 1 | 9:42 | 144 |
| 174 | 29.7 | .4 | 26.3 | .3 | 29.6 | 26.3 | 29.9 | 26.5 | -.80 | -.41 | .1 | -.4 | 130 | 115 | 2 | 2 | 9:44 | 144 |
| 175 | 32.4 | .1 | 31.5 | .1 | 32.5 | 31.5 | 33.0 | 31.6 | -.20 | -.30 | .0 | .5 | 413 | 248 | 7 | 4 | 9:46 | 144 |
| 176 | 32.7 | .1 | 33.7 | .0 | 32.9 | 33.7 | 33.3 | 33.8 | -.21 | .15 | .7 | -.0 | 1233 | 239 | 21 | 16 | 9:48 | 144 |
| 177 | 33.3 | .0 | 34.0 | .0 | 33.2 | 34.0 | 33.5 | 33.9 | -.19 | .48 | .4 | .9 | 2162 | 1651 | 30 | 28 | 9:50 | 144 |
| 178 | 33.9 | .0 | 33.9 | .0 | 33.9 | 34.0 | 33.9 | 33.8 | .32 | .58 | 1.0 | 2.0 | 4069 | 2928 | 139 | 49 | 9:53 | 144 |
| 179 | 34.6 | .0 | 34.5 | .0 | 34.6 | 34.5 | 34.4 | 34.4 | .23 | .45 | .9 | 1.2 | 4077 | 4061 | 179 | 151 | 9:55 | 144 |
| 180 | 34.7 | .0 | 34.9 | .0 | 35.0 | 34.8 | 34.8 | 34.7 | .53 | .39 | 1.0 | .7 | 1061 | 4074 | 203 | 183 | 9:56 | 144 |

Table 3-A. - Concluded.

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $U_{L_B}$ m/sec | $V_{L_B}$ m/sec | $U_{L_t}$ m/sec | $V_{L_t}$ m/sec | $S_{R_U}$ | $S_{R_V}$ | $E_U$ | $E_V$ | $N_U$ | $N_V$ | $DR_U$ $sec^{-1}$ | $DR_V$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 181 | 34.7 | .0 | 34.9 | .0 | 35.0 | 35.0 | 34.5 | 34.8 | .60 | .55 | 1.2 | 1.0 | 4065 | 4075 | 175 | 157 | 9:58 | 144 |
| 182 | 34.9 | .0 | 35.0 | .0 | 35.1 | 35.1 | 34.9 | 34.9 | .50 | .24 | 1.4 | .8 | 4070 | 4068 | 161 | 137 | 10: 0 | 144 |
| 183 | 34.9 | .0 | 35.2 | .0 | 35.2 | 35.2 | 35.0 | 35.1 | .55 | .44 | 1.2 | 1.2 | 4064 | 4076 | 149 | 119 | 10: 2 | 144 |
| 184 | 33.0 | .0 | 38.9 | .0 | 33.1 | 38.9 | 32.9 | 38.7 | .86 | .57 | 1.8 | -.1 | 4064 | 4086 | 264 | 201 | 10: 6 | 144 |
| 185 | 32.4 | .0 | 38.9 | .0 | 32.4 | 38.9 | 32.3 | 38.6 | .06 | .34 | 1.2 | -.5 | 4078 | 4086 | 196 | 160 | 10: 7 | 144 |
| 186 | 32.0 | .0 | 37.4 | .0 | 32.0 | 37.4 | 31.7 | 37.4 | -.08 | .18 | .3 | .0 | 4089 | 3727 | 250 | 62 | 10:10 | 144 |
| 187 | 32.0 | .0 | 36.3 | .0 | 32.0 | 36.3 | 32.0 | 36.4 | -.10 | .06 | .2 | -.1 | 2606 | 2387 | 47 | 40 | 10:11 | 144 |
| 188 | 32.1 | .1 | 36.0 | .1 | 32.1 | 36.0 | 32.4 | 36.0 | .09 | -.07 | -.3 | -.2 | 419 | 250 | 7 | 4 | 10:13 | 144 |
| 189 | 30.6 | .1 | 35.2 | .1 | 30.6 | 35.3 | 30.8 | 35.4 | .12 | .18 | .1 | -.3 | 137 | 122 | 2 | 2 | 10:14 | 144 |
| 190 | 28.1 | .5 | 33.3 | .9 | 28.0 | 33.3 | 28.8 | 33.5 | -1.00 | -.09 | 1.5 | -.6 | 21 | 7 | 0 | 0 | 10:16 | 144 |
| 191 | 25.6 | .9 | 29.7 | 1.9 | 25.5 | 29.6 | 26.0 | .0 | .39 | 1.12 | -.8 | -.7 | 22 | 4 | 0 | 0 | 10:17 | 144 |
| 192 | 26.1 | 1.1 | 23.9 | .5 | 26.0 | 23.2 | 23.6 | 22.1 | .80 | .93 | .5 | 2.1 | 13 | 19 | 0 | 0 | 10:26 | 144 |
| 193 | 26.0 | 1.0 | 25.4 | .6 | 26.0 | 25.3 | 25.8 | 25.7 | .52 | .72 | -.9 | -.2 | 15 | 49 | 0 | 1 | 10:30 | 144 |
| 194 | 28.3 | .6 | 24.7 | .4 | 28.2 | 24.7 | 28.1 | 24.3 | -.44 | .14 | -.4 | -.7 | 51 | 33 | 1 | 1 | 10:32 | 144 |
| 195 | 26.6 | .8 | 25.2 | .4 | 26.5 | 25.2 | 26.0 | 25.3 | -.17 | .34 | -.8 | -.9 | 28 | 25 | 0 | 0 | 10:33 | 144 |
| 196 | 32.4 | .2 | 30.9 | .1 | 32.5 | 30.9 | 32.0 | 30.9 | -.50 | -.20 | .4 | .2 | 290 | 390 | 5 | 6 | 10:35 | 144 |
| 197 | 33.0 | .1 | 32.6 | .1 | 33.1 | 32.6 | 33.0 | 33.0 | -.10 | .09 | .5 | .4 | 704 | 645 | 12 | 11 | 10:36 | 144 |
| 198 | 33.3 | .0 | 34.5 | .0 | 33.3 | 34.4 | 33.1 | 34.5 | -.13 | .20 | .8 | .1 | 3353 | 2251 | 56 | 38 | 10:38 | 144 |
| 199 | 33.8 | .0 | 34.4 | .0 | 33.8 | 34.4 | 33.7 | 34.4 | .07 | .04 | .4 | .3 | 4083 | 1912 | 170 | 32 | 10:39 | 144 |
| 200 | 34.2 | .0 | 34.6 | .0 | 34.3 | 34.6 | 34.0 | 34.4 | .33 | .17 | 1.0 | .9 | 4084 | 4071 | 192 | 134 | 10:41 | 144 |
| 201 | 34.3 | .0 | 34.7 | .0 | 34.3 | 34.7 | 34.2 | 34.7 | .54 | .07 | 1.3 | .8 | 4078 | 2838 | 157 | 47 | 10:42 | 144 |
| 202 | 34.5 | .0 | 34.9 | .0 | 34.5 | 34.9 | 34.4 | 34.9 | .42 | .10 | 1.0 | 1.3 | 4084 | 2411 | 142 | 40 | 10:44 | 144 |
| 203 | 34.6 | .0 | 35.0 | .0 | 34.6 | 35.0 | 34.5 | 35.1 | .33 | .23 | 1.1 | .7 | 2648 | 1749 | 44 | 29 | 10:46 | 144 |

Table 3-B ($\alpha = 4.75^0$)

| Run | $x_c/c$ | $y_c/c$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $U_{f_e}/U_T$ | $V_{f_e}/U_T$ | $U_{R_e}/U_T$ | $\alpha_{R_e}$ deg | $U_{f_B}/U_T$ | $V_{f_B}/U_T$ | $U_{R_B}/U_T$ | $\alpha_{R_B}$ deg | $U_{f_t}/U_t$ | $V_{f_t}/U_t$ | $U_{R_t}/U_t$ | $\alpha_{R_t}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.173 | .277 | 1.6 | .1 | 1.4 | .1 | 1.03 | .07 | 1.04 | 3.9 | 1.03 | .07 | 1.04 | 4.0 | 1.04 | .08 | 1.04 | 4.2 |
| 2 | -.171 | .239 | 1.5 | .0 | 1.4 | .0 | 1.03 | .08 | 1.04 | 4.7 | 1.03 | .09 | 1.04 | 4.8 | 1.03 | .09 | 1.04 | 5.2 |
| 3 | -.166 | .201 | 1.4 | .0 | 1.4 | .0 | 1.03 | .09 | 1.03 | 5.0 | 1.03 | .09 | 1.03 | 5.0 | 1.03 | .09 | 1.03 | 5.1 |
| 4 | -.164 | .161 | 1.4 | .0 | 1.5 | .0 | 1.02 | .10 | 1.02 | 5.6 | 1.02 | .10 | 1.02 | 5.7 | 1.02 | .11 | 1.02 | 6.0 |
| 5 | -.163 | .120 | 1.3 | .0 | 1.4 | .0 | 1.00 | .10 | 1.01 | 5.9 | 1.00 | .10 | 1.01 | 6.0 | 1.00 | .11 | 1.01 | 6.2 |
| 6 | -.161 | .082 | 1.3 | .0 | 1.4 | .0 | .99 | .11 | .99 | 6.1 | .99 | .11 | .99 | 6.2 | .99 | .11 | .99 | 6.3 |
| 7 | -.163 | .041 | 1.2 | .0 | 1.5 | .0 | .97 | .10 | .97 | 5.8 | .97 | .10 | .97 | 5.9 | .97 | .11 | .97 | 6.2 |
| 8 | -.161 | .021 | 1.2 | .0 | 1.5 | .0 | .96 | .09 | .96 | 5.6 | .96 | .10 | .96 | 5.7 | .96 | .10 | .96 | 5.7 |
| 9 | -.162 | .001 | 1.1 | .0 | 1.5 | .0 | .95 | .09 | .96 | 5.3 | .95 | .09 | .96 | 5.4 | .95 | .09 | .95 | 5.7 |
| 10 | -.160 | -.020 | 1.1 | .0 | 1.4 | .0 | .94 | .08 | .95 | 5.0 | .94 | .08 | .95 | 5.0 | .94 | .09 | .94 | 5.4 |
| 11 | -.162 | -.040 | 1.0 | .0 | 1.5 | .0 | .94 | .07 | .95 | 4.4 | .94 | .07 | .94 | 4.4 | .94 | .07 | .94 | 4.5 |
| 12 | -.090 | .276 | 1.5 | .1 | 1.3 | .1 | 1.07 | .09 | 1.07 | 4.8 | 1.06 | .09 | 1.07 | 4.9 | 1.07 | .09 | 1.07 | 5.0 |
| 13 | -.086 | .240 | 1.5 | .1 | 1.2 | .1 | 1.06 | .10 | 1.07 | 5.6 | 1.06 | .11 | 1.07 | 5.7 | 1.06 | .11 | 1.07 | 6.0 |
| 14 | -.084 | .199 | 1.5 | .1 | 1.2 | .0 | 1.06 | .12 | 1.07 | 6.5 | 1.06 | .12 | 1.07 | 6.6 | 1.06 | .12 | 1.07 | 6.6 |
| 15 | -.083 | .160 | 1.5 | .0 | 1.3 | .0 | 1.04 | .14 | 1.05 | 7.5 | 1.04 | .14 | 1.05 | 7.6 | 1.04 | .14 | 1.05 | 7.6 |
| 16 | -.080 | .121 | 1.6 | .0 | 1.4 | .0 | 1.02 | .15 | 1.03 | 8.5 | 1.02 | .15 | 1.03 | 8.6 | 1.03 | .16 | 1.04 | 8.7 |
| 17 | -.078 | .080 | 1.5 | .0 | 1.7 | .0 | .99 | .17 | 1.00 | 9.7 | .99 | .17 | 1.00 | 9.7 | .99 | .17 | 1.01 | 10.0 |
| 18 | -.077 | .061 | 1.3 | .0 | 1.6 | .0 | .96 | .17 | .98 | 10.2 | .96 | .18 | .97 | 10.4 | .96 | .18 | .98 | 10.3 |
| 19 | -.080 | .040 | 1.2 | .0 | 1.8 | .0 | .94 | .16 | .95 | 9.9 | .94 | .16 | .95 | 10.0 | .94 | .17 | .95 | 10.0 |
| 20 | -.077 | .021 | 1.1 | .0 | 1.9 | .1 | .92 | .15 | .93 | 9.5 | .91 | .15 | .93 | 9.6 | .92 | .16 | .93 | 9.7 |
| 21 | -.079 | .010 | 1.2 | .0 | 2.9 | .0 | .94 | .10 | .94 | 6.4 | .94 | .10 | .94 | 6.4 | .93 | .11 | .94 | 6.6 |
| 22 | -.077 | .002 | 1.2 | .0 | 3.3 | .0 | .93 | .10 | .94 | 5.8 | .93 | .10 | .94 | 5.8 | .93 | .10 | .93 | 6.2 |
| 23 | -.078 | -.010 | 1.2 | .0 | 3.3 | .0 | .94 | .08 | .94 | 4.8 | .94 | .08 | .94 | 4.8 | .92 | .09 | .92 | 5.8 |
| 24 | -.078 | -.019 | 1.2 | .0 | 3.0 | .1 | .93 | .07 | .93 | 4.6 | .93 | .08 | .93 | 4.7 | .92 | .09 | .92 | 5.4 |
| 25 | -.078 | -.030 | 1.4 | .0 | 2.7 | .0 | .92 | .07 | .93 | 4.3 | .92 | .07 | .92 | 4.3 | .91 | .08 | .92 | 4.9 |
| 26 | -.048 | .280 | 2.1 | .1 | 1.7 | .0 | 1.06 | .08 | 1.06 | 4.1 | 1.06 | .08 | 1.06 | 4.2 | 1.06 | .07 | 1.06 | 4.0 |
| 27 | -.045 | .240 | 2.1 | .0 | 1.7 | .0 | 1.06 | .10 | 1.07 | 5.3 | 1.07 | .10 | 1.07 | 5.3 | 1.07 | .10 | 1.07 | 5.5 |
| 28 | -.044 | .200 | 2.5 | .0 | 1.7 | .0 | 1.06 | .11 | 1.06 | 6.2 | 1.06 | .12 | 1.07 | 6.3 | 1.06 | .12 | 1.07 | 6.6 |
| 29 | -.041 | .159 | 2.0 | .0 | 1.5 | .0 | 1.07 | .16 | 1.03 | 8.5 | 1.07 | .16 | 1.08 | 8.5 | 1.07 | .16 | 1.09 | 8.5 |
| 30 | -.038 | .140 | 2.0 | .0 | 1.6 | .0 | 1.06 | .18 | 1.08 | 9.4 | 1.06 | .18 | 1.08 | 9.4 | 1.06 | .18 | 1.08 | 9.7 |
| 31 | -.036 | .100 | 2.2 | .0 | 1.5 | .0 | 1.04 | .22 | 1.06 | 11.9 | 1.03 | .22 | 1.06 | 12.0 | 1.04 | .22 | 1.06 | 12.1 |
| 32 | -.034 | .080 | 2.3 | .0 | 1.8 | .0 | 1.01 | .24 | 1.03 | 13.6 | 1.00 | .25 | 1.03 | 13.7 | 1.01 | .25 | 1.04 | 13.9 |
| 33 | -.037 | .060 | 2.0 | .0 | 2.2 | .0 | .97 | .26 | 1.00 | 14.8 | .97 | .26 | 1.00 | 14.9 | .97 | .26 | 1.00 | 15.2 |
| 34 | -.036 | .041 | 1.8 | .0 | 2.5 | .0 | .91 | .27 | .95 | 16.4 | .91 | .27 | .94 | 16.6 | .90 | .27 | .94 | 16.7 |
| 35 | -.034 | .030 | 1.4 | .0 | 2.4 | .0 | .87 | .26 | .91 | 16.7 | .86 | .26 | .90 | 17.0 | .85 | .28 | .90 | 18.2 |
| 36 | -.036 | .021 | 1.0 | .0 | 3.2 | .1 | .86 | .22 | .89 | 14.5 | .86 | .23 | .89 | 14.8 | .86 | .23 | .89 | 15.2 |
| 37 | -.036 | .010 | .9 | .1 | 4.4 | .2 | .85 | .18 | .87 | 11.8 | .85 | .18 | .87 | 11.9 | .85 | .18 | .87 | 11.7 |
| 38 | -.036 | .001 | 1.0 | .1 | 3.6 | .2 | .83 | .17 | .85 | 11.6 | .83 | .17 | .85 | 11.8 | .83 | .18 | .85 | 12.0 |
| 39 | -.037 | -.009 | 1.3 | .1 | 2.7 | .2 | .82 | .14 | .83 | 9.8 | .82 | .15 | .83 | 10.1 | .81 | .15 | .83 | 10.6 |
| 40 | -.036 | -.019 | 1.4 | .1 | 2.8 | .3 | .83 | .11 | .84 | 7.8 | .83 | .12 | .83 | 7.9 | .83 | .11 | .84 | 7.6 |
| 41 | -.036 | -.029 | 1.8 | .1 | 2.7 | .1 | .82 | .11 | .83 | 7.4 | .82 | .11 | .83 | 7.5 | .81 | .12 | .82 | 8.1 |
| 42 | -.006 | -.030 | 1.6 | .3 | 2.0 | .2 | .73 | .05 | .73 | 4.2 | .72 | .06 | .72 | 4.5 | .72 | .06 | .72 | 4.8 |
| 43 | -.006 | .279 | 1.3 | .0 | 1.4 | .0 | 1.10 | .09 | 1.10 | 4.7 | 1.10 | .09 | 1.10 | 4.7 | 1.10 | .09 | 1.11 | 4.7 |
| 44 | -.003 | .240 | 1.4 | .0 | 1.3 | .0 | 1.10 | .11 | 1.11 | 5.9 | 1.10 | .11 | 1.11 | 5.9 | 1.11 | .11 | 1.11 | 5.9 |
| 45 | -.000 | .199 | 1.6 | .0 | 1.5 | .0 | 1.10 | .14 | 1.11 | 7.1 | 1.10 | .14 | 1.11 | 7.1 | 1.11 | .14 | 1.12 | 7.4 |
| 46 | .002 | .160 | 2.5 | .0 | 1.5 | .0 | 1.09 | .16 | 1.10 | 8.2 | 1.09 | .16 | 1.10 | 8.3 | 1.09 | .16 | 1.11 | 8.5 |
| 47 | .002 | .119 | 2.8 | .0 | 1.5 | .0 | 1.08 | .21 | 1.10 | 10.9 | 1.08 | .21 | 1.10 | 11.0 | 1.09 | .22 | 1.11 | 11.3 |
| 48 | .005 | .080 | 3.5 | .0 | 1.6 | .0 | 1.06 | .30 | 1.10 | 15.7 | 1.05 | .30 | 1.09 | 15.8 | 1.06 | .30 | 1.11 | 16.0 |
| 49 | .005 | .058 | 3.9 | .0 | 1.7 | .0 | 1.00 | .39 | 1.08 | 21.4 | 1.00 | .39 | 1.07 | 21.6 | 1.01 | .41 | 1.09 | 21.9 |
| 50 | .005 | .040 | 3.9 | .1 | 4.8 | .1 | .92 | .43 | 1.02 | 25.0 | .92 | .43 | 1.01 | 25.2 | .91 | .45 | 1.01 | 26.5 |
| 51 | .005 | .038 | 2.9 | .1 | 3.6 | .3 | .91 | .41 | 1.00 | 24.0 | .90 | .42 | 1.00 | 24.7 | .91 | .42 | 1.00 | 24.8 |
| 52 | .006 | .031 | 3.6 | .2 | 6.1 | .5 | .99 | .25 | 1.02 | 14.5 | .98 | .26 | 1.02 | 14.6 | .97 | .29 | 1.02 | 16.5 |
| 53 | .011 | .035 | 3.2 | .1 | 2.0 | .1 | .73 | .01 | .73 | .4 | .73 | .01 | .73 | .6 | .68 | -.03 | .68 | -2.4 |
| 54 | .035 | .290 | 1.3 | .0 | 1.4 | .0 | 1.12 | .09 | 1.12 | 4.4 | 1.12 | .09 | 1.12 | 4.4 | 1.12 | .09 | 1.13 | 4.4 |
| 55 | .037 | .273 | 1.2 | .0 | 1.4 | .0 | 1.12 | .09 | 1.13 | 4.3 | 1.12 | .09 | 1.13 | 4.8 | 1.13 | .09 | 1.13 | 4.8 |
| 56 | .039 | .231 | 1.3 | .0 | 1.5 | .0 | 1.14 | .11 | 1.14 | 5.6 | 1.14 | .11 | 1.14 | 5.6 | 1.14 | .11 | 1.15 | 5.6 |
| 57 | .042 | .193 | 1.7 | .0 | 1.6 | .0 | 1.14 | .14 | 1.15 | 7.1 | 1.14 | .14 | 1.15 | 7.2 | 1.14 | .14 | 1.15 | 7.1 |
| 58 | .045 | .163 | 2.2 | .0 | 1.7 | .0 | 1.14 | .16 | 1.15 | 8.2 | 1.14 | .16 | 1.15 | 8.2 | 1.15 | .17 | 1.16 | 8.3 |
| 59 | .047 | .133 | 2.5 | .0 | 1.8 | .0 | 1.15 | .20 | 1.17 | 10.0 | 1.15 | .20 | 1.17 | 10.0 | 1.16 | [illegible] | 1.18 | 10.3 |
| 60 | .046 | .102 | 3.0 | .0 | 2.1 | .0 | 1.16 | .27 | 1.19 | 12.9 | 1.17 | .27 | 1.20 | 13.0 | 1.18 | .27 | 1.21 | 13.0 |

Table 3-B. - Continued.

| Run | $x_c/c$ | $y_c/c$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $U_{f_e}/U_T$ | $V_{f_e}/U_T$ | $U_{R_e}/U_T$ | $\alpha_{R_e}$ deg | $U_{f_B}/U_T$ | $V_{f_B}/U_T$ | $U_{R_B}/U_T$ | $\alpha_{R_B}$ deg | $U_{f_t}/U_T$ | $V_{f_t}/U_T$ | $U_{R_t}/U_T$ | $\alpha_{R_t}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | .048 | .083 | 3.4 | .0 | 2.4 | .0 | 1.18 | .34 | 1.23 | 16.0 | 1.19 | .34 | 1.23 | 16.1 | 1.20 | .34 | 1.24 | 16.0 |
| 62 | .046 | .063 | 3.5 | .1 | 2.7 | .0 | 1.21 | .48 | 1.30 | 21.7 | 1.21 | .48 | 1.30 | 21.9 | 1.21 | .49 | 1.31 | 21.8 |
| 63 | .046 | .057 | 3.5 | .1 | 3.8 | .1 | 1.18 | .56 | 1.30 | 25.5 | 1.17 | .57 | 1.30 | 26.0 | 1.19 | .56 | 1.32 | 25.1 |
| 64 | .046 | .056 | 4.0 | .1 | 4.1 | .1 | 1.18 | .56 | 1.30 | 25.3 | 1.18 | .57 | 1.31 | 25.8 | 1.19 | .56 | 1.32 | 25.2 |
| 65 | .047 | .052 | 8.4 | .6 | 4.7 | .2 | 1.08 | .33 | 1.13 | 17.0 | 1.08 | .33 | 1.13 | 16.8 | 1.07 | .35 | 1.13 | 18.3 |
| 66 | .026 | .064 | 6.5 | .1 | 3.4 | .0 | 1.08 | .38 | 1.15 | 19.4 | 1.08 | .38 | 1.14 | 19.4 | 1.10 | .40 | 1.17 | 20.1 |
| 67 | .027 | .055 | 7.1 | .1 | 4.7 | .1 | 1.05 | .45 | 1.15 | 23.3 | 1.05 | .45 | 1.14 | 23.2 | 1.07 | .48 | 1.17 | 24.1 |
| 68 | .026 | .045 | 8.7 | .1 | 8.9 | .1 | 1.02 | .52 | 1.15 | 27.2 | 1.01 | .53 | 1.14 | 27.5 | 1.02 | .57 | 1.17 | 29.2 |
| 69 | .076 | .328 | 1.4 | .1 | 1.6 | .1 | 1.11 | .07 | 1.11 | 3.8 | 1.11 | .07 | 1.11 | 3.8 | 1.12 | .08 | 1.12 | 3.9 |
| 70 | .078 | .303 | 1.2 | .0 | 1.5 | .0 | 1.13 | .08 | 1.13 | 3.9 | 1.13 | .08 | 1.13 | 3.9 | 1.13 | .08 | 1.13 | 4.0 |
| 71 | .082 | .264 | 1.7 | .0 | 1.8 | .0 | 1.12 | .08 | 1.13 | 4.0 | 1.12 | .08 | 1.13 | 4.1 | 1.12 | .08 | 1.13 | 3.9 |
| 72 | .085 | .224 | 1.4 | .0 | 1.8 | .0 | 1.15 | .11 | 1.15 | 5.3 | 1.15 | .11 | 1.15 | 5.3 | 1.15 | .10 | 1.16 | 5.2 |
| 73 | .088 | .186 | 1.5 | .0 | 2.0 | .0 | 1.17 | .13 | 1.17 | 6.4 | 1.17 | .13 | 1.18 | 6.5 | 1.17 | .13 | 1.18 | 6.3 |
| 74 | .088 | .146 | 1.5 | .0 | 2.4 | .0 | 1.21 | .17 | 1.22 | 7.8 | 1.21 | .17 | 1.22 | 7.9 | 1.22 | .16 | 1.23 | 7.7 |
| 75 | .089 | .126 | 1.7 | .0 | 2.7 | .0 | 1.23 | .19 | 1.25 | 8.7 | 1.23 | .19 | 1.25 | 8.7 | 1.24 | .19 | 1.25 | 8.5 |
| 76 | .089 | .105 | 1.5 | .0 | 2.9 | .0 | 1.27 | .21 | 1.28 | 9.6 | 1.27 | .21 | 1.29 | 9.6 | 1.27 | .21 | 1.29 | 9.4 |
| 77 | .089 | .085 | 1.6 | .0 | 4.0 | .0 | 1.30 | .27 | 1.33 | 11.5 | 1.31 | .27 | 1.33 | 11.6 | 1.31 | .26 | 1.34 | 11.3 |
| 78 | .087 | .066 | 1.9 | .1 | 6.7 | .3 | 1.30 | .30 | 1.33 | 12.2 | 1.30 | .31 | 1.34 | 13.3 | 1.32 | .29 | 1.35 | 12.4 |
| 79 | .083 | .066 | 6.9 | .3 | 11.1 | 4.4 | 1.12 | .37 | 1.18 | 18.0 | 1.11 | .37 | 1.17 | 18.6 | 1.18 | .34 | 1.23 | 15.9 |
| 80 | .059 | .077 | 4.4 | .0 | 3.1 | .0 | 1.20 | .37 | 1.26 | 17.0 | 1.21 | .37 | 1.26 | 17.1 | 1.22 | .38 | 1.28 | 17.1 |
| 81 | .058 | .069 | 5.8 | .1 | 3.8 | .0 | 1.24 | .44 | 1.31 | 19.7 | 1.24 | .45 | 1.32 | 19.9 | 1.25 | .45 | 1.33 | 19.7 |
| 82 | .059 | .059 | 8.1 | .3 | 3.6 | .2 | 1.11 | .27 | 1.14 | 13.9 | 1.10 | .27 | 1.13 | 13.8 | 1.10 | .30 | 1.14 | 15.1 |
| 83 | .060 | .053 | 3.4 | .3 | 3.4 | .7 | 1.03 | .19 | 1.05 | 10.4 | 1.03 | .19 | 1.05 | 10.4 | 1.06 | .19 | 1.07 | 10.1 |
| 84 | .119 | .308 | 1.2 | .0 | 1.6 | .0 | 1.14 | .05 | 1.14 | 2.7 | 1.14 | .05 | 1.14 | 2.7 | 1.14 | .05 | 1.14 | 2.5 |
| 85 | .121 | .271 | 1.2 | .0 | 1.9 | .0 | 1.15 | .07 | 1.16 | 3.4 | 1.15 | .07 | 1.16 | 3.4 | 1.16 | .06 | 1.16 | 3.1 |
| 86 | .123 | .231 | 1.2 | .0 | 1.9 | .1 | 1.17 | .08 | 1.18 | 4.0 | .75 | .52 | .91 | 34.9 | 1.19 | .08 | 1.19 | 3.6 |
| 87 | .128 | .191 | 1.5 | .0 | 2.5 | .0 | 1.18 | .11 | 1.18 | 5.4 | 1.18 | .11 | 1.18 | 5.4 | 1.19 | .11 | 1.19 | 5.2 |
| 88 | .128 | .151 | 1.9 | .0 | 3.0 | .0 | 1.21 | .14 | 1.22 | 6.4 | 1.22 | .14 | 1.22 | 6.4 | 1.22 | .13 | 1.23 | 6.1 |
| 89 | .132 | .131 | 2.0 | .0 | 3.4 | .0 | 1.23 | .14 | 1.24 | 6.5 | 1.24 | .14 | 1.24 | 6.6 | 1.24 | .14 | 1.25 | 6.5 |
| 90 | .130 | .112 | 2.1 | .0 | 3.8 | .0 | 1.26 | .16 | 1.27 | 7.3 | 1.27 | .16 | 1.23 | 7.3 | 1.27 | .16 | 1.23 | 7.2 |
| 91 | .130 | .091 | 2.2 | .0 | 4.7 | .0 | 1.29 | .22 | 1.31 | 9.5 | 1.30 | .22 | 1.32 | 9.6 | 1.31 | .21 | 1.32 | 9.2 |
| 92 | .162 | .274 | 1.8 | .0 | 2.2 | .0 | 1.14 | .07 | 1.14 | 3.5 | 1.14 | .07 | 1.14 | 3.4 | 1.14 | .07 | 1.14 | 3.3 |
| 93 | .165 | .236 | 1.7 | .0 | 2.4 | .0 | 1.15 | .09 | 1.16 | 4.4 | 1.16 | .09 | 1.16 | 4.3 | 1.16 | .09 | 1.16 | 4.3 |
| 94 | .169 | .196 | 1.8 | .0 | 2.7 | .0 | 1.18 | .09 | 1.18 | 4.5 | 1.18 | .09 | 1.18 | 4.5 | 1.19 | .09 | 1.19 | 4.1 |
| 95 | .171 | .156 | 1.7 | .0 | 3.1 | .0 | 1.22 | .10 | 1.23 | 4.5 | 1.23 | .10 | 1.23 | 4.5 | 1.23 | .09 | 1.23 | 4.3 |
| 96 | .171 | .136 | 2.3 | .0 | 3.5 | .0 | 1.25 | .09 | 1.25 | 4.0 | 1.25 | .09 | 1.25 | 4.0 | 1.26 | .08 | 1.26 | 3.8 |
| 97 | .172 | .116 | 1.6 | .0 | 2.6 | .0 | 1.30 | .08 | 1.31 | 3.5 | 1.31 | .08 | 1.31 | 3.4 | 1.31 | .08 | 1.31 | 3.4 |
| 98 | .170 | .101 | 2.1 | .0 | 3.4 | .1 | 1.24 | .21 | 1.26 | 9.7 | 1.24 | .21 | 1.26 | 9.7 | 1.24 | .21 | 1.26 | 9.5 |
| 99 | .287 | .317 | 1.6 | .0 | 2.0 | .0 | 1.15 | .01 | 1.15 | .3 | 1.15 | .01 | 1.15 | .4 | 1.16 | .00 | 1.16 | .1 |
| 100 | .288 | .280 | 1.6 | .0 | 2.1 | .0 | 1.17 | .00 | 1.17 | .2 | 1.17 | .00 | 1.17 | .2 | 1.17 | .00 | 1.17 | .0 |
| 101 | .293 | .240 | 1.6 | .0 | 2.4 | .0 | 1.19 | .01 | 1.19 | .3 | 1.19 | .01 | 1.19 | .3 | 1.19 | -.00 | 1.19 | -.1 |
| 102 | .295 | .201 | 1.6 | .0 | 2.4 | .0 | 1.21 | -.01 | 1.21 | -.6 | 1.21 | -.01 | 1.21 | -.6 | 1.21 | -.02 | 1.21 | -.8 |
| 103 | .297 | .161 | 1.8 | .0 | 2.7 | .0 | 1.23 | -.02 | 1.23 | -.7 | 1.23 | -.02 | 1.23 | -.8 | 1.23 | -.02 | 1.23 | -1.2 |
| 104 | .296 | .141 | 2.0 | .0 | 2.9 | .0 | 1.23 | -.01 | 1.23 | -.3 | 1.23 | -.01 | 1.23 | -.4 | 1.23 | -.01 | 1.23 | -.7 |
| 105 | .411 | .314 | 1.5 | .0 | 1.8 | .1 | 1.15 | -.05 | 1.15 | -2.5 | 1.15 | -.05 | 1.15 | -2.6 | 1.15 | -.05 | 1.15 | -2.6 |
| 106 | .414 | .277 | 1.8 | .1 | 2.7 | .0 | 1.15 | -.04 | 1.15 | -1.9 | 1.16 | -.03 | 1.16 | -1.7 | 1.16 | -.04 | 1.16 | -2.1 |
| 107 | .413 | .277 | 1.7 | .0 | 2.8 | .0 | 1.14 | -.04 | 1.14 | -1.9 | 1.14 | -.04 | 1.14 | -2.0 | 1.15 | -.05 | 1.15 | -2.5 |
| 108 | .418 | .238 | 1.9 | .0 | 2.8 | .0 | 1.16 | -.04 | 1.16 | -2.0 | 1.16 | -.04 | 1.16 | -2.1 | 1.16 | -.05 | 1.17 | -2.4 |
| 109 | .419 | .199 | 2.1 | .0 | 2.8 | .0 | 1.18 | -.03 | 1.13 | -1.5 | 1.18 | -.03 | 1.18 | -1.6 | 1.18 | -.04 | 1.18 | -1.9 |
| 110 | .422 | .158 | 2.5 | .0 | 2.7 | .0 | 1.21 | -.04 | 1.21 | -1.7 | 1.21 | -.04 | 1.21 | -1.7 | 1.21 | -.05 | 1.21 | -2.3 |
| 111 | .421 | .148 | 2.2 | .0 | 2.2 | .0 | 1.18 | -.05 | 1.18 | -2.5 | 1.18 | -.05 | 1.18 | -2.5 | 1.18 | -.06 | 1.18 | -2.9 |
| 112 | .422 | .118 | 1.8 | .0 | 1.1 | .0 | 1.20 | -.09 | 1.20 | -4.3 | 1.20 | -.09 | 1.20 | -4.4 | 1.20 | -.09 | 1.20 | -4.3 |
| 113 | .579 | .304 | 1.6 | .0 | 2.0 | .0 | 1.12 | -.09 | 1.12 | -4.4 | 1.12 | -.09 | 1.12 | -4.5 | 1.12 | -.09 | 1.12 | -4.5 |
| 114 | .578 | .287 | 1.9 | .0 | 1.9 | .0 | 1.13 | -.08 | 1.14 | -4.0 | 1.13 | -.08 | 1.14 | -4.0 | 1.13 | -.09 | 1.13 | -4.3 |
| 115 | .581 | .268 | 2.0 | .0 | 2.1 | .0 | 1.13 | -.09 | 1.14 | -4.3 | 1.14 | -.09 | 1.14 | -4.4 | 1.13 | -.08 | 1.13 | -4.3 |
| 116 | .582 | .249 | 1.9 | .0 | 2.0 | .1 | 1.15 | -.08 | 1.16 | -3.6 | 1.15 | -.08 | 1.16 | -3.8 | 1.15 | -.08 | 1.15 | -3.7 |
| 117 | .584 | .228 | 2.4 | .0 | 2.5 | .0 | 1.14 | -.09 | 1.14 | -4.3 | 1.14 | -.09 | 1.14 | -4.4 | 1.14 | -.10 | 1.14 | -4.9 |
| 118 | .586 | .207 | 2.3 | .0 | 2.0 | .0 | 1.13 | -.10 | 1.14 | -5.3 | 1.14 | -.11 | 1.14 | -5.3 | 1.13 | -.11 | 1.14 | -5.6 |
| 119 | .586 | .187 | 2.2 | .0 | 2.4 | .0 | 1.13 | -.11 | 1.13 | -5.7 | 1.13 | -.12 | 1.13 | -5.8 | 1.13 | -.12 | 1.14 | -6.3 |
| 120 | .587 | .167 | 3.0 | .0 | 2.6 | .0 | 1.14 | -.10 | 1.14 | -5.0 | 1.14 | -.10 | 1.14 | -5.1 | 1.14 | -.12 | 1.15 | -6.0 |

Table 3-B. - Continued.

| Run | $\frac{x_c}{c}$ | $\frac{y_c}{c}$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $\frac{U_{f_e}}{U_T}$ | $\frac{V_{f_e}}{U_T}$ | $\frac{U_{R_e}}{U_T}$ | $\alpha_{R_e}$ deg | $\frac{U_{f_B}}{U_T}$ | $\frac{V_{f_B}}{U_T}$ | $\frac{U_{R_B}}{U_T}$ | $\alpha_{R_B}$ deg | $\frac{U_{f_t}}{U_T}$ | $\frac{V_{f_t}}{U_T}$ | $\frac{U_{R_t}}{U_T}$ | $\alpha_{R_t}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | .589 | .158 | 2.7 | .0 | 2.8 | .1 | 1.15 | -.11 | 1.15 | -5.4 | 1.15 | -.11 | 1.16 | -5.5 | 1.15 | -.12 | 1.16 | -5.7 |
| 122 | .578 | .145 | 2.2 | .0 | 1.1 | .0 | 1.14 | -.11 | 1.15 | -5.6 | 1.14 | -.11 | 1.15 | -5.7 | 1.14 | -.12 | 1.14 | -5.8 |
| 123 | .578 | .126 | 1.8 | .0 | .9 | .0 | 1.14 | -.13 | 1.14 | -6.5 | 1.14 | -.13 | 1.14 | -6.5 | 1.14 | -.13 | 1.14 | -6.7 |
| 124 | .579 | .106 | 1.3 | .1 | .8 | .1 | 1.13 | -.14 | 1.14 | -7.3 | 1.13 | -.14 | 1.14 | -7.3 | 1.13 | -.15 | 1.14 | -7.3 |
| 125 | .744 | .309 | 2.1 | .0 | 1.9 | .0 | 1.10 | -.09 | 1.11 | -4.8 | 1.11 | -.09 | 1.11 | -4.7 | 1.10 | -.10 | 1.11 | -5.0 |
| 126 | .746 | .291 | 2.0 | .0 | 1.7 | .0 | 1.10 | -.11 | 1.10 | -5.6 | 1.10 | -.11 | 1.10 | -5.6 | 1.09 | -.11 | 1.10 | -5.7 |
| 127 | .746 | .271 | 1.8 | .0 | 1.9 | .1 | 1.11 | -.08 | 1.11 | -4.0 | 1.11 | -.08 | 1.12 | -4.0 | 1.11 | -.08 | 1.11 | -3.9 |
| 128 | .747 | .251 | 2.4 | .0 | 2.1 | .0 | 1.09 | -.10 | 1.10 | -5.4 | 1.10 | -.11 | 1.10 | -5.6 | 1.09 | -.11 | 1.10 | -6.0 |
| 129 | .750 | .232 | 2.4 | .0 | 2.1 | .0 | 1.09 | -.11 | 1.09 | -5.9 | 1.09 | -.12 | 1.10 | -6.1 | 1.08 | -.13 | 1.09 | -6.6 |
| 130 | .751 | .212 | 2.5 | .0 | 2.0 | .0 | 1.10 | -.12 | 1.10 | -6.5 | 1.10 | -.13 | 1.11 | -6.5 | 1.09 | -.13 | 1.10 | -6.8 |
| 131 | .751 | .192 | 2.8 | .0 | 2.0 | .0 | 1.10 | -.12 | 1.11 | -6.4 | 1.10 | -.13 | 1.11 | -6.6 | 1.09 | -.13 | 1.10 | -7.1 |
| 132 | .754 | .171 | 2.8 | .0 | 1.9 | .0 | 1.11 | -.13 | 1.12 | -6.8 | 1.11 | -.13 | 1.12 | -6.9 | 1.10 | -.14 | 1.11 | -7.2 |
| 133 | .755 | .151 | 1.8 | .0 | 1.5 | .0 | 1.10 | -.16 | 1.11 | -8.0 | 1.10 | -.16 | 1.11 | -8.1 | 1.10 | -.16 | 1.11 | -8.1 |
| 134 | .743 | .149 | 2.3 | .0 | 1.2 | .0 | 1.10 | -.12 | 1.10 | -6.4 | 1.10 | -.12 | 1.10 | -6.4 | 1.07 | -.13 | 1.10 | -6.6 |
| 135 | .745 | .130 | 1.9 | .0 | 1.0 | .0 | 1.09 | -.14 | 1.10 | -7.3 | 1.09 | -.14 | 1.10 | -7.3 | 1.08 | -.14 | 1.09 | -7.4 |
| 136 | .746 | .111 | 1.5 | .0 | 1.0 | .0 | 1.08 | -.16 | 1.09 | -8.2 | 1.08 | -.16 | 1.09 | -8.2 | 1.08 | -.16 | 1.09 | -8.3 |
| 137 | .749 | .091 | 1.3 | .0 | .9 | .0 | 1.07 | -.17 | 1.09 | -8.8 | 1.07 | -.17 | 1.09 | -8.8 | 1.07 | -.17 | 1.03 | -8.9 |
| 138 | .952 | .185 | 2.3 | .0 | 1.4 | .0 | 1.03 | -.11 | 1.04 | -6.3 | 1.03 | -.11 | 1.04 | -6.2 | 1.03 | -.12 | 1.03 | -6.5 |
| 139 | .954 | .145 | 1.9 | .0 | 1.4 | .0 | 1.03 | -.13 | 1.04 | -7.4 | 1.03 | -.13 | 1.04 | -7.4 | 1.03 | -.13 | 1.04 | -7.3 |
| 140 | .957 | .107 | 1.4 | .0 | 1.0 | .0 | 1.00 | -.14 | 1.01 | -7.9 | 1.00 | -.14 | 1.01 | -7.9 | 1.00 | -.14 | 1.01 | -7.9 |
| 141 | .961 | .087 | 1.3 | .0 | .9 | .0 | .99 | -.15 | 1.00 | -8.6 | .99 | -.15 | 1.00 | -8.6 | .98 | -.15 | 1.00 | -8.6 |
| 142 | .960 | .068 | 1.2 | .0 | .9 | .0 | .98 | -.16 | .99 | -9.0 | .98 | -.16 | .99 | -9.0 | .98 | -.15 | .99 | -8.9 |
| 143 | 1.007 | -.009 | 1.6 | .0 | 1.1 | .0 | .92 | .03 | .92 | 1.9 | .92 | .03 | .92 | 1.9 | .92 | .03 | .92 | 2.2 |
| 144 | 1.005 | -.029 | 1.3 | .0 | .9 | .0 | .95 | .03 | .95 | 1.5 | .95 | .03 | .95 | 1.5 | .95 | .02 | .95 | 1.5 |
| 145 | 1.005 | -.039 | 1.3 | .0 | 1.0 | .0 | .96 | .02 | .96 | 1.1 | .96 | .02 | .96 | 1.1 | .96 | .02 | .96 | 1.0 |
| 146 | 1.007 | -.059 | 1.3 | .0 | .9 | .0 | .96 | .01 | .96 | .8 | .96 | .01 | .96 | .8 | .96 | .01 | .96 | .8 |
| 147 | 1.006 | -.078 | 1.3 | .0 | .9 | .0 | .97 | .01 | .97 | .5 | .97 | .01 | .97 | .5 | .97 | .01 | .97 | .7 |
| 148 | 1.006 | -.099 | 1.3 | .0 | 1.0 | .0 | .97 | .00 | .97 | .2 | .97 | .00 | .97 | .2 | .97 | .00 | .97 | .2 |
| 149 | 1.014 | .188 | 1.8 | .0 | 1.3 | .0 | 1.01 | -.11 | 1.01 | -6.0 | 1.01 | -.11 | 1.01 | -6.0 | 1.01 | -.10 | 1.01 | -5.9 |
| 150 | 1.017 | .149 | 1.5 | .1 | 1.6 | .0 | 1.03 | -.12 | 1.04 | -6.5 | 1.03 | -.12 | 1.03 | -6.5 | 1.03 | -.11 | 1.03 | -6.1 |
| 151 | 1.021 | .110 | 1.4 | .0 | 1.2 | .0 | .98 | -.12 | .99 | -6.9 | .98 | -.12 | .99 | -6.9 | .99 | -.12 | .99 | -6.8 |
| 152 | 1.021 | .080 | 1.2 | .0 | .8 | .0 | .96 | -.12 | .97 | -7.1 | .96 | -.12 | .97 | -7.1 | .96 | -.12 | .96 | -7.3 |
| 153 | 1.024 | .060 | 1.1 | .0 | .7 | .0 | .94 | -.12 | .95 | -7.1 | .94 | -.12 | .95 | -7.1 | .94 | -.12 | .95 | -7.1 |
| 154 | 1.025 | .000 | 3.8 | .4 | 1.6 | .1 | .84 | .04 | .84 | 2.7 | .84 | .04 | .85 | 2.8 | .65 | .24 | .69 | 20.6 |
| 155 | 1.028 | -.010 | 1.5 | .1 | 1.0 | .0 | .92 | .02 | .92 | 1.1 | .92 | .02 | .92 | 1.2 | .92 | .01 | .92 | .9 |
| 156 | 1.026 | -.019 | 1.3 | .0 | .9 | .0 | .94 | .02 | .94 | 1.4 | .94 | .02 | .94 | 1.4 | .94 | .02 | .94 | 1.1 |
| 157 | 1.027 | -.030 | 1.4 | .0 | 1.0 | .0 | .95 | .02 | .95 | 1.2 | .95 | .02 | .95 | 1.2 | .95 | .02 | .95 | 1.2 |
| 158 | 1.027 | -.039 | 1.5 | .0 | 1.3 | .0 | .96 | .01 | .96 | .8 | .96 | .01 | .96 | .9 | .96 | .01 | .96 | .8 |
| 159 | 1.026 | -.060 | 1.6 | .0 | 1.2 | .0 | .97 | .01 | .97 | .4 | .97 | .01 | .97 | .6 | .96 | .01 | .96 | .5 |
| 160 | 1.026 | -.079 | 1.5 | .0 | 1.2 | .0 | .97 | .00 | .97 | .1 | .97 | .00 | .97 | .3 | .96 | -.00 | .96 | -.2 |
| 161 | 1.027 | -.099 | 1.5 | .0 | 1.2 | .0 | .97 | .00 | .97 | .1 | .98 | .00 | .98 | .2 | .97 | .00 | .97 | .0 |
| 162 | 1.026 | -.140 | 1.4 | .0 | 1.2 | .0 | .98 | -.00 | .93 | -.0 | .98 | .00 | .98 | .0 | .96 | -.00 | .93 | -.1 |
| 163 | 1.027 | -.141 | 1.4 | .0 | 1.0 | .0 | .97 | -.00 | .97 | -.2 | .97 | -.00 | .97 | -.2 | .97 | -.01 | .97 | -.3 |
| 164 | 1.076 | .177 | 2.4 | .0 | 1.8 | .0 | 1.02 | -.10 | 1.02 | -5.5 | 1.02 | -.09 | 1.03 | -5.3 | 1.00 | -.11 | 1.01 | -6.1 |
| 165 | 1.078 | .139 | 1.7 | .1 | 1.7 | .0 | 1.00 | -.11 | 1.01 | -6.1 | 1.00 | -.11 | 1.01 | -6.1 | 1.00 | -.11 | 1.01 | -6.1 |
| 166 | 1.083 | .100 | 1.3 | .0 | 1.0 | .0 | .96 | -.10 | .97 | -5.8 | .96 | -.10 | .97 | -5.8 | .97 | -.10 | .97 | -5.7 |
| 167 | 1.085 | .061 | 1.2 | .0 | .8 | .0 | .94 | -.09 | .95 | -5.4 | .94 | -.09 | .95 | -5.4 | .94 | -.09 | .95 | -5.4 |
| 168 | 1.086 | .041 | 1.2 | .0 | .8 | .0 | .94 | -.08 | .94 | -4.7 | .94 | -.08 | .94 | -4.6 | .94 | -.08 | .94 | -4.7 |
| 169 | 1.088 | .032 | 1.4 | .1 | 1.8 | .2 | .91 | -.07 | .92 | -4.2 | .91 | -.07 | .92 | -4.3 | .92 | -.07 | .92 | -4.2 |
| 170 | 1.087 | .026 | 1.5 | .1 | 2.4 | .3 | .86 | -.09 | .87 | -5.9 | .86 | -.09 | .87 | -5.9 | .86 | -.09 | .87 | -6.1 |
| 171 | 1.088 | .021 | 2.0 | .3 | 2.2 | .4 | .81 | -.12 | .82 | -8.2 | .81 | -.12 | .82 | -8.2 | .81 | -.12 | .82 | -8.2 |
| 172 | 1.088 | .015 | 4.6 | .4 | 3.0 | .3 | .64 | .02 | .64 | 1.4 | .64 | .02 | .64 | 1.4 | .66 | .03 | .66 | 2.3 |
| 173 | 1.089 | .012 | 5.8 | .3 | 2.6 | .2 | .66 | .04 | .66 | 3.6 | .67 | .05 | .67 | 4.0 | .68 | .06 | .68 | 4.7 |
| 174 | 1.088 | .007 | 4.7 | .3 | 3.0 | .2 | .78 | .04 | .73 | 2.9 | .79 | .04 | .78 | 2.8 | .79 | .04 | .79 | 2.5 |
| 175 | 1.088 | .001 | 2.5 | .1 | 1.7 | .1 | .89 | .00 | .89 | .2 | .89 | .00 | .89 | .3 | .90 | .01 | .90 | .7 |
| 176 | 1.089 | -.004 | 2.0 | .0 | 1.4 | .0 | .92 | -.02 | .92 | -1.4 | .92 | -.02 | .92 | -1.3 | .92 | -.03 | .92 | -1.9 |
| 177 | 1.089 | -.008 | 1.5 | .0 | 1.2 | .0 | .93 | -.02 | .93 | -1.2 | .93 | -.02 | .93 | -1.2 | .94 | -.01 | .91 | -.9 |
| 178 | 1.088 | -.019 | 1.5 | .0 | 1.1 | .0 | .94 | -.01 | .94 | -.6 | .94 | -.01 | .94 | -.7 | .94 | -.01 | .94 | -.6 |
| 179 | 1.088 | -.029 | 1.6 | .0 | 1.3 | .0 | .96 | -.01 | .96 | -.6 | .96 | -.01 | .96 | -.5 | .95 | -.01 | .95 | -.6 |
| 180 | 1.089 | -.038 | 1.8 | .0 | 1.4 | .0 | .97 | -.01 | .97 | -.7 | .97 | -.01 | .97 | -.5 | .97 | -.01 | .97 | -.6 |

Table 3-B. - Concluded.

| Run | $\frac{x_c}{c}$ | $\frac{y_c}{c}$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $\frac{U_{f_e}}{U_T}$ | $\frac{V_{f_e}}{U_T}$ | $\frac{U_{R_e}}{U_T}$ | $\alpha_{R_e}$ deg | $\frac{U_{f_B}}{U_T}$ | $\frac{V_{f_B}}{U_T}$ | $\frac{U_{R_B}}{U_T}$ | $\alpha_{R_B}$ deg | $\frac{U_{f_t}}{U_T}$ | $\frac{V_{f_t}}{U_T}$ | $\frac{U_{R_t}}{U_T}$ | $\alpha_{R_t}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 181 | 1.091 | -.058 | 1.7 | .0 | 1.4 | .0 | .97 | -.01 | .97 | -.8 | .97 | -.01 | .97 | -.6 | .96 | -.01 | .96 | -.8 |
| 182 | 1.089 | -.078 | 1.7 | .0 | 1.3 | .0 | .97 | -.01 | .97 | -.7 | .98 | -.01 | .98 | -.6 | .97 | -.01 | .97 | -.6 |
| 183 | 1.089 | -.099 | 1.7 | .0 | 1.3 | .0 | .97 | -.01 | .97 | -.8 | .98 | -.01 | .98 | -.6 | .97 | -.01 | .97 | -.7 |
| 184 | 1.116 | .178 | 1.9 | .0 | 1.6 | .0 | 1.00 | -.09 | 1.00 | -5.3 | 1.00 | -.09 | 1.00 | -5.2 | .99 | -.09 | 1.00 | -5.2 |
| 185 | 1.120 | .139 | 1.5 | .0 | 1.6 | .0 | .99 | -.10 | 1.00 | -5.8 | .99 | -.10 | 1.00 | -5.8 | .99 | -.10 | .99 | -5.7 |
| 186 | 1.122 | .100 | 1.4 | .0 | 1.0 | .0 | .97 | -.09 | .97 | -5.1 | .97 | -.09 | .97 | -5.1 | .96 | -.09 | .97 | -5.3 |
| 187 | 1.126 | .060 | 1.1 | .0 | .8 | .0 | .95 | -.07 | .95 | -4.2 | .95 | -.07 | .95 | -4.2 | .95 | -.07 | .95 | -4.2 |
| 188 | 1.127 | .041 | 1.1 | .0 | .9 | .0 | .95 | -.06 | .95 | -3.8 | .95 | -.06 | .95 | -3.9 | .95 | -.06 | .95 | -3.6 |
| 189 | 1.128 | .031 | 1.4 | .1 | 1.4 | .1 | .91 | -.07 | .92 | -4.6 | .92 | -.07 | .92 | -4.7 | .92 | -.07 | .92 | -4.6 |
| 190 | 1.128 | .026 | 2.2 | .4 | 2.4 | .5 | .85 | -.08 | .86 | -5.5 | .85 | -.08 | .86 | -5.5 | .87 | -.07 | .87 | -4.9 |
| 191 | 1.128 | .021 | 4.1 | .5 | 3.8 | 1.1 | .77 | -.07 | .77 | -4.9 | .77 | -.07 | .77 | -4.9 | .37 | .36 | .51 | 44.4 |
| 192 | 1.128 | .019 | 3.9 | .9 | 2.3 | .5 | .70 | .02 | .70 | 1.9 | .69 | .03 | .69 | 2.7 | .64 | .01 | .64 | 1.3 |
| 193 | 1.128 | .018 | 3.9 | .5 | 4.3 | .4 | .72 | .00 | .72 | .1 | .71 | .00 | .71 | .2 | .72 | -.01 | .72 | -.5 |
| 194 | 1.129 | .013 | 4.3 | .4 | 2.5 | .2 | .74 | .04 | .74 | 3.3 | .74 | .04 | .74 | 3.2 | .73 | .04 | .73 | 3.5 |
| 195 | 1.129 | .013 | 4.2 | .4 | 1.9 | .2 | .72 | .01 | .72 | .9 | .72 | .01 | .72 | .9 | .71 | .00 | .71 | .2 |
| 196 | 1.129 | .005 | 2.8 | .1 | 1.7 | .1 | .88 | .01 | .88 | .8 | .88 | .01 | .88 | .9 | .88 | .01 | .88 | .4 |
| 197 | 1.130 | .001 | 2.2 | .1 | 1.6 | .0 | .91 | -.00 | .91 | -.2 | .92 | -.00 | .92 | -.2 | .92 | -.01 | .92 | -.6 |
| 198 | 1.132 | -.010 | 1.6 | .0 | 1.1 | .0 | .94 | -.03 | .94 | -1.6 | .94 | -.03 | .94 | -1.6 | .94 | -.03 | .94 | -1.8 |
| 199 | 1.132 | -.018 | 1.4 | .0 | 1.0 | .0 | .95 | -.02 | .95 | -1.1 | .95 | -.02 | .95 | -1.1 | .95 | -.02 | .95 | -1.3 |
| 200 | 1.130 | -.039 | 1.5 | .0 | 1.1 | .0 | .96 | -.02 | .96 | -.9 | .96 | -.02 | .96 | -.9 | .95 | -.02 | .95 | -.9 |
| 201 | 1.132 | -.060 | 1.5 | .0 | 1.1 | .0 | .96 | -.02 | .96 | -1.0 | .96 | -.02 | .96 | -.9 | .96 | -.02 | .96 | -1.0 |
| 202 | 1.131 | -.079 | 1.5 | .0 | 1.1 | .0 | .97 | -.02 | .97 | -.9 | .97 | -.02 | .97 | -.9 | .97 | -.02 | .97 | -1.0 |
| 203 | 1.131 | -.100 | 1.4 | .0 | 1.0 | .0 | .97 | -.02 | .97 | -.9 | .97 | -.02 | .97 | -.9 | .97 | -.02 | .97 | -1.1 |

## Table-4 ($\alpha = 0.6^0$)

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $S_{R_u}$ | $S_{R_v}$ | $E_u$ | $E_v$ | $N_u$ | $N_v$ | $DR_u$ $sec^{-1}$ | $DR_v$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.9 | .0 | 33.6 | .0 | -.28 | .36 | .1 | 1.3 | 482 | 248 | 8 | 4 | 13:52 | 130 |
| 2 | 36.7 | .1 | 33.0 | .0 | -.19 | .05 | .0 | .1 | 258 | 374 | 4 | 6 | 13:55 | 130 |
| 3 | 36.5 | .1 | 33.1 | .0 | -.07 | -.15 | .2 | .9 | 161 | 353 | 3 | 6 | 13:57 | 130 |
| 4 | 36.5 | .0 | 32.8 | .0 | -.33 | -.27 | -.1 | .6 | 307 | 356 | 5 | 6 | 13:58 | 130 |
| 5 | 36.4 | .0 | 32.5 | .0 | -.06 | -.12 | -.1 | .5 | 362 | 245 | 6 | 4 | 14: 0 | 130 |
| 6 | 36.3 | .0 | 32.2 | .0 | -.34 | -.09 | -.3 | .2 | 287 | 257 | 5 | 4 | 14: 1 | 130 |
| 7 | 36.2 | .1 | 32.3 | .0 | -.39 | .20 | -.3 | .4 | 221 | 236 | 4 | 4 | 14: 3 | 130 |
| 8 | 35.8 | .1 | 31.9 | .0 | .09 | .47 | -.6 | 1.0 | 145 | 266 | 2 | 4 | 14: 4 | 130 |
| 9 | 35.4 | .0 | 31.8 | .0 | -.02 | .54 | -.1 | .4 | 593 | 679 | 10 | 11 | 14: 6 | 130 |
| 10 | 35.3 | .0 | 31.8 | .0 | -.20 | .42 | -.1 | .7 | 416 | 859 | 7 | 14 | 14:10 | 130 |
| 11 | 34.8 | .0 | 32.0 | .1 | -.09 | .67 | -.1 | .3 | 660 | 252 | 11 | 4 | 14:38 | 130 |
| 12 | 34.6 | .0 | 32.0 | .1 | .18 | .51 | -.4 | -.2 | 221 | 149 | 4 | 2 | 14:41 | 130 |
| 13 | 34.2 | .1 | 32.1 | .1 | .02 | .39 | -.3 | -.3 | 157 | 136 | 3 | 2 | 14:43 | 130 |
| 14 | 33.9 | .0 | 32.3 | .1 | .19 | .28 | -.2 | -.7 | 198 | 87 | 3 | 1 | 14:44 | 130 |
| 15 | 33.6 | .0 | 32.6 | .1 | .34 | -.44 | .1 | .6 | 198 | 105 | 3 | 2 | 14:46 | 130 |
| 16 | 33.4 | .1 | 33.0 | .1 | .26 | .34 | -.4 | .2 | 123 | 64 | 2 | 1 | 14:48 | 130 |
| 17 | 37.2 | .0 | 33.4 | .0 | -.67 | 1.03 | .8 | 1.0 | 3769 | 1352 | 63 | 23 | 9:19 | 131 |
| 18 | 37.3 | .0 | 32.9 | .0 | -.28 | .53 | .2 | 1.2 | 3990 | 2376 | 144 | 40 | 9:21 | 131 |
| 19 | 37.4 | .0 | 32.5 | .0 | -.32 | -.01 | .4 | .4 | 4014 | 2356 | 125 | 39 | 9:23 | 131 |
| 20 | 37.2 | .0 | 31.8 | .0 | -.29 | .23 | .3 | .3 | 4005 | 2575 | 133 | 43 | 9:25 | 131 |
| 21 | 37.1 | .0 | 31.4 | .0 | -.22 | .46 | .1 | 1.0 | 4011 | 2638 | 129 | 44 | 9:27 | 131 |
| 22 | 36.9 | .0 | 31.0 | .0 | -.21 | .18 | .0 | .8 | 3995 | 2780 | 141 | 46 | 9:28 | 131 |
| 23 | 36.7 | .0 | 30.5 | .0 | -.22 | .31 | .1 | 2.3 | 3915 | 2771 | 137 | 46 | 9:30 | 131 |
| 24 | 36.4 | .0 | 29.9 | .0 | -.04 | .54 | .1 | 1.4 | 3777 | 2730 | 63 | 45 | 9:32 | 131 |
| 25 | 36.0 | .0 | 29.6 | .0 | .00 | .24 | .3 | 1.1 | 3714 | 2634 | 62 | 44 | 9:33 | 131 |
| 26 | 35.3 | .0 | 29.1 | .0 | -.05 | .47 | .2 | .7 | 3597 | 2573 | 60 | 43 | 9:35 | 131 |
| 27 | 34.5 | .0 | 28.8 | .0 | .02 | .10 | -.1 | .4 | 3427 | 2648 | 57 | 44 | 9:37 | 131 |
| 28 | 33.8 | .0 | 28.8 | .0 | .11 | .13 | .1 | .8 | 3555 | 2392 | 59 | 40 | 9:38 | 131 |
| 29 | 33.2 | .0 | 28.9 | .0 | .03 | .61 | .0 | 1.3 | 3675 | 2538 | 61 | 42 | 9:40 | 131 |
| 30 | 32.7 | .0 | 29.1 | .0 | .19 | .41 | .2 | .0 | 3822 | 2417 | 64 | 40 | 9:42 | 131 |
| 31 | 32.3 | .0 | 29.7 | .0 | .29 | .47 | -.1 | -.6 | 3892 | 2774 | 65 | 46 | 9:44 | 131 |
| 32 | 31.9 | .0 | 29.9 | .0 | .31 | .28 | -.2 | -.6 | 3948 | 2942 | 144 | 49 | 9:45 | 131 |
| 33 | 31.8 | .0 | 30.8 | .0 | .37 | .59 | -.1 | -.3 | 3951 | 3683 | 129 | 61 | 9:50 | 131 |
| 34 | 31.5 | .0 | 30.7 | .0 | .33 | .57 | -.1 | -.2 | 4044 | 3847 | 132 | 64 | 9:47 | 131 |
| 35 | 31.4 | .0 | 31.0 | .0 | .31 | .53 | -.1 | .0 | 3967 | 3877 | 96 | 65 | 9:48 | 131 |
| 36 | 38.2 | .0 | 33.5 | .0 | -.12 | .63 | .4 | .8 | 2930 | 1081 | 49 | 13 | 9:59 | 131 |
| 37 | 38.1 | .0 | 33.0 | .0 | -.20 | .50 | .2 | 1.6 | 3842 | 973 | 64 | 16 | 10: 1 | 131 |
| 38 | 38.3 | .0 | 32.6 | .0 | -.17 | -.09 | .0 | 1.4 | 4052 | 2129 | 117 | 35 | 10: 3 | 131 |
| 39 | 38.5 | .0 | 31.7 | .0 | -.12 | .41 | -.0 | .5 | 4056 | 1140 | 120 | 19 | 10: 5 | 131 |
| 40 | 38.5 | .0 | 31.2 | .0 | -.17 | .63 | -.2 | 1.2 | 3894 | 1886 | 65 | 31 | 10: 7 | 131 |
| 41 | 38.4 | .0 | 30.6 | .0 | -.27 | -.09 | .0 | 1.4 | 3824 | 2153 | 64 | 36 | 10: 9 | 131 |
| 42 | 38.2 | .0 | 30.0 | .0 | -.24 | -.17 | -.0 | 1.6 | 3976 | 2332 | 170 | 39 | 10:12 | 131 |
| 43 | 37.8 | .0 | 29.4 | .0 | -.15 | -.26 | -.1 | 1.7 | 4000 | 2401 | 159 | 40 | 10:15 | 131 |
| 44 | 37.4 | .0 | 28.6 | .0 | -.02 | -.17 | -.2 | 1.7 | 3995 | 2483 | 158 | 41 | 10:18 | 131 |
| 45 | 36.6 | .0 | 27.7 | .0 | -.01 | .27 | -.0 | .2 | 3951 | 2287 | 151 | 38 | 10:20 | 131 |
| 46 | 35.7 | .0 | 26.8 | .0 | -.36 | .33 | .2 | .8 | 3725 | 1997 | 62 | 33 | 10:22 | 131 |
| 47 | 34.2 | .0 | 26.2 | .1 | -.23 | .53 | 1.1 | -.1 | 2407 | 367 | 40 | 6 | 10:25 | 131 |
| 48 | 32.9 | .0 | 26.5 | .2 | -.03 | -.05 | .7 | -.8 | 485 | 41 | 8 | 1 | 10:58 | 131 |
| 49 | 32.0 | .0 | 26.6 | .2 | .20 | .18 | .5 | -.1 | 372 | 23 | 6 | 0 | 11: 1 | 131 |
| 50 | 31.8 | .1 | 26.8 | .3 | .44 | -.00 | .2 | -1.5 | 453 | 15 | 8 | 0 | 11: 5 | 131 |
| 51 | 30.9 | .3 | 27.1 | .2 | -.24 | -.27 | -.2 | -.9 | 21 | 17 | 0 | 0 | 11:10 | 131 |
| 52 | 30.7 | .1 | 30.5 | .1 | .23 | .09 | .3 | -.1 | 365 | 255 | 6 | 4 | 11:13 | 131 |
| 53 | 30.0 | .1 | 30.2 | .1 | -.27 | .50 | -.1 | -.1 | 160 | 285 | 3 | 5 | 11:15 | 131 |
| 54 | 38.3 | .0 | 34.0 | .0 | -.75 | .27 | .7 | .3 | 1193 | 1036 | 20 | 17 | 13:34 | 131 |
| 55 | 38.4 | .0 | 33.3 | .0 | -.72 | .23 | 1.0 | .5 | 2086 | 1495 | 35 | 25 | 13:35 | 131 |
| 56 | 38.6 | .0 | 32.7 | .0 | -.49 | .73 | 1.5 | .5 | 2143 | 996 | 36 | 17 | 13:37 | 131 |
| 57 | 38.9 | .0 | 31.7 | .0 | -.45 | .03 | .6 | 3.0 | 2442 | 2119 | 41 | 35 | 13:39 | 131 |
| 58 | 39.4 | .0 | 31.2 | .0 | -.26 | .25 | -.1 | 2.2 | 3933 | 2476 | 115 | 41 | 13:40 | 131 |
| 59 | 39.5 | .0 | 30.6 | .0 | -.33 | -.18 | -.1 | 1.5 | 3947 | 2358 | 126 | 39 | 13:42 | 131 |
| 60 | 39.7 | .0 | 29.9 | .0 | -.39 | -.19 | -.1 | .7 | 3989 | 2458 | 138 | 41 | 13:44 | 131 |

Table 4-A. - Continued.

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $S_{R_u}$ | $S_{R_v}$ | $E_u$ | $E_v$ | $N_u$ | $N_v$ | $DR_u$ $sec^{-1}$ | $DR_v$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 39.8 | .0 | 28.9 | .0 | -.26 | -.07 | -.1 | .9 | 4017 | 2232 | 139 | 37 | 13:45 | 131 |
| 62 | 39.7 | .0 | 27.6 | .0 | -.31 | .07 | -.2 | .3 | 4055 | 1482 | 125 | 25 | 13:47 | 131 |
| 63 | 39.5 | .0 | 25.6 | .0 | -.31 | .74 | -.3 | .9 | 4068 | 549 | 110 | 9 | 13:48 | 131 |
| 64 | 39.1 | .0 | 23.5 | .1 | -.18 | .40 | -.5 | .9 | 4073 | 338 | 103 | 6 | 13:50 | 131 |
| 65 | 38.6 | .0 | 22.3 | .1 | -.11 | .09 | -.5 | .3 | 4079 | 182 | 98 | 3 | 13:52 | 131 |
| 66 | 37.3 | .0 | 22.8 | .5 | .12 | .71 | -.5 | -.1 | 1816 | 33 | 30 | 1 | 13:54 | 131 |
| 67 | 34.4 | .1 | 24.0 | 1.1 | .41 | .49 | .2 | -1.3 | 219 | 7 | 4 | 0 | 13:57 | 131 |
| 68 | 39.4 | .0 | 34.4 | .0 | .03 | .04 | -.1 | 1.6 | 2391 | 283 | 40 | 5 | 14: 4 | 131 |
| 69 | 39.3 | .0 | 33.6 | .0 | -.01 | .12 | -.1 | .3 | 2768 | 422 | 46 | 7 | 14: 7 | 131 |
| 70 | 40.5 | .0 | 33.2 | .0 | .00 | .26 | -.1 | -.5 | 2031 | 305 | 34 | 5 | 15:12 | 131 |
| 71 | 40.7 | .0 | 32.4 | .0 | -.21 | -.07 | -.0 | 1.8 | 4005 | 2108 | 283 | 35 | 15:24 | 131 |
| 72 | 40.7 | .0 | 32.1 | .0 | -.55 | .53 | .1 | 2.1 | 3805 | 1480 | 63 | 25 | 15:26 | 131 |
| 73 | 41.0 | .0 | 31.4 | .0 | -.19 | -.23 | -.0 | 2.3 | 3826 | 1767 | 64 | 29 | 15:28 | 131 |
| 74 | 41.7 | .0 | 30.8 | .0 | -.36 | -.27 | -.0 | 1.6 | 3867 | 1734 | 64 | 29 | 15:29 | 131 |
| 75 | 42.5 | .0 | 30.1 | .0 | -.57 | -.04 | .0 | .5 | 3923 | 1690 | 184 | 28 | 15:31 | 131 |
| 76 | 43.2 | .0 | 28.8 | .0 | -.50 | .36 | -.1 | .7 | 3945 | 1042 | 181 | 17 | 15:33 | 131 |
| 77 | 44.7 | .0 | 27.2 | .1 | -.55 | .87 | -.2 | .5 | 3977 | 453 | 200 | 8 | 15:35 | 131 |
| 78 | 47.3 | .0 | 24.1 | .2 | -.57 | 1.66 | -.2 | 2.3 | 3873 | 91 | 65 | 2 | 15:37 | 131 |
| 79 | 39.8 | .0 | 34.8 | .0 | -.02 | 1.02 | .1 | 1.1 | 2770 | 735 | 46 | 12 | 15:47 | 131 |
| 80 | 40.3 | .0 | 34.4 | .1 | -.16 | .12 | .1 | .2 | 2176 | 226 | 36 | 4 | 15:48 | 131 |
| 81 | 40.3 | .0 | 33.9 | .0 | -.23 | .68 | .2 | .4 | 2628 | 411 | 44 | 7 | 15:50 | 131 |
| 82 | 41.7 | .0 | 33.4 | .0 | -.30 | -.14 | .2 | -.1 | 2351 | 938 | 39 | 16 | 15:52 | 131 |
| 83 | 42.1 | .0 | 33.1 | .0 | -.21 | -.15 | .0 | -.2 | 1996 | 763 | 33 | 13 | 15:54 | 131 |
| 84 | 42.6 | .0 | 32.7 | .0 | -.52 | -.01 | .2 | -.5 | 1166 | 372 | 19 | 6 | 15:56 | 131 |
| 85 | 43.6 | .0 | 32.6 | .1 | -.05 | -.14 | .1 | -.1 | 1149 | 179 | 19 | 3 | 15:58 | 131 |
| 86 | 43.9 | .0 | 32.7 | .0 | -.79 | -.46 | .8 | .4 | 2852 | 644 | 48 | 11 | 16: 1 | 131 |
| 87 | 45.2 | .0 | 32.7 | .0 | -1.11 | -.45 | 3.0 | .6 | 3427 | 582 | 57 | 10 | 16: 2 | 131 |
| 88 | 45.7 | .0 | 32.1 | .0 | -.70 | -.53 | .7 | .0 | 3970 | 1046 | 275 | 17 | 16:24 | 131 |
| 89 | 46.3 | .0 | 31.3 | .1 | -.88 | -.06 | .9 | -.8 | 3872 | 632 | 65 | 11 | 16:26 | 131 |
| 90 | 46.9 | .0 | 30.8 | .1 | -.93 | -.03 | .7 | -.5 | 3790 | 528 | 63 | 9 | 16:28 | 131 |
| 91 | 48.3 | .0 | 30.6 | .1 | -.84 | -.34 | .7 | -.1 | 3815 | 343 | 64 | 6 | 16:30 | 131 |
| 92 | 50.5 | .0 | 30.5 | .2 | -.76 | -.92 | 2.2 | .2 | 3500 | 64 | 58 | 1 | 16:37 | 131 |
| 93 | 40.0 | .0 | 35.6 | .0 | -.01 | .80 | -.0 | 1.1 | 3887 | 2145 | 65 | 36 | 16:45 | 131 |
| 94 | 40.3 | .0 | 35.0 | .0 | -.07 | -.19 | -.1 | .7 | 2848 | 733 | 47 | 12 | 16:47 | 131 |
| 95 | 41.1 | .0 | 34.4 | .0 | -.25 | -.76 | .5 | .7 | 3653 | 1349 | 61 | 22 | 16:51 | 131 |
| 96 | 41.9 | .0 | 33.9 | .0 | -.37 | -.61 | 1.0 | 1.2 | 3486 | 1770 | 58 | 29 | 16:53 | 131 |
| 97 | 42.5 | .0 | 34.1 | .0 | -.59 | -.58 | 1.7 | 1.2 | 3616 | 2027 | 60 | 34 | 16:55 | 131 |
| 98 | 43.2 | .0 | 34.0 | .0 | -.73 | -.54 | 2.1 | .7 | 3677 | 1761 | 61 | 29 | 16:57 | 131 |
| 99 | 43.8 | .0 | 33.8 | .0 | -.78 | -.60 | 1.2 | .6 | 3714 | 1883 | 62 | 31 | 16:58 | 131 |
| 100 | 44.7 | .0 | 34.0 | .0 | -.81 | -.67 | 1.3 | .8 | 3650 | 1939 | 61 | 32 | 17: 0 | 131 |
| 101 | 46.3 | .0 | 34.4 | .0 | -.72 | -.62 | 1.5 | 1.0 | 3672 | 2020 | 61 | 34 | 17: 2 | 131 |
| 102 | 47.7 | .0 | 34.7 | .0 | -.62 | -.33 | 1.3 | .3 | 3532 | 1930 | 59 | 32 | 17: 4 | 131 |
| 103 | 48.8 | .0 | 34.0 | .1 | -.64 | -.61 | 1.5 | .3 | 3651 | 1181 | 61 | 20 | 17: 6 | 131 |
| 104 | 40.1 | .0 | 35.9 | .0 | -.16 | .12 | .3 | .5 | 3827 | 2164 | 64 | 36 | 17:14 | 131 |
| 105 | 40.6 | .0 | 35.8 | .0 | -.11 | .30 | .2 | .5 | 3868 | 2261 | 64 | 33 | 17:15 | 131 |
| 106 | 41.4 | .0 | 35.9 | .0 | -.21 | -.22 | .6 | .8 | 3635 | 2562 | 61 | 43 | 17:17 | 131 |
| 107 | 42.5 | .0 | 35.5 | .0 | .00 | .02 | .2 | 1.2 | 3879 | 1702 | 65 | 28 | 17:19 | 131 |
| 108 | 42.9 | .0 | 35.6 | .0 | .00 | .21 | .7 | .6 | 3832 | 2013 | 64 | 34 | 17:20 | 131 |
| 109 | 43.6 | .0 | 36.0 | .0 | -.01 | -.02 | .3 | .5 | 3929 | 3046 | 152 | 51 | 17:22 | 131 |
| 110 | 44.2 | .0 | 36.4 | .0 | -.09 | -.26 | .5 | .5 | 4015 | 2955 | 149 | 49 | 17:24 | 131 |
| 111 | 45.0 | .0 | 36.7 | .0 | .09 | -.22 | .1 | 1.5 | 4029 | 3250 | 164 | 54 | 17:26 | 131 |
| 112 | 46.1 | .0 | 37.1 | .0 | .22 | -.37 | .1 | .8 | 3789 | 2634 | 63 | 44 | 17:28 | 131 |
| 113 | 38.8 | .0 | 37.4 | .0 | -.04 | .19 | .5 | .7 | 3937 | 3866 | 112 | 64 | 9: 6 | 132 |
| 114 | 39.3 | .0 | 37.6 | .0 | .08 | .25 | .5 | .7 | 3960 | 3864 | 125 | 64 | 9: 8 | 132 |
| 115 | 39.8 | .0 | 38.0 | .0 | .07 | .14 | .0 | .3 | 4012 | 3883 | 130 | 65 | 9:10 | 132 |
| 116 | 40.2 | .0 | 38.7 | .0 | .24 | .34 | .3 | 2.4 | 3999 | 3928 | 135 | 176 | 9:12 | 132 |
| 117 | 40.5 | .0 | 39.1 | .0 | .21 | -.02 | .4 | 2.1 | 3994 | 3955 | 117 | 158 | 9:14 | 132 |
| 118 | 40.7 | .0 | 39.4 | .0 | .34 | .10 | .3 | 2.7 | 2810 | 3864 | 47 | 64 | 9:16 | 132 |
| 119 | 41.1 | .0 | 39.8 | .0 | .37 | .30 | 2.2 | 3.0 | 1726 | 2753 | 29 | 46 | 9:18 | 132 |
| 120 | 41.0 | .0 | 40.1 | .0 | .52 | .92 | .7 | 2.1 | 2596 | 2268 | 43 | 38 | 9:23 | 132 |

Table 4-A. - Concluded.

| Run | $U_{L_e}$ m/sec | $\pm U_{L_e}$ m/sec | $V_{L_e}$ m/sec | $\pm V_{L_e}$ m/sec | $S_{R_u}$ | $S_{R_v}$ | $E_u$ | $E_v$ | $N_u$ | $N_v$ | $DR_u$ $sec^{-1}$ | $DR_v$ $sec^{-1}$ | Time | Julian day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | 41.6 | .0 | 42.8 | .0 | .61 | -.06 | .7 | .5 | 2906 | 857 | 48 | 14 | 9:27 | 132 |
| 122 | 42.7 | .1 | 43.3 | .1 | .03 | -.49 | .3 | 1.1 | 117 | 248 | 2 | 4 | 9:26 | 132 |
| 123 | 36.1 | .0 | 37.9 | .0 | .04 | -.02 | -.2 | -.1 | 4050 | 3923 | 170 | 306 | 9:30 | 132 |
| 124 | 38.3 | .0 | 38.6 | .0 | .02 | -.26 | -.2 | .2 | 4067 | 4026 | 178 | 294 | 9:32 | 132 |
| 125 | 38.5 | .0 | 39.2 | .0 | -.04 | -.29 | -.3 | .2 | 4050 | 4026 | 170 | 356 | 9:34 | 132 |
| 126 | 36.5 | .0 | 39.3 | .0 | .03 | -.24 | -.3 | .2 | 4047 | 4019 | 180 | 349 | 9:36 | 132 |
| 127 | 38.5 | .0 | 39.7 | .0 | .15 | -.16 | -.2 | .5 | 4029 | 4027 | 119 | 299 | 9:37 | 132 |
| 128 | 38.7 | .0 | 40.2 | .0 | .30 | .13 | .3 | 1.0 | 3678 | 3992 | 61 | 211 | 9:39 | 132 |
| 129 | 39.0 | .0 | 40.5 | .0 | .21 | .38 | 1.4 | .7 | 1446 | 3849 | 24 | 64 | 9:41 | 132 |
| 130 | 39.9 | .1 | 40.8 | .1 | .45 | .26 | -.3 | .0 | 693 | 663 | 12 | 11 | 9:45 | 132 |
| 131 | 40.7 | .2 | 41.1 | .1 | -.43 | -.07 | .2 | .1 | 51 | 110 | 1 | 2 | 9:43 | 132 |
| 132 | 37.0 | .0 | 38.8 | .0 | .61 | -.32 | 1.2 | .2 | 2355 | 3966 | 39 | 141 | 9:48 | 132 |
| 133 | 36.9 | .0 | 39.0 | .0 | .35 | -.29 | .5 | -.1 | 2711 | 3977 | 45 | 143 | 9:49 | 132 |
| 134 | 36.9 | .0 | 39.5 | .0 | .37 | -.80 | .6 | 1.4 | 3365 | 3957 | 56 | 212 | 9:51 | 132 |
| 135 | 37.0 | .0 | 39.6 | .0 | .56 | -.70 | .2 | .6 | 2229 | 3902 | 37 | 94 | 9:53 | 132 |
| 136 | 36.9 | .0 | 39.7 | .0 | .87 | -.57 | .7 | .2 | 2278 | 3731 | 38 | 62 | 9:55 | 132 |
| 137 | 37.2 | .0 | 40.1 | .0 | 1.04 | -1.13 | .6 | 1.4 | 1341 | 3238 | 22 | 54 | 9:57 | 132 |
| 138 | 38.2 | .1 | 40.3 | .0 | .10 | -1.12 | -.8 | 1.5 | 533 | 2064 | 9 | 34 | 9:59 | 132 |
| 139 | 39.7 | .2 | 39.6 | .2 | .52 | -.73 | .6 | 2.2 | 33 | 87 | 1 | 1 | 10: 1 | 132 |
| 140 | 36.3 | .1 | 38.4 | .0 | .76 | -.75 | .1 | .5 | 225 | 1958 | 4 | 33 | 10:25 | 132 |
| 141 | 36.0 | .0 | 38.9 | .0 | .58 | -.60 | .7 | 1.0 | 1703 | 2971 | 28 | 50 | 10:32 | 132 |
| 142 | 35.6 | .0 | 39.2 | .0 | .17 | -1.01 | .4 | 2.4 | 1399 | 2255 | 23 | 38 | 10:34 | 132 |
| 143 | 35.5 | .0 | 39.7 | .0 | .42 | -.57 | 1.6 | 2.0 | 766 | 1747 | 13 | 29 | 10:35 | 132 |
| 144 | 36.0 | .0 | 39.8 | .0 | 1.28 | -1.31 | 1.5 | 3.3 | 921 | 2558 | 15 | 43 | 10:39 | 132 |
| 145 | 35.7 | .0 | 40.0 | .0 | 1.63 | -1.03 | 2.5 | 3.5 | 1026 | 1948 | 17 | 32 | 10:41 | 132 |
| 146 | 35.7 | .1 | 40.1 | .0 | 1.57 | -1.23 | 1.8 | 2.4 | 790 | 855 | 13 | 14 | 10:43 | 132 |
| 147 | 39.6 | .1 | 40.1 | .0 | -.27 | -.29 | -.5 | 2.3 | 237 | 2160 | 4 | 36 | 10:46 | 132 |
| 148 | 39.4 | .1 | 39.6 | .1 | -.22 | -.18 | -.7 | 1.4 | 96 | 292 | 2 | 5 | 10:44 | 132 |

Table 4-B ($\alpha = 0.6^{0}$)

| Run | $\frac{x_c}{c}$ | $\frac{y_c}{c}$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $\frac{U_{f_e}}{U_T}$ | $\frac{V_{f_e}}{U_T}$ | $\frac{U_{R_e}}{U_T}$ | $\alpha_{R_e}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.173 | .315 | .8 | .0 | .6 | .0 | .97 | .04 | .97 | 2.1 |
| 2 | -.171 | .250 | 1.0 | .0 | .6 | .0 | .96 | .04 | .96 | 2.4 |
| 3 | -.173 | .230 | .9 | .1 | .6 | .0 | .96 | .04 | .96 | 2.3 |
| 4 | -.173 | .211 | .8 | .0 | .7 | .0 | .96 | .04 | .95 | 2.5 |
| 5 | -.172 | .190 | .7 | .0 | .6 | .0 | .95 | .04 | .95 | 2.6 |
| 6 | -.173 | .170 | .7 | .0 | .6 | .0 | .94 | .05 | .94 | 2.8 |
| 7 | -.171 | .151 | .8 | .0 | .7 | .0 | .95 | .04 | .95 | 2.6 |
| 8 | -.172 | .130 | .8 | .0 | .7 | .0 | .94 | .04 | .94 | 2.7 |
| 9 | -.172 | .110 | .8 | .0 | .8 | .0 | .93 | .04 | .93 | 2.4 |
| 10 | -.173 | .100 | .7 | .0 | .7 | .0 | .93 | .04 | .93 | 2.3 |
| 11 | -.173 | .079 | .8 | .0 | .9 | .0 | .92 | .03 | .92 | 1.8 |
| 12 | -.171 | .059 | .7 | .0 | .9 | .0 | .92 | .03 | .92 | 1.6 |
| 13 | -.172 | .039 | .6 | .0 | 1.0 | .1 | .91 | .02 | .91 | 1.2 |
| 14 | -.172 | .021 | .7 | .0 | .8 | .1 | .91 | .01 | .91 | .8 |
| 15 | -.172 | .001 | .7 | .0 | .8 | .1 | .91 | .00 | .91 | .3 |
| 16 | -.172 | -.019 | .7 | .0 | .6 | .1 | .92 | -.00 | .92 | -.3 |
| 17 | -.093 | .319 | 1.2 | .0 | 1.3 | .0 | .98 | .04 | .98 | 2.5 |
| 18 | -.090 | .279 | 1.0 | .0 | .9 | .0 | .97 | .05 | .97 | 3.0 |
| 19 | -.088 | .240 | 1.0 | .0 | .6 | .0 | .97 | .06 | .97 | 3.4 |
| 20 | -.089 | .201 | 1.0 | .0 | .6 | .0 | .96 | .07 | .96 | 3.9 |
| 21 | -.089 | .181 | 1.0 | .0 | .6 | .0 | .95 | .07 | .95 | 4.1 |
| 22 | -.089 | .161 | 1.0 | .0 | .6 | .0 | .94 | .07 | .94 | 4.4 |
| 23 | -.089 | .141 | 1.0 | .0 | .8 | .0 | .93 | .08 | .93 | 4.6 |
| 24 | -.089 | .121 | .9 | .0 | .7 | .0 | .91 | .08 | .92 | 5.0 |
| 25 | -.088 | .101 | 1.0 | .0 | .7 | .0 | .90 | .08 | .91 | 5.0 |
| 26 | -.088 | .082 | .9 | .0 | .6 | .0 | .89 | .08 | .89 | 4.9 |
| 27 | -.088 | .060 | .9 | .0 | .7 | .0 | .88 | .07 | .88 | 4.6 |
| 28 | -.088 | .041 | .9 | .0 | .8 | .0 | .87 | .06 | .87 | 4.0 |
| 29 | -.087 | .031 | .8 | .0 | .9 | .0 | .86 | .05 | .86 | 3.4 |
| 30 | -.088 | .021 | .8 | .0 | .8 | .0 | .86 | .04 | .86 | 2.8 |
| 31 | -.088 | .011 | .9 | .0 | 1.0 | .0 | .86 | .03 | .86 | 1.8 |
| 32 | -.088 | .002 | .9 | .0 | .9 | .0 | .86 | .02 | .86 | 1.3 |
| 33 | -.088 | -.002 | .9 | .0 | 1.5 | .0 | .86 | .00 | .86 | .3 |
| 34 | -.088 | -.010 | .9 | .0 | 1.3 | .0 | .86 | .00 | .86 | .2 |
| 35 | -.088 | -.018 | 1.0 | .0 | 1.1 | .0 | .86 | -.00 | .86 | -.3 |
| 36 | -.047 | .317 | 1.0 | .0 | .8 | .0 | .99 | .05 | .99 | 3.2 |
| 37 | -.047 | .280 | .9 | .0 | .8 | .0 | .98 | .06 | .98 | 3.5 |
| 38 | -.046 | .240 | .9 | .0 | .7 | .0 | .98 | .07 | .98 | 4.0 |
| 39 | -.045 | .201 | .9 | .0 | .6 | .0 | .97 | .08 | .97 | 4.9 |
| 40 | -.047 | .181 | 1.0 | .0 | .7 | .0 | .97 | .09 | .97 | 5.4 |
| 41 | -.046 | .160 | 1.0 | .0 | .8 | .0 | .96 | .10 | .96 | 5.8 |
| 42 | -.048 | .141 | 1.1 | .0 | .8 | .0 | .94 | .10 | .95 | 6.2 |
| 43 | -.047 | .121 | 1.2 | .0 | .7 | .0 | .93 | .11 | .94 | 6.6 |
| 44 | -.047 | .101 | 1.2 | .0 | .7 | .0 | .91 | .11 | .92 | 6.9 |
| 45 | -.047 | .081 | 1.1 | .0 | .7 | .0 | .89 | .11 | .90 | 7.3 |
| 46 | -.047 | .060 | 1.0 | .0 | .9 | .0 | .86 | .11 | .87 | 7.5 |
| 47 | -.047 | .041 | 1.0 | .0 | 1.0 | .0 | .83 | .10 | .84 | 7.0 |
| 48 | -.047 | .031 | 1.0 | .0 | 1.1 | .1 | .82 | .08 | .82 | 5.5 |
| 49 | -.045 | .021 | .9 | .0 | .9 | .1 | .81 | .07 | .81 | 4.6 |
| 50 | -.047 | .011 | 1.1 | .0 | 1.0 | .1 | .81 | .06 | .81 | 4.3 |
| 51 | -.046 | .002 | 1.2 | .2 | .7 | .1 | .80 | .04 | .80 | 3.1 |
| 52 | -.047 | -.009 | 1.5 | .1 | 1.3 | .1 | .84 | -.01 | .84 | -.4 |
| 53 | -.047 | -.018 | 1.5 | .1 | 1.3 | .1 | .83 | -.01 | .83 | -.9 |
| 54 | -.004 | .317 | 1.3 | .0 | 1.2 | .0 | 1.00 | .05 | 1.00 | 2.8 |
| 55 | -.006 | .279 | 1.3 | .0 | 1.0 | .0 | .99 | .06 | .99 | 3.5 |
| 56 | -.006 | .241 | 1.3 | .0 | 1.2 | .0 | .99 | .07 | .99 | 4.1 |
| 57 | -.005 | .201 | 1.2 | .0 | 1.1 | .0 | .97 | .09 | .98 | 5.2 |
| 58 | -.006 | .181 | 1.1 | .0 | .7 | .0 | .97 | .10 | .98 | 6.0 |
| 59 | -.006 | .160 | 1.2 | .0 | .8 | .0 | .97 | .11 | .97 | 6.7 |
| 60 | -.006 | .140 | 1.3 | .0 | .8 | .0 | .96 | .12 | .97 | 7.4 |

Table 4-B. - Continued.

| Run | $\frac{x_c}{c}$ | $\frac{y_c}{c}$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $\frac{U_{f_e}}{U_T}$ | $\frac{V_{f_e}}{U_T}$ | $\frac{U_{R_e}}{U_T}$ | $\alpha_{R_e}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | -.004 | .121 | 1.3 | .0 | .6 | .0 | .95 | .14 | .96 | 8.5 |
| 62 | -.005 | .101 | 1.4 | .0 | .6 | .0 | .93 | .16 | .94 | 9.6 |
| 63 | -.005 | .081 | 1.6 | .0 | .7 | .0 | .90 | .18 | .91 | 11.4 |
| 64 | -.005 | .060 | 1.8 | .0 | .9 | .0 | .86 | .21 | .89 | 13.4 |
| 65 | -.006 | .050 | 1.9 | .0 | 1.1 | .1 | .84 | .21 | .86 | 14.4 |
| 66 | -.004 | .041 | 1.9 | .0 | 2.7 | .3 | .83 | .19 | .85 | 12.9 |
| 67 | -.006 | .031 | 1.4 | .1 | 3.0 | .5 | .80 | .13 | .81 | 9.5 |
| 68 | .037 | .317 | .8 | .0 | .7 | .0 | 1.02 | .06 | 1.02 | 3.3 |
| 69 | .037 | .280 | .8 | .0 | .6 | .0 | 1.02 | .07 | 1.02 | 4.2 |
| 70 | .036 | .241 | .9 | .0 | .6 | .0 | 1.02 | .09 | 1.02 | 5.0 |
| 71 | .037 | .201 | 1.1 | .0 | 1.0 | .0 | 1.01 | .10 | 1.01 | 5.9 |
| 72 | .038 | .181 | 1.3 | .0 | 1.1 | .0 | 1.00 | .11 | 1.01 | 6.2 |
| 73 | .037 | .160 | 1.5 | .0 | .9 | .0 | 1.00 | .12 | 1.00 | 7.0 |
| 74 | .036 | .141 | 1.6 | .0 | .8 | .0 | 1.00 | .14 | 1.01 | 7.9 |
| 75 | .037 | .122 | 1.7 | .0 | .8 | .0 | 1.00 | .16 | 1.01 | 9.1 |
| 76 | .037 | .101 | 1.9 | .0 | .8 | .0 | .99 | .19 | 1.01 | 10.8 |
| 77 | .037 | .081 | 2.1 | .0 | 1.3 | .0 | .99 | .23 | 1.02 | 13.1 |
| 78 | .037 | .059 | 2.7 | .0 | 1.8 | .2 | .98 | .31 | 1.03 | 17.4 |
| 79 | .078 | .318 | .9 | .0 | 1.0 | .0 | 1.02 | .06 | 1.02 | 3.2 |
| 80 | .078 | .278 | .9 | .0 | 1.0 | .1 | 1.02 | .07 | 1.03 | 3.9 |
| 81 | .078 | .240 | .9 | .0 | .7 | .0 | 1.02 | .08 | 1.03 | 4.7 |
| 82 | .078 | .201 | 1.1 | .0 | .6 | .0 | 1.03 | .10 | 1.04 | 5.7 |
| 83 | .077 | .181 | 1.0 | .0 | .7 | .0 | 1.04 | .11 | 1.04 | 6.2 |
| 84 | .076 | .160 | 1.1 | .0 | .8 | .0 | 1.04 | .13 | 1.05 | 6.9 |
| 85 | .077 | .140 | 1.2 | .0 | .8 | .0 | 1.05 | .14 | 1.06 | 7.7 |
| 86 | .077 | .121 | 2.1 | .0 | .9 | .0 | 1.05 | .14 | 1.06 | 7.8 |
| 87 | .078 | .111 | 1.5 | .0 | .7 | .0 | 1.07 | .16 | 1.09 | 8.6 |
| 88 | .078 | .102 | 1.6 | .0 | 1.3 | .0 | 1.07 | .18 | 1.08 | 9.4 |
| 89 | .073 | .091 | 1.9 | .0 | 1.5 | .0 | 1.07 | .19 | 1.08 | 10.3 |
| 90 | .079 | .081 | 2.3 | .0 | 1.4 | .0 | 1.07 | .21 | 1.09 | 11.1 |
| 91 | .078 | .071 | 2.3 | .0 | 1.4 | .1 | 1.08 | .23 | 1.11 | 12.0 |
| 92 | .078 | .060 | 1.6 | .0 | 1.8 | .2 | 1.11 | .26 | 1.14 | 13.3 |
| 93 | .117 | .318 | .9 | .0 | 1.1 | .0 | 1.04 | .05 | 1.04 | 2.7 |
| 94 | .117 | .279 | .8 | .0 | .7 | .0 | 1.03 | .06 | 1.04 | 3.4 |
| 95 | .119 | .240 | 1.0 | .0 | 1.2 | .0 | 1.04 | .08 | 1.05 | 4.5 |
| 96 | .119 | .201 | 1.1 | .0 | 1.2 | .0 | 1.05 | .10 | 1.05 | 5.4 |
| 97 | .119 | .181 | 1.2 | .0 | 1.3 | .0 | 1.06 | .11 | 1.06 | 5.7 |
| 98 | .119 | .160 | 1.4 | .0 | 1.5 | .0 | 1.06 | .11 | 1.07 | 6.1 |
| 99 | .119 | .141 | 1.4 | .0 | 1.6 | .0 | 1.07 | .13 | 1.08 | 6.7 |
| 100 | .117 | .121 | 1.5 | .0 | 1.5 | .0 | 1.08 | .14 | 1.09 | 7.2 |
| 101 | .118 | .101 | 1.4 | .0 | 1.6 | .0 | 1.11 | .15 | 1.12 | 7.8 |
| 102 | .118 | .081 | 1.5 | .0 | 1.5 | .0 | 1.13 | .17 | 1.14 | 8.4 |
| 103 | .118 | .072 | 1.4 | .0 | 1.9 | .0 | 1.14 | .19 | 1.16 | 9.5 |
| 104 | .160 | .318 | .8 | .0 | .7 | .0 | 1.05 | .05 | 1.05 | 2.5 |
| 105 | .160 | .278 | .9 | .0 | .7 | .0 | 1.05 | .05 | 1.05 | 3.0 |
| 106 | .161 | .240 | .8 | .0 | .7 | .0 | 1.06 | .06 | 1.07 | 3.5 |
| 107 | .160 | .201 | 1.0 | .0 | .9 | .0 | 1.07 | .09 | 1.08 | 4.5 |
| 108 | .161 | .180 | 1.0 | .0 | .8 | .0 | 1.08 | .09 | 1.08 | 4.7 |
| 109 | .160 | .160 | 1.0 | .0 | .9 | .0 | 1.09 | .09 | 1.10 | 4.8 |
| 110 | .160 | .141 | 1.0 | .0 | .8 | .0 | 1.11 | .10 | 1.11 | 4.9 |
| 111 | .160 | .121 | 1.0 | .0 | .9 | .0 | 1.13 | .10 | 1.13 | 5.2 |
| 112 | .160 | .101 | 1.0 | .0 | 1.1 | .0 | 1.14 | .11 | 1.15 | 5.6 |
| 113 | .293 | .318 | .7 | .0 | .8 | .0 | 1.05 | .01 | 1.05 | .5 |
| 114 | .294 | .280 | .8 | .0 | .8 | .0 | 1.07 | .01 | 1.07 | .7 |
| 115 | .294 | .241 | .7 | .0 | .7 | .0 | 1.08 | .01 | 1.08 | .7 |
| 116 | .293 | .202 | .7 | .0 | .9 | .0 | 1.09 | .01 | 1.09 | .5 |
| 117 | .294 | .181 | .8 | .0 | .9 | .0 | 1.10 | .01 | 1.10 | .4 |
| 118 | .294 | .161 | .8 | .0 | 1.0 | .0 | 1.11 | .01 | 1.11 | .3 |
| 119 | .294 | .142 | 1.0 | .0 | 1.1 | .0 | 1.13 | .01 | 1.13 | .3 |
| 120 | .294 | .121 | .8 | .0 | 1.2 | .0 | 1.13 | .00 | 1.13 | .1 |

Table 4-B. - Concluded.

| Run | $\frac{x_c}{c}$ | $\frac{y_c}{c}$ | $\sigma_u$ m/sec | $\pm\sigma_u$ m/sec | $\sigma_v$ m/sec | $\pm\sigma_v$ m/sec | $\frac{U_{f_e}}{U_T}$ | $\frac{V_{f_e}}{U_T}$ | $\frac{U_{R_e}}{U_T}$ | $\alpha_{R_e}$ deg |
|---|---|---|---|---|---|---|---|---|---|---|
| 121 | .293 | .107 | 1.0 | .0 | 1.5 | .0 | 1.17 | -.03 | 1.17 | -1.4 |
| 122 | .295 | .102 | 1.4 | .1 | 1.4 | .1 | 1.19 | -.02 | 1.19 | -1.0 |
| 123 | .409 | .319 | .6 | .0 | .6 | .0 | 1.05 | -.01 | 1.05 | -.5 |
| 124 | .410 | .280 | .6 | .0 | .7 | .0 | 1.06 | -.02 | 1.06 | -.9 |
| 125 | .410 | .240 | .6 | .0 | .7 | .0 | 1.07 | -.02 | 1.07 | -1.1 |
| 126 | .410 | .201 | .6 | .0 | .7 | .0 | 1.07 | -.02 | 1.07 | -1.2 |
| 127 | .411 | .180 | .7 | .0 | .7 | .0 | 1.08 | -.03 | 1.08 | -1.5 |
| 128 | .411 | .161 | .7 | .0 | .8 | .0 | 1.08 | -.03 | 1.09 | -1.7 |
| 129 | .413 | .141 | .8 | .0 | .8 | .0 | 1.09 | -.03 | 1.09 | -1.6 |
| 130 | .411 | .128 | 1.4 | .0 | 1.4 | .0 | 1.11 | -.02 | 1.11 | -1.2 |
| 131 | .412 | .121 | 1.3 | .1 | 1.2 | .1 | 1.13 | -.02 | 1.13 | -.9 |
| 132 | .578 | .318 | .8 | .0 | .8 | .0 | 1.04 | -.03 | 1.04 | -1.9 |
| 133 | .578 | .280 | .7 | .0 | .9 | .0 | 1.05 | -.04 | 1.05 | -2.1 |
| 134 | .578 | .241 | .8 | .0 | .8 | .0 | 1.06 | -.05 | 1.06 | -2.6 |
| 135 | .578 | .201 | 1.0 | .0 | 1.0 | .0 | 1.06 | -.05 | 1.06 | -2.6 |
| 136 | .578 | .180 | 1.0 | .0 | 1.1 | .0 | 1.06 | -.05 | 1.06 | -2.7 |
| 137 | .578 | .161 | 1.3 | .0 | 1.1 | .0 | 1.07 | -.05 | 1.07 | -2.7 |
| 138 | .577 | .140 | 1.7 | .0 | 1.1 | .0 | 1.08 | -.04 | 1.08 | -2.2 |
| 139 | .578 | .127 | 1.2 | .2 | 1.6 | .2 | 1.09 | -.01 | 1.09 | -.5 |
| 140 | .701 | .317 | 1.0 | .0 | 1.0 | .0 | 1.03 | -.04 | 1.03 | -2.2 |
| 141 | .702 | .279 | .8 | .0 | .9 | .0 | 1.03 | -.05 | 1.03 | -2.9 |
| 142 | .702 | .240 | .7 | .0 | .8 | .0 | 1.03 | -.06 | 1.04 | -3.4 |
| 143 | .703 | .202 | .7 | .0 | .6 | .0 | 1.04 | -.07 | 1.04 | -3.8 |
| 144 | .702 | .181 | 1.4 | .0 | .9 | .0 | 1.04 | -.06 | 1.04 | -3.4 |
| 145 | .703 | .161 | 1.5 | .0 | 1.0 | .0 | 1.04 | -.07 | 1.04 | -3.8 |
| 146 | .703 | .140 | 1.7 | .1 | 1.3 | .0 | 1.04 | -.07 | 1.04 | -3.9 |
| 147 | .701 | .127 | 1.5 | .1 | .7 | .0 | 1.09 | -.02 | 1.09 | -1.0 |
| 148 | .703 | .121 | 1.4 | .1 | 1.1 | .1 | 1.09 | -.01 | 1.09 | -.8 |

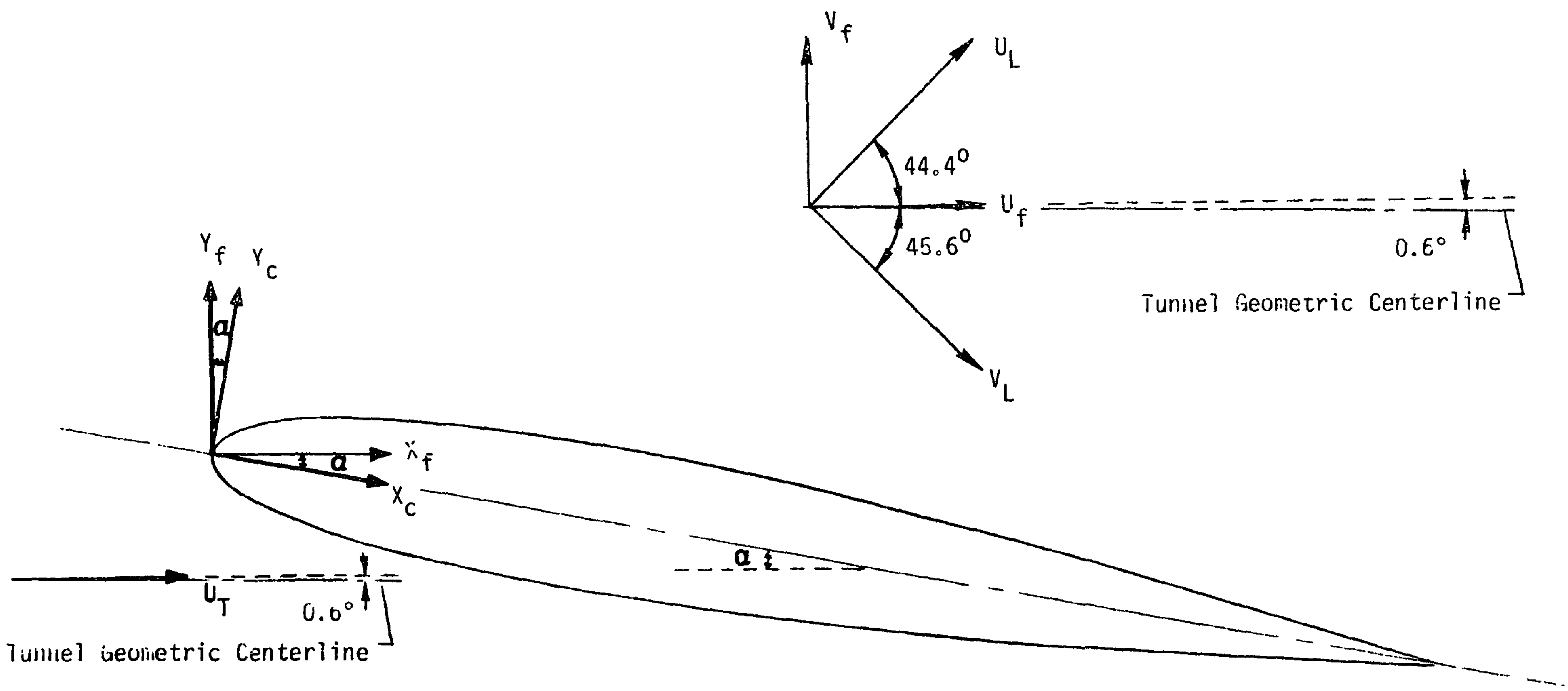



Figure 1. - Sketch of axis system used including directions of velocity components computed.

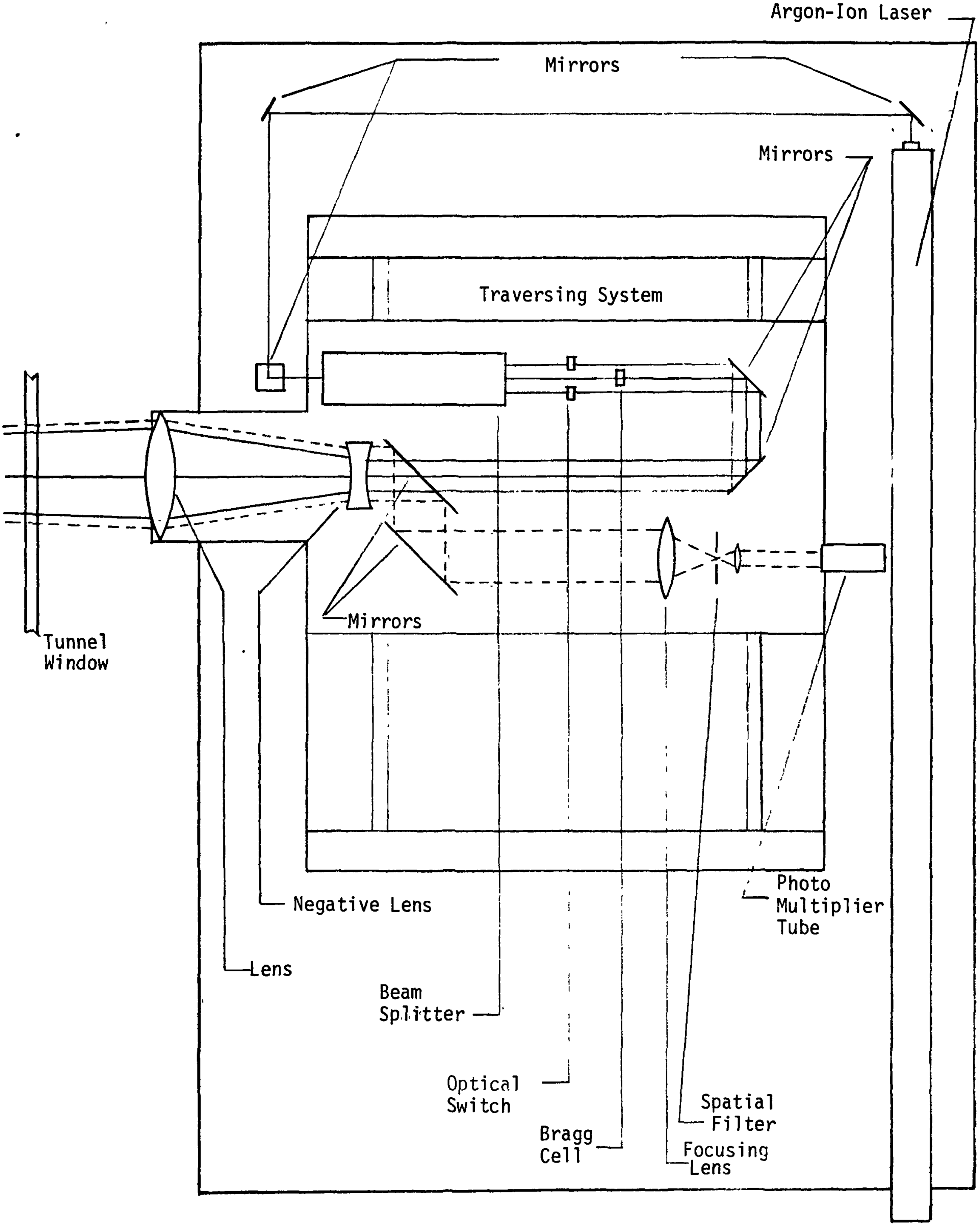



Figure 2.- Schematic of the laser velocimeter optics..

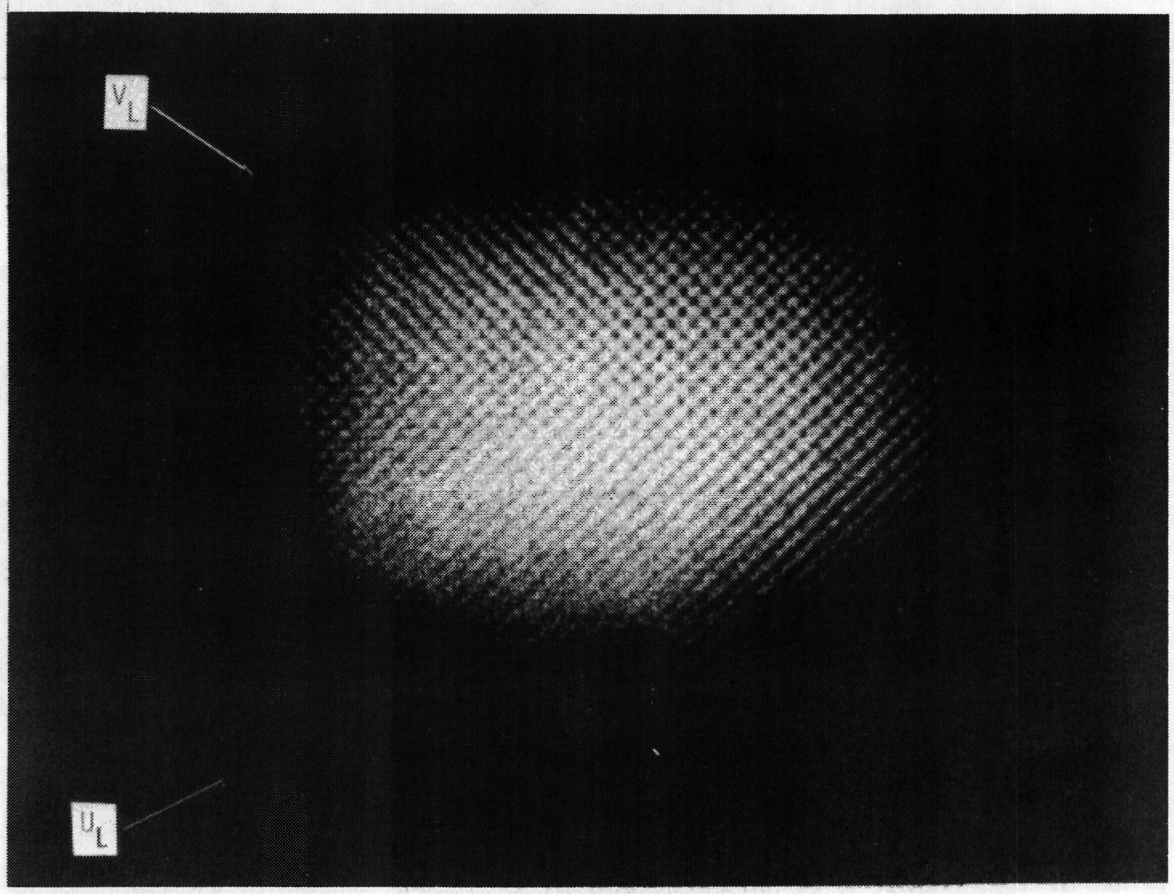



Figure 3. - Two-velocity-component fringes in the sample volume.

Figure 4. Laser velocimeter optics platform in V/STOL tunnel.

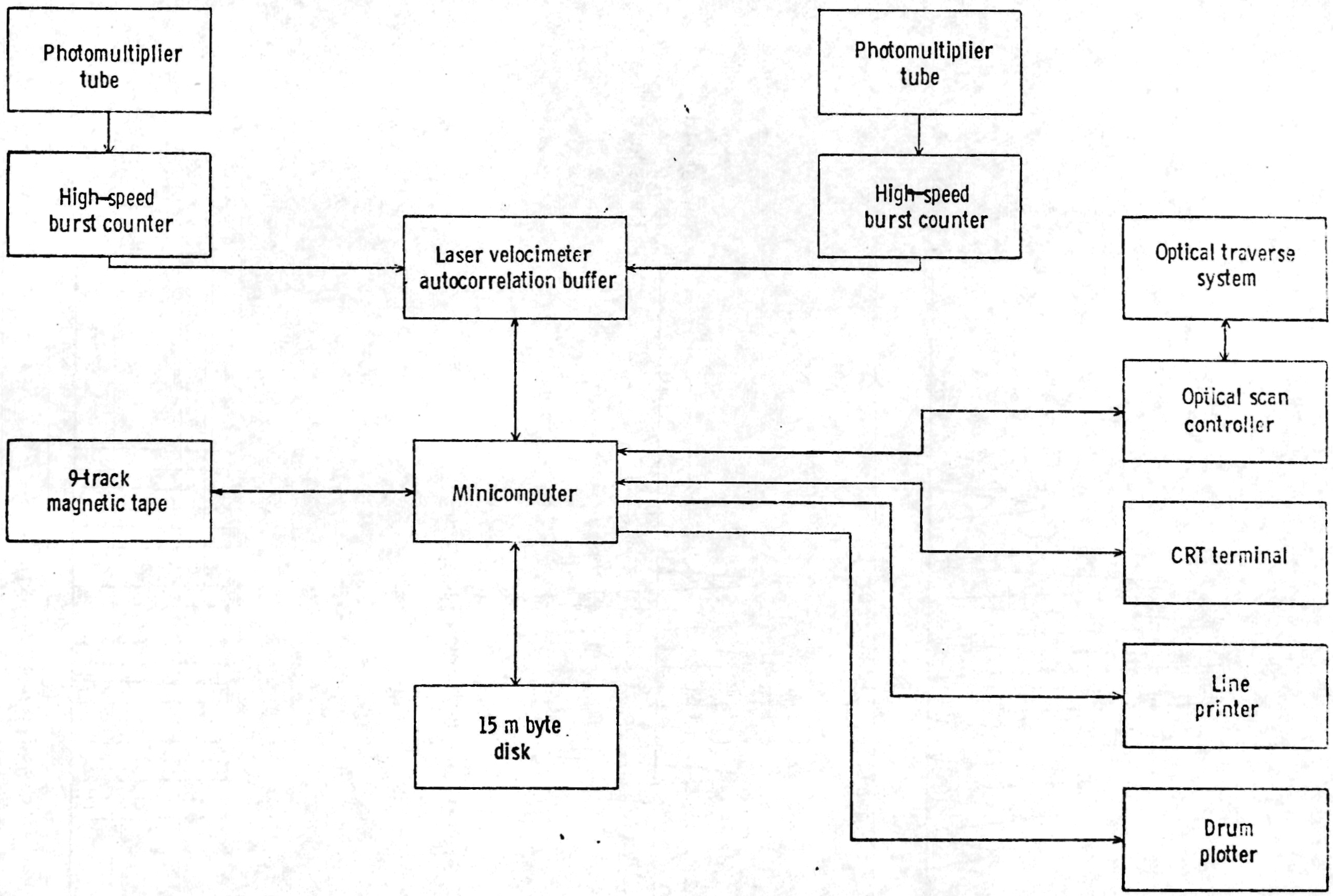



Figure 5.- Block diagram of the laser velocimeter data acquisition system.

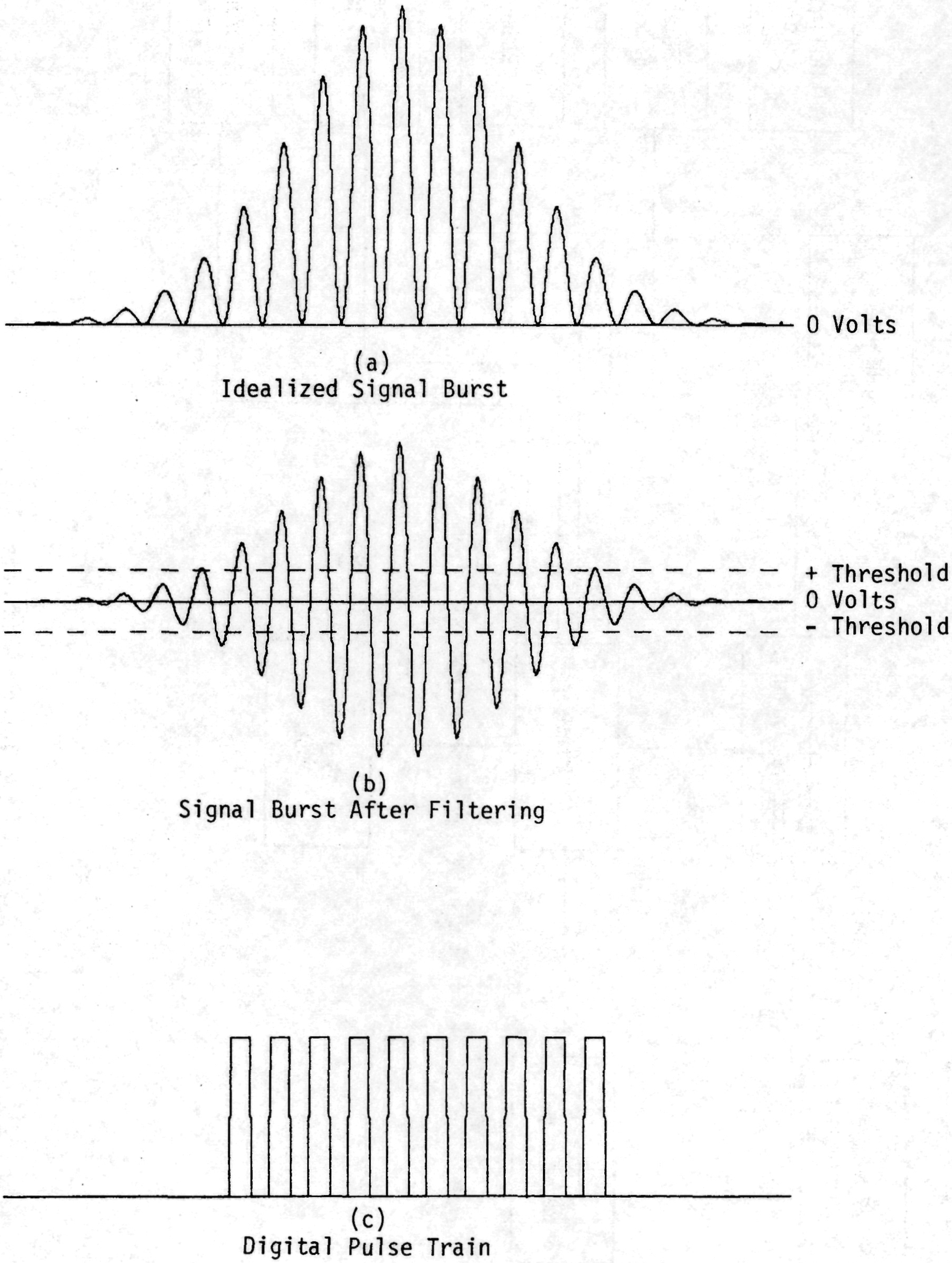



Figure 6. - Processing of burst received from laser velocimeter.

Figure 7. - Straight wing with NACA 0012 airfoil sections installed in the 4- by 7-meter low-speed (V/STOL) tunnel.

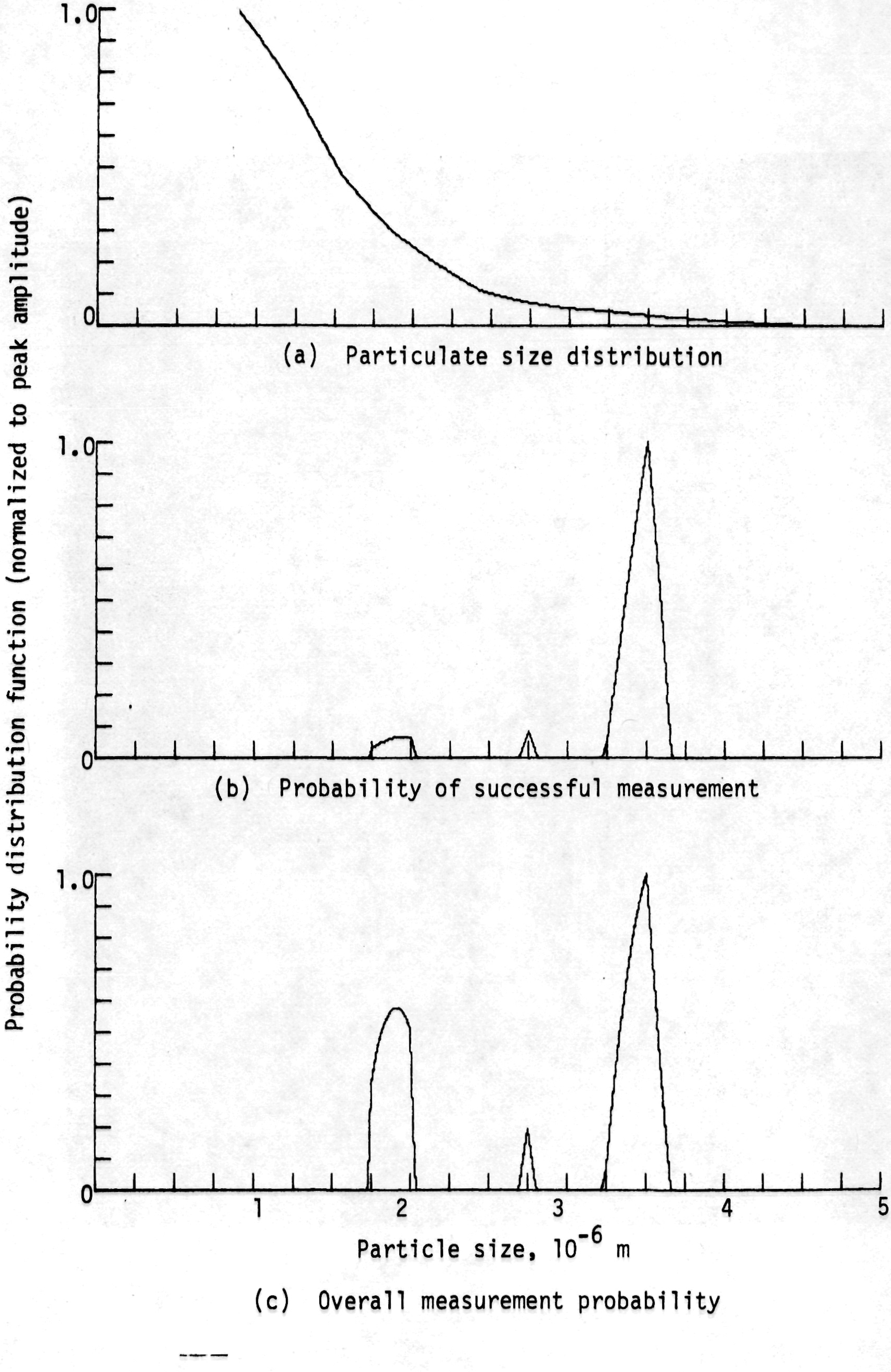



Figure 8. - Particle size distribution measured by the laser velocimeter.

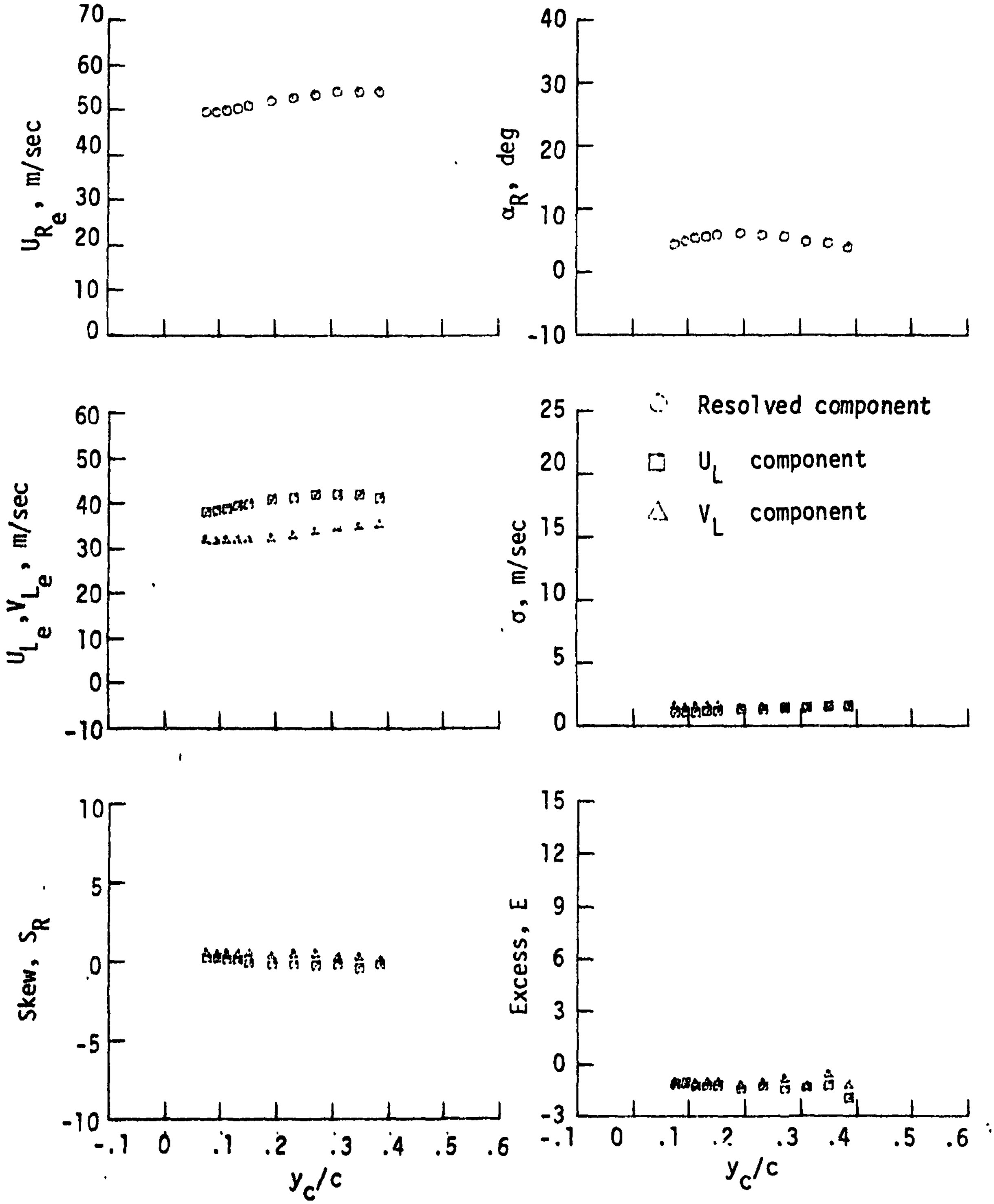



Figure 9. Statistical characteristics of the LV measured velocities at constant $x_c/c = -.16$. $\alpha = 4.75°$.

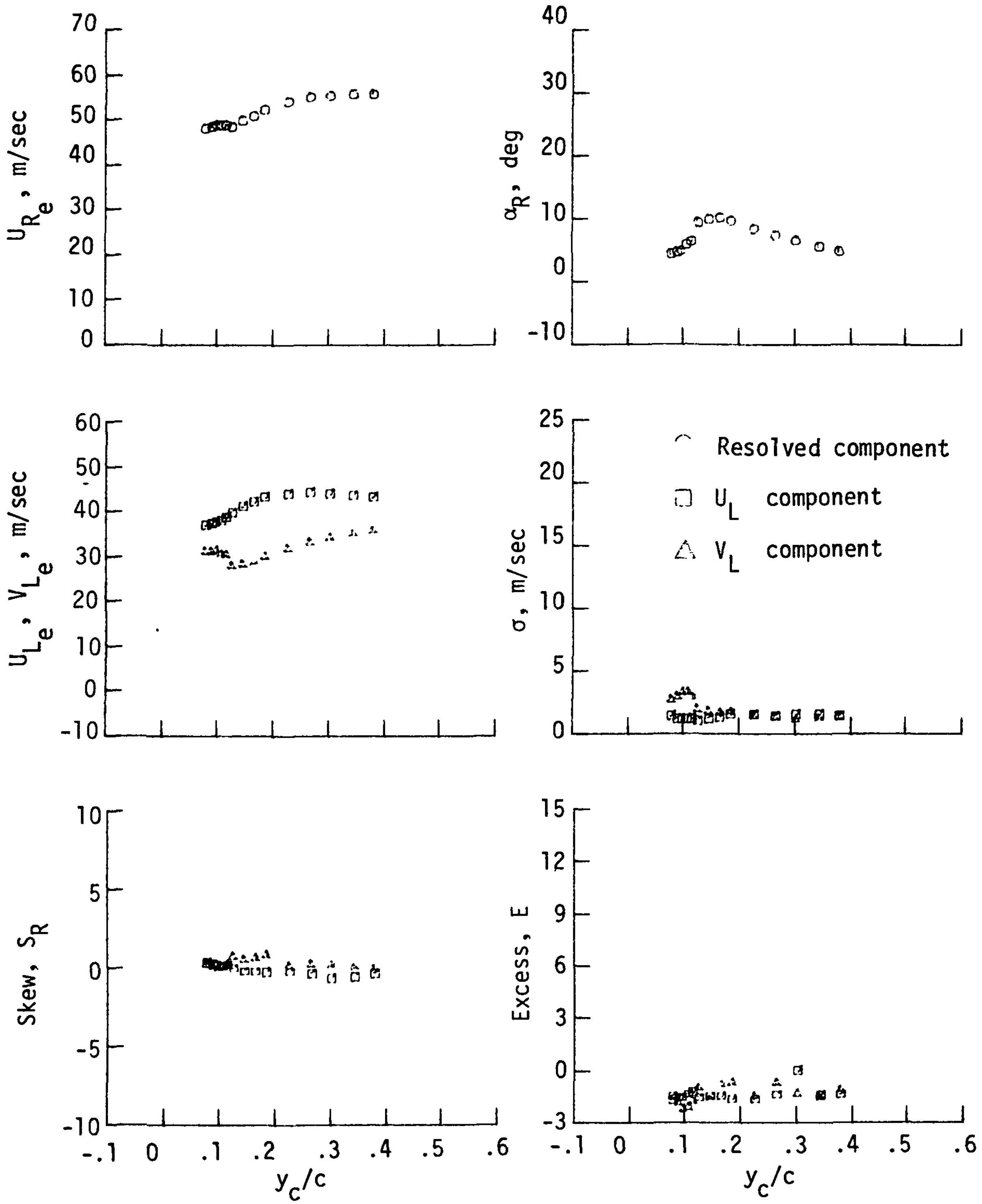



Figure 10. Statistical characteristics of the LV measured velocities at constant $x_c/c = -.08$. $\alpha = 4.75°$.

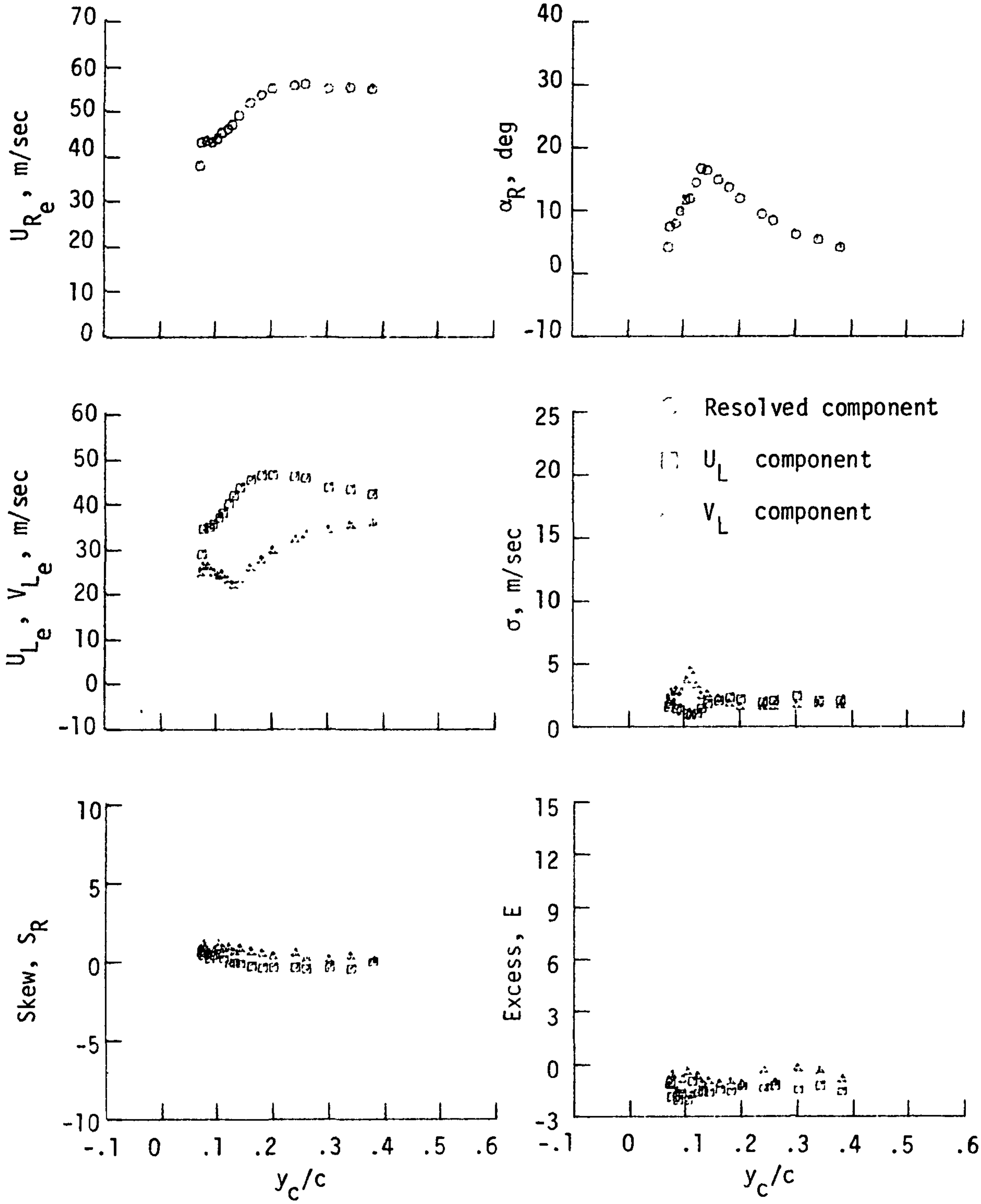



Figure 11. Statistical characteristics of the LV measured velocities at constant $x_c/c = -.04$. $\alpha = 4.75°$.

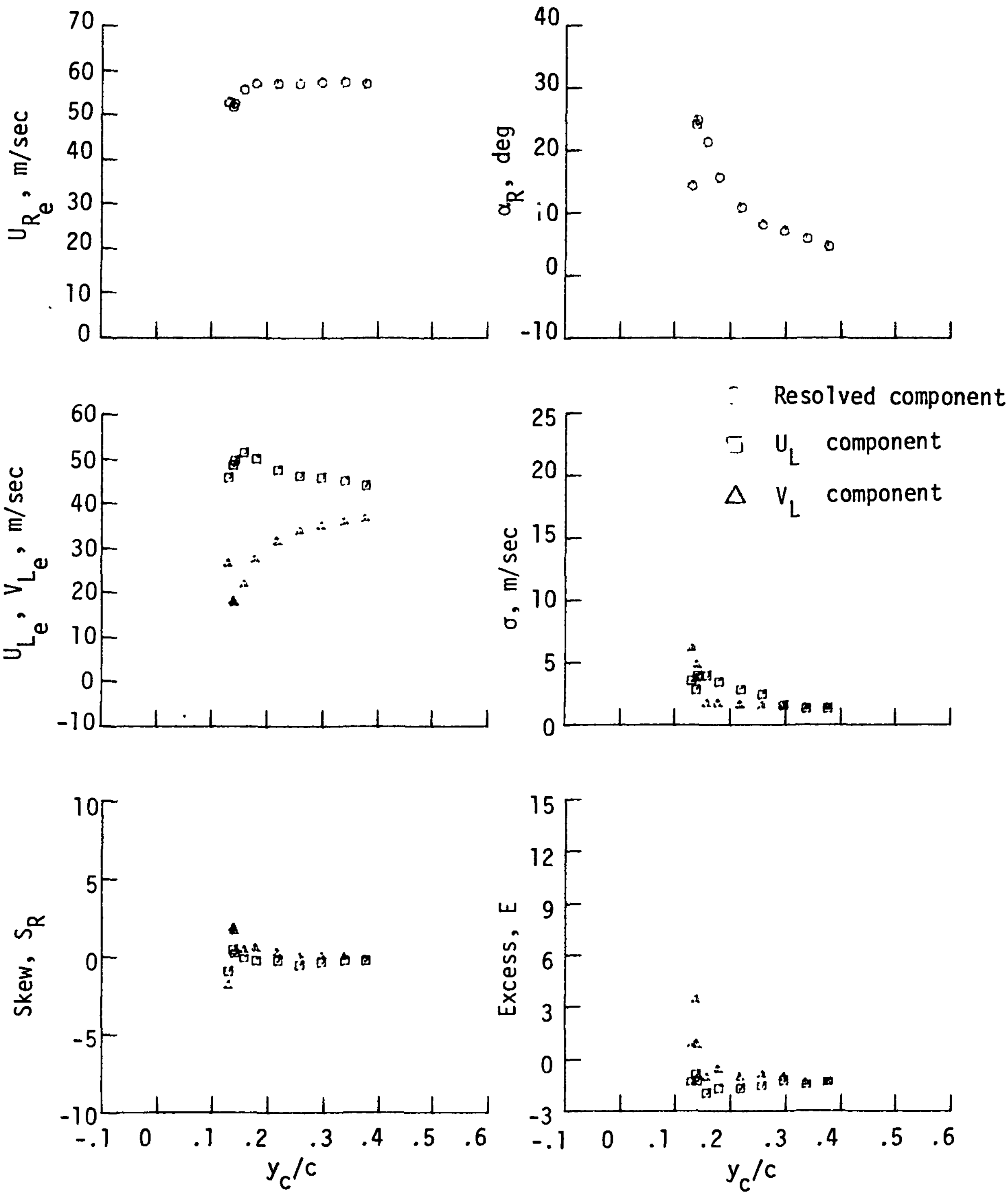



Figure 12. Statistical characteristics of the LV measured velocities at constant $x_c/c = .02$. $\alpha = 4.75°$.

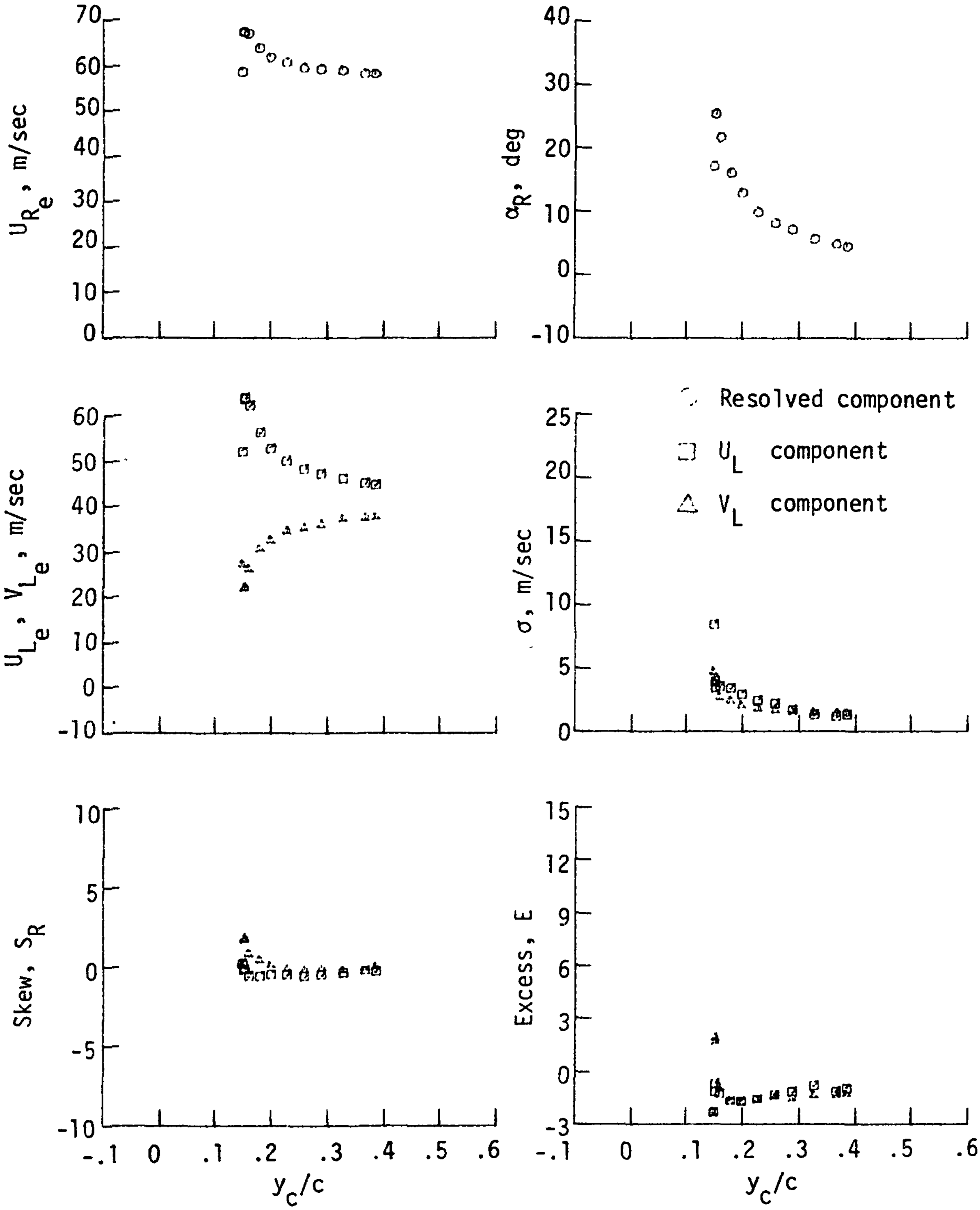



Figure 13. Statistical characteristics of the LV measured velocities at constant $x_c/c = .03$. $\alpha = 4.75°$.

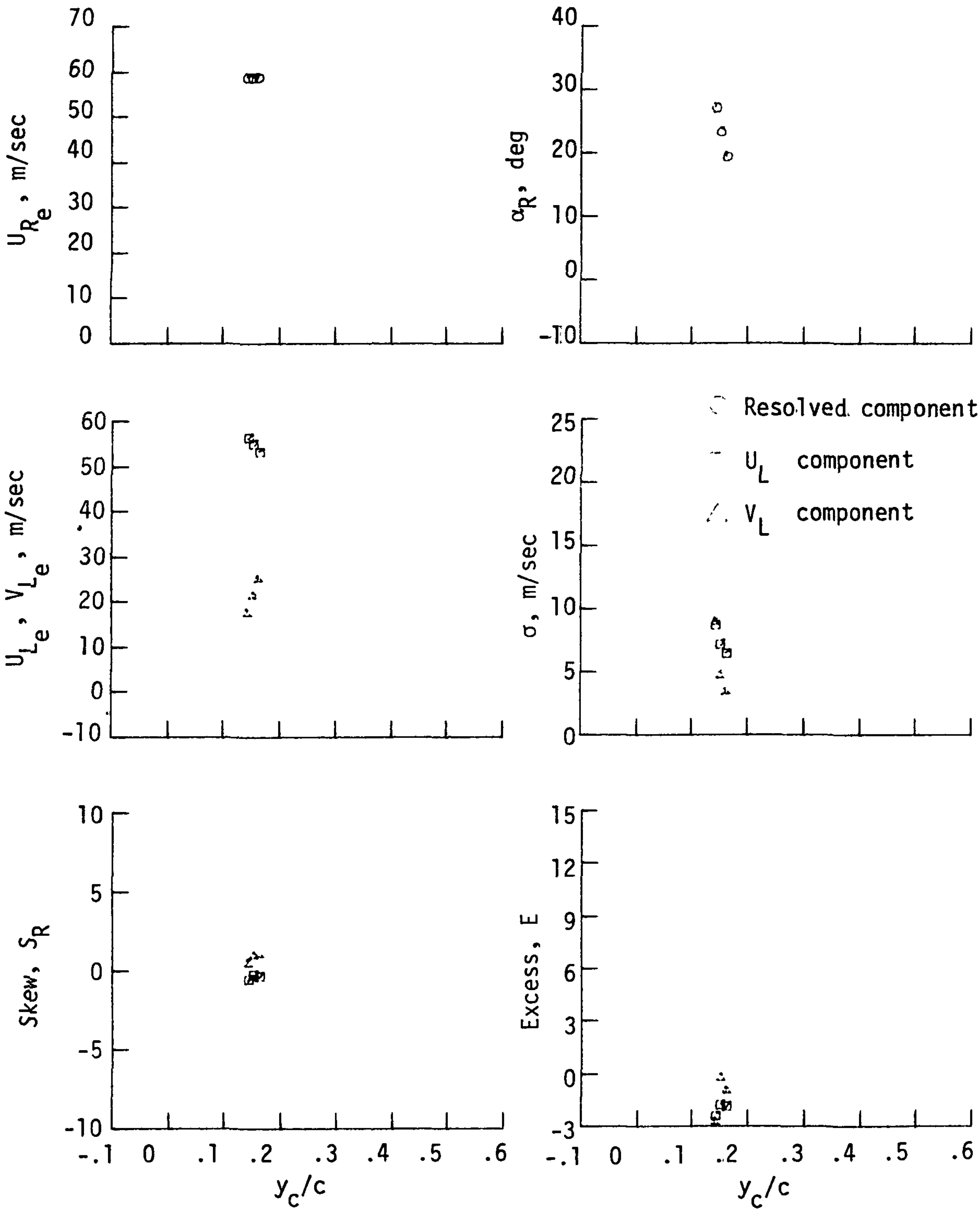



Figure 14. Statistical characteristics of the LV measured velocities at constant $x_c/c = .04$. $\alpha = 4.75°$.

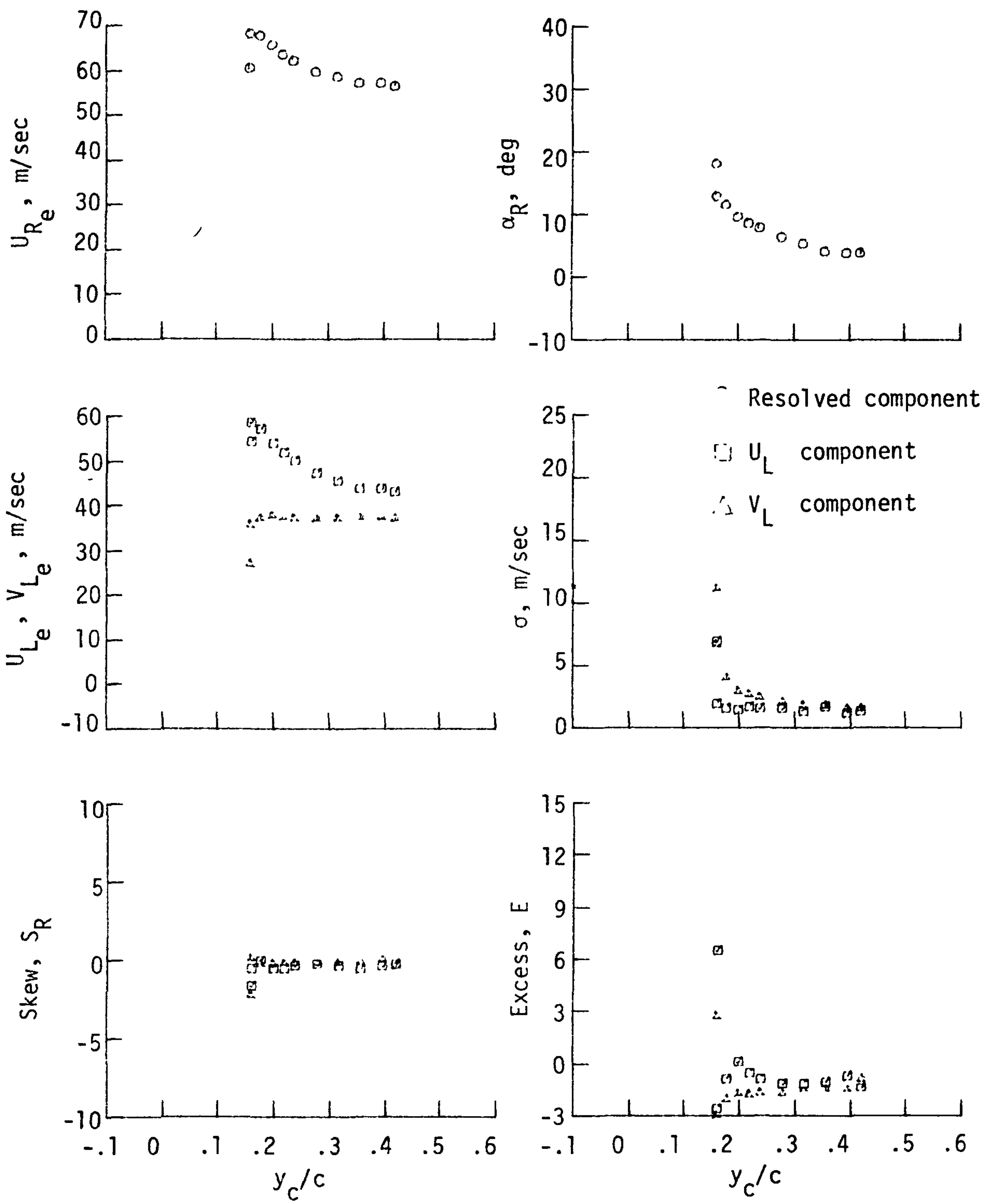



Figure 15. Statistical characteristics of the LV measured velocities at constant $x_c/c = .06$. $\alpha = 4.75$

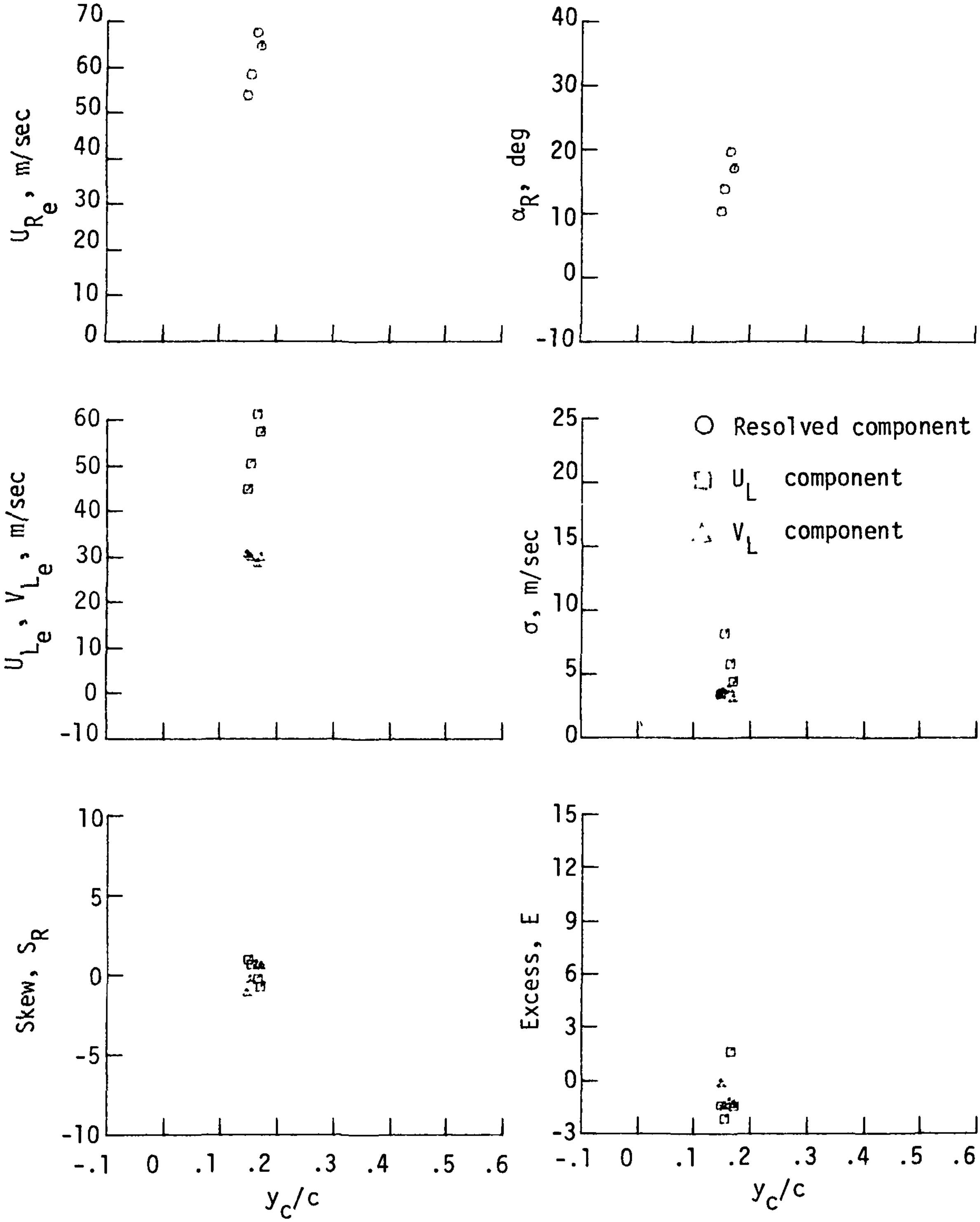



Figure 16. Statistical characteristics of the LV measured velocities at constant $x_c/c = .09$. $\alpha = 4.75°$.

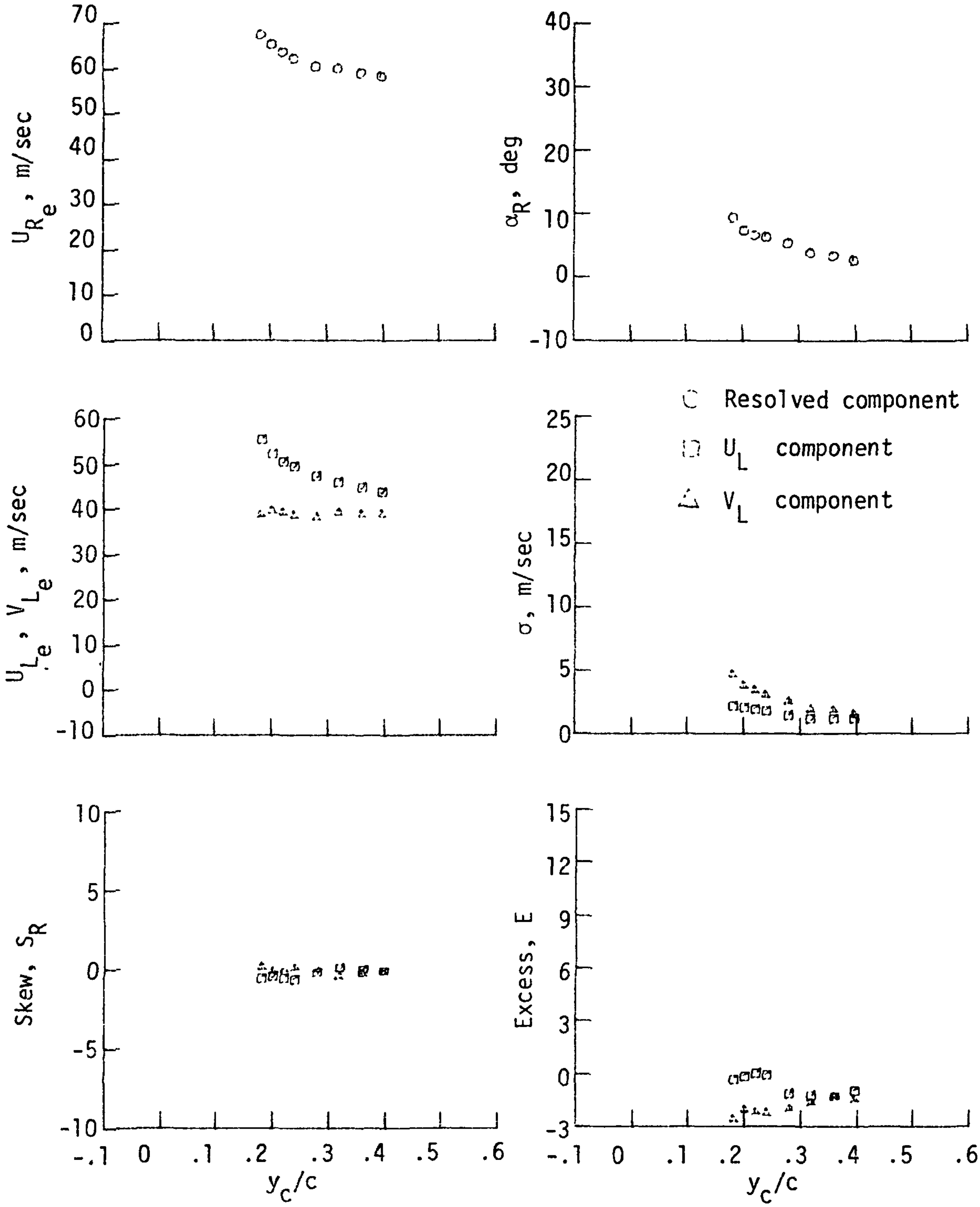



Figure 17. Statistical characteristics of the LV measured velocities at constant $x_c/c = .13$. $\alpha = 4.75°$.

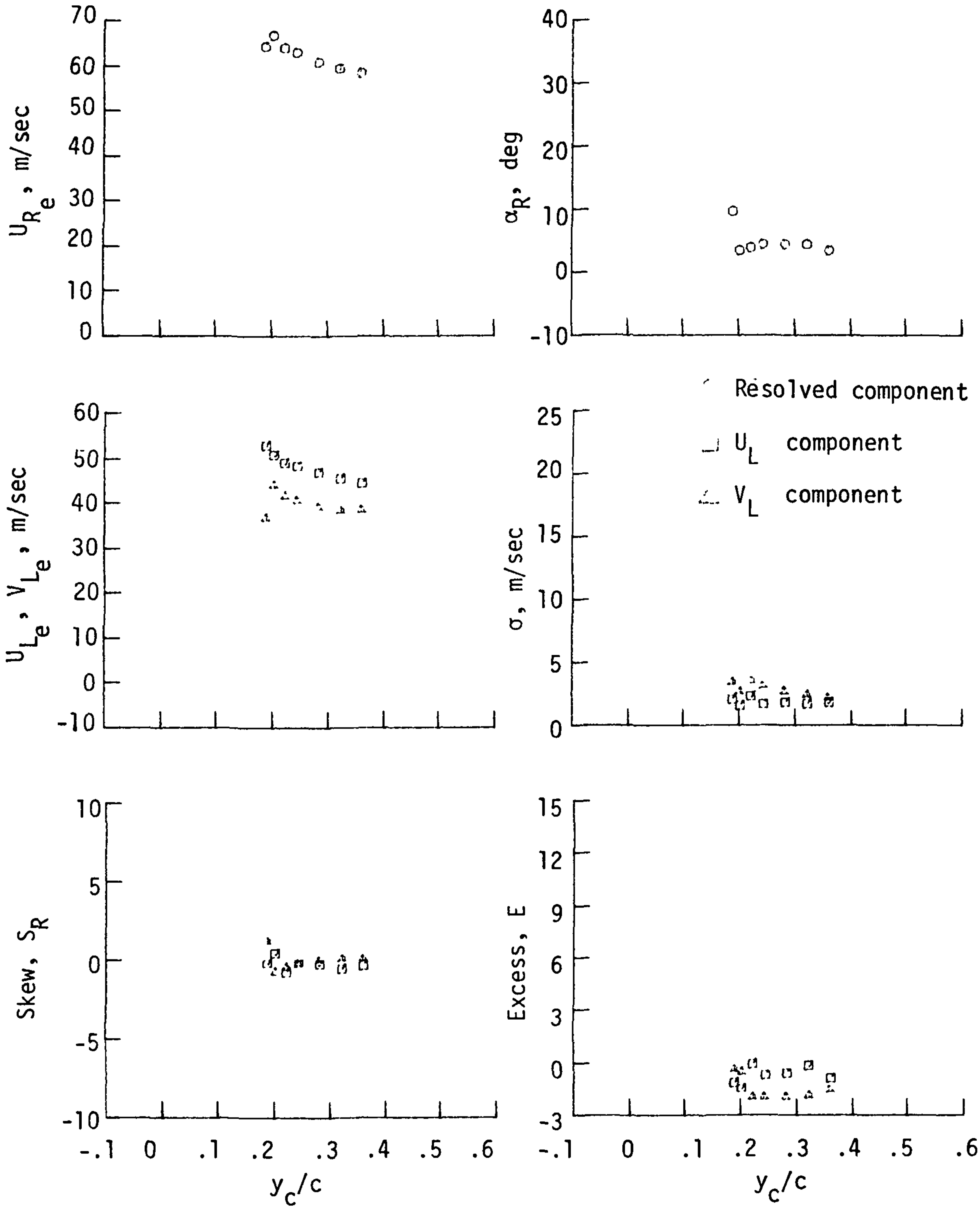



Figure 18. Statistical characteristics of the LV measured velocities at constant $x_c/c$ = .17. $\alpha$ = 4.75°.

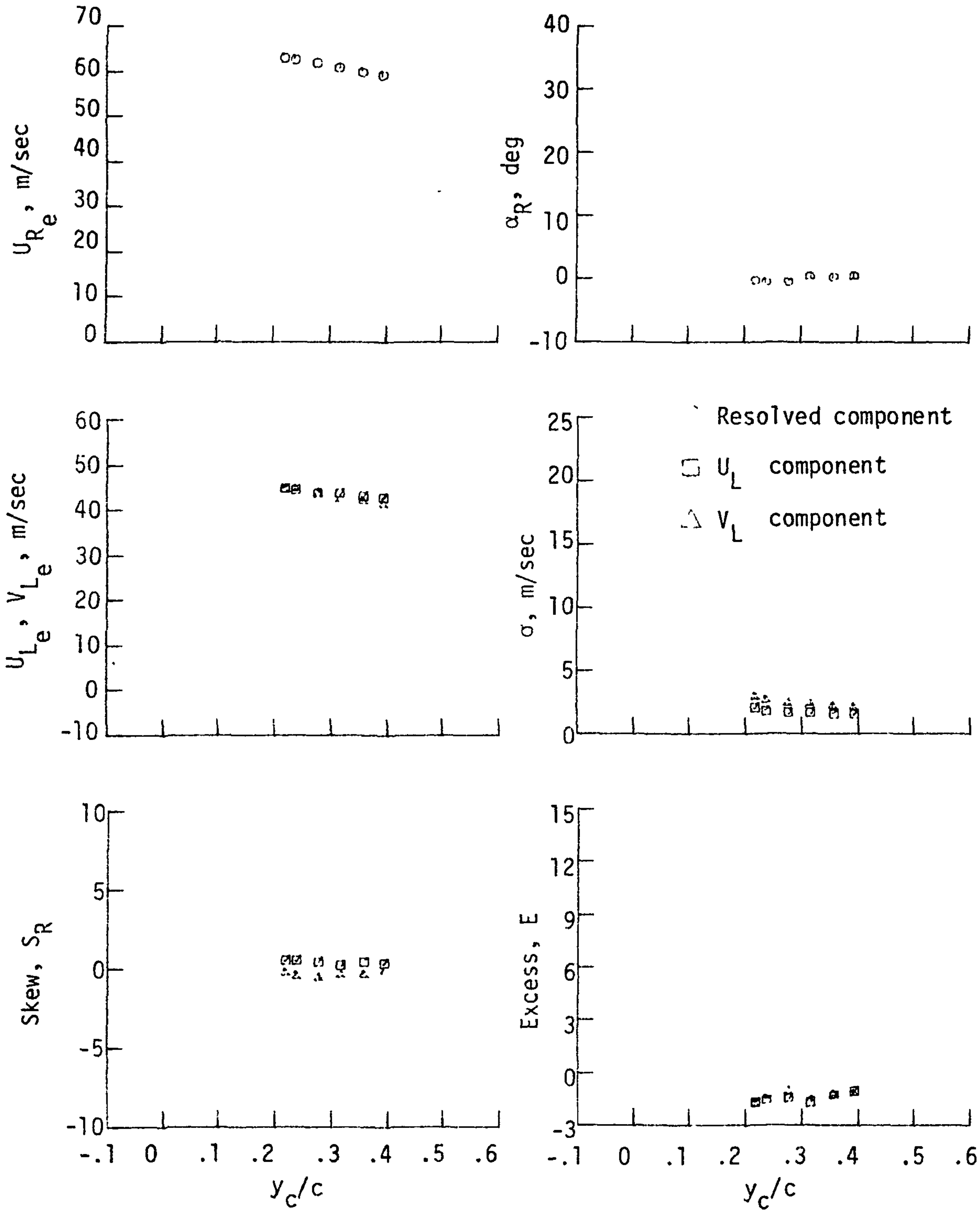



Figure 19. Statistical characteristics of the LV measured velocities at constant $x_c/c = .29$. $\alpha = 4.75°$.

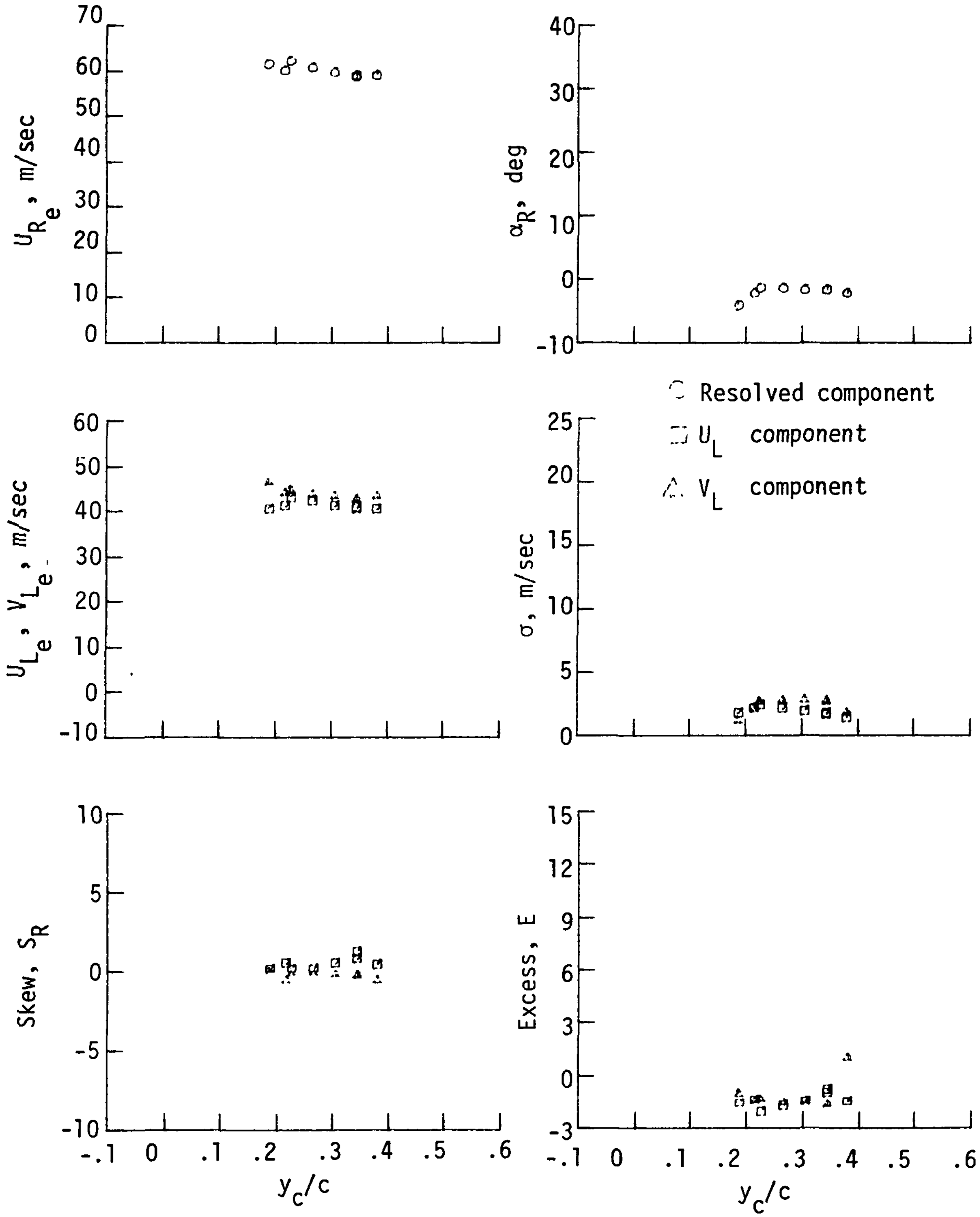



Figure 20. Statistical characteristics of the LV measured velocities at constant $x_c/c = .42$. $\alpha = 4.75°$.

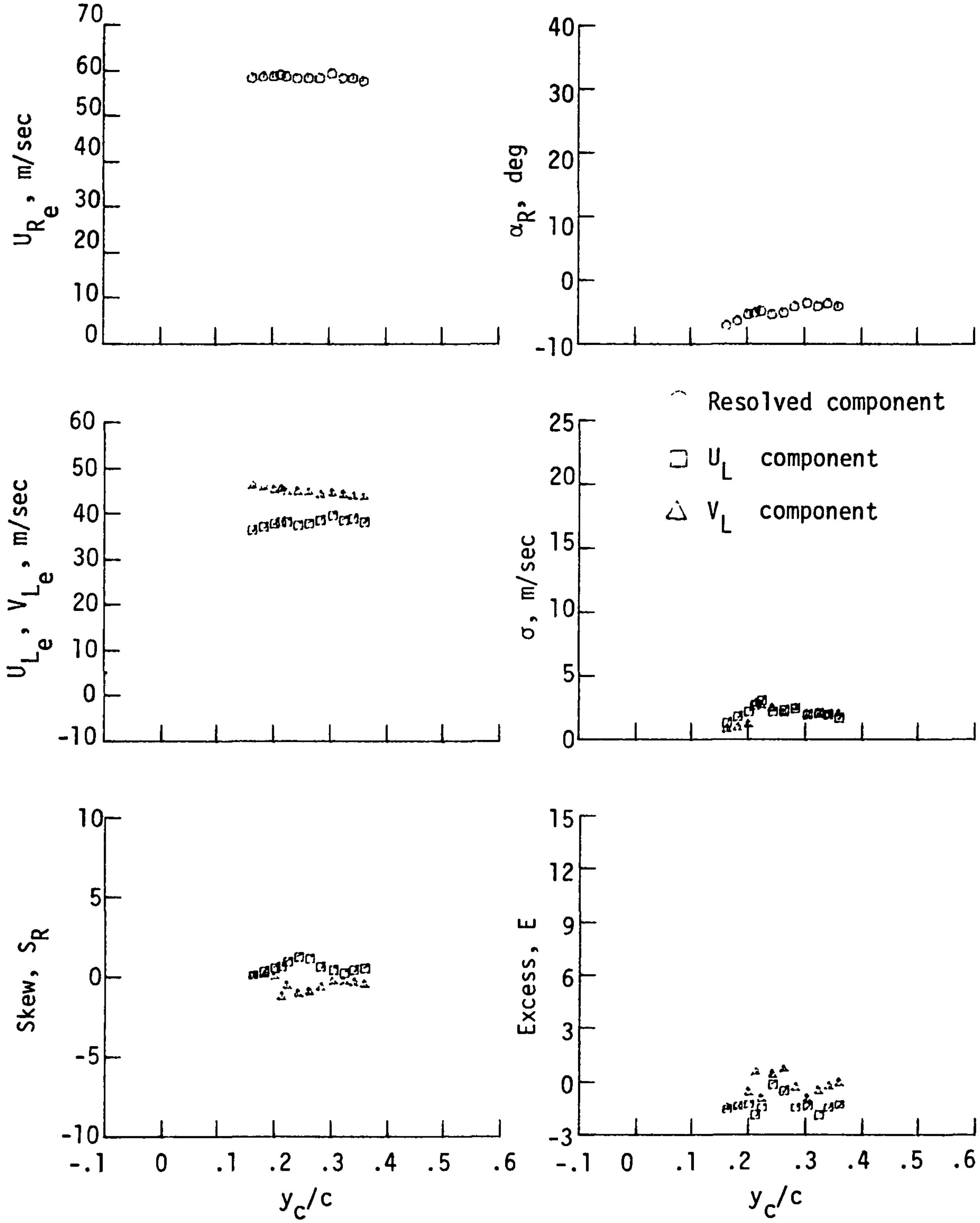



Figure 21. Statistical characteristics of the LV measured velocities at constant $x_c/c = .58$. $\alpha = 4.75°$.

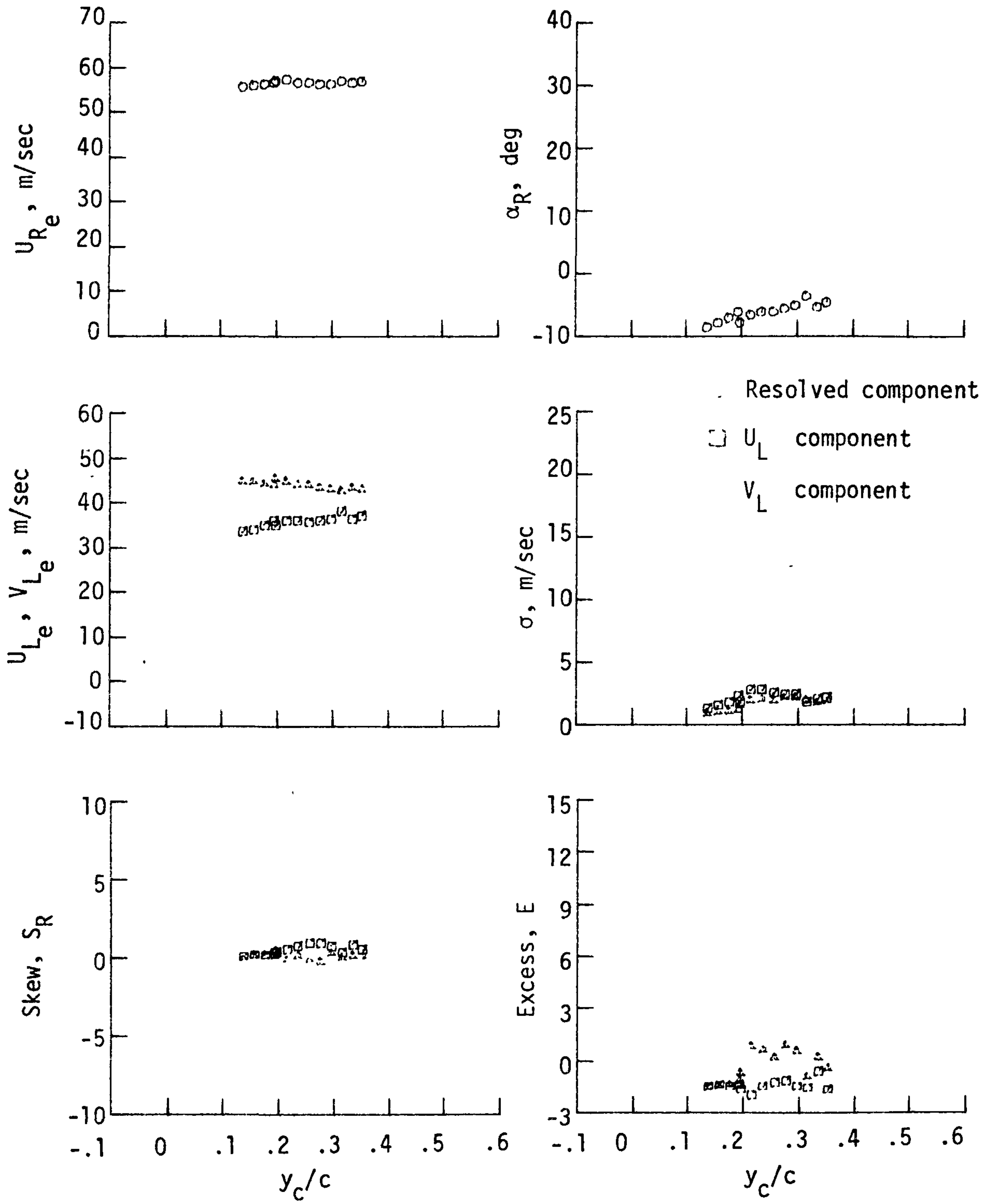



Figure 22. Statistical characteristics of the LV measured velocities at constant $x_c/c$ = .75. $\alpha$ = 4.75°.

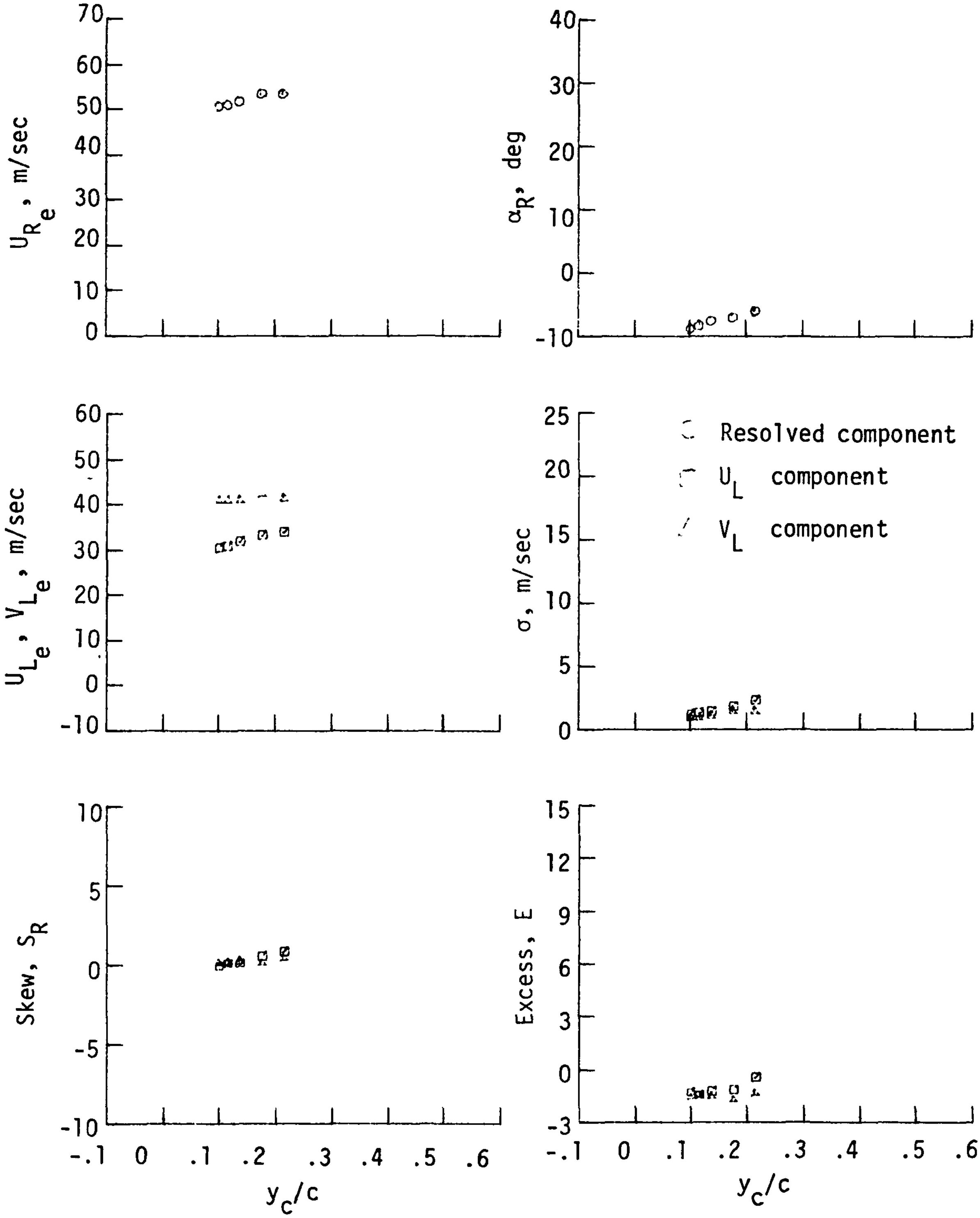



Figure 23. Statistical characteristics of the LV measured velocities at constant $x_c/c$ = .96. $\alpha$ = 4.75°.

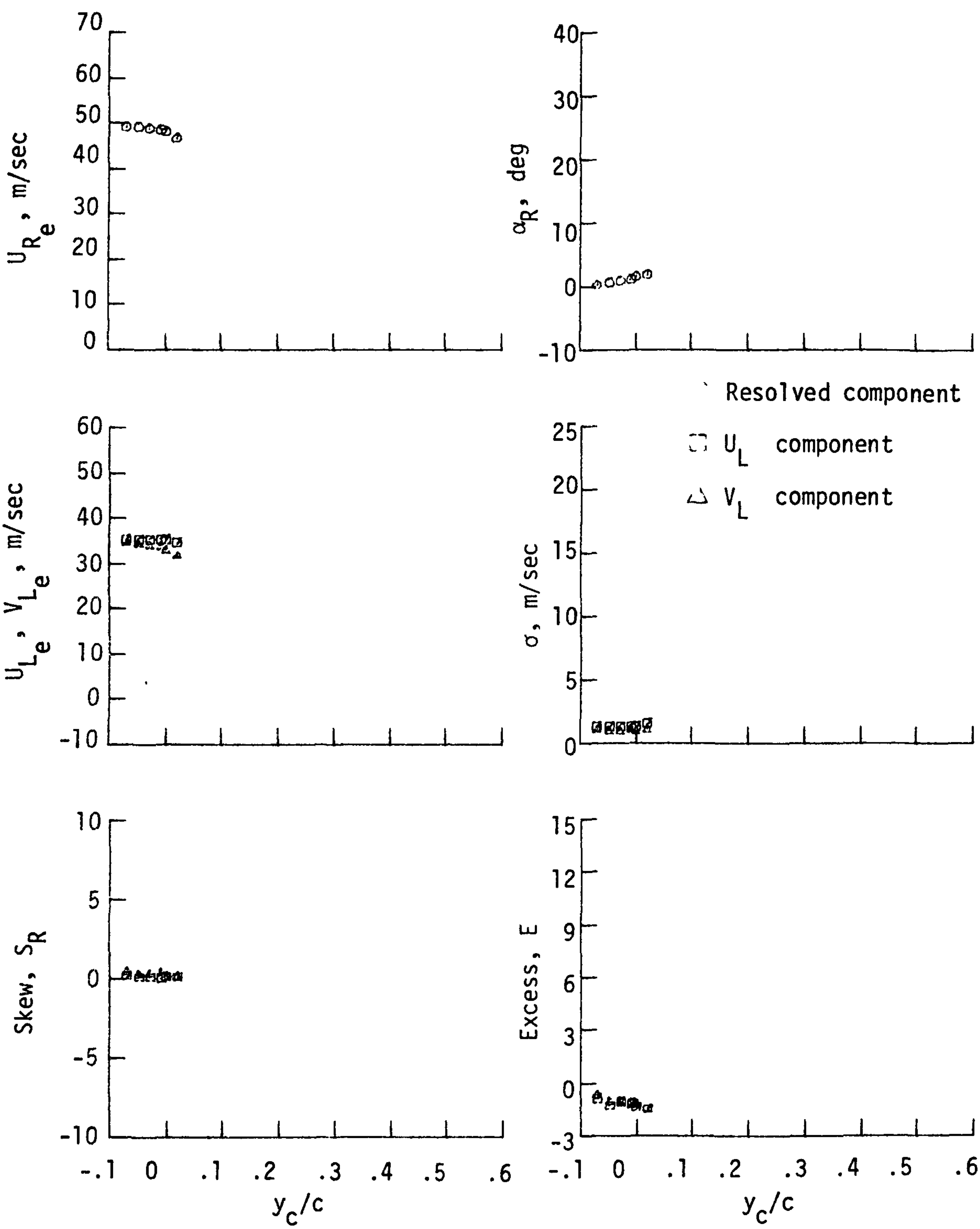



Figure 24. Statistical characteristics of the LV measured velocities at constant $x_c/c = 1.01$. $\alpha = 4.75°$.

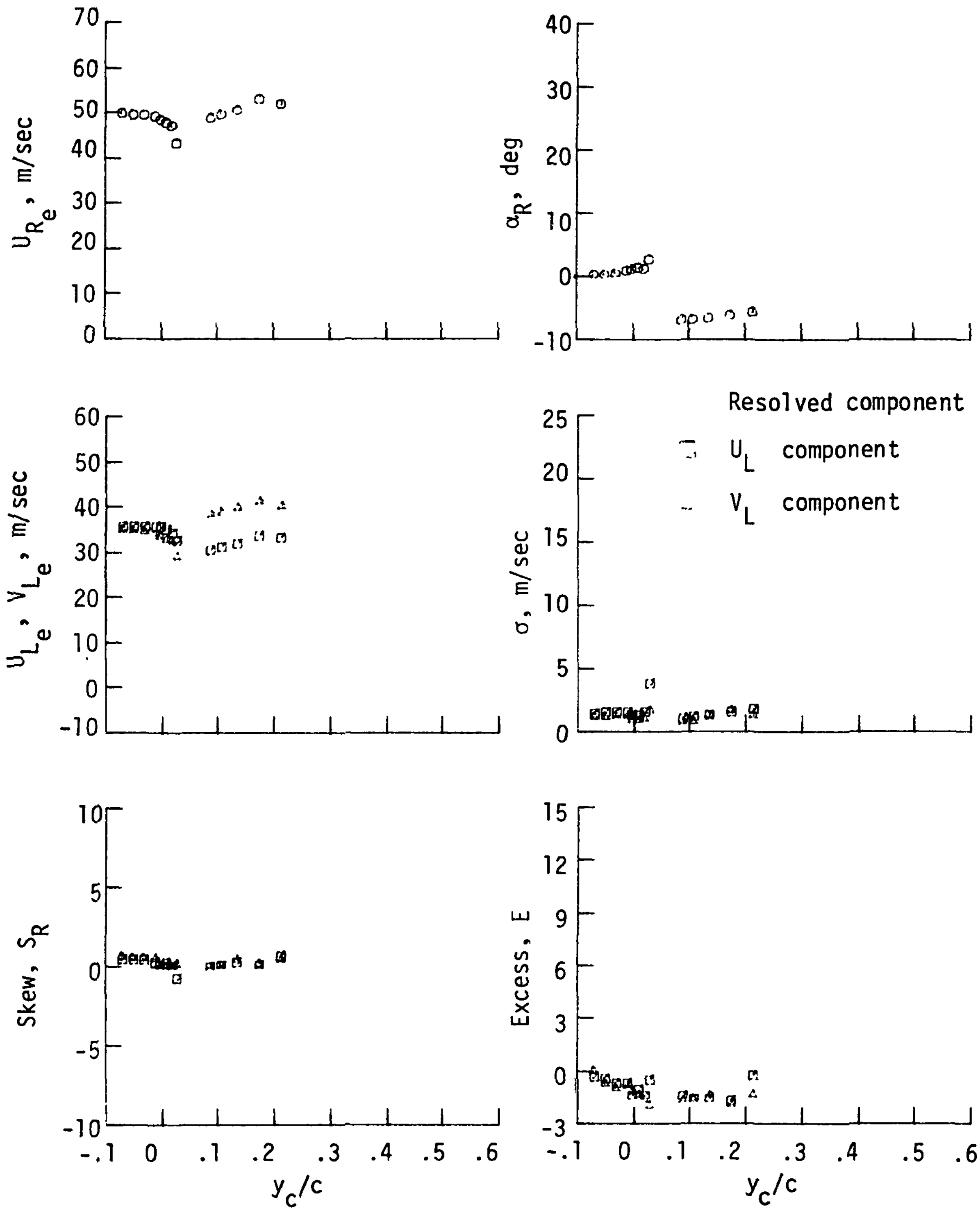



Figure 25. Statistical characteristics of the LV measured velocities at constant $x_c/c = 1.03$. $\alpha = 4.75°$.

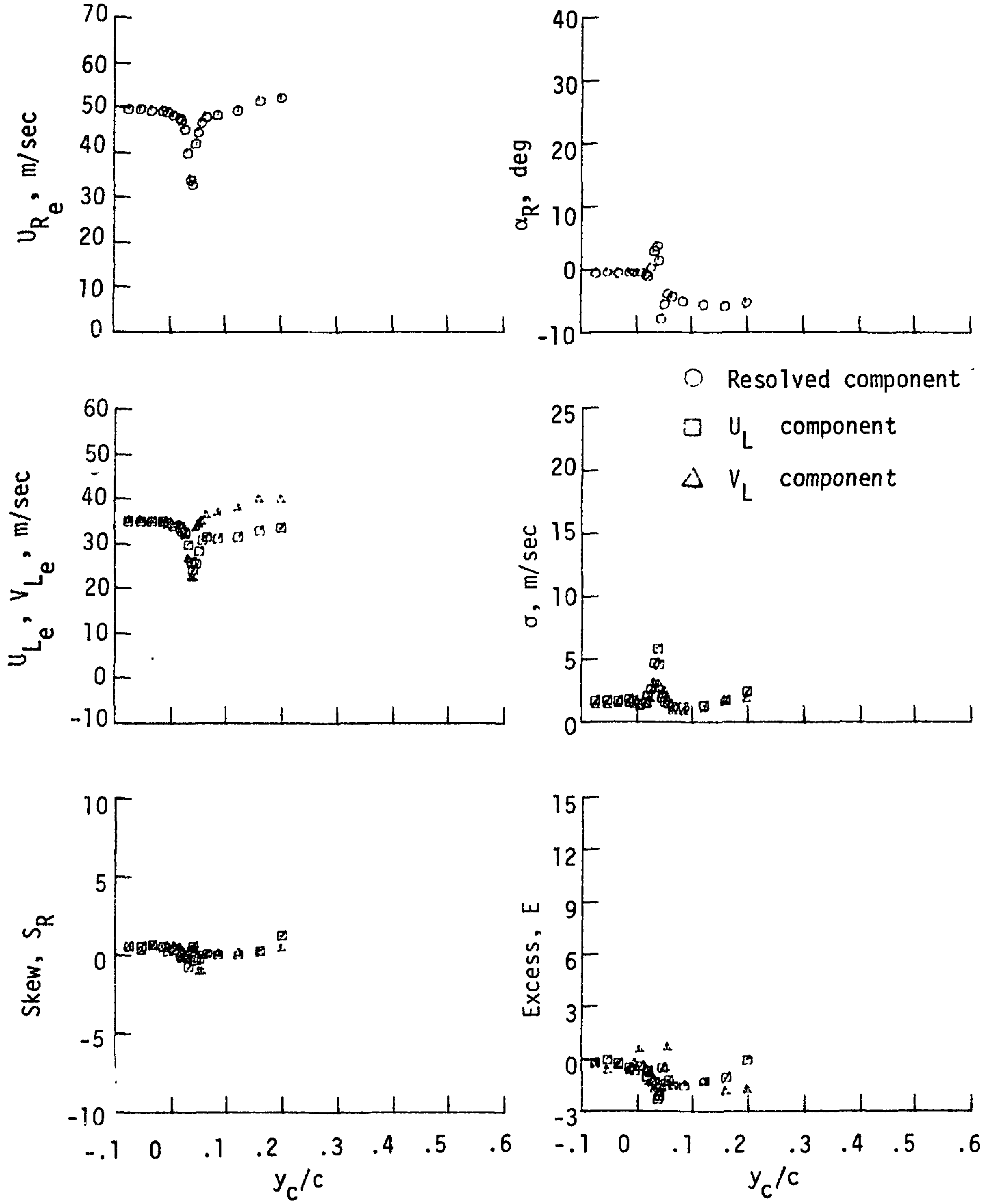



Figure 26. Statistical characteristics of the LV measured velocities at constant $x_c/c = 1.09$. $\alpha = 4.75°$.

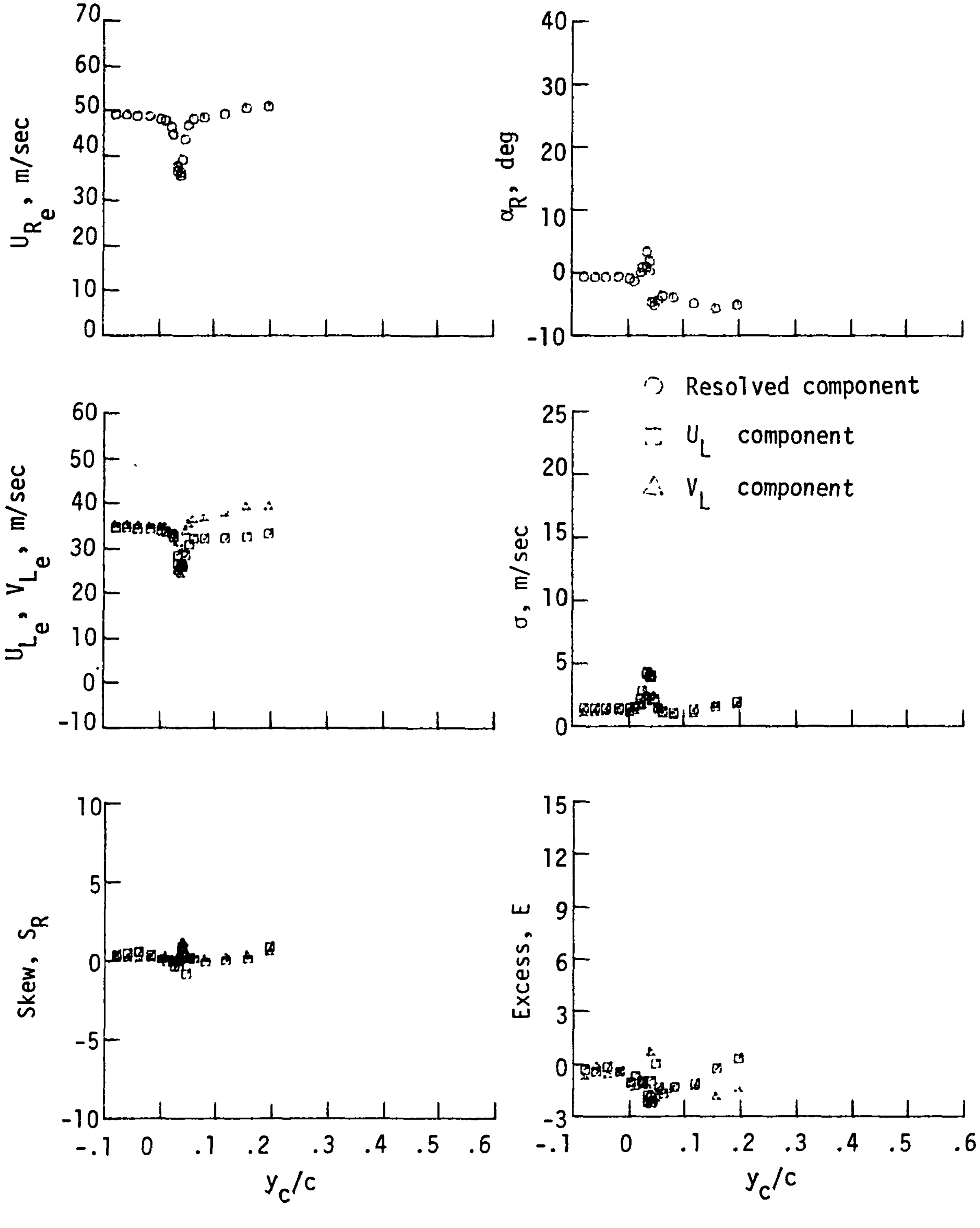



Figure 27. Statistical characteristics of the LV measured velocities at constant $x_c/c = 1.13$. $\alpha = 4.75°$.

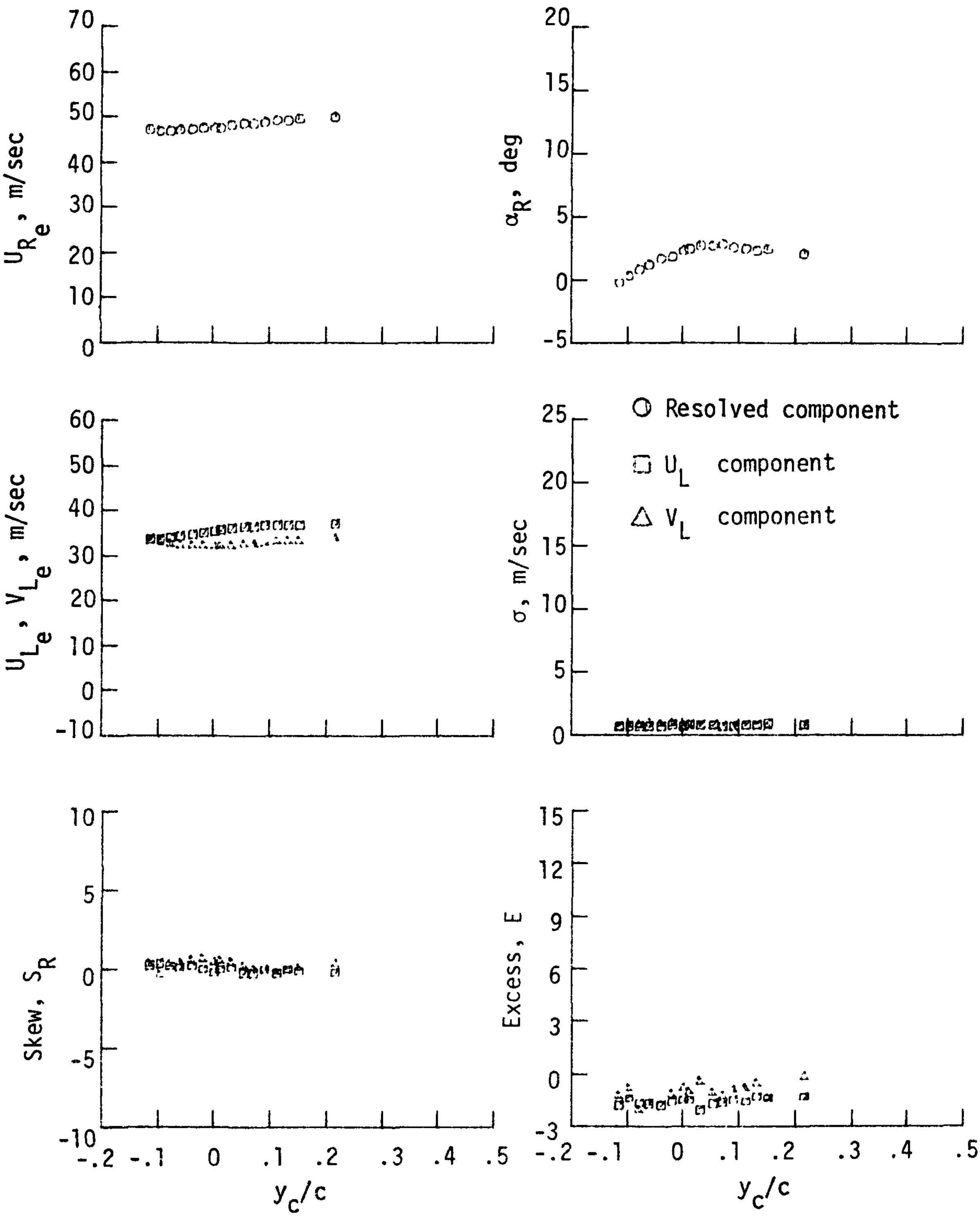



Figure 28. Statistical characteristics of the LV measured velocities at constant $x_c/c = -0.17$. $\alpha = 0.6°$.

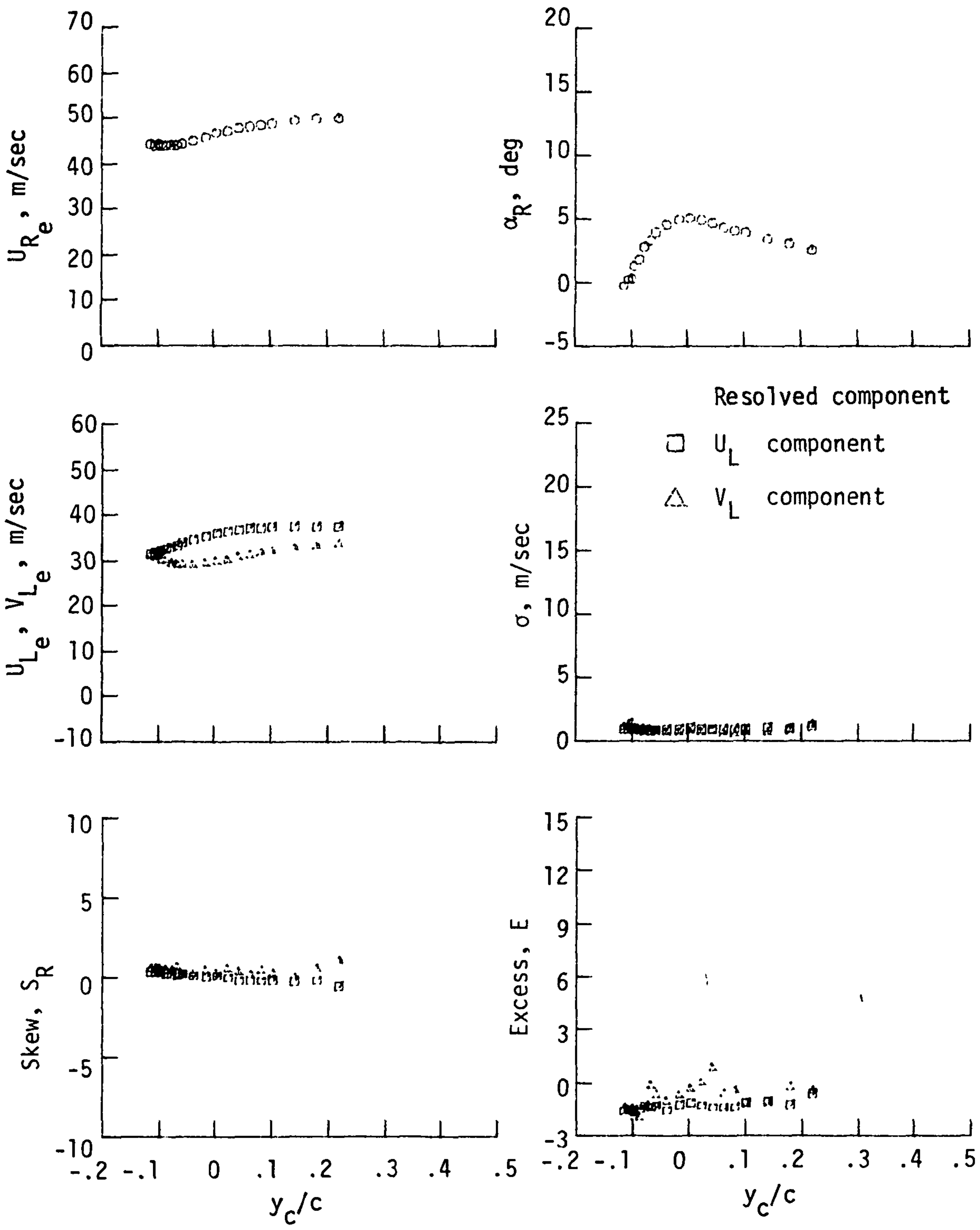



Figure 29. Statistical characteristics of the LV measured velocities at constant $x_c/c = -0.09$. $\alpha = 0.6°$.

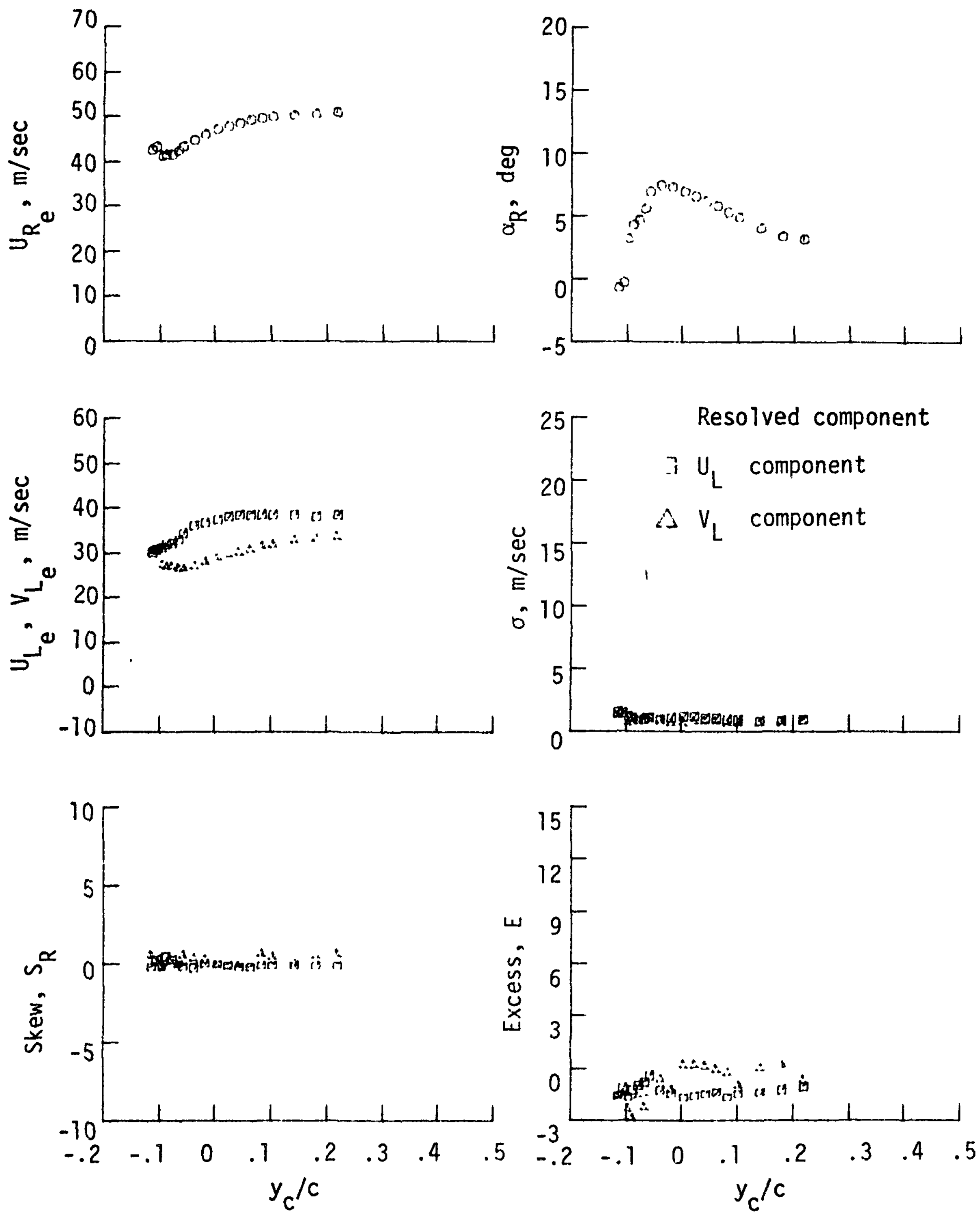



Figure 30. Statistical characteristics of the LV measured velocities at constant $x_c/c$ =-0.05. $\alpha$ = 0.6°.

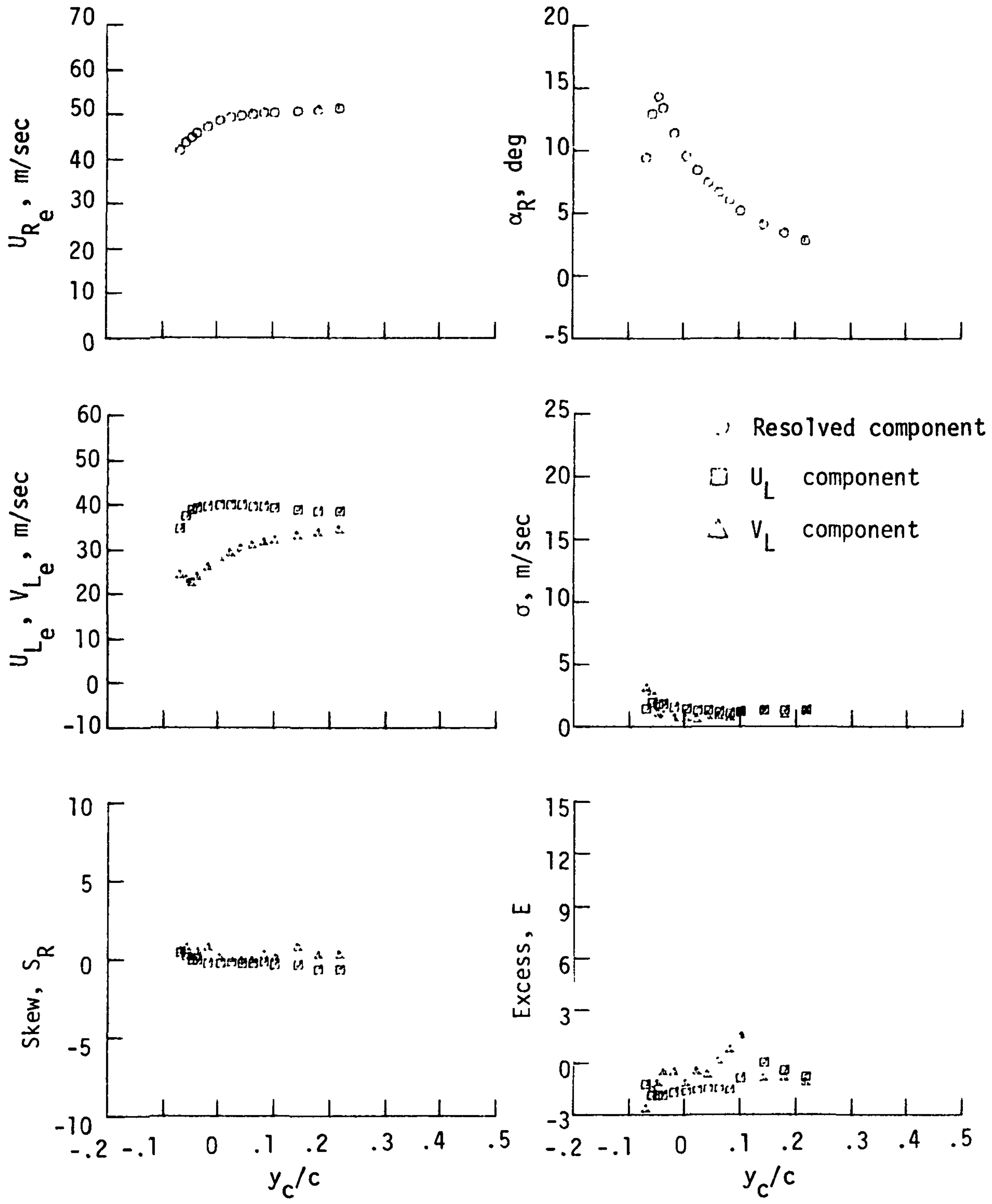



Figure 31. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0$. $\alpha = 0.6°$.

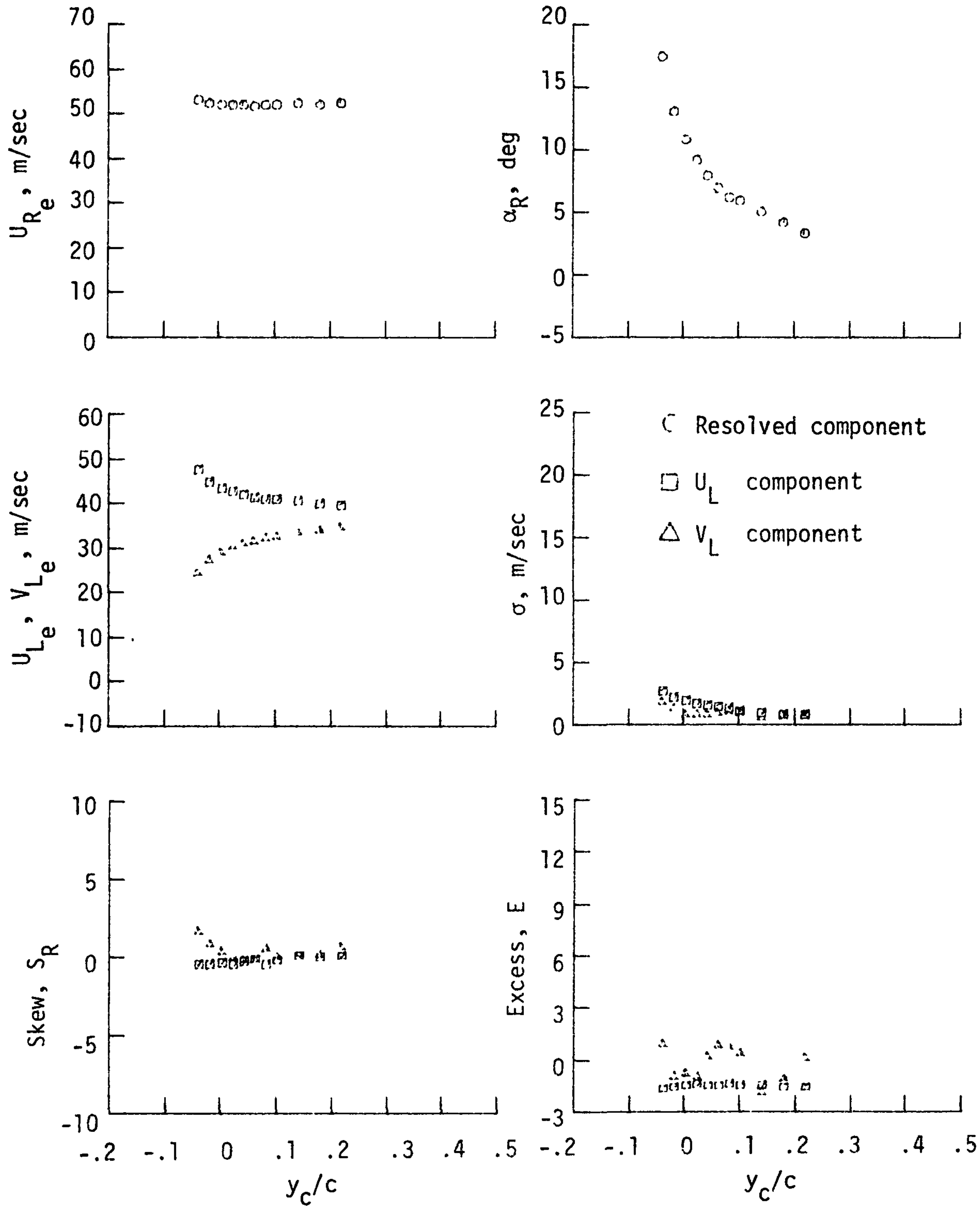



Figure 32. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.04$. $\alpha = 0.6°$.

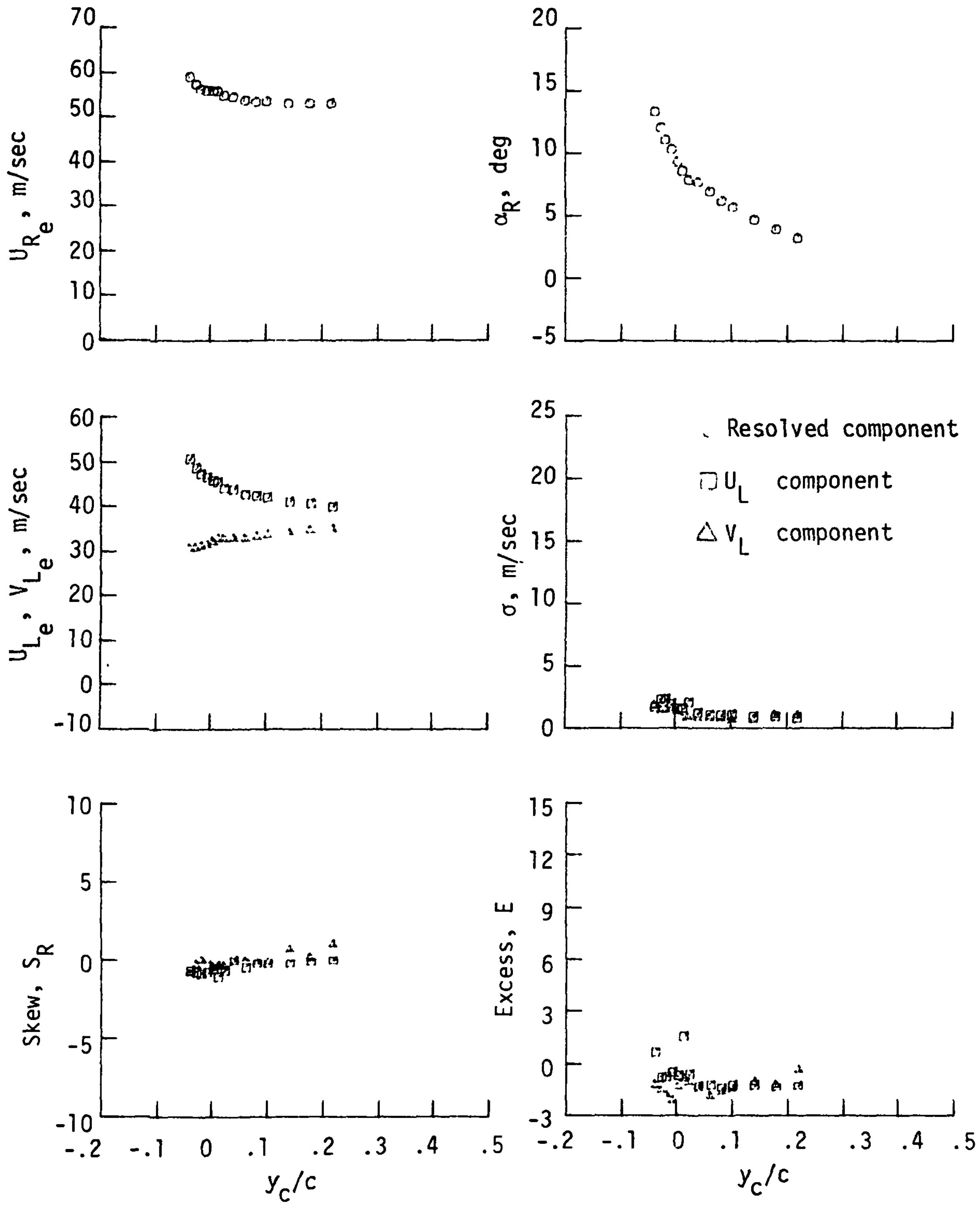



Figure 33. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.08$. $\alpha = 0.6°$.

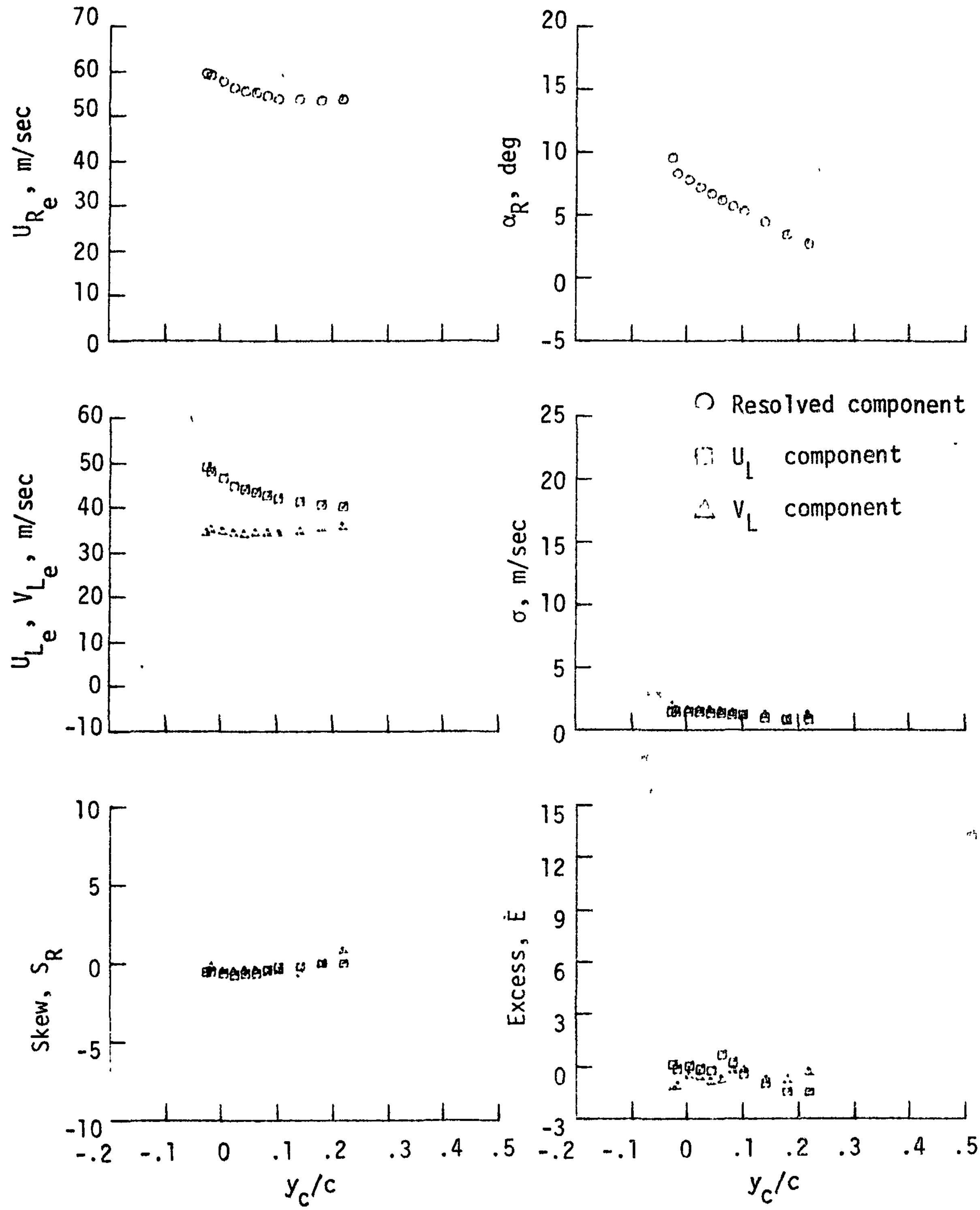



Figure 34. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.12$, $\alpha = 0.6°$.

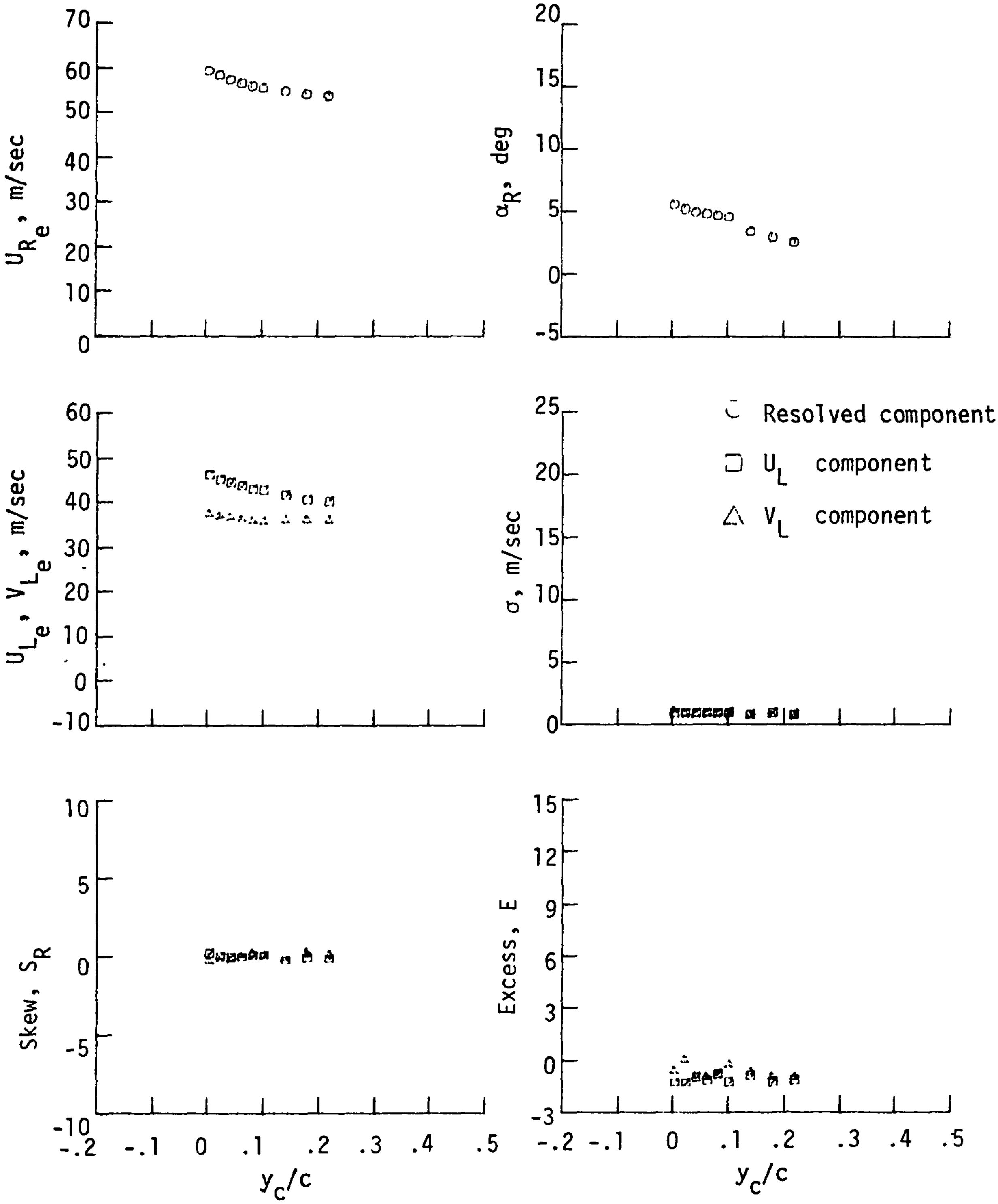



Figure 35. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.16$. $\alpha = 0.6°$.

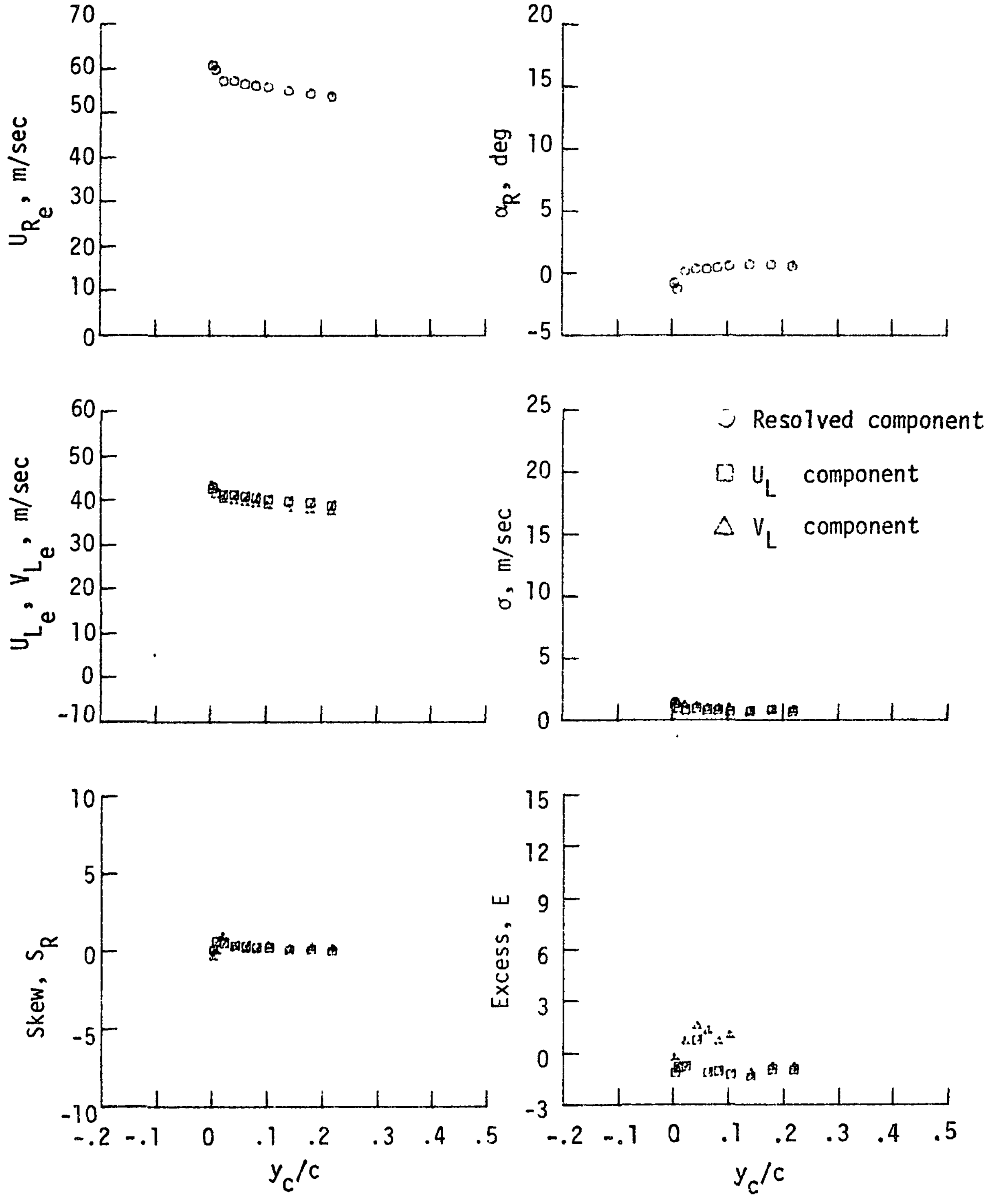



Figure 36. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.29$. $\alpha = 0.6°$.

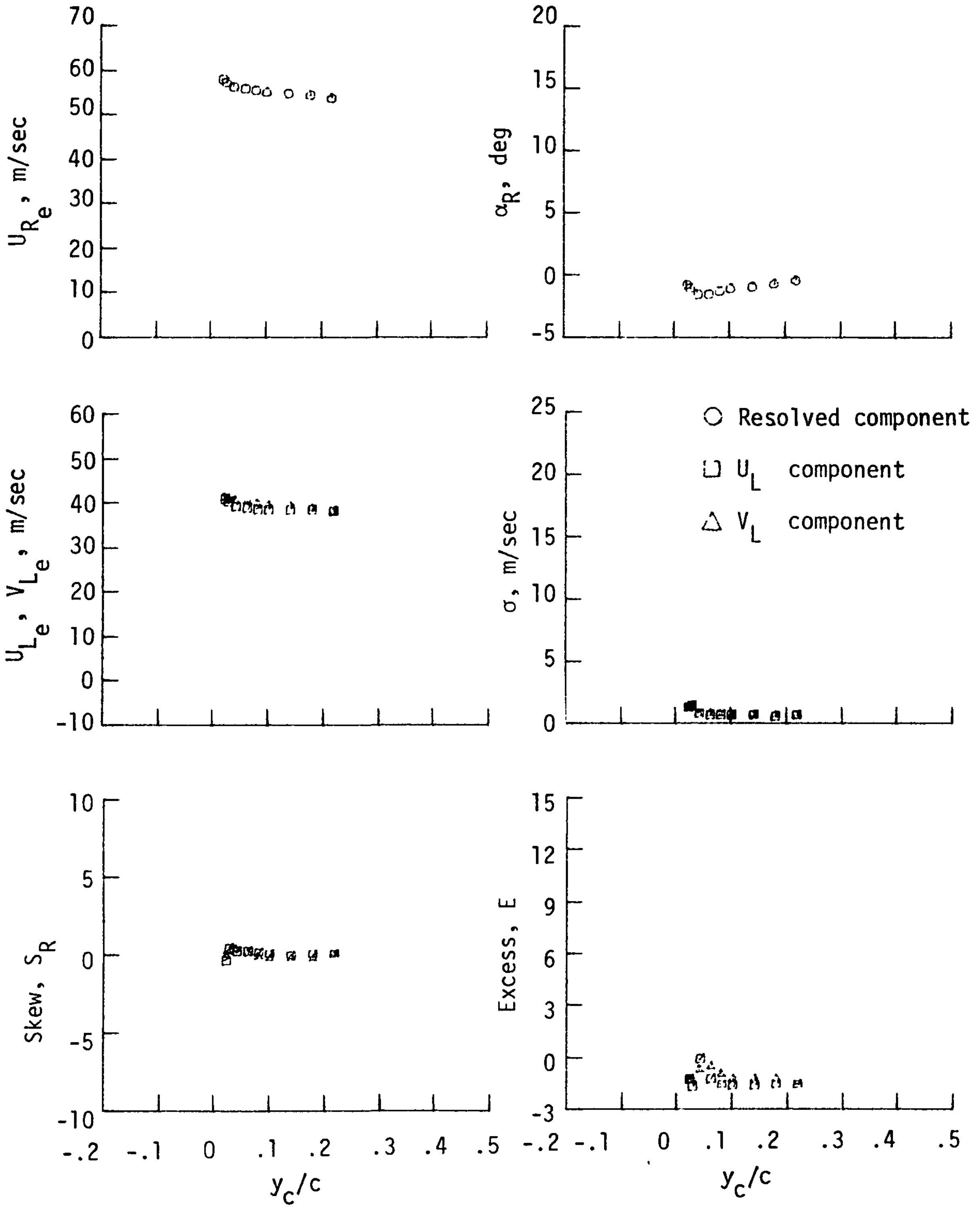



Figure 37. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.41$. $\alpha = 0.6°$.

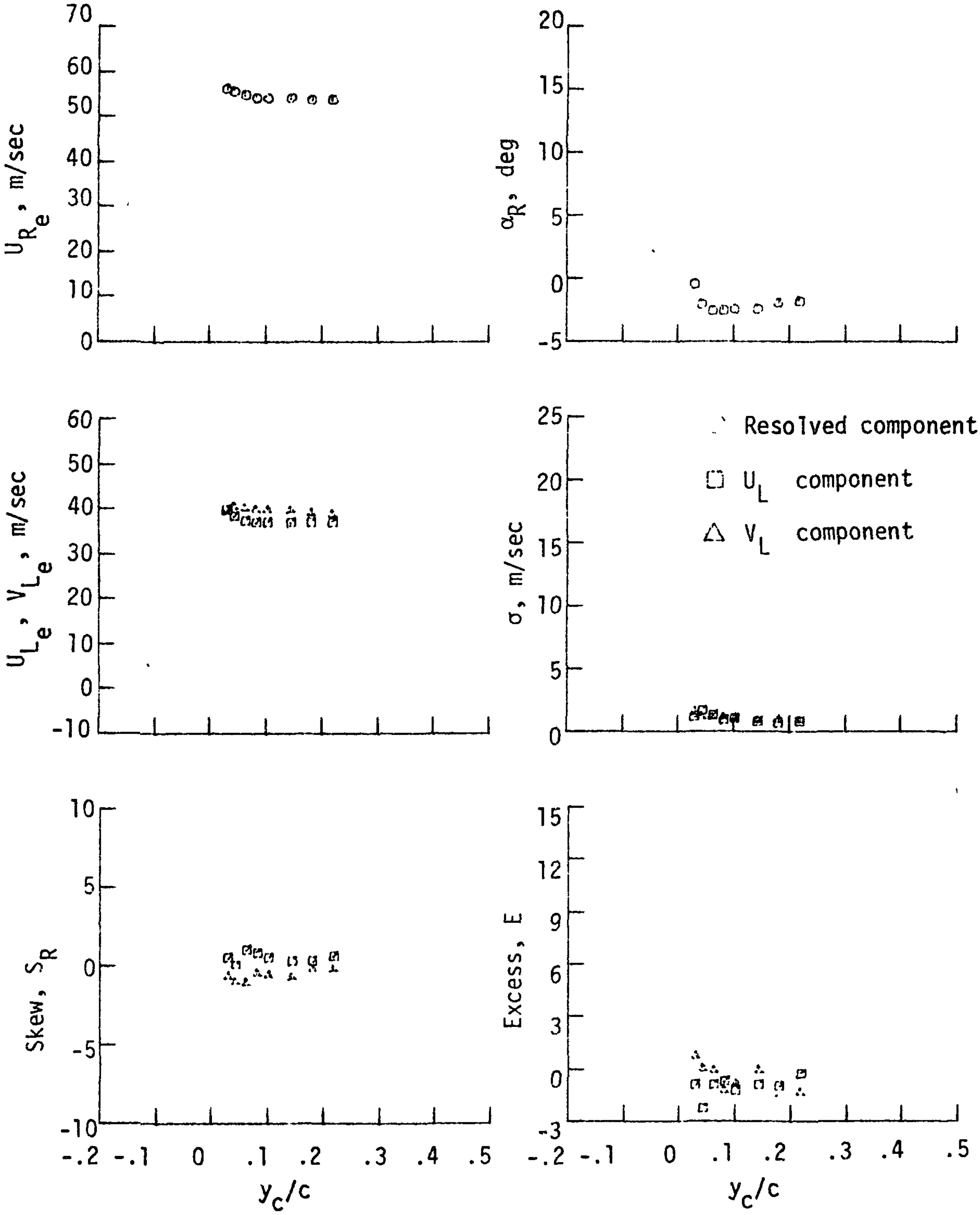



Figure 38. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.58$. $\alpha = 0.6°$.

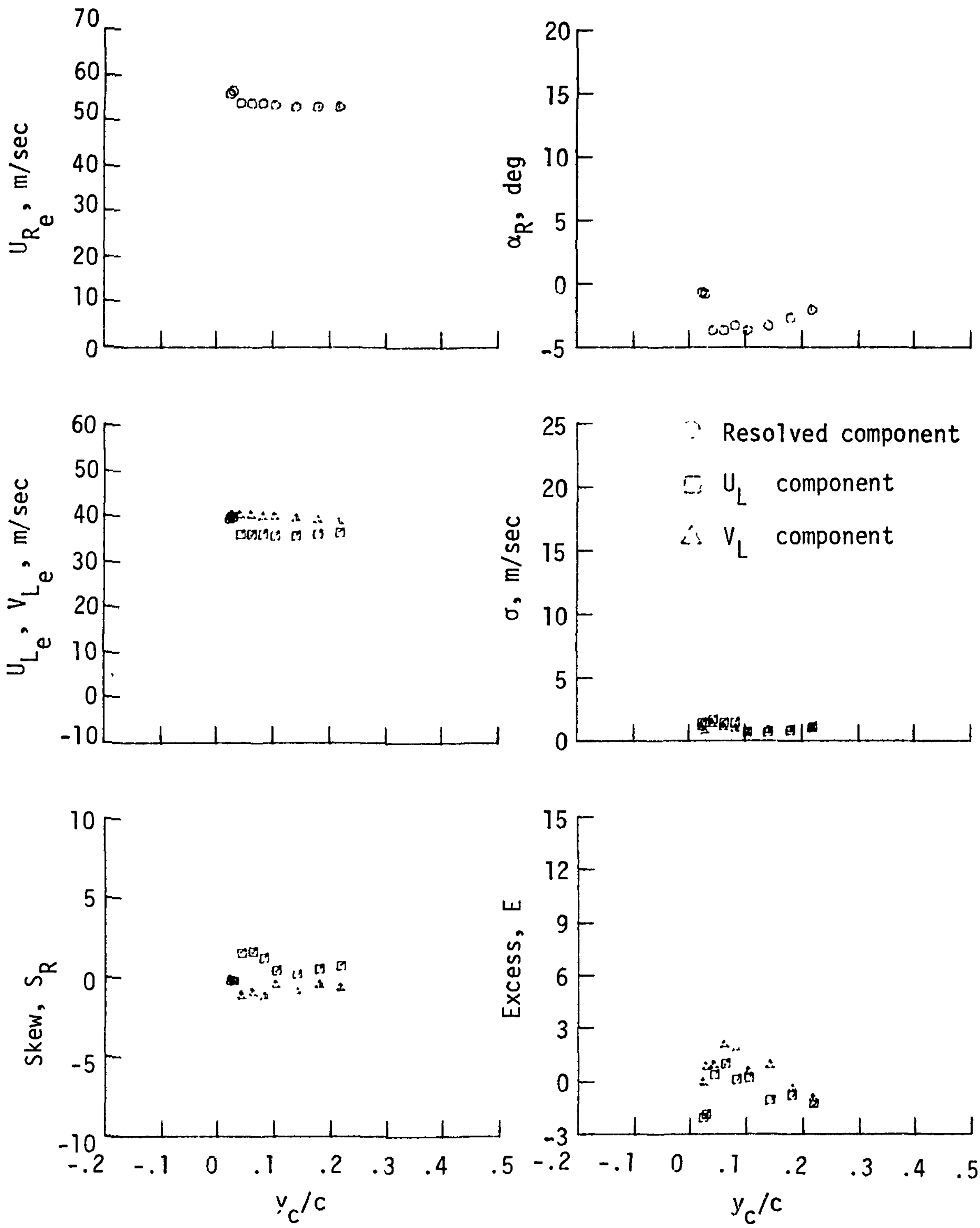



Figure 39. Statistical characteristics of the LV measured velocities at constant $x_c/c = 0.70$. $\alpha = 0.60°$.

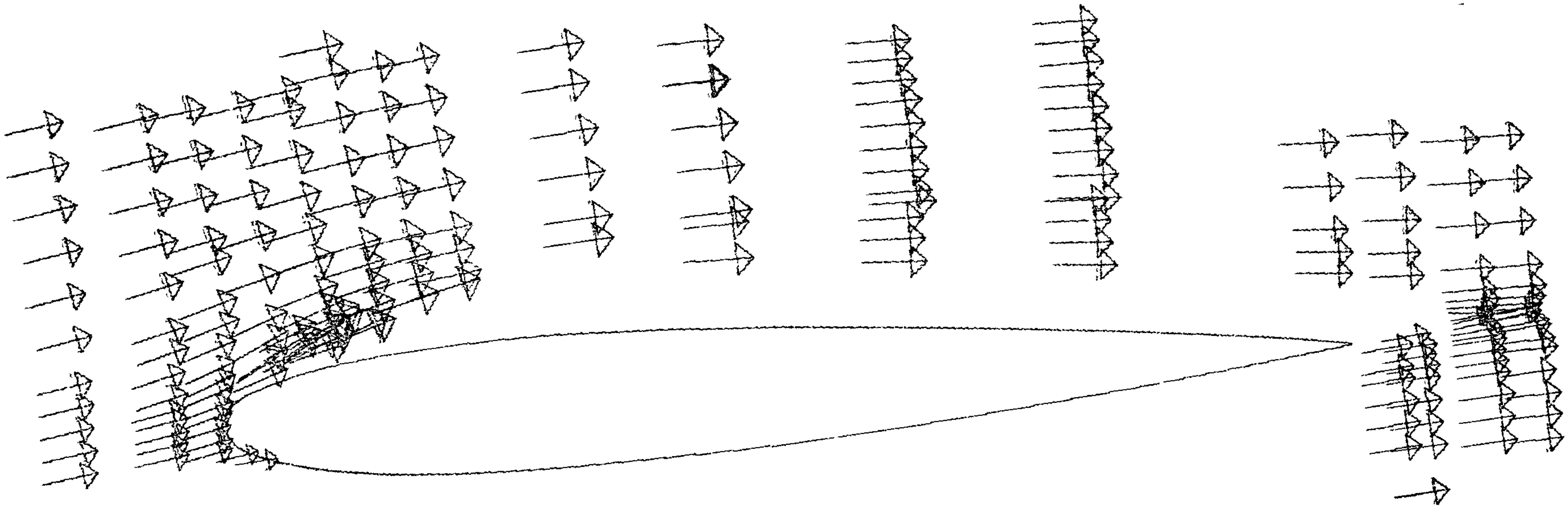


Figure 40.- Velocity vectors computed from measurements over the wing at $\alpha = 4.75^{\circ}$.

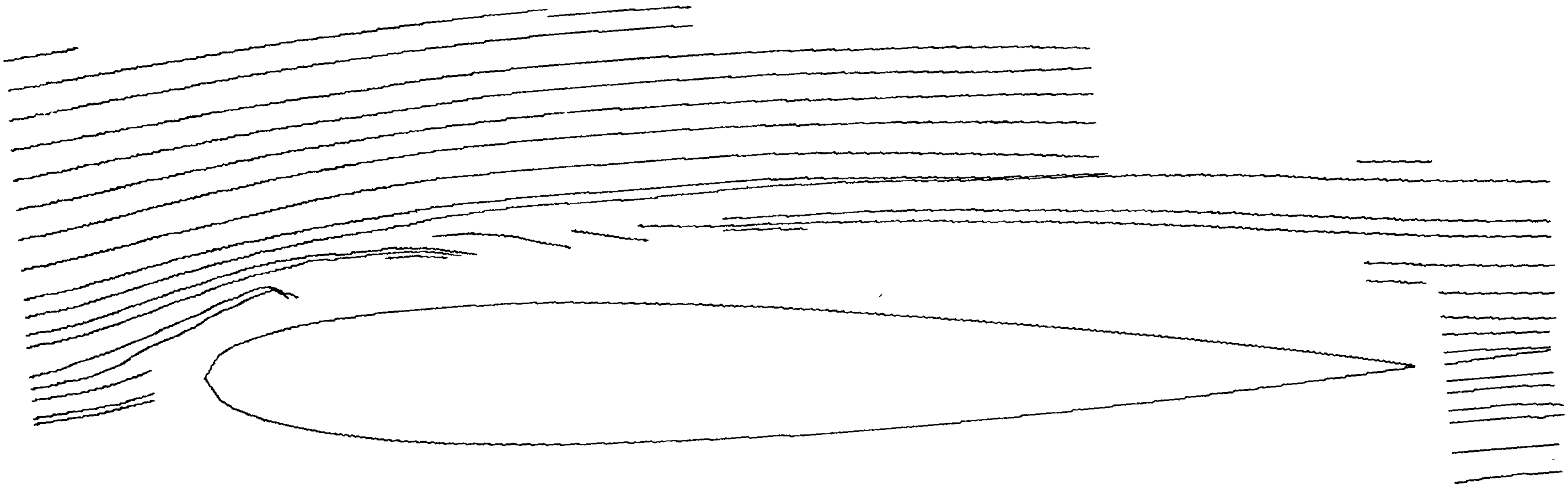


Figure 41.- Streamlines computed from interpolated flow angle distribution over the wing at $\alpha = 4.75^{\circ}$.


Figure 42.- Contours of constant local flow angle measured over the wing at $\alpha = 4.75^0$.

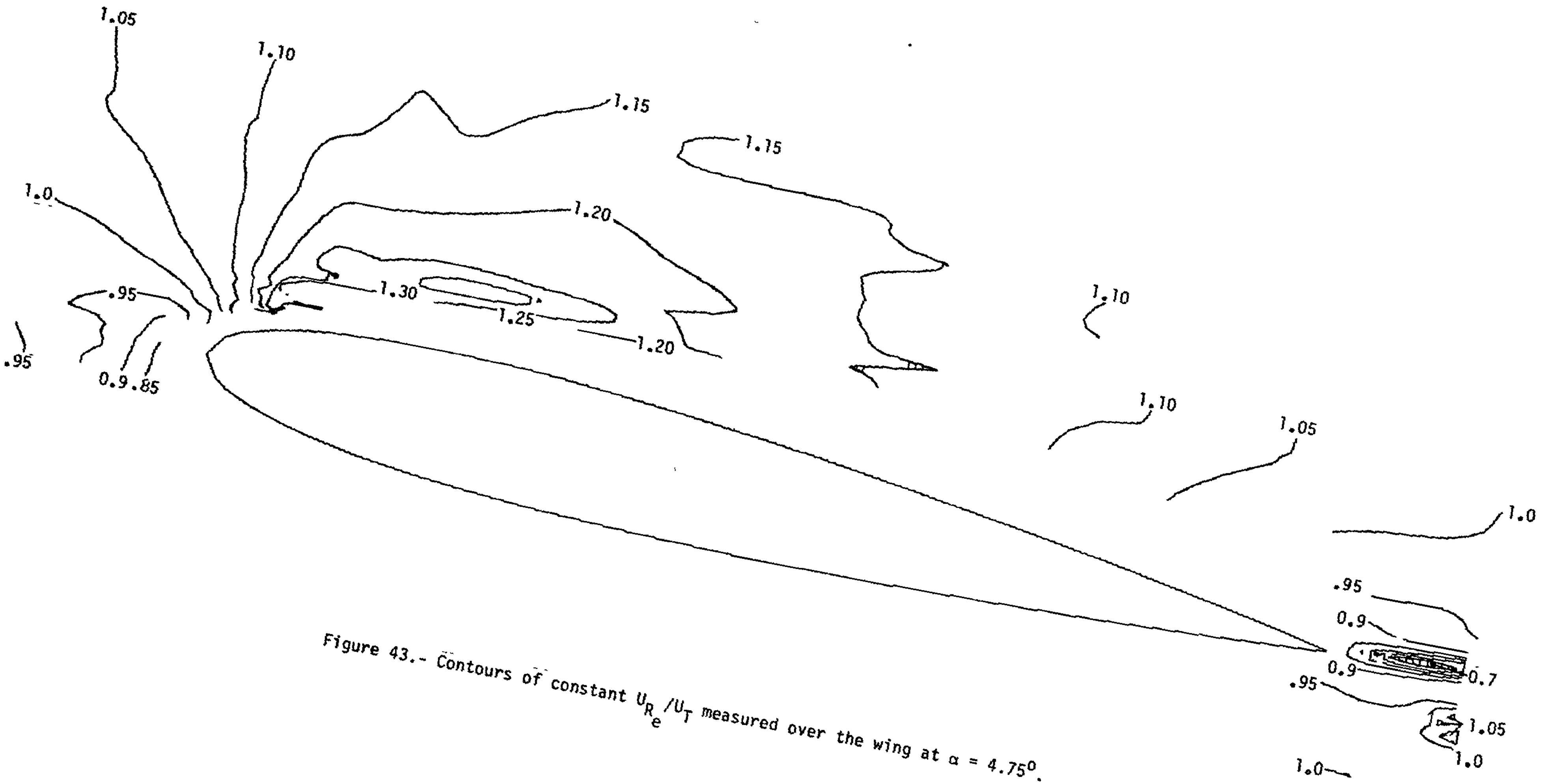



Figure 43.- Contours of constant $U_{R_e}/U_T$ measured over the wing at $\alpha = 4.75^0$.

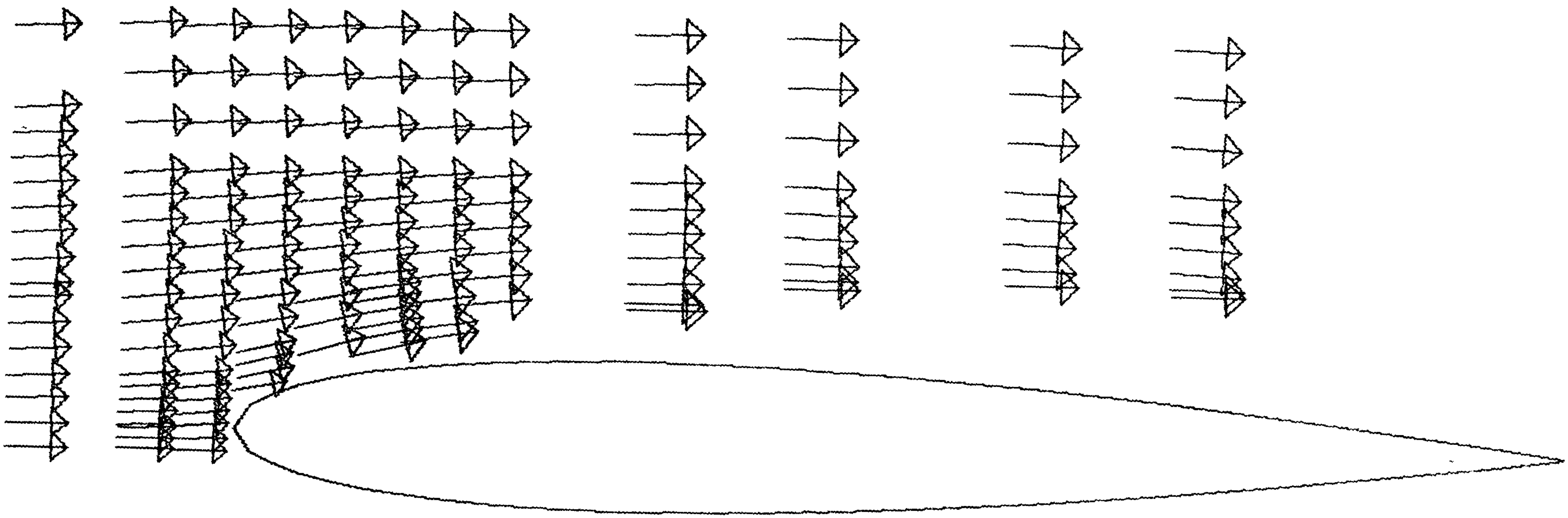


Figure 44.- Velocity vectors computed from measurements over the wing at $\alpha = 0.6^{o}$.

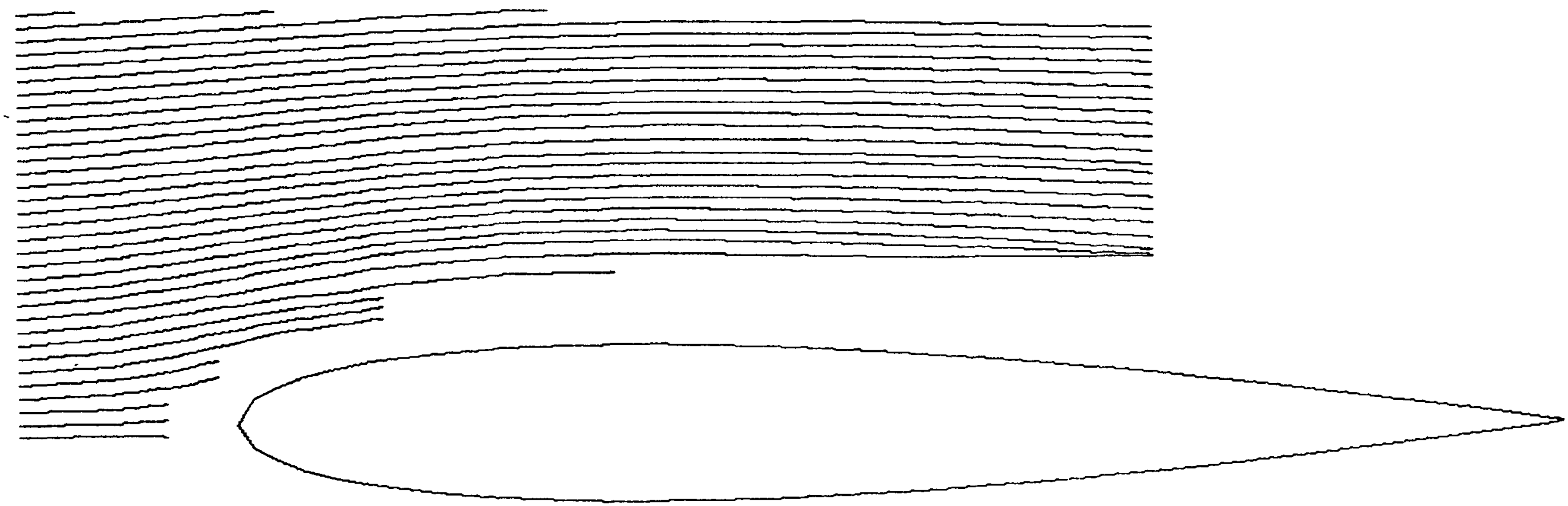


Figure 45.- Streamlines computed from interpolated flow angle distribution over the wing at $\alpha = 0.6^{o}$.

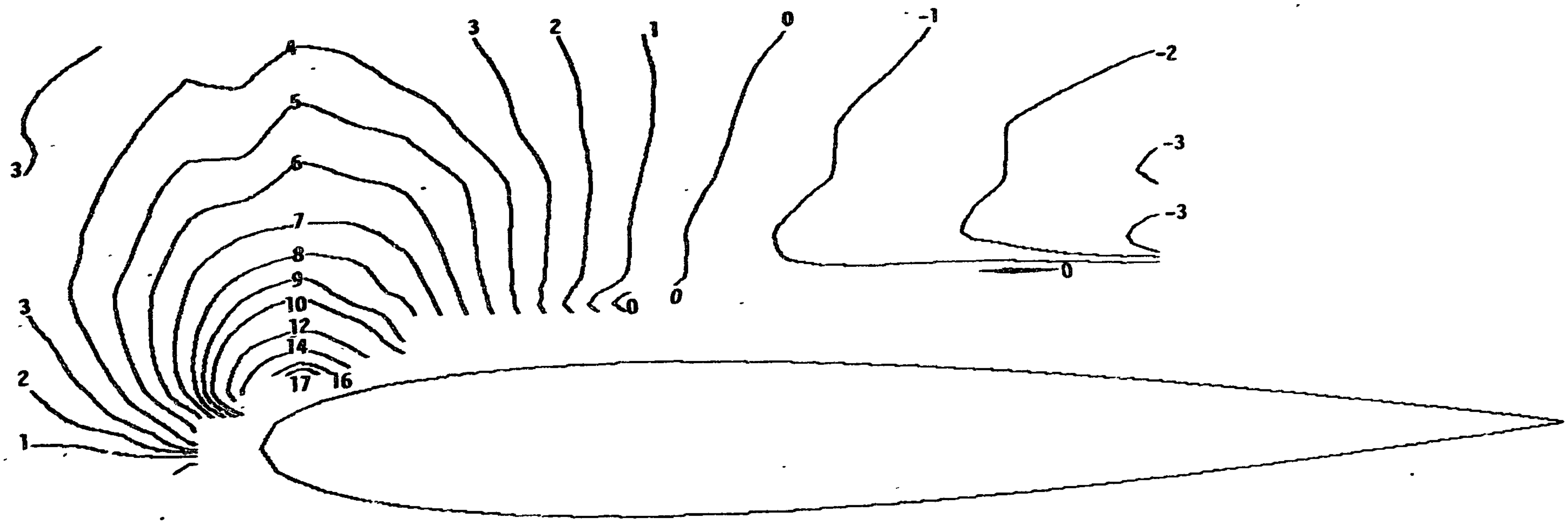



Figure 46.- Contours of constant local flow angle measured over the wing at $\alpha = 0.6^0$.

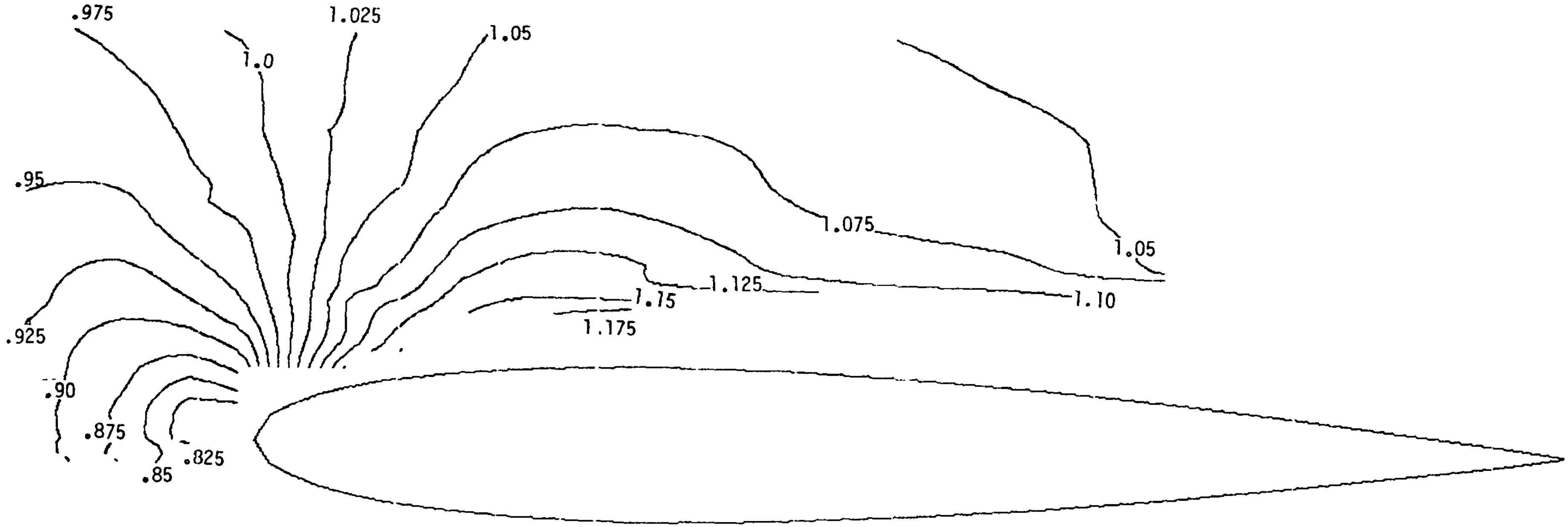



Figure 47.- Contours of constant $U_{R_e}/U_T$ measured over the wing at $\alpha = 0.6^0$.

# APPENDIX A

## A LASER VELOCIMETER BUFFER INTERFACE

By James I. Clemmons, Jr.

The laser velocity buffer interface (LVBI) is an electronic instrument for determining the interarrival times of laser velocimeter (LV) data and for the temporary storage of the LV velocity data and the interarrival time data. Interarrival time is an important parameter which can be used for autocorrelation, or as in this case, used to evaluate an approximate time average for comparison with ensemble average. One or two LV high-speed burst counters provide inputs to the LVBI. The velocity data and interarrival time data are sent to a computer for processing. The computer also provides various controls for the proper operation of the interface.

General purpose computers do not have the hardware or software capability for determining the interarrival times of LV data at a rate of 1 million measurements per second. Also, few if any, general purpose computers can input data at a high enough rate and not impair the functioning of the two-component LV. The LVBI has two data acquisition channels each independently capable of receiving data at a rate of up to 1 million velocity measurements per second and determining the interarrival time between successive measurements. Each data acquisition channel has its own data storage memory.

A computer program uses the velocity data and the interarrival time data to produce a history of the velocity of the tunnel flow and to produce a power spectra analysis of the flow at the points of observation (ref. 12). A program is also used to control the LVBI enabling computer definition of the number of data sets (velocity/interarrival time pair) to be acquired, control of data transfer from the LVBI to the computer, and the testing of the LVBI. Figure A-1 is a block diagram of the LVBI, Table A-1 gives the specifications for the LVBI and figure A-2 shows how a typical data set is stored in memory.

### CIRCUIT DESCRIPTION

The LVBI has two major divisions: the data acquisition circuits and the computer interface circuits. There may be two data acquisition circuits (two-channel operation) each having its own interarrival time circuit, memory, and necessary control circuits. The computer interface circuitry serves both data acquisition circuits (fig. A-1).

## Interarrival Time Circuits

The interarrival time circuit does not directly produce a value of the real time between two successive LV velocity measurements. It instead counts the number of cycles of a very precise square wave reference signal that occur during successive LV velocity measurements. The period of the square wave specifies the resolution to which the interarrival time may be measured. In order to achieve a reasonable resolution at a 1-MHz data rate, a 10-MHz square wave reference is used. The period for 10 MHz is 100 nsec, therefore resolving the 1 MHz data rate interval to one part in ten.

If a 16-bit wide word is used for the transferring of data to the computer and if a single 16-bit word is used for the interarrival time measurement, then the maximum interarrival time that could be measured is $(2^{16} - 1) \times (100\ \text{nsec})$ or 65,535 x 100 nsec or 6.5535 msec. If two 16-bit words were used for the interarrival time measurement then the maximum interarrival time that could be measured is $(2^{32} - 1) \times (100\ \text{nsec})$ or 4,294,967,304 x 100 nsec or 429.4967304 sec. The use of a 32-bit interarrival time data word would require an excessively large memory (4096 46-bit memory), and it would require the transferring of three 16-bit words per data set per data acquisition channel to the computer. In order to solve these problems, the LVBI uses a variable resolution interarrival time circuit allowing the use of a single 16-bit data word for the storage and transfer of the interarrival time. As previously discussed, a 16-bit interarrival time data word will alow time measurement to 6.5535 msec when using a 10-MHz reference signal. If a 1-MHz signal were used, then a time measurement to 65.535 msec could be made with a resolution of 1 μsec, and if a 100-KHz reference signal were used, then the maximum time measurement would be 655.35 msec with a resolution of 10 μsec. The change in the reference signal is noted by generating a 2-bit reference signal status ($\Delta t$ status). These two bits may be stored with the 14-bit LV velocity data making up a 16-bit-wide data word (fig. A-2).

The interarrival time circuit thus consists of a 16-bit $(2^{16} - 1)$ binary cycle counter, a 2-bit binary reference signal status counter, and controls (fig. A-3). The counters are started by a data ready signal from the LV high-speed burst counter. If the interarrival time being measured is less than 6.5535 msec, the resultant cycle and the 2-bit status ($00_2$) is stored into the memory along with the LV velocity data. During data reduction, the computer will multiply the cycle count by the resolution indicated by the status bits ($00_2$), 100 nsec in this case, to obtain the real-time value.

If the interarrival time exceeds 6.5535 msec, the 16-bit cycle counter overflows, incrementing the 2-bit status counter ($01_2$). The overflow also switches the reference signal to 1 MHz and a correction value of 6553 is loaded into the interarrival time 16-bit cycle counter. The correction value adjusts the counter to the count which would have occurred had the 1-MHz reference signal been used from the beginning of the interval. The worse-case error when using the 1-MHz reference signal is one part in 6553.

Should the cycle counter overflow again, the status counter is incremented ($10_2$), the 100-KHz reference signal is switched in, the correction value of 6553 is loaded into the cycle counter, and counting resumes. If an additional overflow occurs, the status counter is incremented ($11_2$), and the cycle counter is filled with zeroes. Either the cycle count, now zero, or the status information ($11_2$) may be used to indicate that the interarrival time was greater than 655.35 msec and that the interarrival time cannot be computed. A subsequent data ready will reset the status counter to zero ($00_2$) and switch the reference to 10-MHz allowing normal operation. All calculations involving power spectra will be resumed with this new count.

## Data Storage Circuits

The data storage circuits consists of a 4096 x 32-bit memory. The semiconductor memory circuits used allow data to be stored or retrieved in 250 nsec assuring the high-speed operation of the LVBI.

Memory address, the location in memory where data will be stored or retrieved, is generated by a 12-bit ($2^{12}$) binary counter (fig. A-4). During the data acquisition phase, the entire data set (velocity and interarrival time data) is stored simultaneously, and the address counter is incremented awaiting the next data set. The address counter is usually set to zero at the beginning of the data acquisition phase, but it may be set to any desired value by the computer.

The last memory location into which data is stored or retrieved is set by the computer. This information is stored in the last address latch. Continuous comparison is made between the memory address and the last address and when a true comparison is made the data acquisition is terminated and the computer is flagged.

## Computer Interface Circuit

The LVBI communicates with the computer vis two-computer input/output (I/O) channels. Each channel has a 16-bit wide input bus and a 16-bit wide output bus. The first channel is the control/status channel over which the computer sends all major control commands to the LVBI and the LVBI returns information on its status. The data portion of the control commands and the LV velocity/interarrival time data stored in the LVBI memory are transferred over the second channel, the data channel. Stored LVBI data are always transferred to the computer in an LV velocity-interarrival time status/interarrival time data word sequence beginning and ending at the memory address as defined by the computer software. Data from a single data acquisition channel may be transferred or data from both data acquisition channels, in a channel 1/channel 2 sequence, may be transferred. Table A-II gives a listing of the various functions of the two computer I/O channels and figure A-5 is a detailed block diagram of the LVBI.

## TABLE A-I -LVBI SPECIFICATIONS

| | |
|---|---|
| LV data acquisition rates: | 1 million data words/second/LV component<br>14 bits (10-bit mantissa, 4-bit exponent;<br>2-bit LV counter mode information (not stored)) |
| Interarrival time measured: | 1 microsecond to 655.35 milliseconds |
| Interarrival time resolution: | 1 μsec to 6.5535 msec; 100 nsec resolution<br>6.5535 msec to 65.535 msec; 1 μsec resolution<br>65.535 msec to 655.35 msec; 10 μsec resolution |
| Interarrival time data word: | 18 bits (16 bits time data, 2-bit status) |
| Data storage: | 4096 32-bit data sets (LV velocity, Δt, Δt status) per data acquisition channel |
| Computer interface | 16-bit data I/O (input/output)<br>16-bit control I/O |
| Data transfer rate: | 1 million 16-bit data or control words/second |

Operational specifications:

Software - computer definition of:
- first data storage location in memory
- last data storage location in memory
- time alloted for LV data acquisition (0 to 9 minutes, 59 seconds; 1 second resolution)
- data for memory diagnostic tests

Electronics: Transistor-transistor logic (TTL), Schottky and low-power Schottky TTL integrated circuits except memory.

Memory - 1K static N-channel metal-oxide-semiconductor (NMOS) circuits.

TABLE A-II

LVBI/COMPUTER I/O SPECIFICATIONS

| Control/Status Channel (type of control/status) | Data Channel (Type of data) |
|---|---|
| **Computer to LVBI (Control)** | **Computer to LVBI** |
| Set memory address | Memory address |
| Set last data address | Last data address |
| Set real-time clock | Time |
| Send diagnostic data | Diagnostic data |
| Start data acquisition | No action |
| Stop data acquisition | No action |
| **Computer to LVBI (Control)** | **LVBI to Computer** |
| Send LVBI data to computer | Data |
| Read memory address, channel 1 | Memory address, channel 1 |
| Read memory address, channel 2 | Memory address, channel 2 |
| **LVBI to Computer (Status)** | **LVBI to Computer** |
| Memory full/time limit | No action |
| Channel 1 active | " |
| Channel 2 active | " |
| Channel 1 transferring data | " |
| Channel 2 transferring data | " |
| LV or Δt data being transferred | " |
| LV counters in 5/8 or 10/16 mode | " |
| LV counters in time or velocity mode | " |

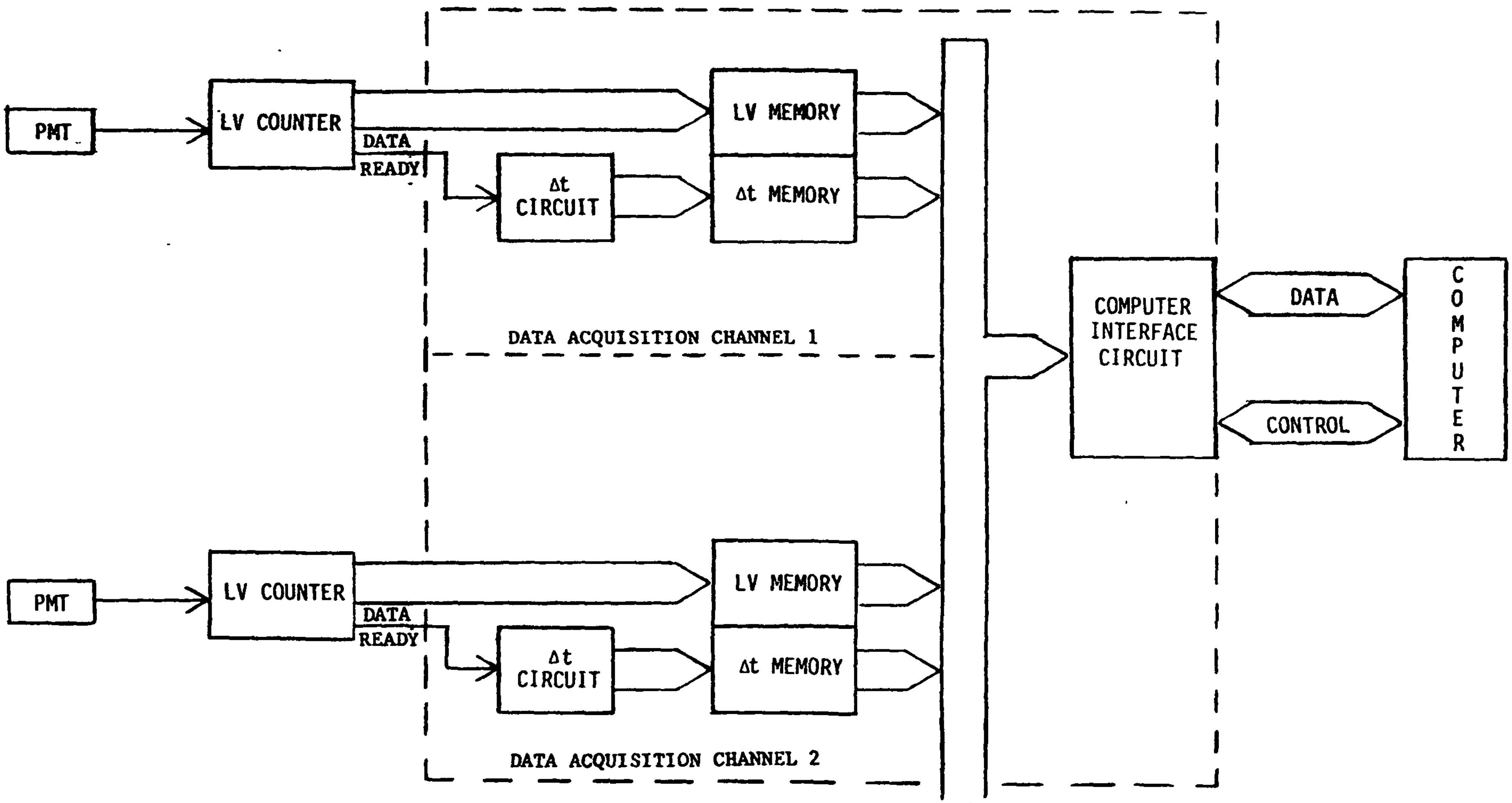



Figure A1. - Laser velocimeter buffer interface (2-component configuration).

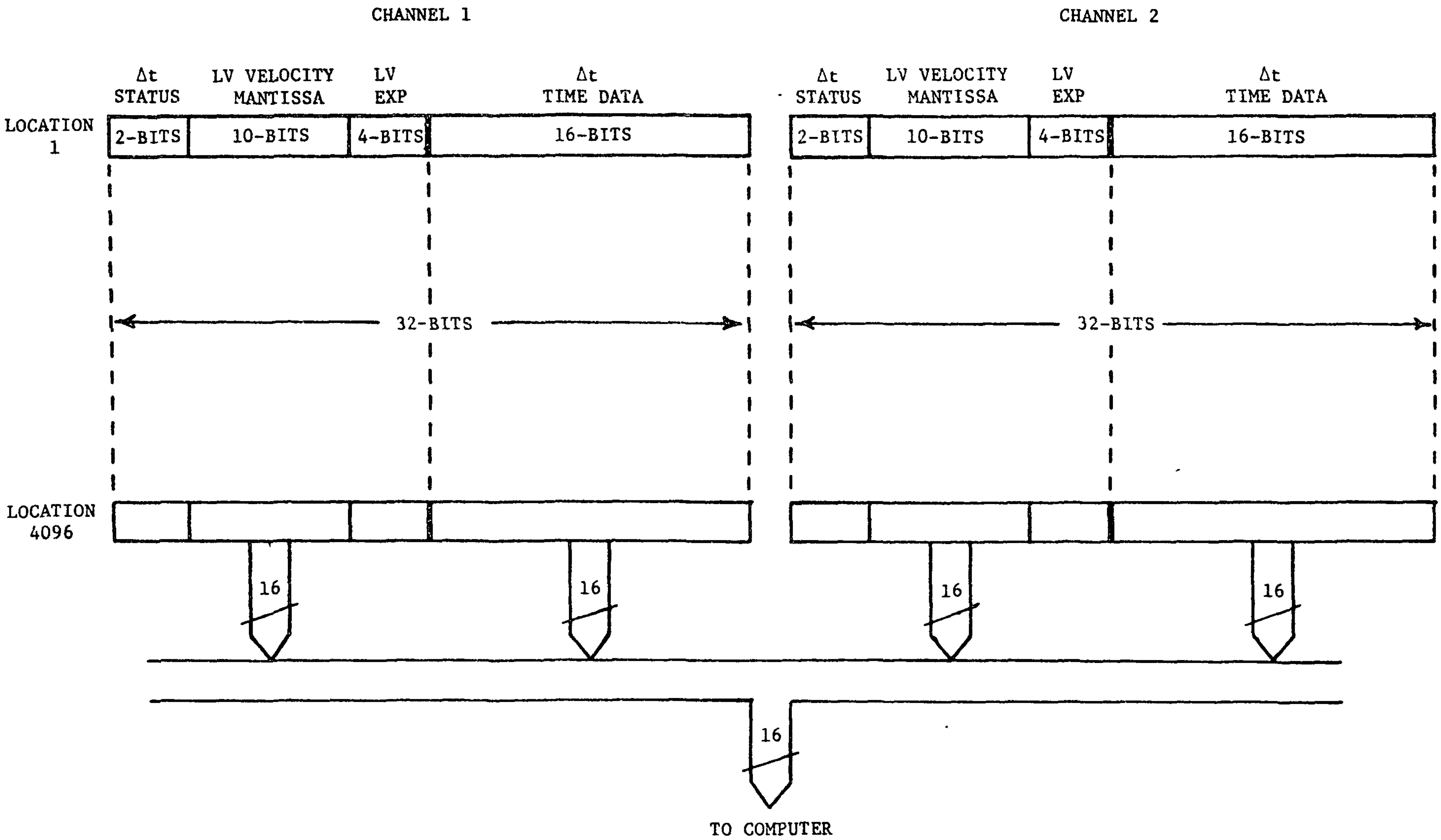



Figure A2.- Data store diagram.

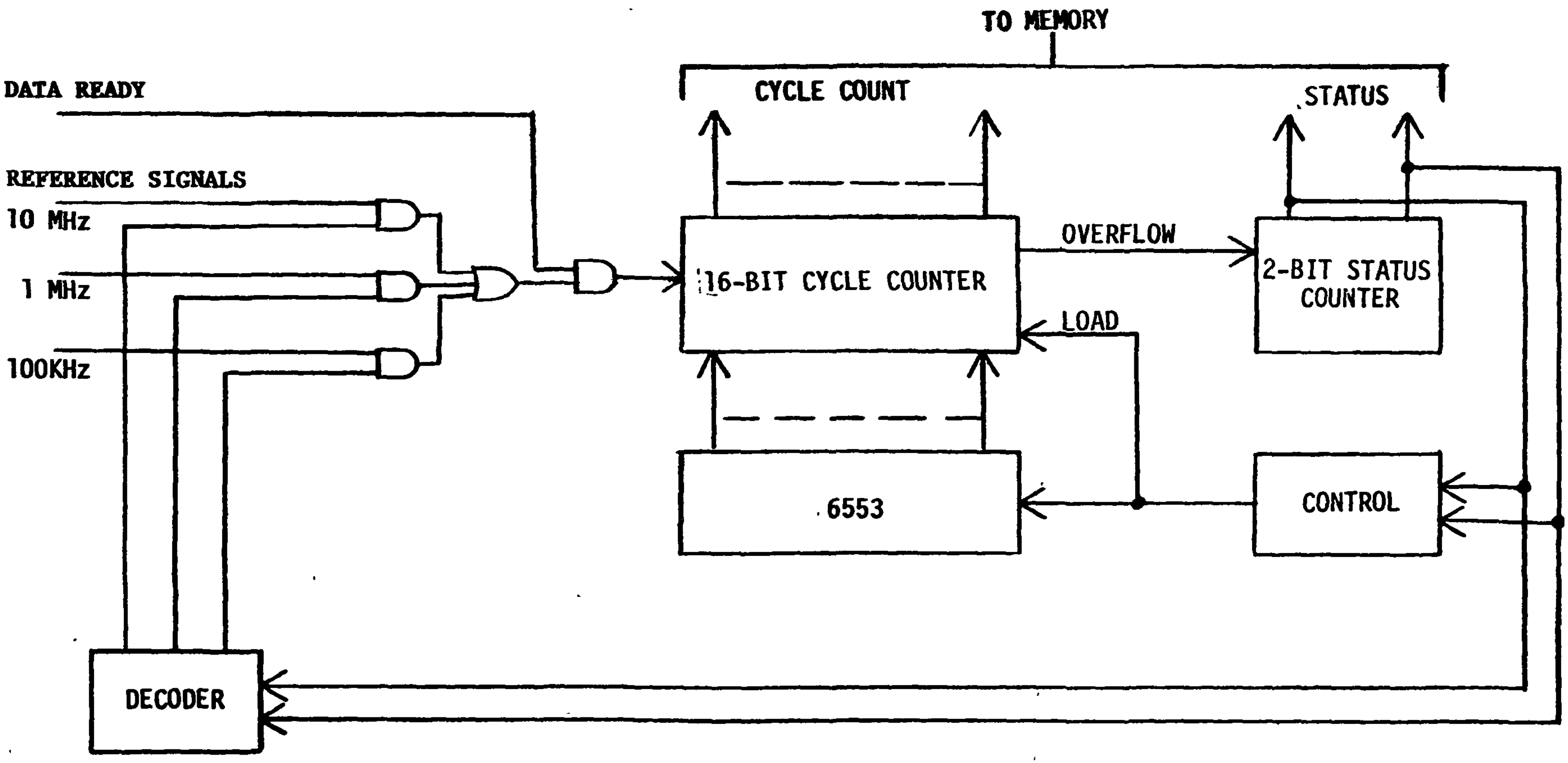



Figure A3.- Interarrival time circuit.

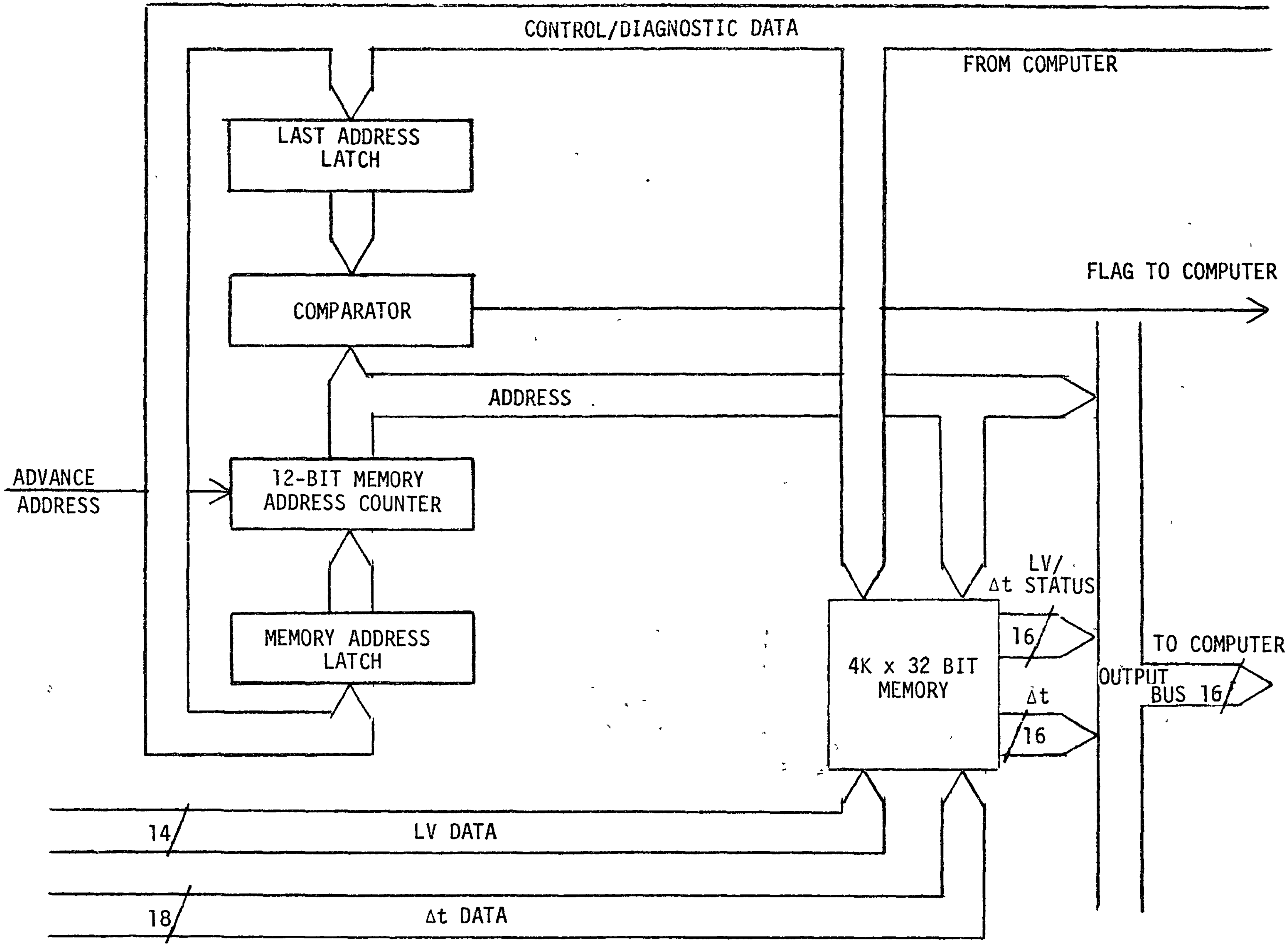



Figure A4. - Data Storage Circuits

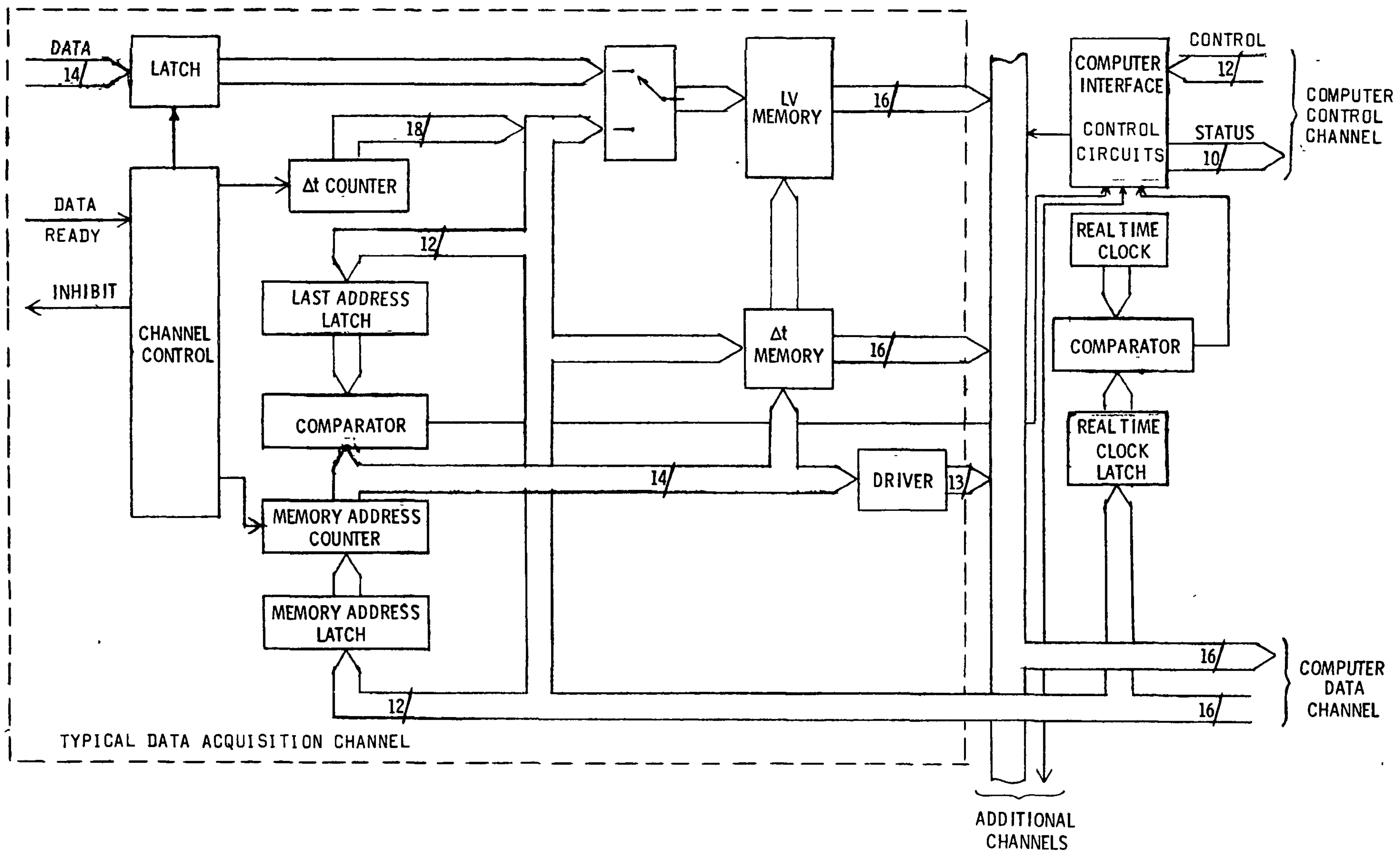



Figure A5. - Laser velocimeter and buffer memory.

# APPENDIX B

## LASER VELOCIMETER HISTOGRAMS WITH INTERPRETATION

The histograms for every data run recorded during this investigation are presented in this appendix. The order of presentation is as follows:

| | Figure |
|---|---|
| Free Stream | B-1 |
| Wing at $\alpha$ = 4.75° | B-2 to B-15 |
| Wing at $\alpha$ = 0.6° | B-16 to B-22 |

Each figure is presented (except free-stream data) with a sketch of the wing cross section with arrows indicating the position, direction, and relative magnitude of the mean velocity vector. A run consisted of an ensemble of data acquired at the position desired. The scan, therefore, is a series of runs at various $y_c/c$ positions at constant chordwise position. The histogram is a graphical representation of the variation of velocity measured over a time period as mentioned in the text. Statistical analysis of each run can be found in corresponding tables.

To interpret the histograms, one must be prepared to consider a velocity measurement not as a single measurement, but as a large number of measurements (ensemble) which is assumed to describe the time-average nature of the flow at the measurement location. Thus, more than just the average velocity can be obtained from the velocity measurements. It is necessary to mention that the LV is not a continuous measurement device such as a hot-wire anemometer but acquires data randomly (Poisson distributed in time) depending upon the rate at which particles of proper size pass through the sample volume. Only when this data rate is continuously large can the system be considered to be quasi-continuous.

The histograms are presented with $C_i$, percentage of that number of measurements within incremental velocity band, as a function of velocity. In all cases, the $U_L$ component is presented on the left and the $V_L$ component on the right.

The method of determining the expected value of the velocity from a histogram is described in the text. The breadth of the histogram provides a means of relative determination on the unsteadiness of the flow. For example, the last two runs in figure B-1 are data for higher tunnel speeds than the first five. These histograms would indicate that the unsteadiness of the flow is greater at higher speeds.

Most of the histograms have a form of being Gaussian in nature indicating that the flow has just as great a probability to fluctuate towards lower velocities as to higher velocities. In some cases, particularly near the leading edge of the wing (see fig. B-4, runs 31-37), the histogram is skewed. A histogram resulting from a random velocity unsteadiness in magnitude would be symmetrical about the peak. However, if a steady velocity were oscillating in angle, skewness in the histogram would result. Consider the measurement direction ±45° to free stream. A steady free-stream flow oscillating in angle would have mean velocity components of magnitude cos 45° in the two measurement directions. A positive oscillation in angle would result in positive deviation from the mean in the -45° histogram. Similarly, the negative oscillation in angle affects the component histograms. Thus, an unsteadiness in flow angle could, if the mean unsteady angle is nonzero, generate the skewed histograms in the measurement directions ±45° to flow direction.

In many situations, a velocity measurement at a point experiences a peculiar phenomenon. If the velocity at a point does not fluctuate randomly, but oscillates between two pronounced velocity values, a so-called double-peaked histogram will occur. (See figs. B-4, B-5, B-6, and B-7, runs 37, 50-53, 63-68, and 78-79, respectively.) These double-peaked histograms indicate that for a large percentage of the time the velocities are centered about one velocity, and at other times they are centered at another velocity. This unexpected phenomenon, at least for the wing at $\alpha = 4.75°$, is discussed fully in the text.

An intuitive confidence in the velocity measurement can be obtained by analysis of the histograms. If the histogram generated is a well-defined shape (whatever it may be), then one may consider that there is a sufficient number of samples in the ensemble to obtain a reasonable measure of the velocity characteristics. However, if the histogram is very ragged (see fig. B-15, runs 190, 191, and 192), it can be very difficult to associate a great detail of confidence in the statistical parameters calculated from such an ensemble. In these cases, however, realizing that the measurements were obtained very close together in space, the mean velocity calculations are reasonable.

The statistical parameters calculated from these histograms are presented in: Table 2 for the free-stream condition; Table 3 for the wing at $\alpha = 4.75°$; and Table 4 for the wing at $\alpha = 0.6°$.

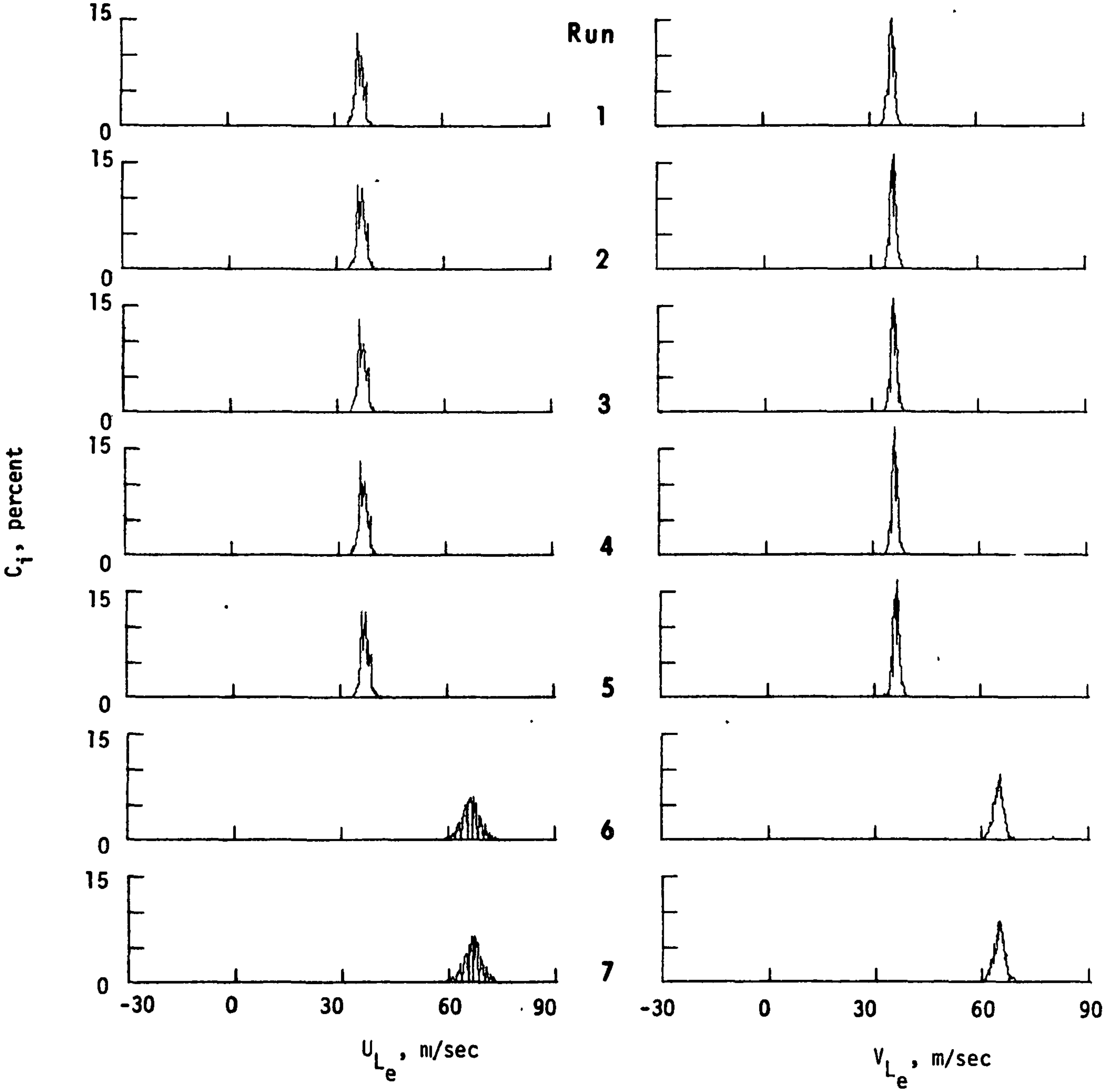



Figure B-1.- Histograms for free-stream measurements.

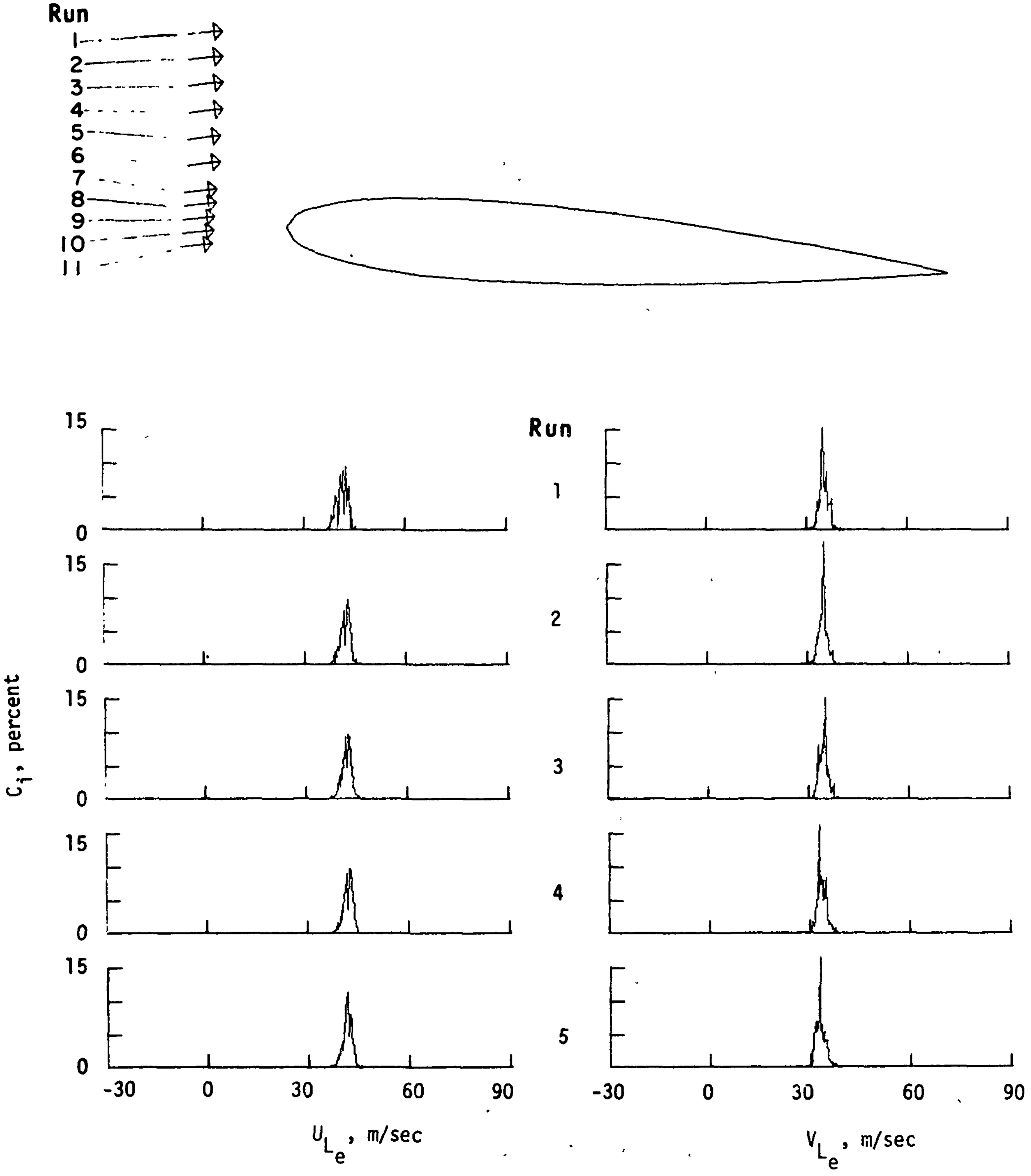



Figure B-2.- Histograms in scan at constant $x_c/c = -0.16$, $\alpha = 4.75^0$.

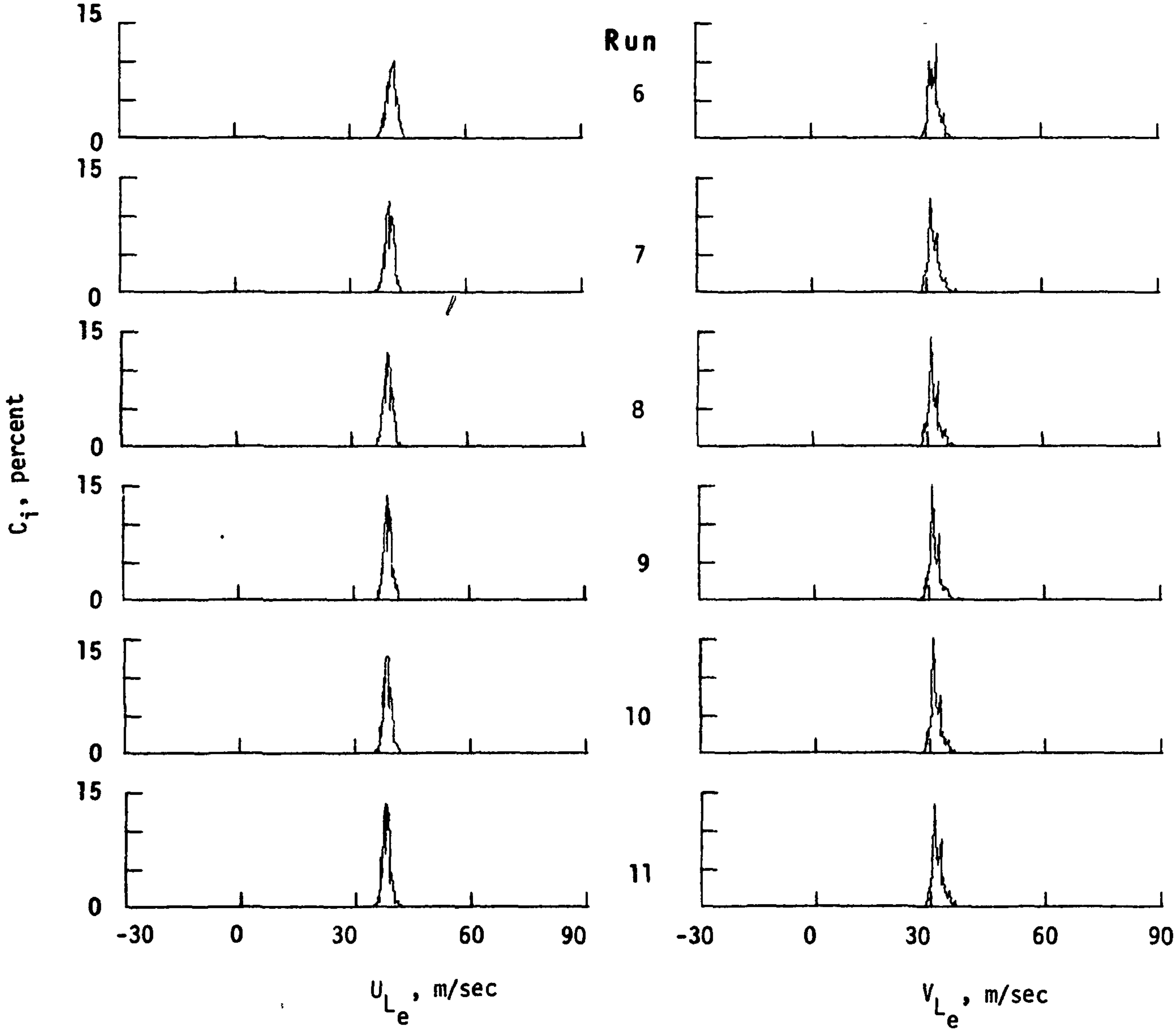



Figure B-2.- Concluded.

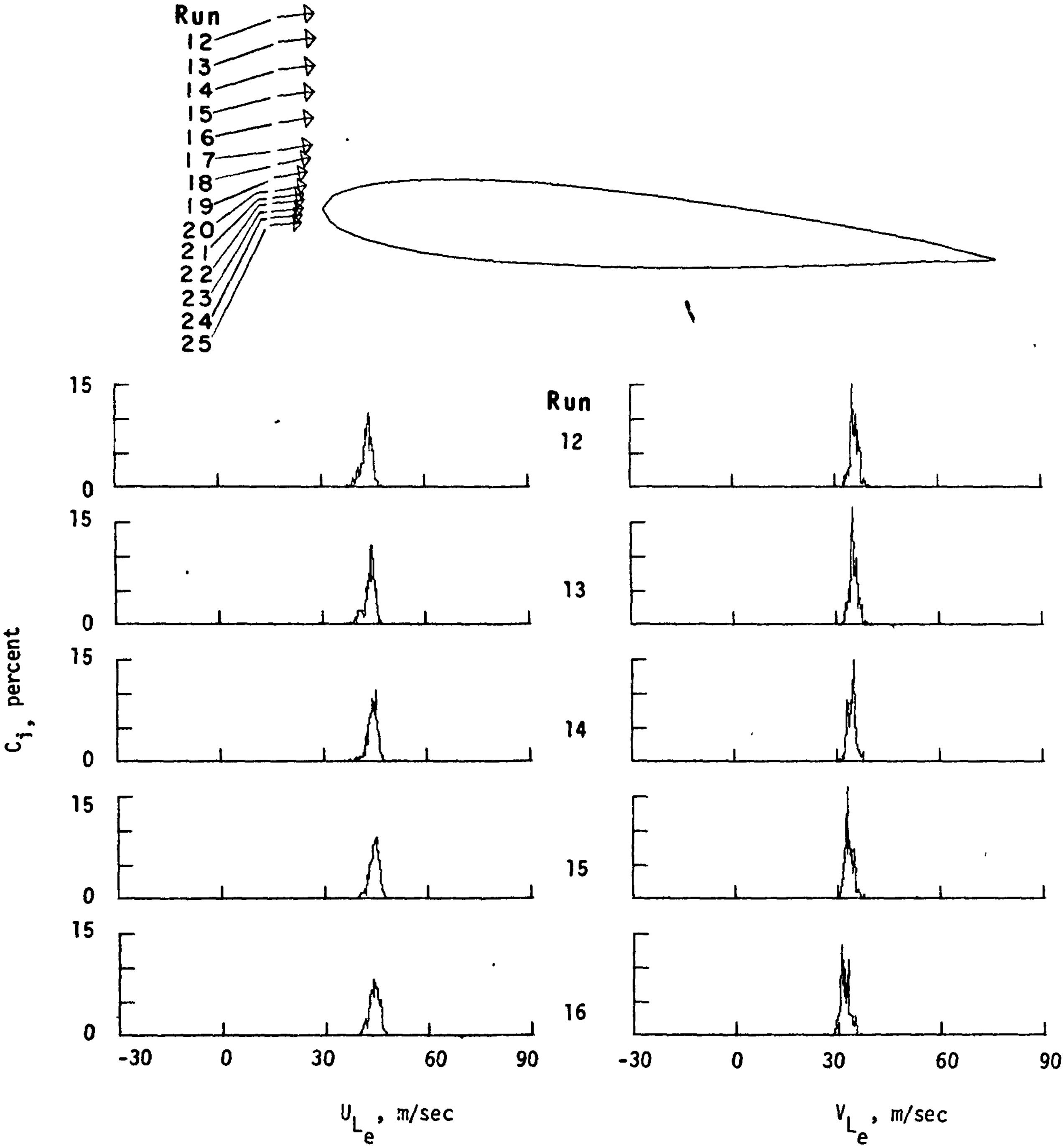
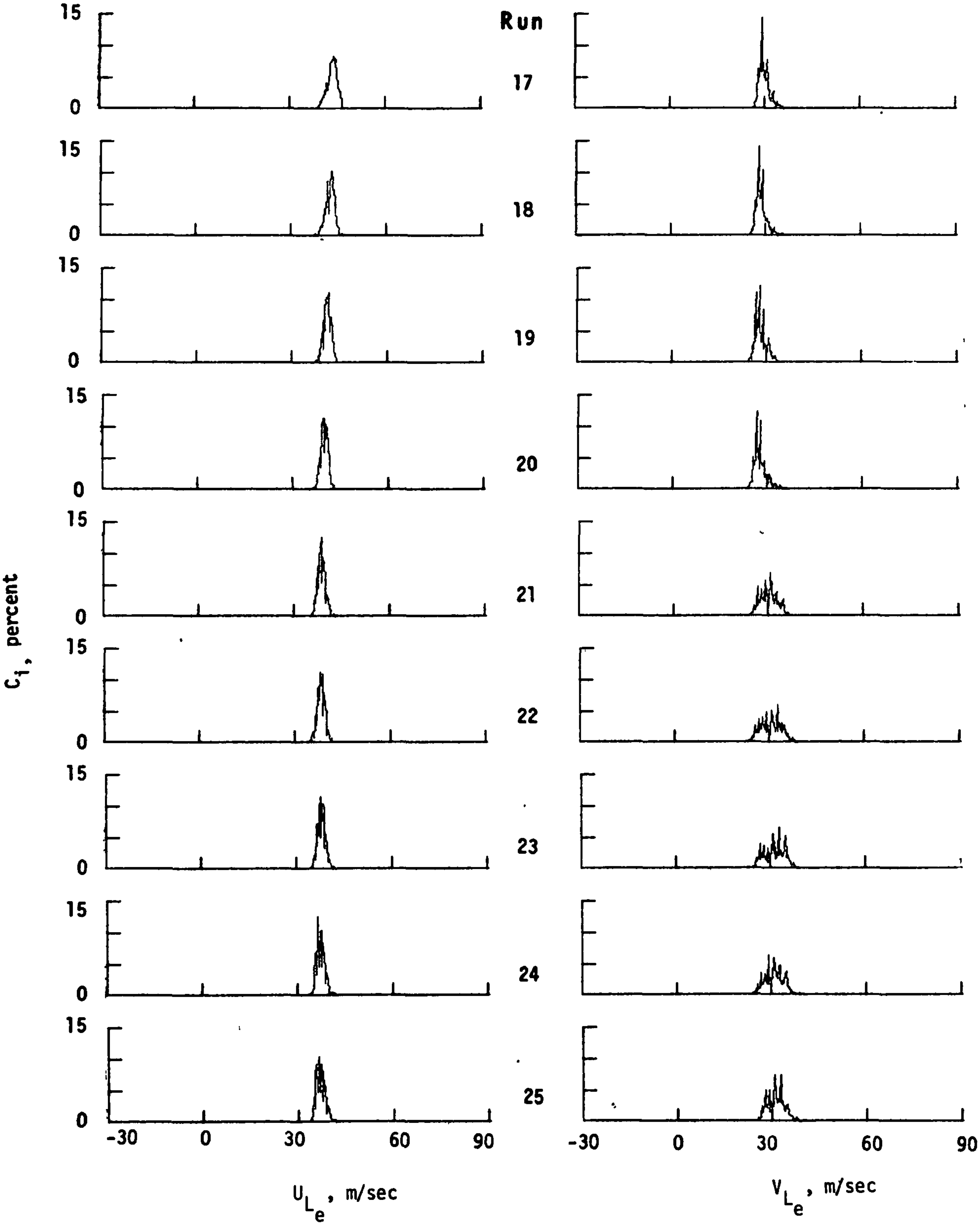



Figure B-3.- Histograms in scan at constant $x_c/c = -0.08$, $\alpha = 4.75^0$.

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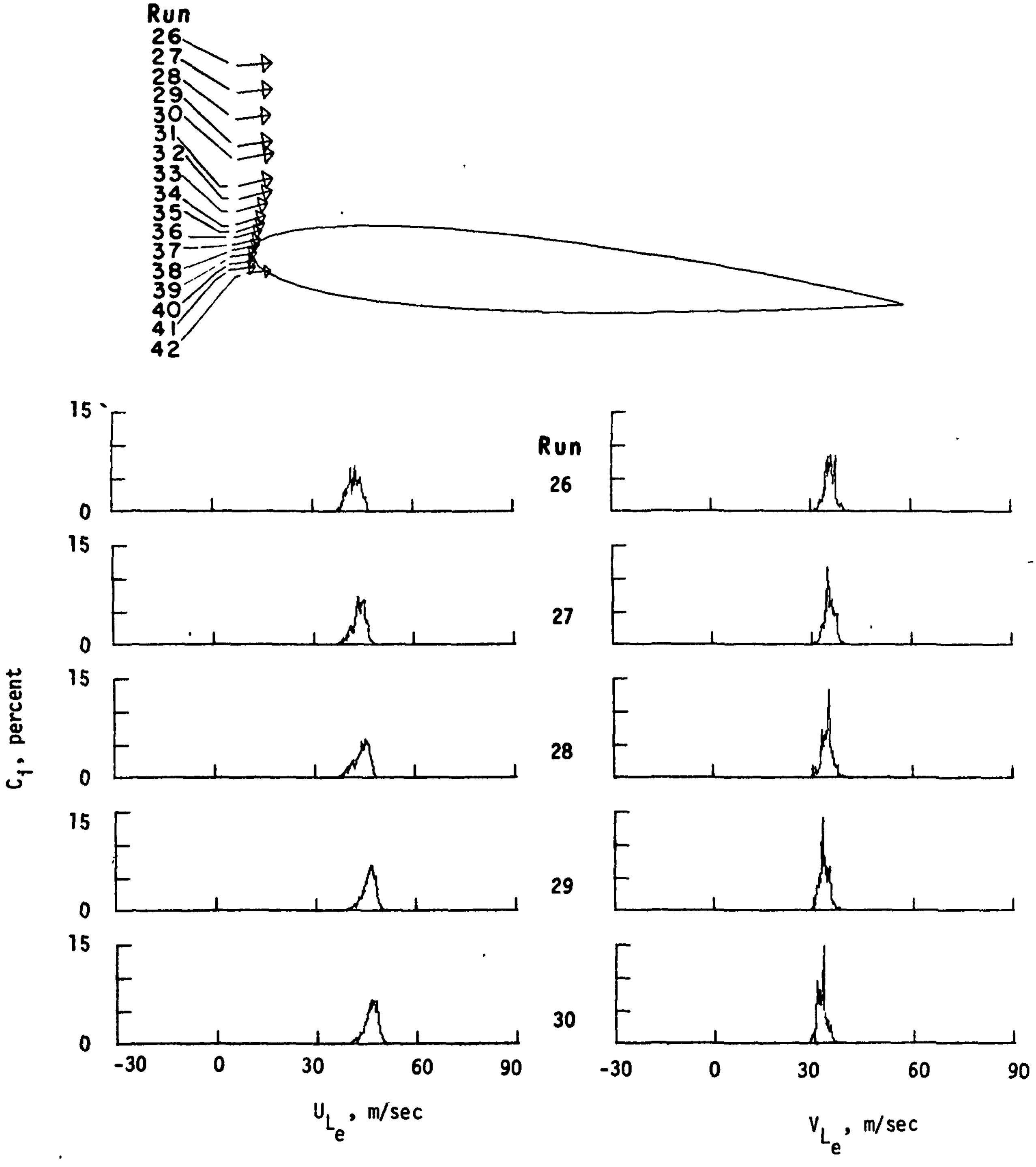
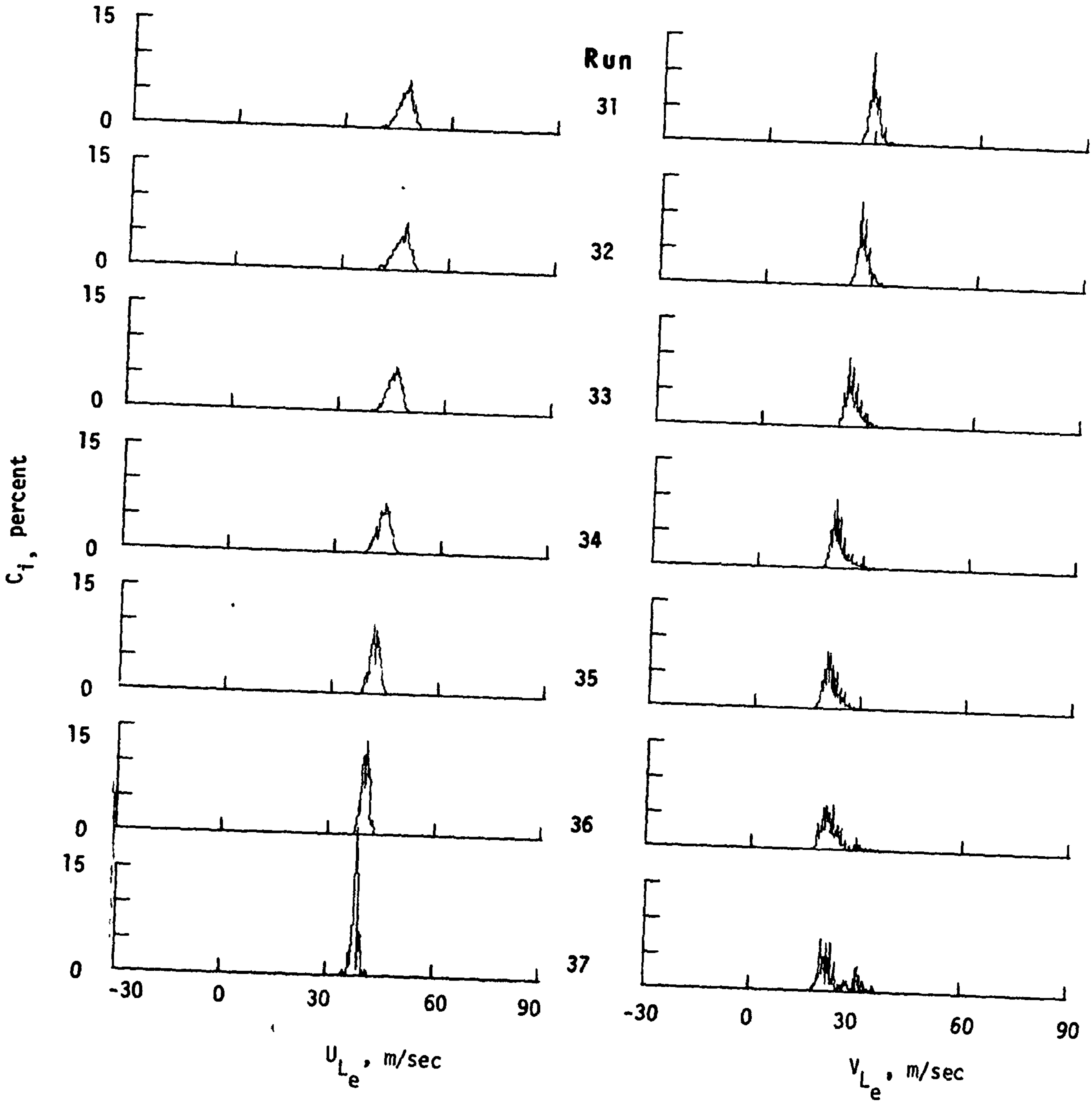



Figure B-4.- Histograms in scan at constant $x_c/c = -0.04$, $\alpha = 4.75^{0}$.

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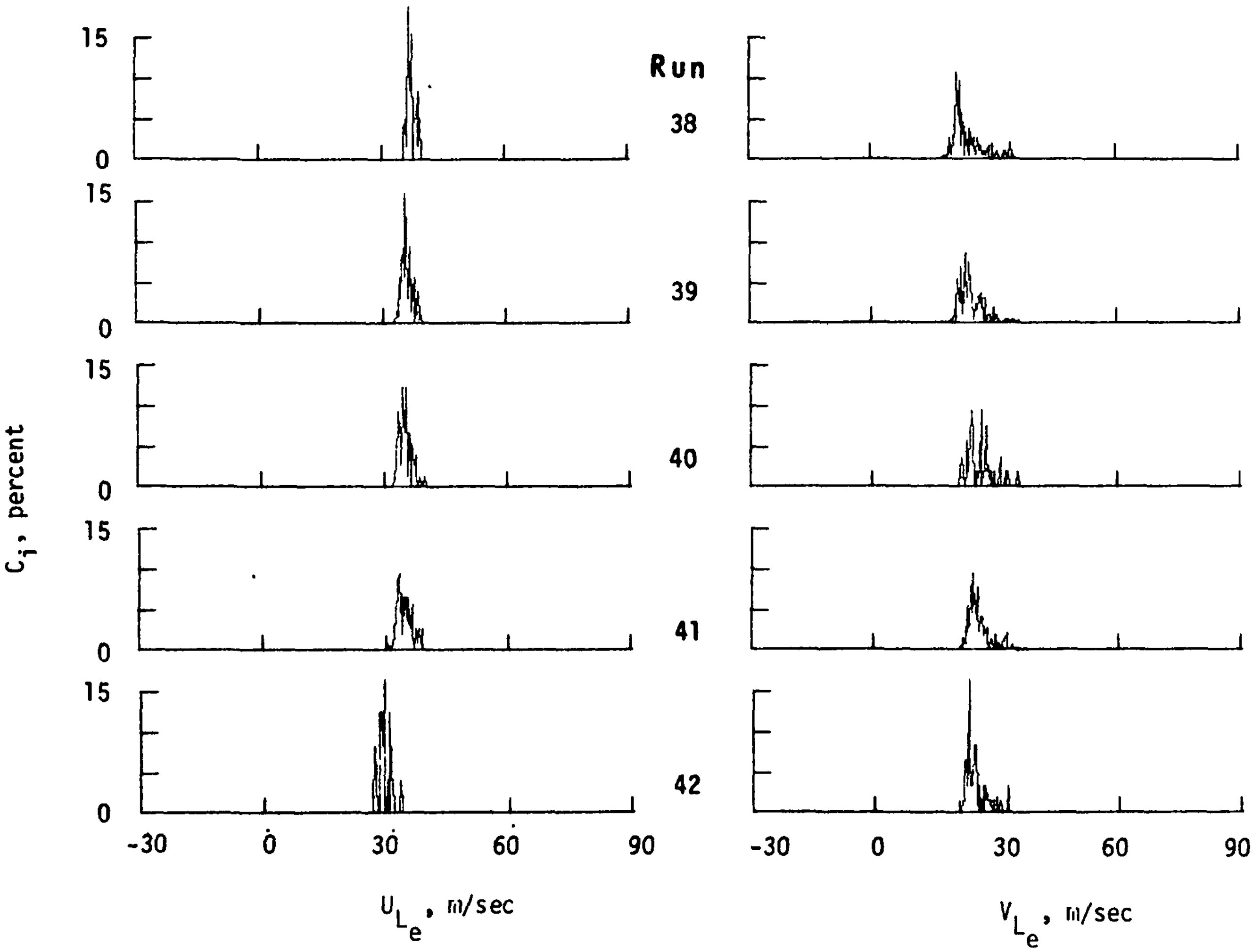


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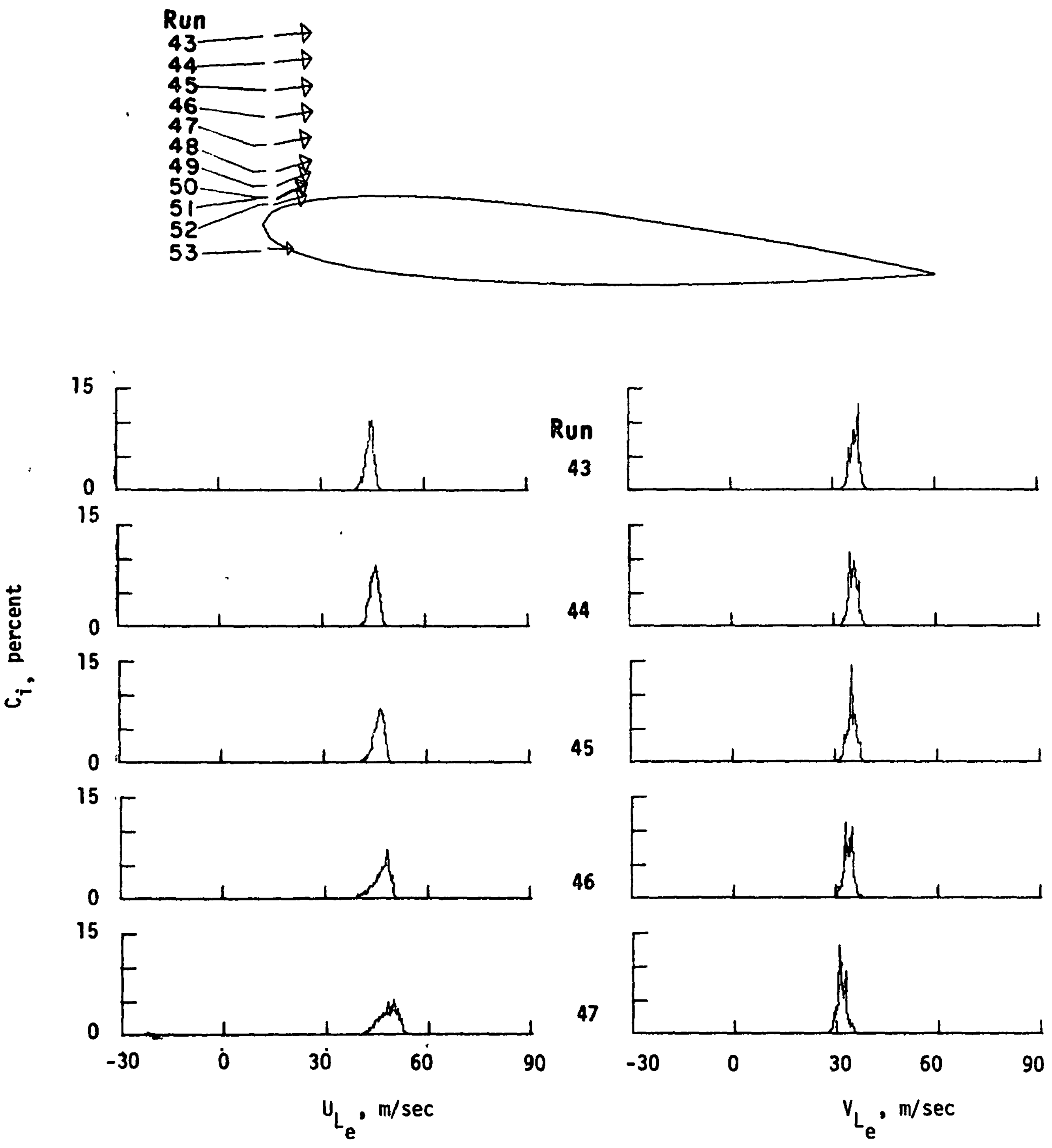
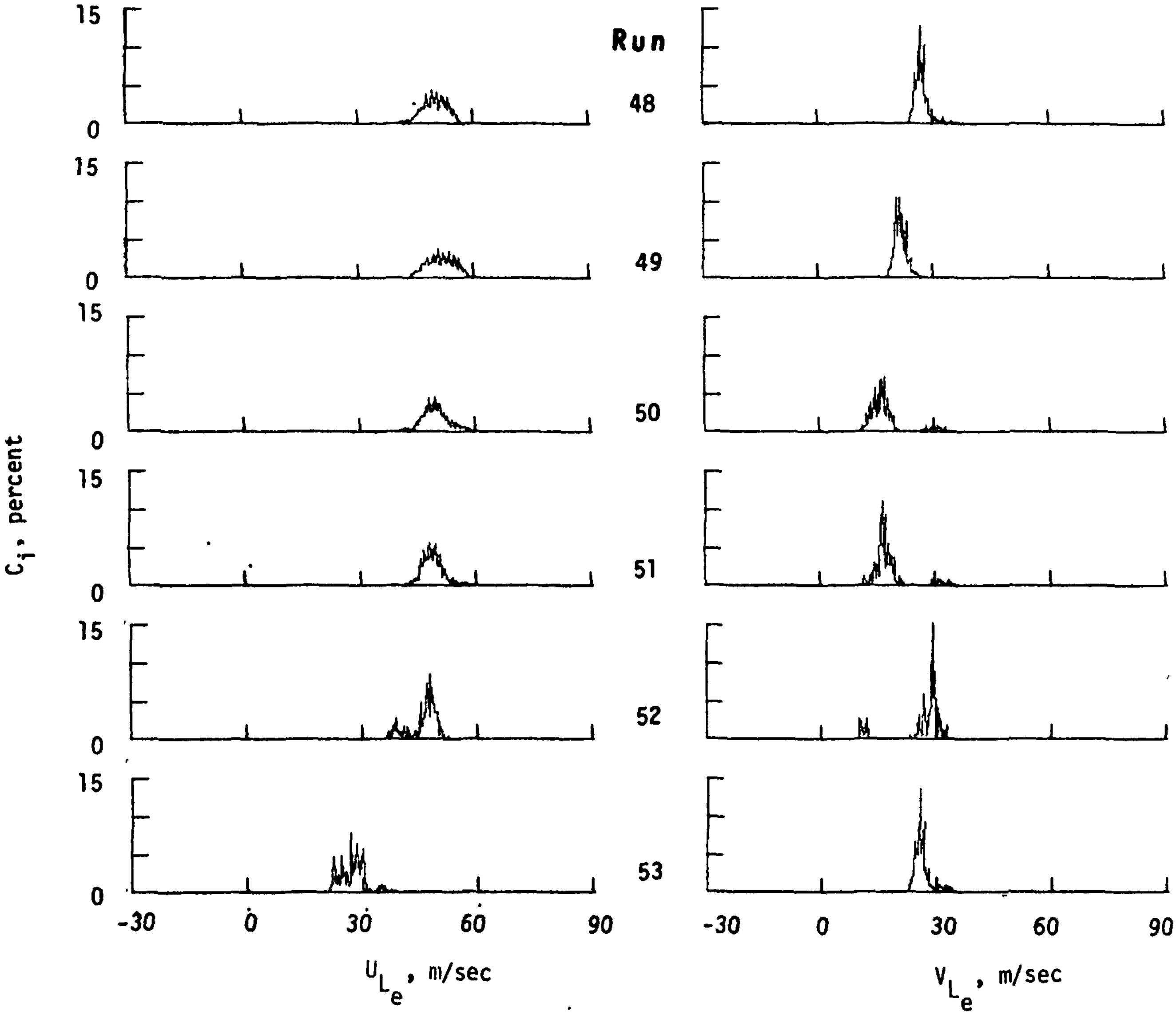



Figure B-5.- Histograms in scan at constant $x_c/c = 0$, $\alpha = 4.75^o$.

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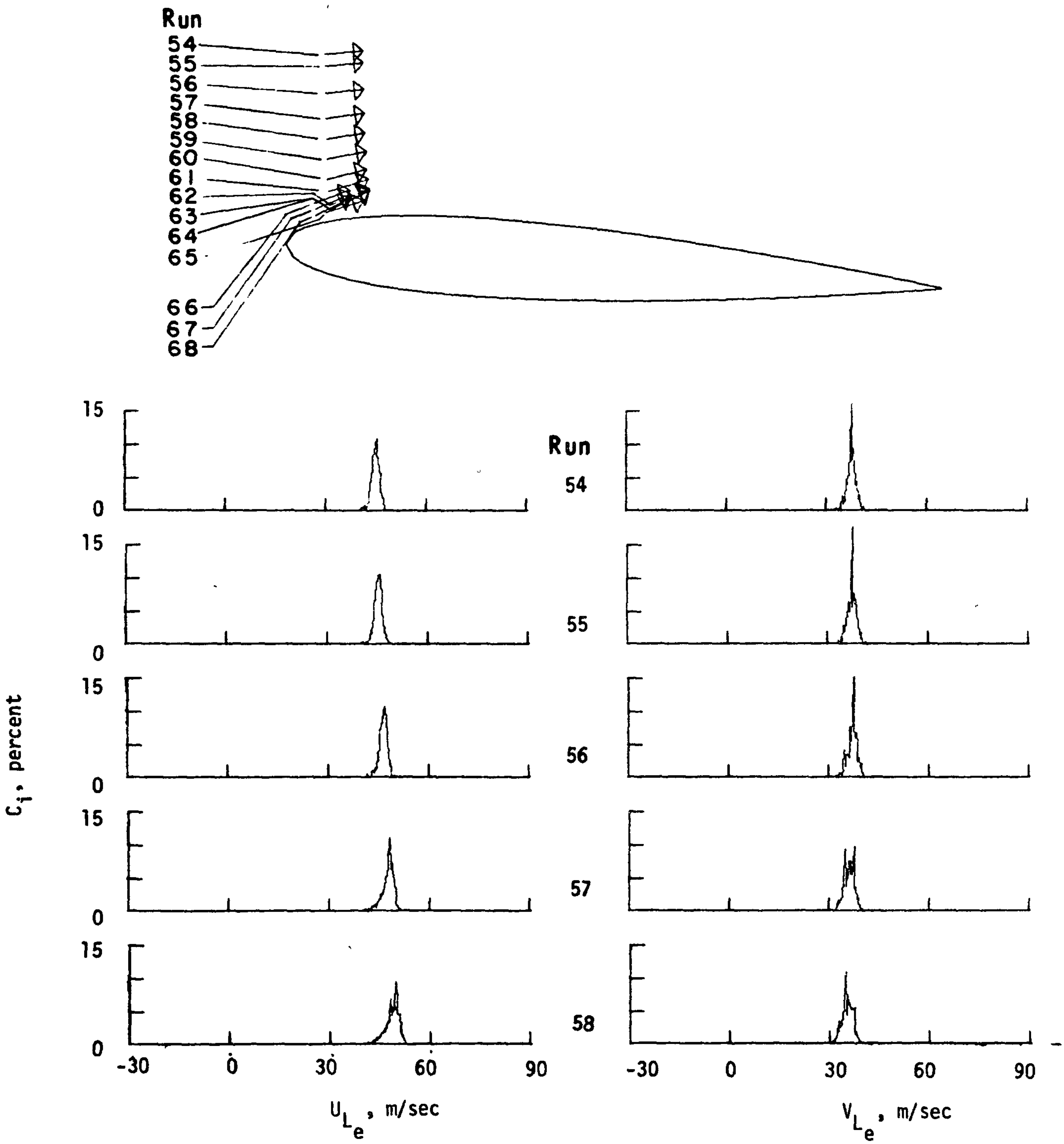



Figure B-6.- Histograms in scan at constant $x_c/c = 0.03$ and 0.04, $\alpha = 4.75^o$.

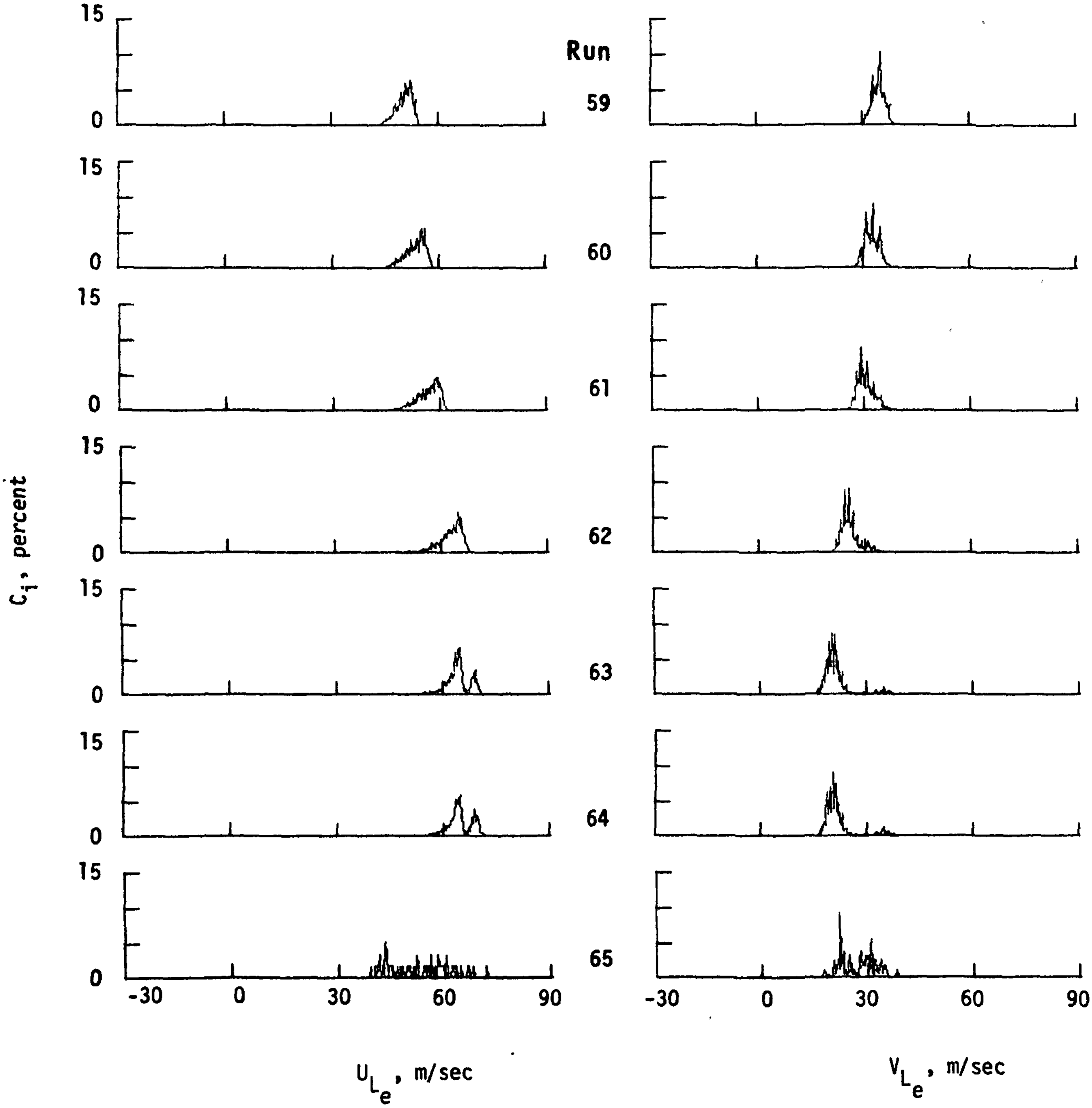



Figure B-6.- Continued.

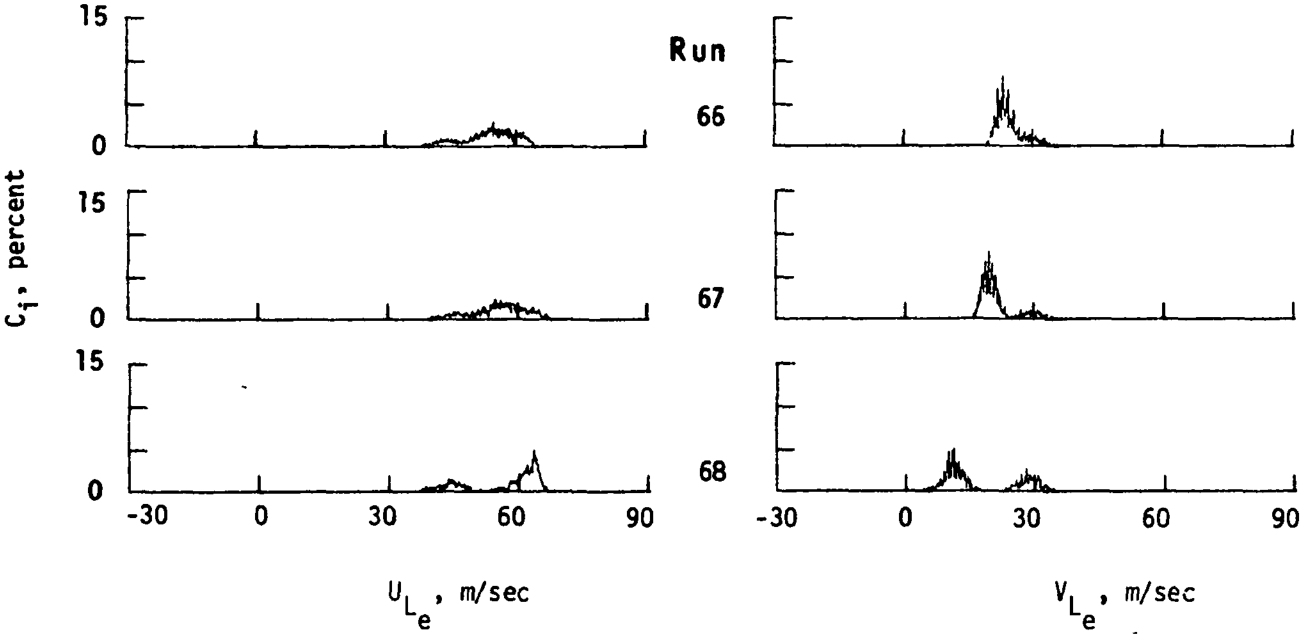



Figure B-6.- Concluded.

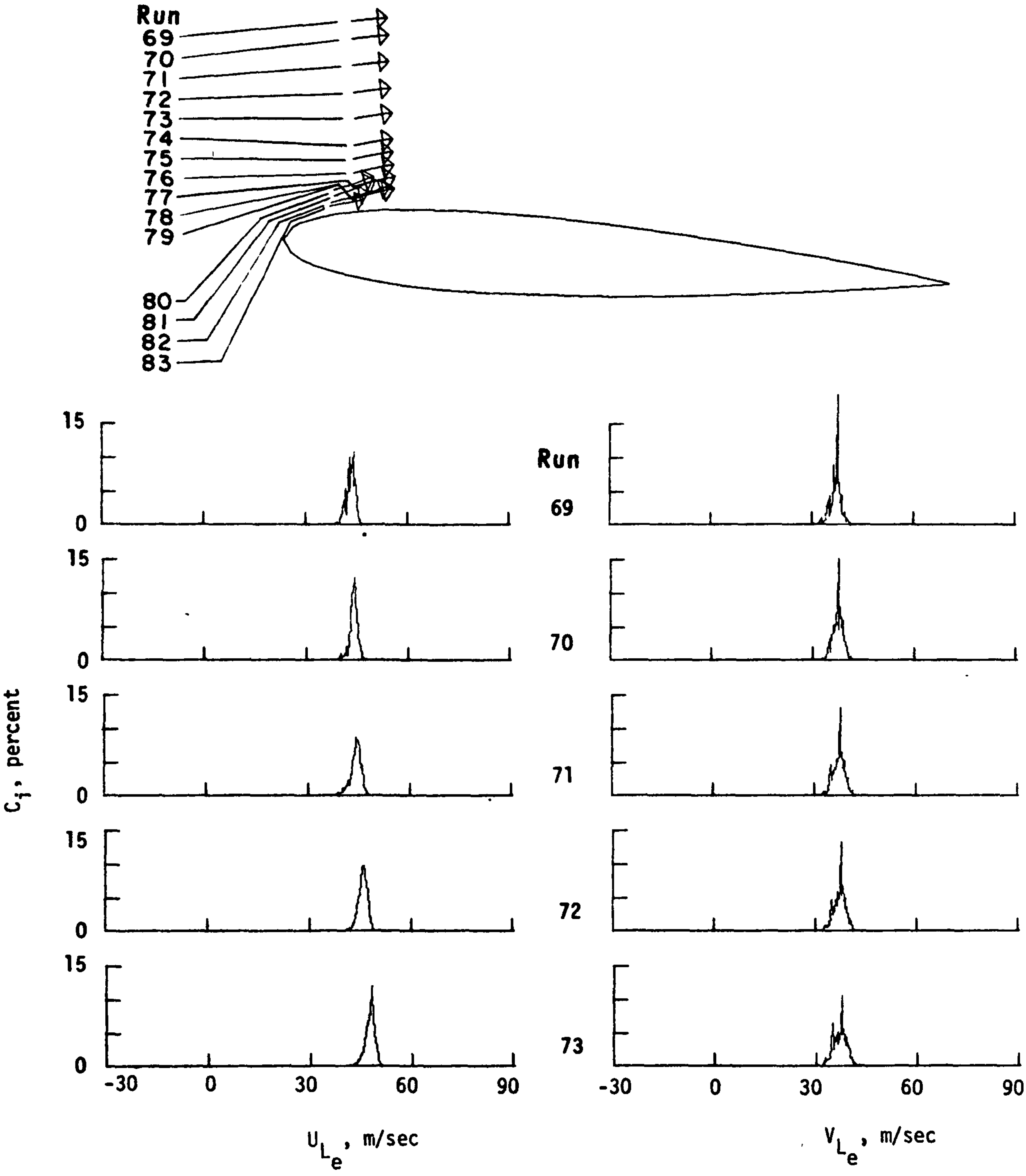



Figure B-7.- Histograms in scan at constant $x_c/c$ = 0.06 and 0.09, $\alpha = 4.75^o$.

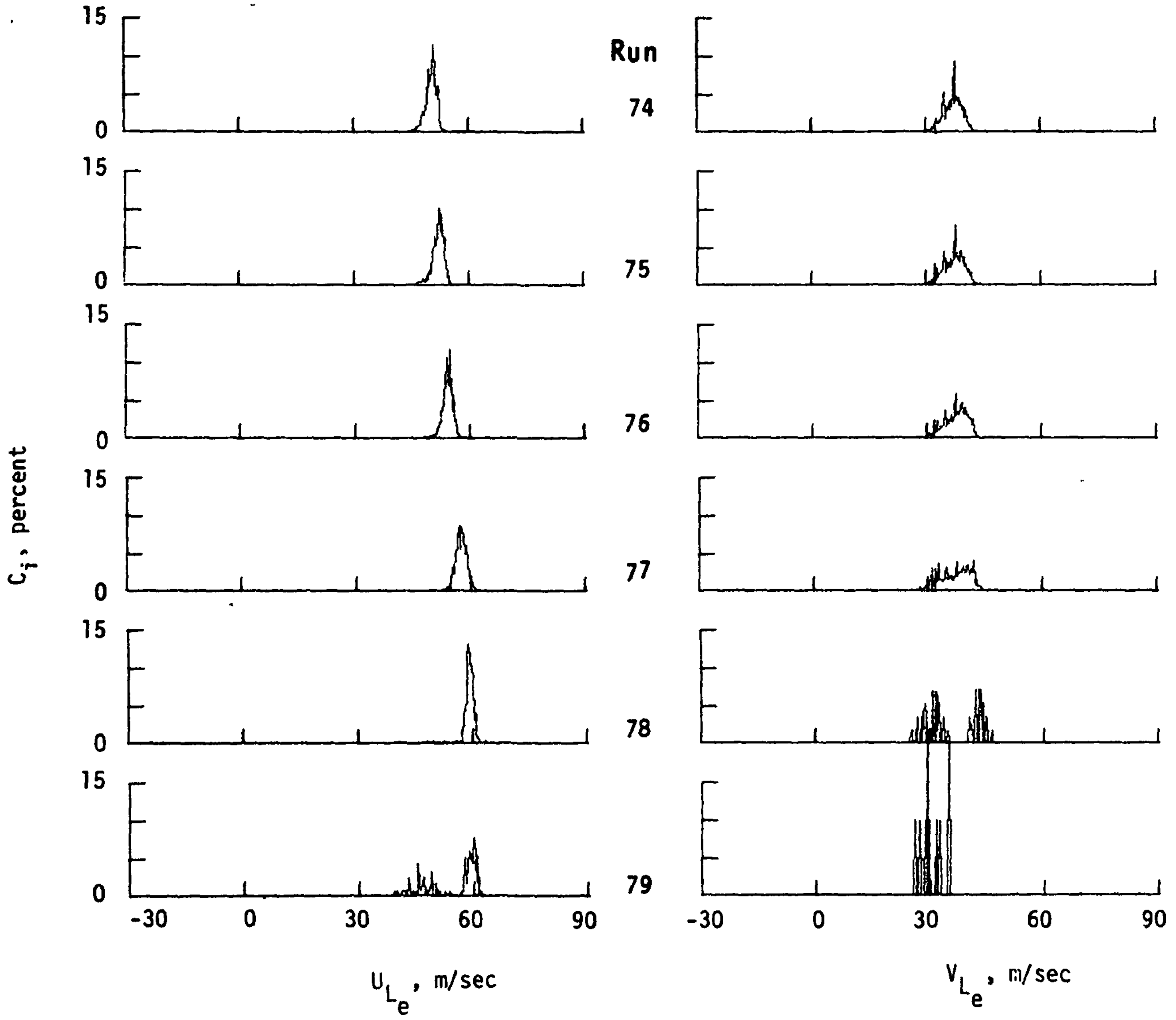
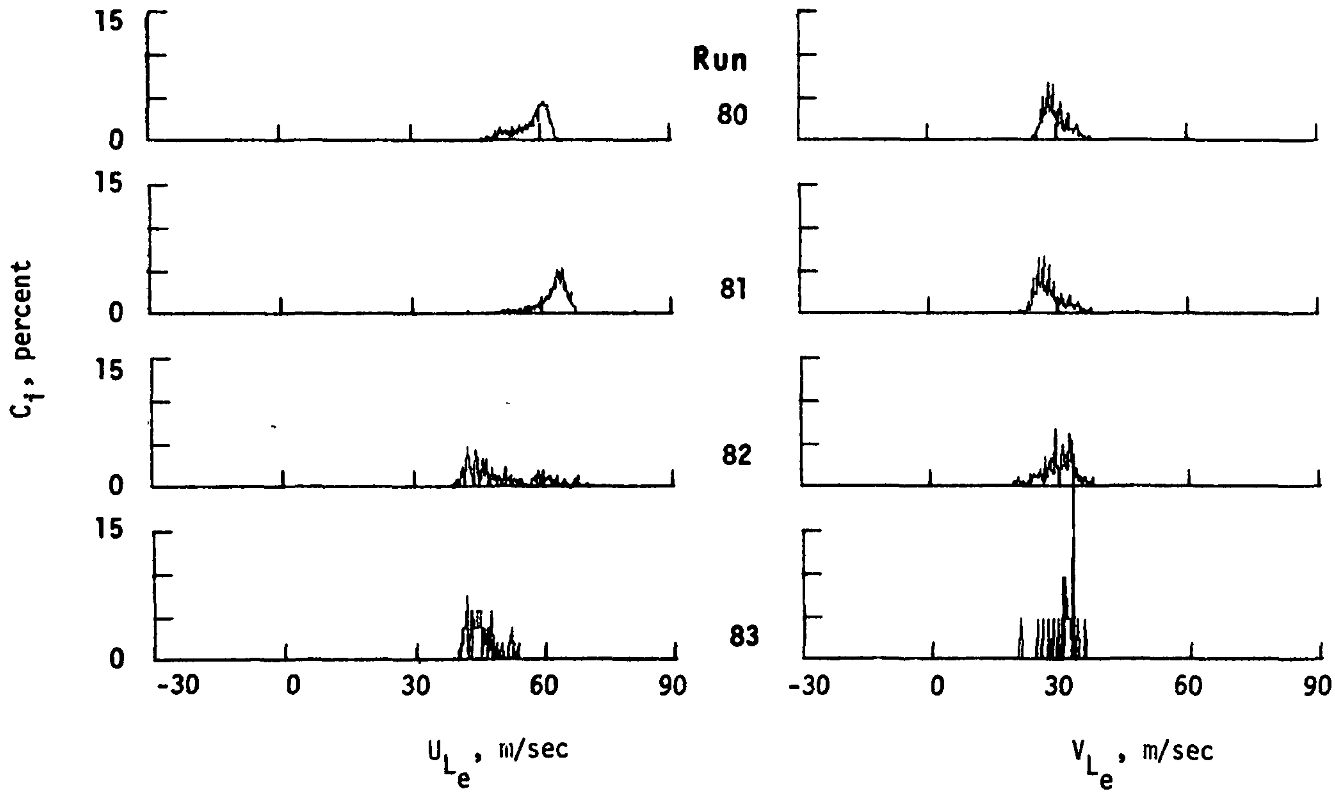



Figure B-7.- Continued.

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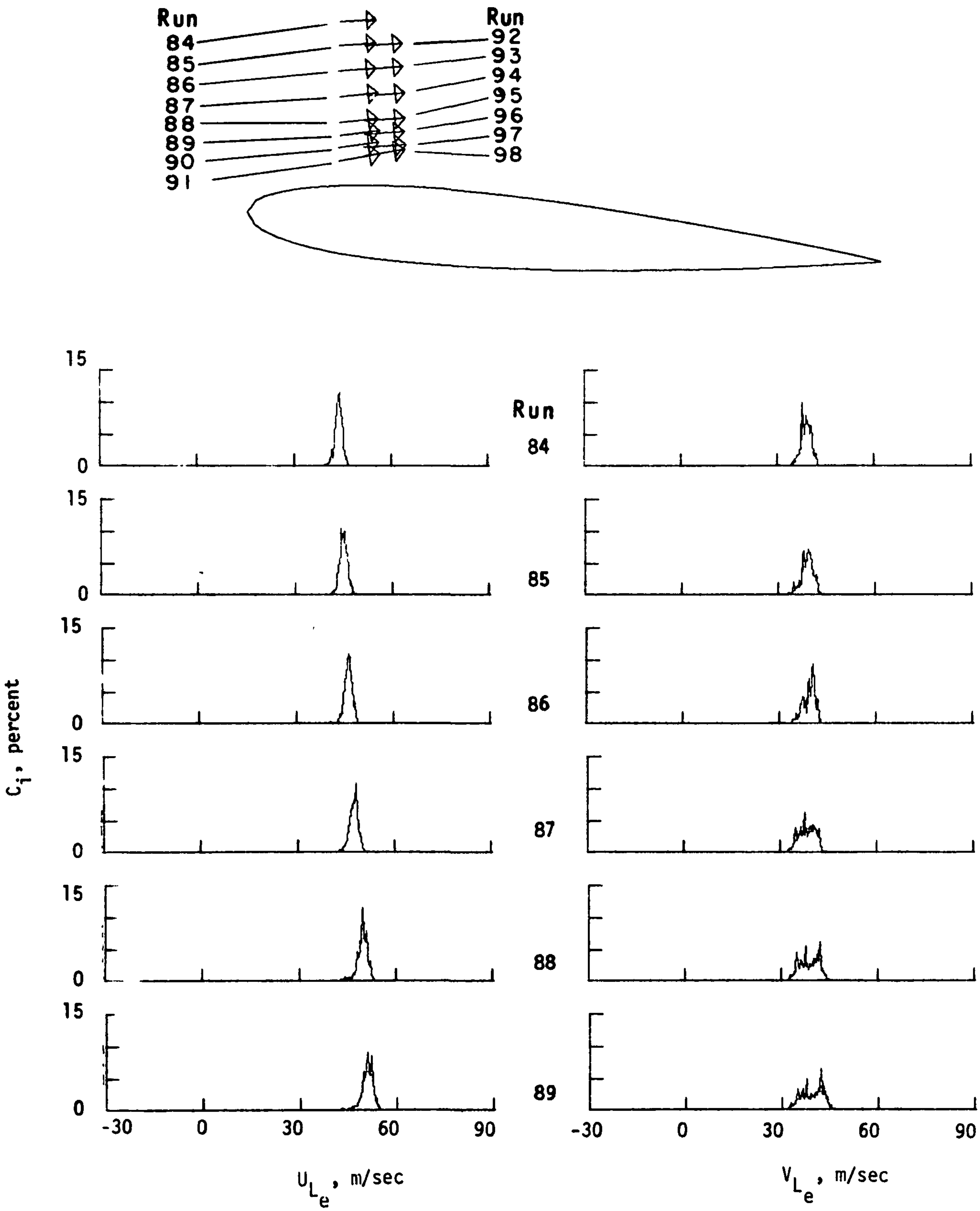
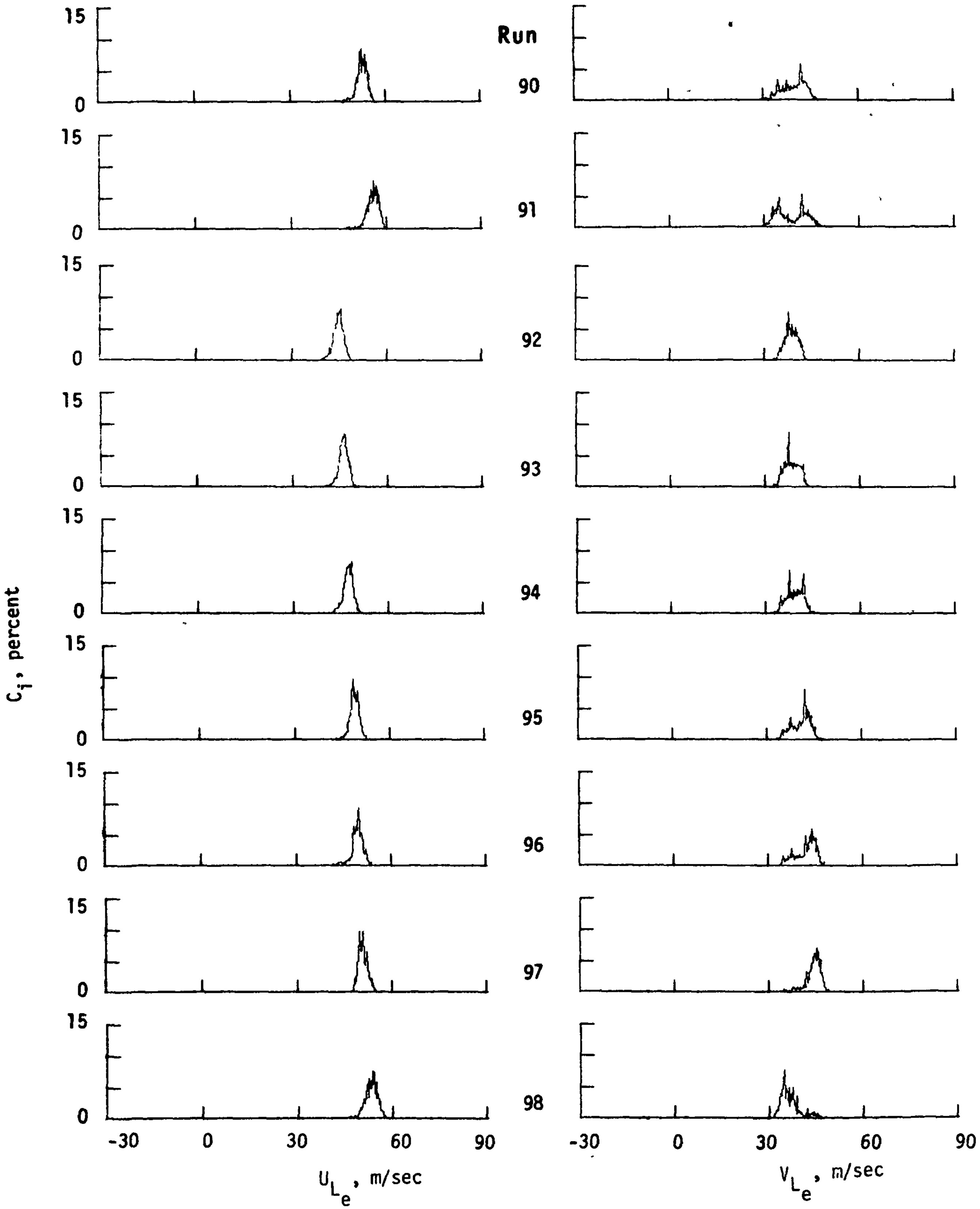



Figure B-8.- Histograms in scan at constant $x_c/c$ = 0 13 and 0.17, $\alpha = 4.75^0$.

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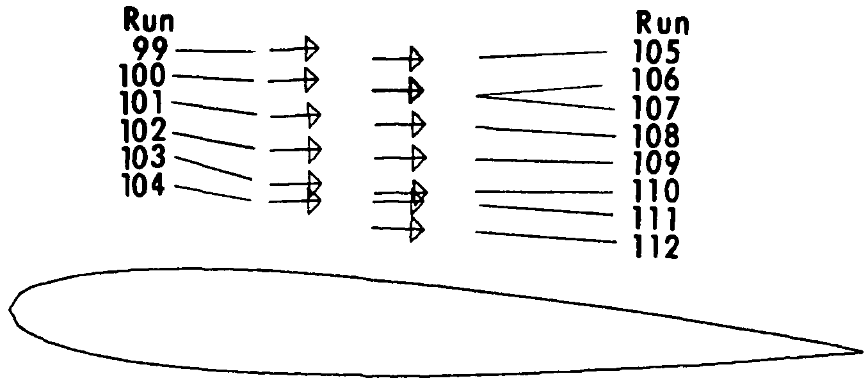


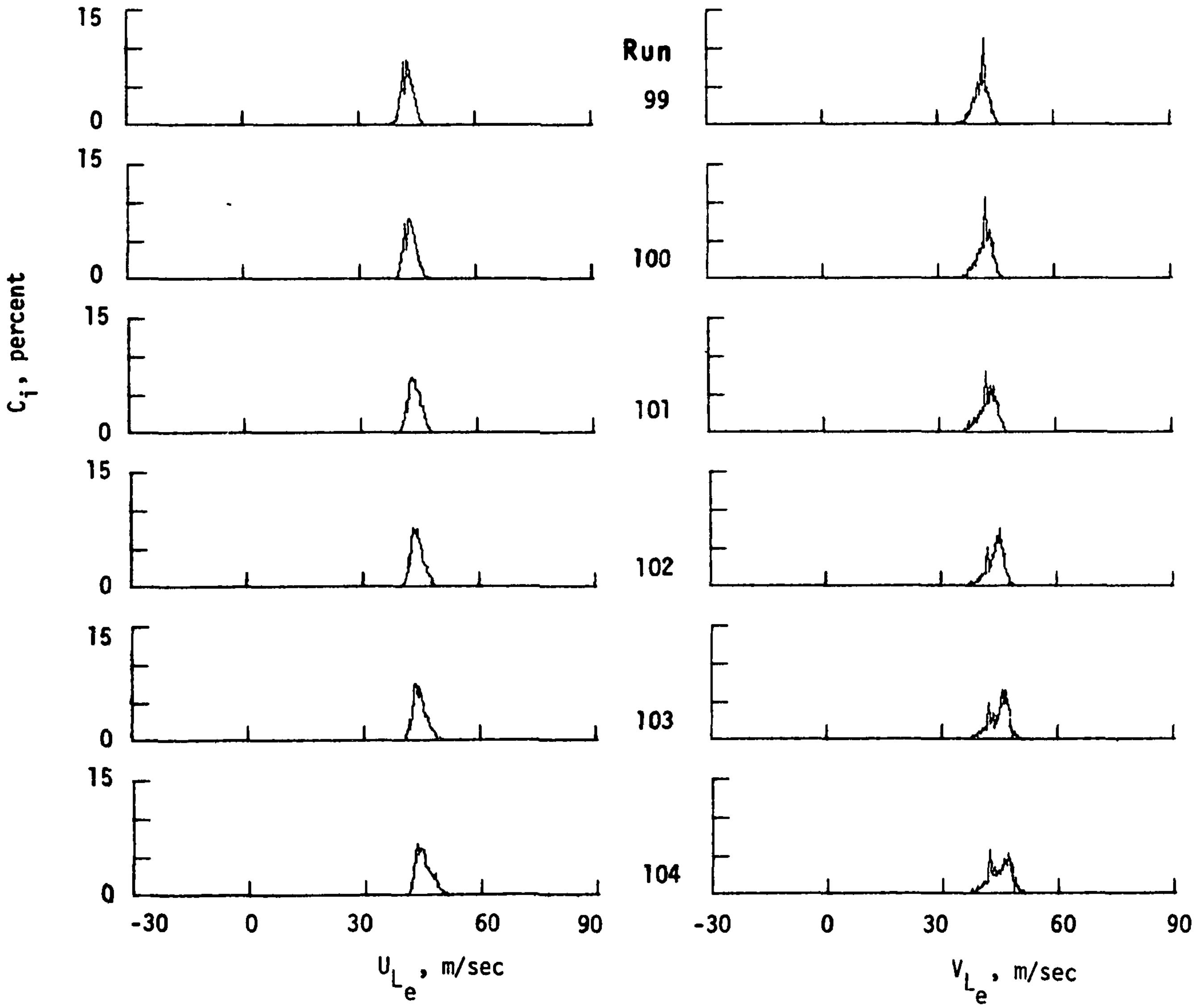
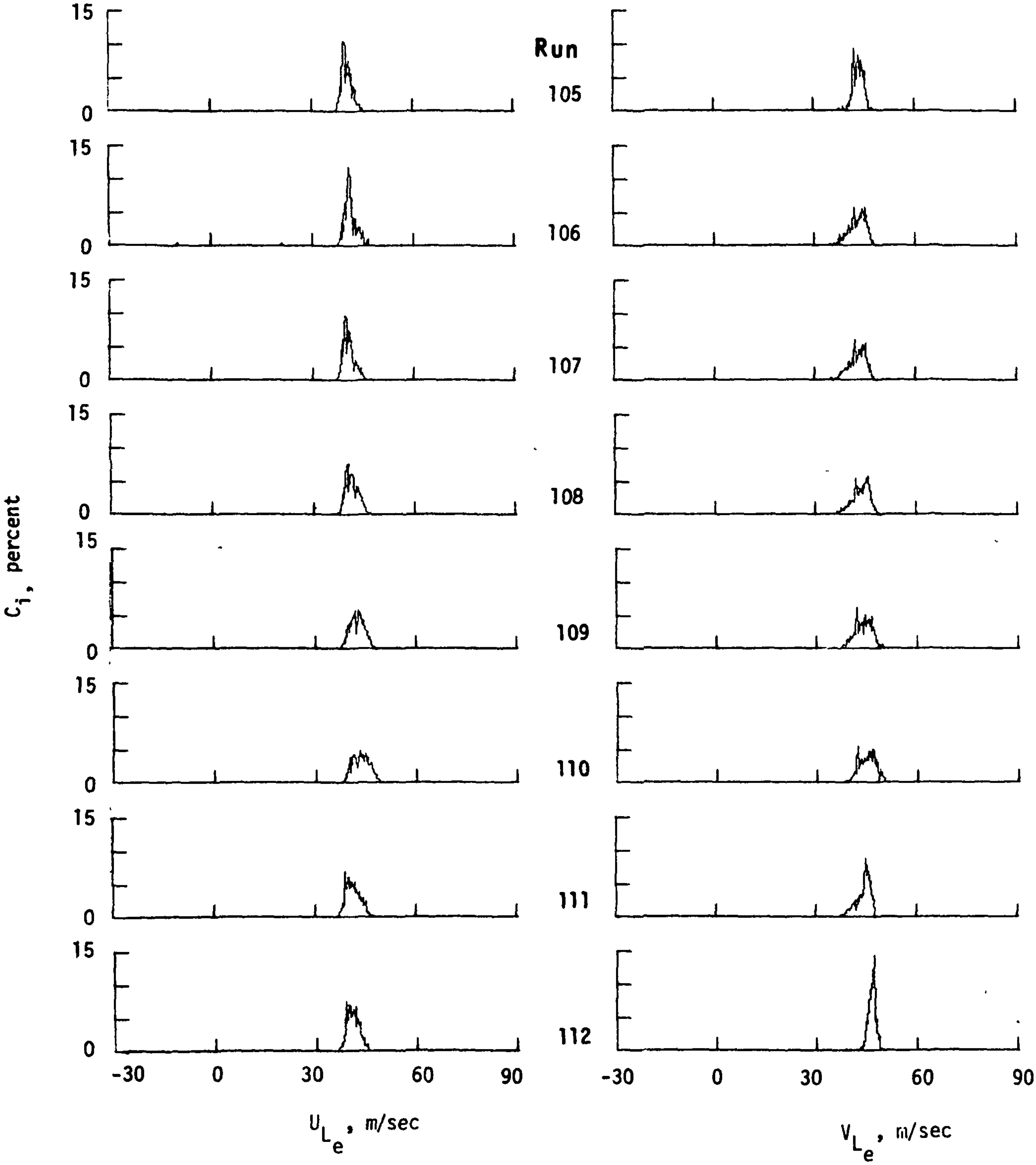




Figure B-9.- Histograms in scan at constant $x_c/c$ = 0.29 and 0.42, $\alpha$ = 4.75°.

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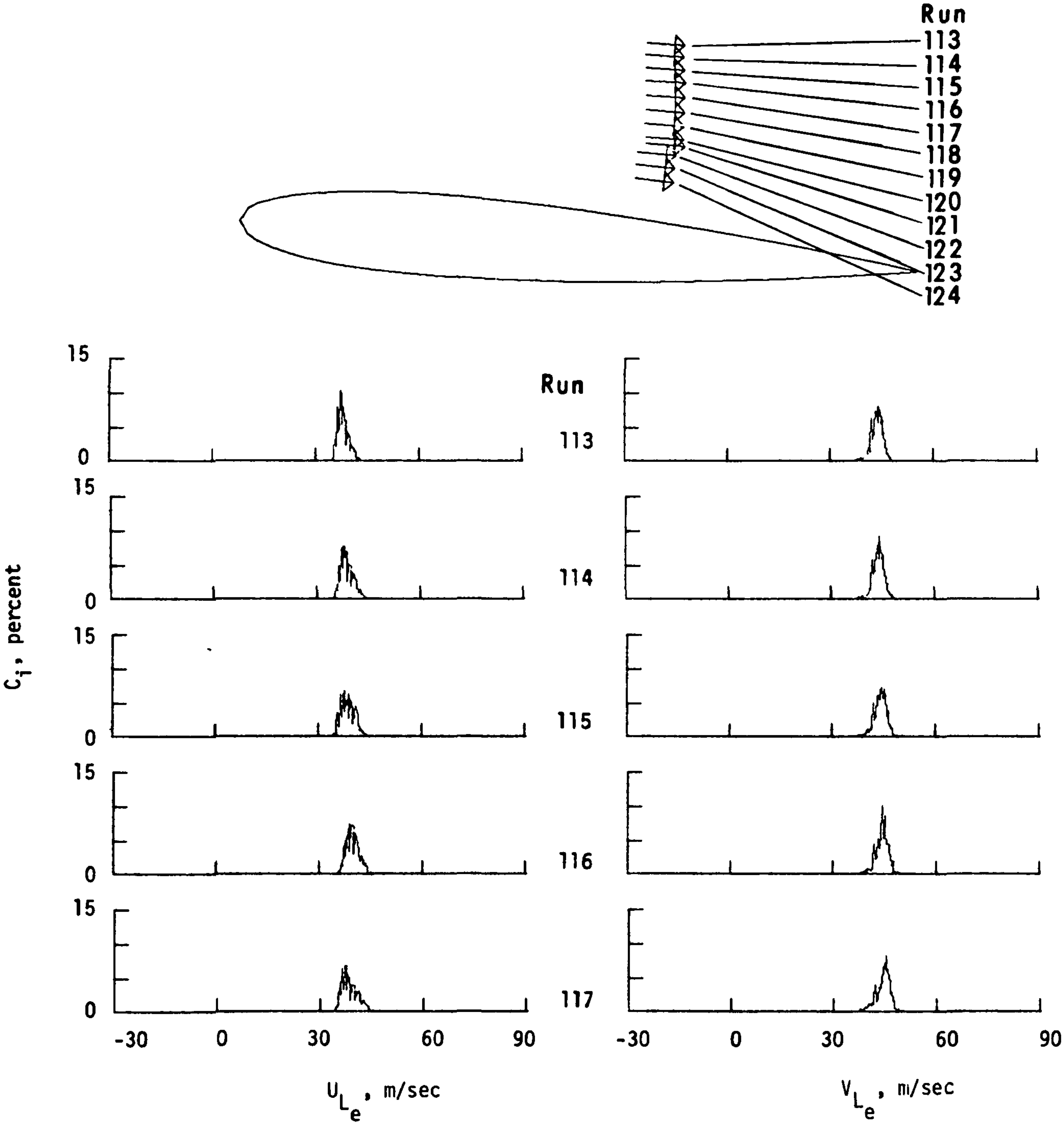
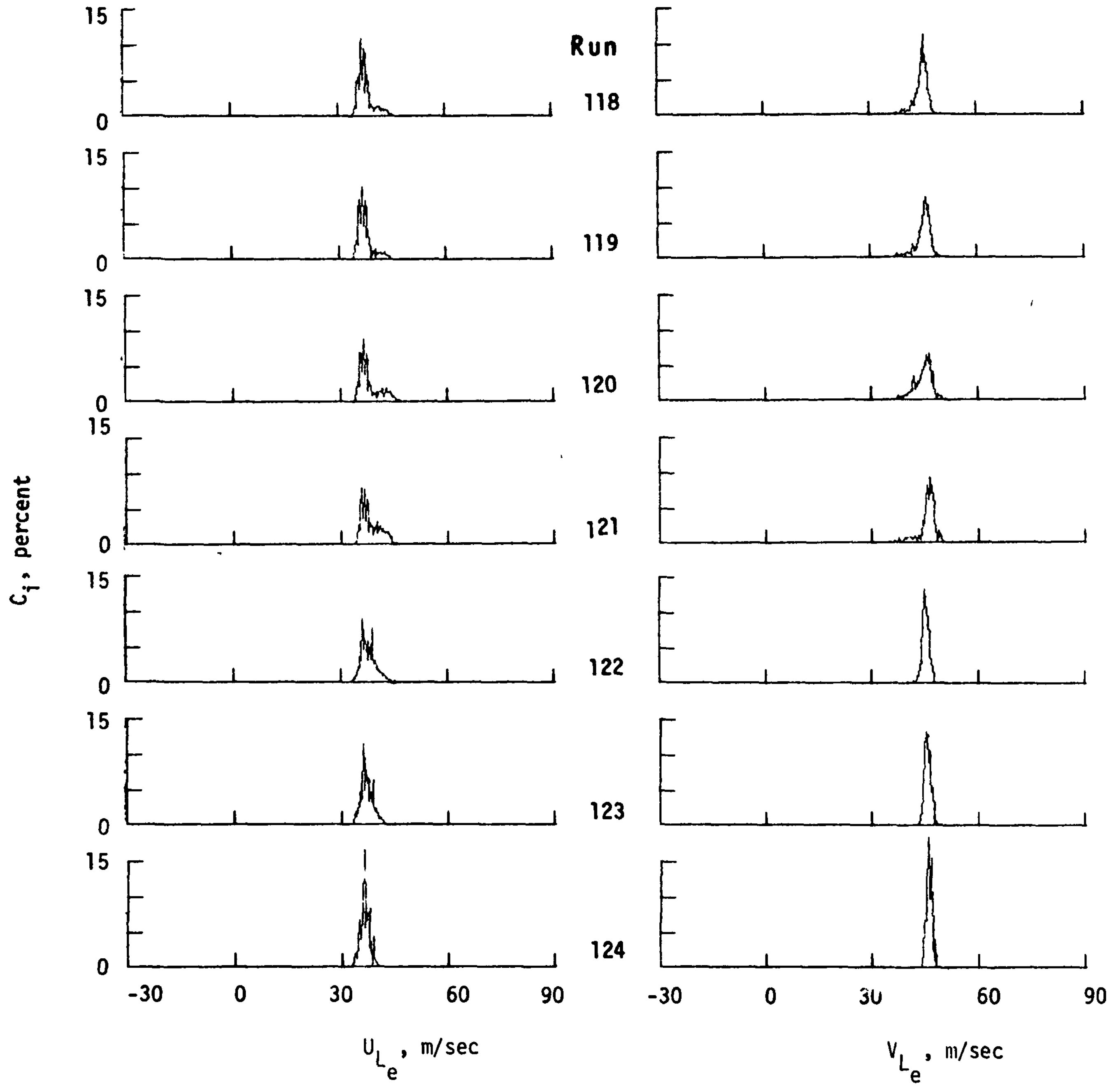



Figure B-10.- Histograms in scan at constant $x_c/c = 0.58$, $\alpha = 4.75^o$.

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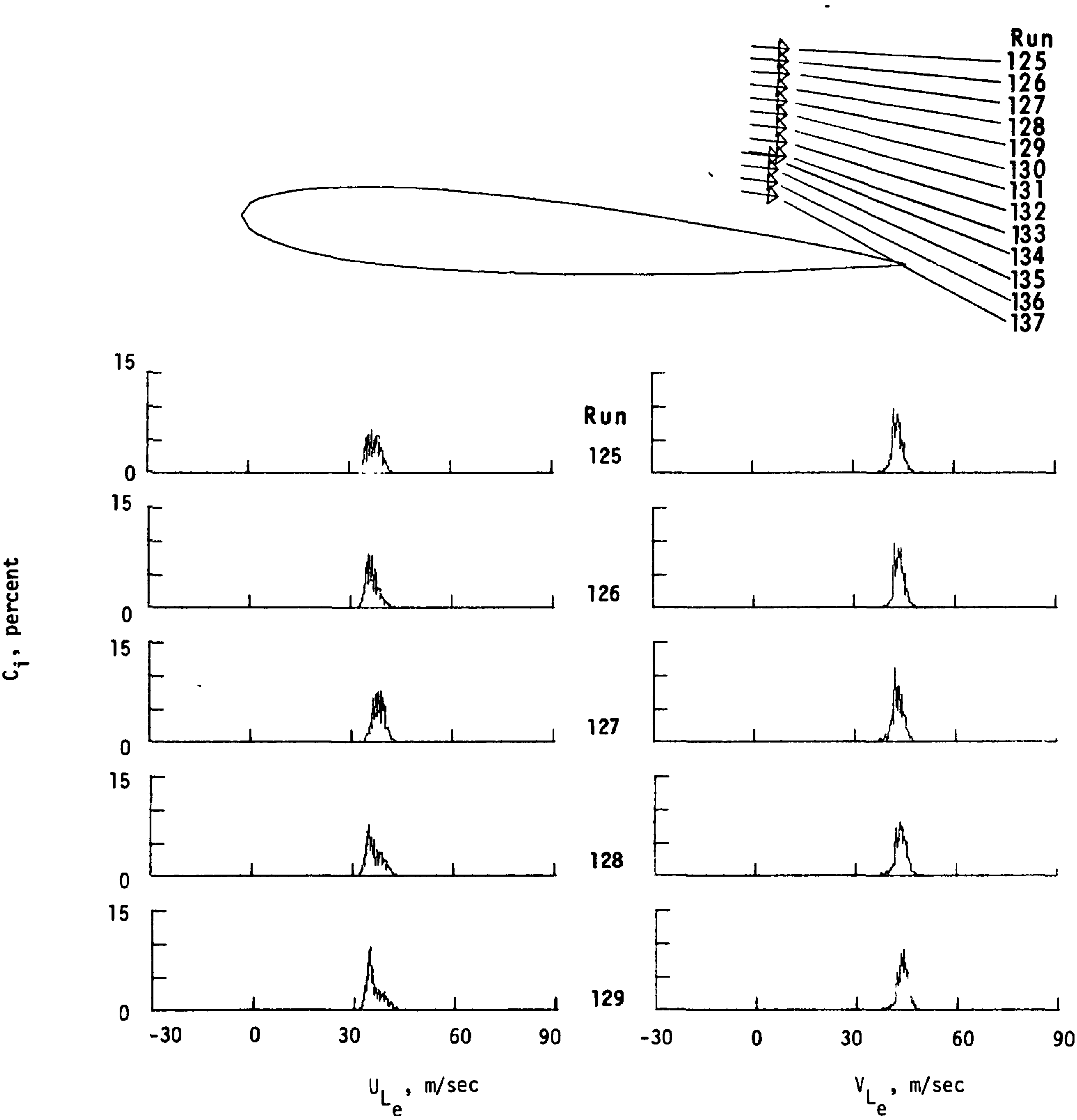
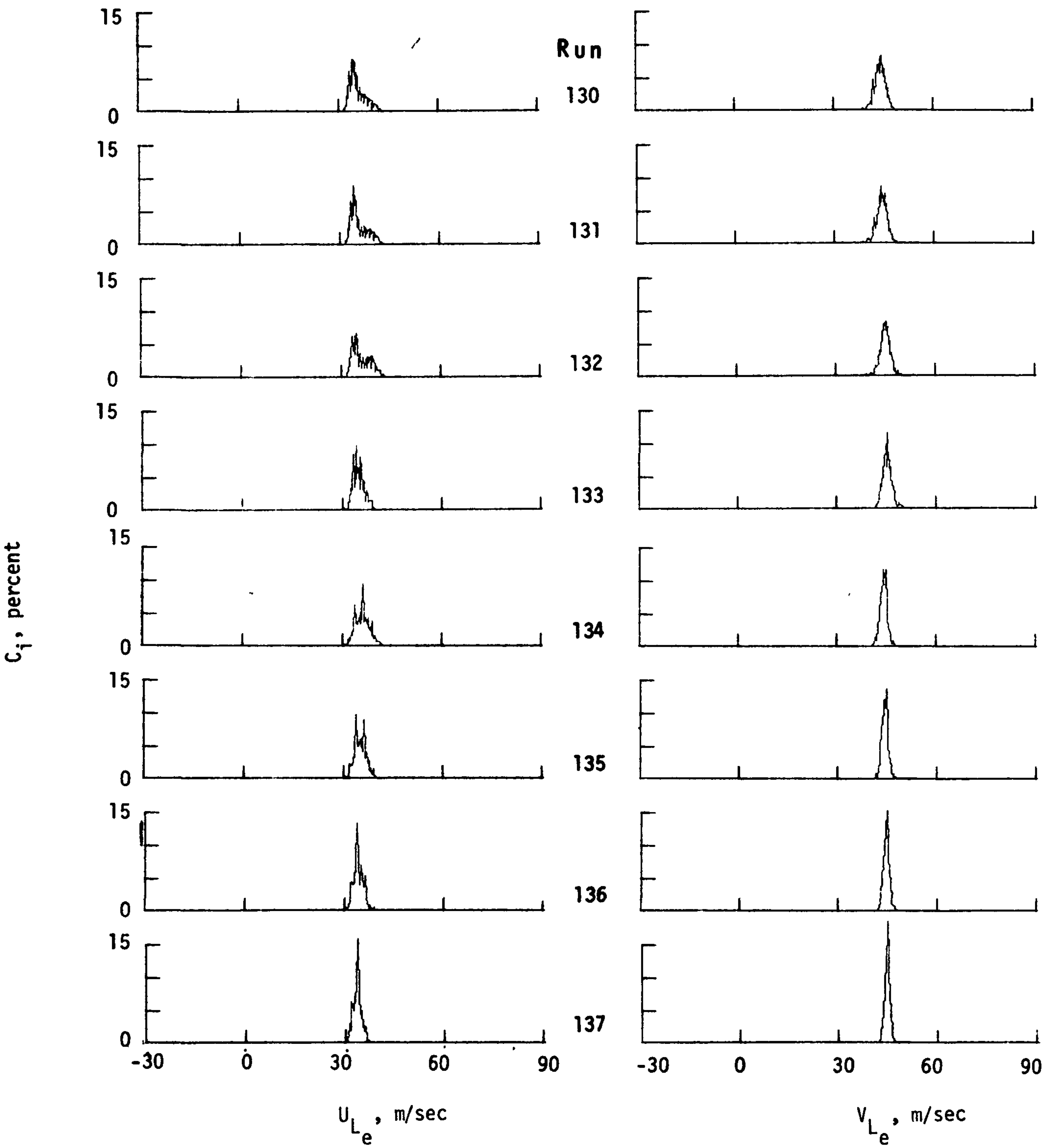



Figure B-11.- Histograms in scan at constant $x_c/c = 0.75$, $\alpha = 4.75^{\circ}$.

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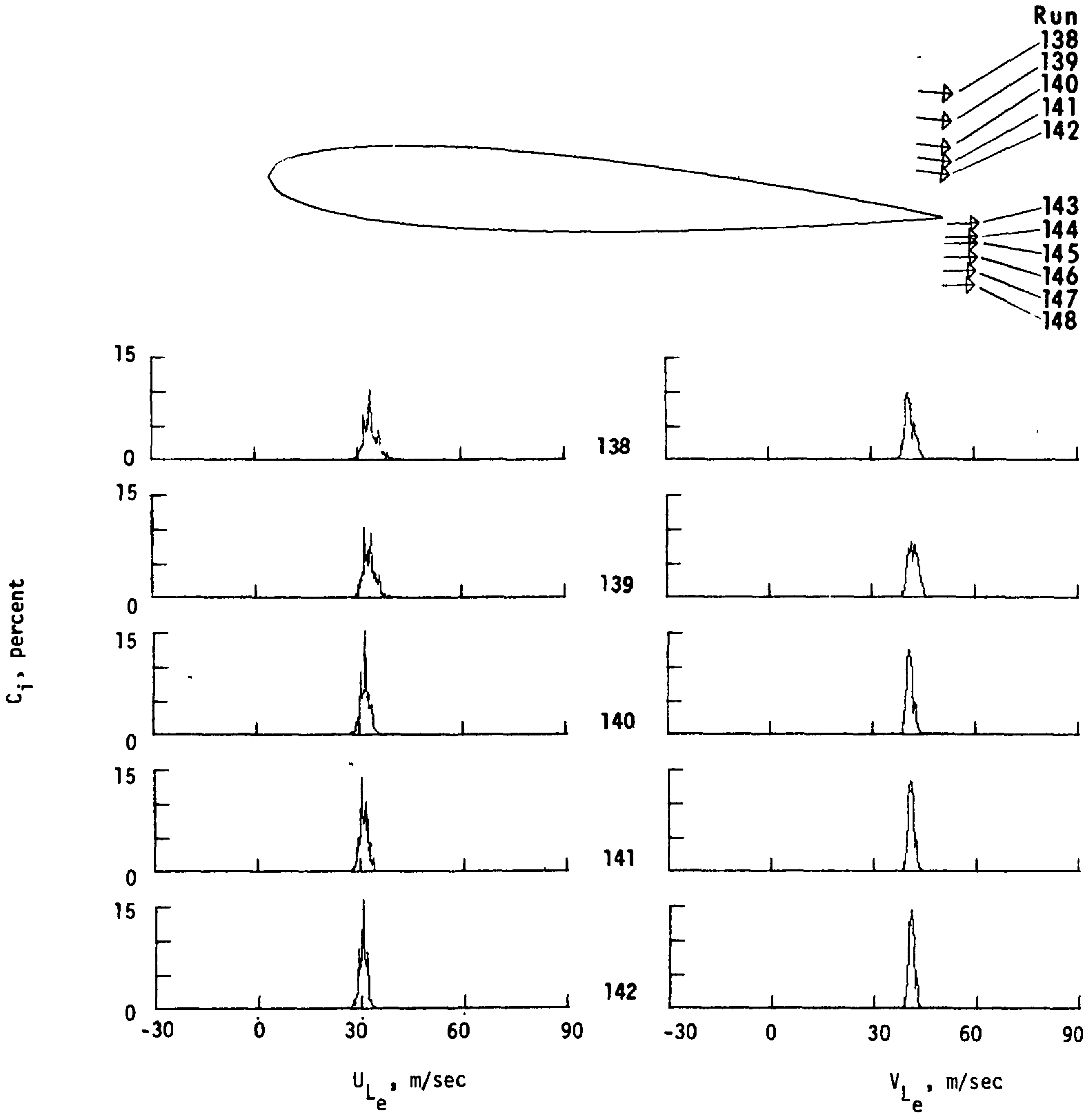
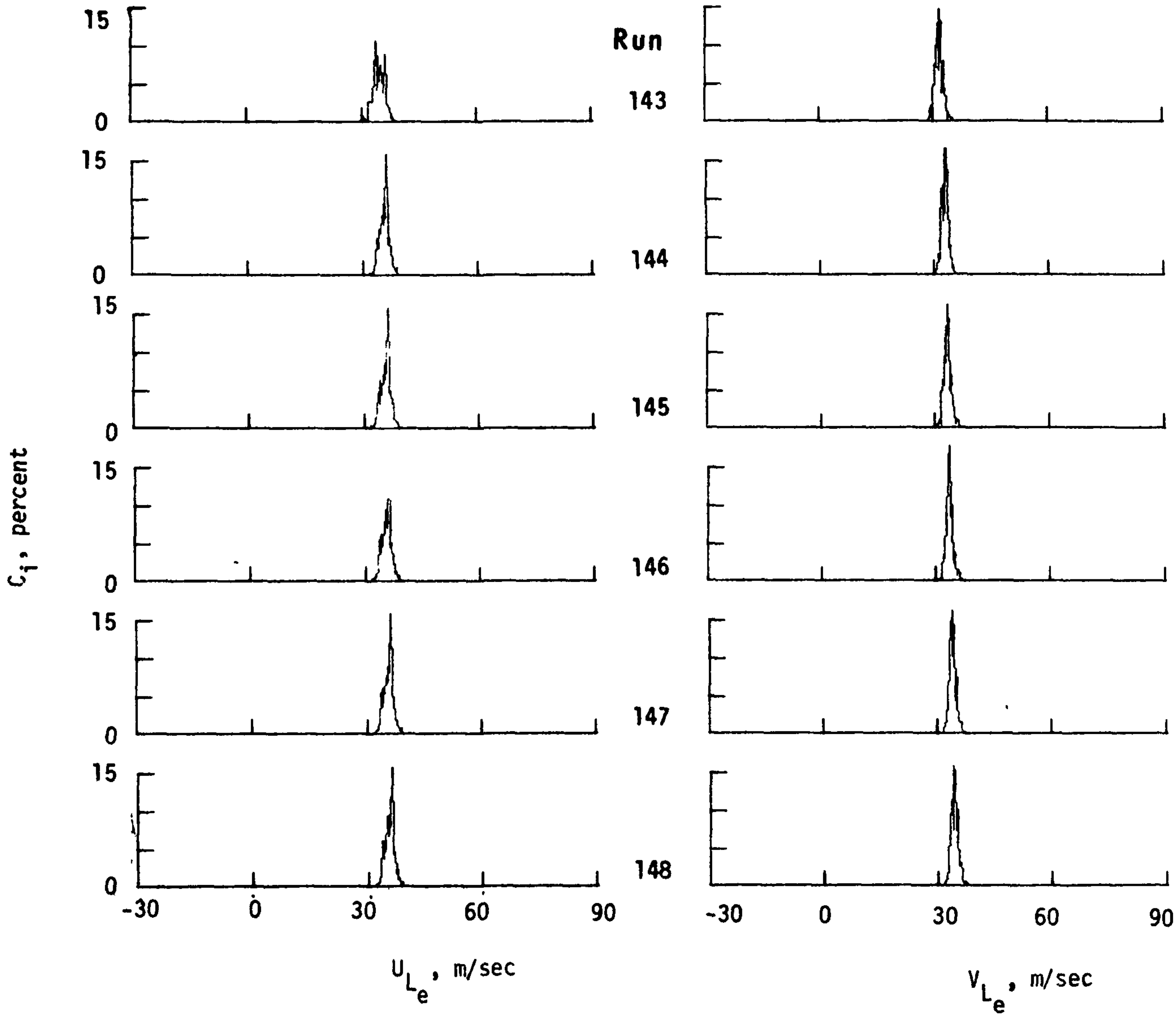



Figure B-12.- Histograms in scan at constant $x_c/c$ = 0.96 and 1.01, $\alpha$ = 4.75°.

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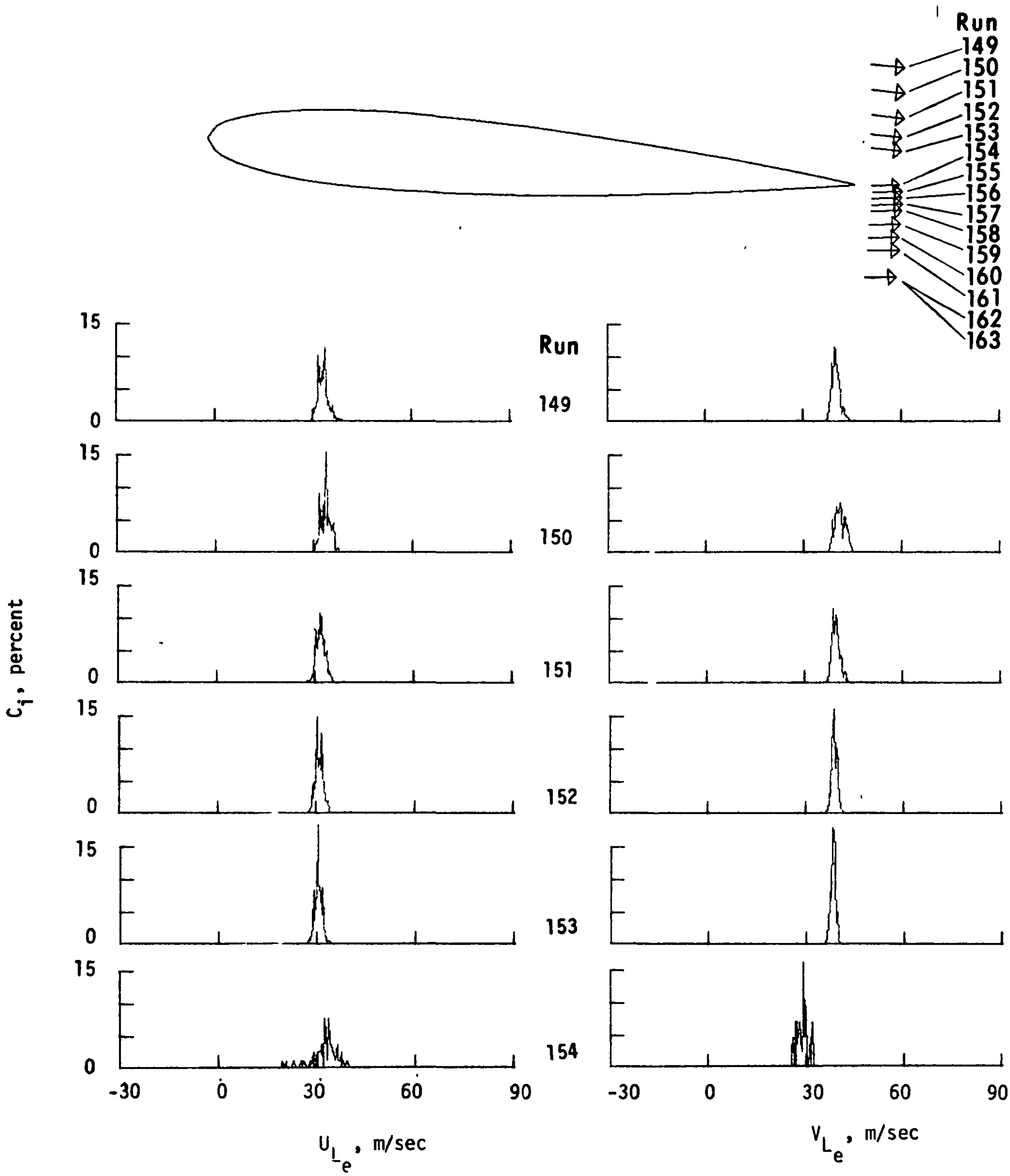
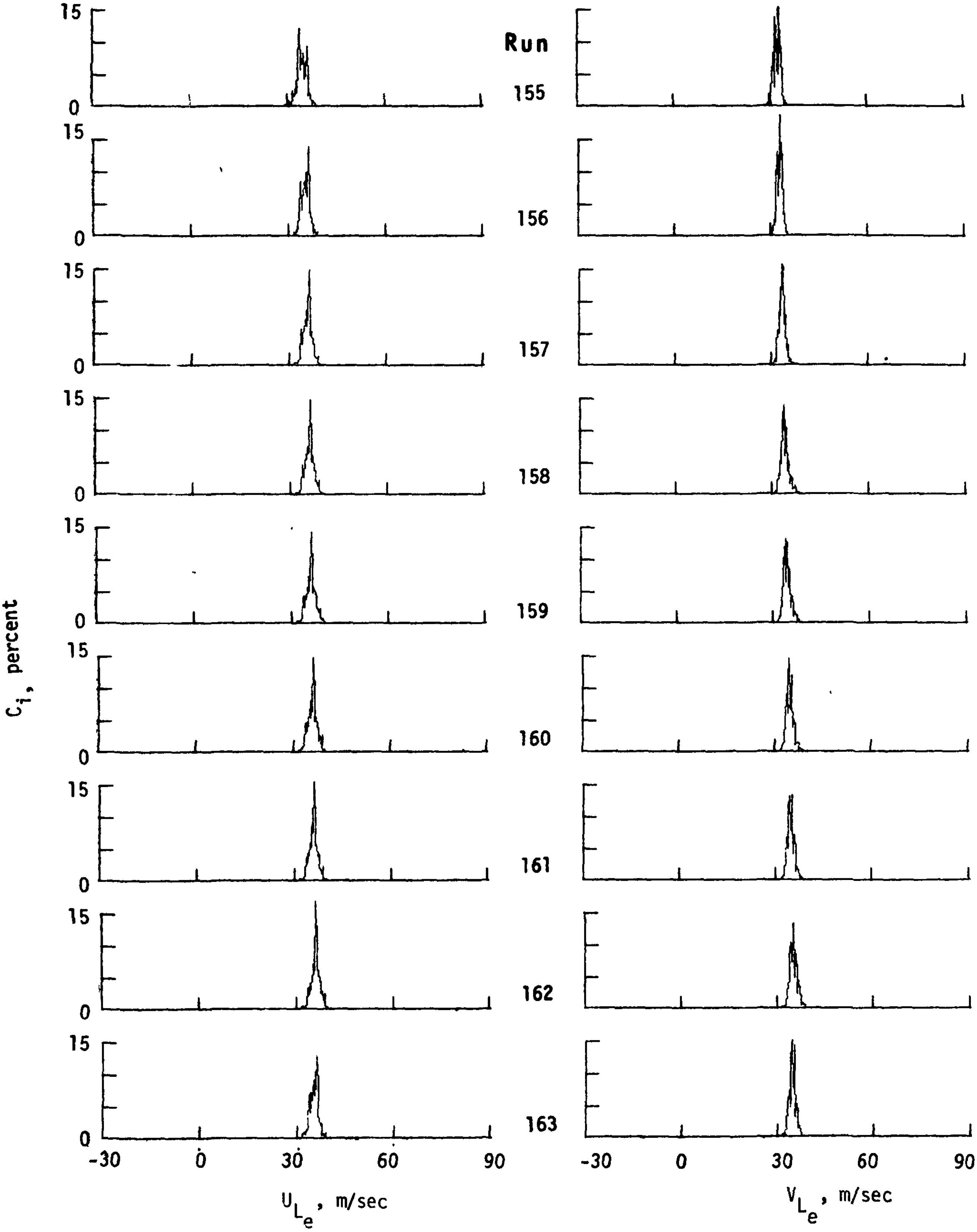



Figure B-13.- Histograms in scan at constant $x_c/c = 1.03$, $\alpha = 4.75^0$.

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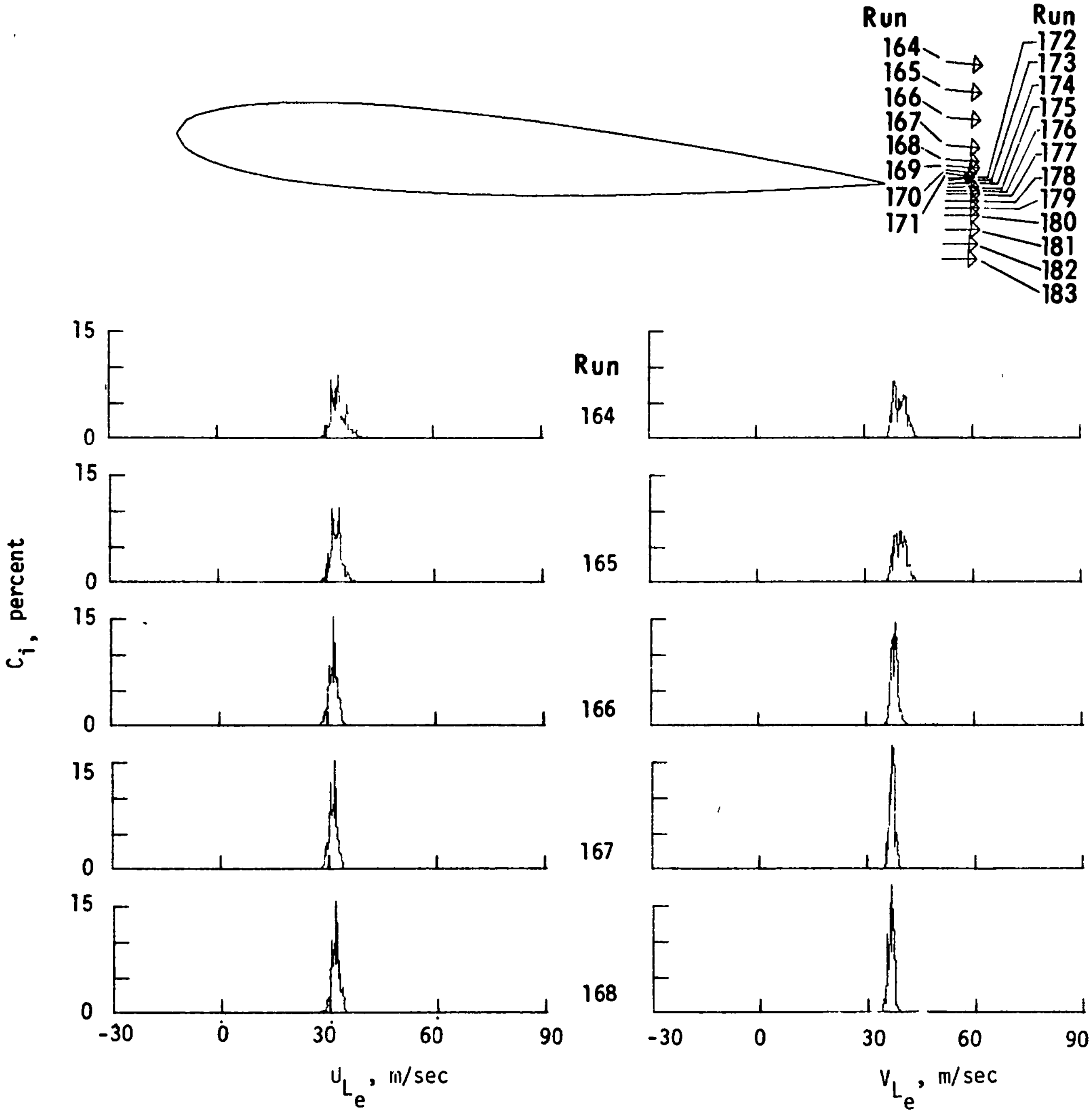
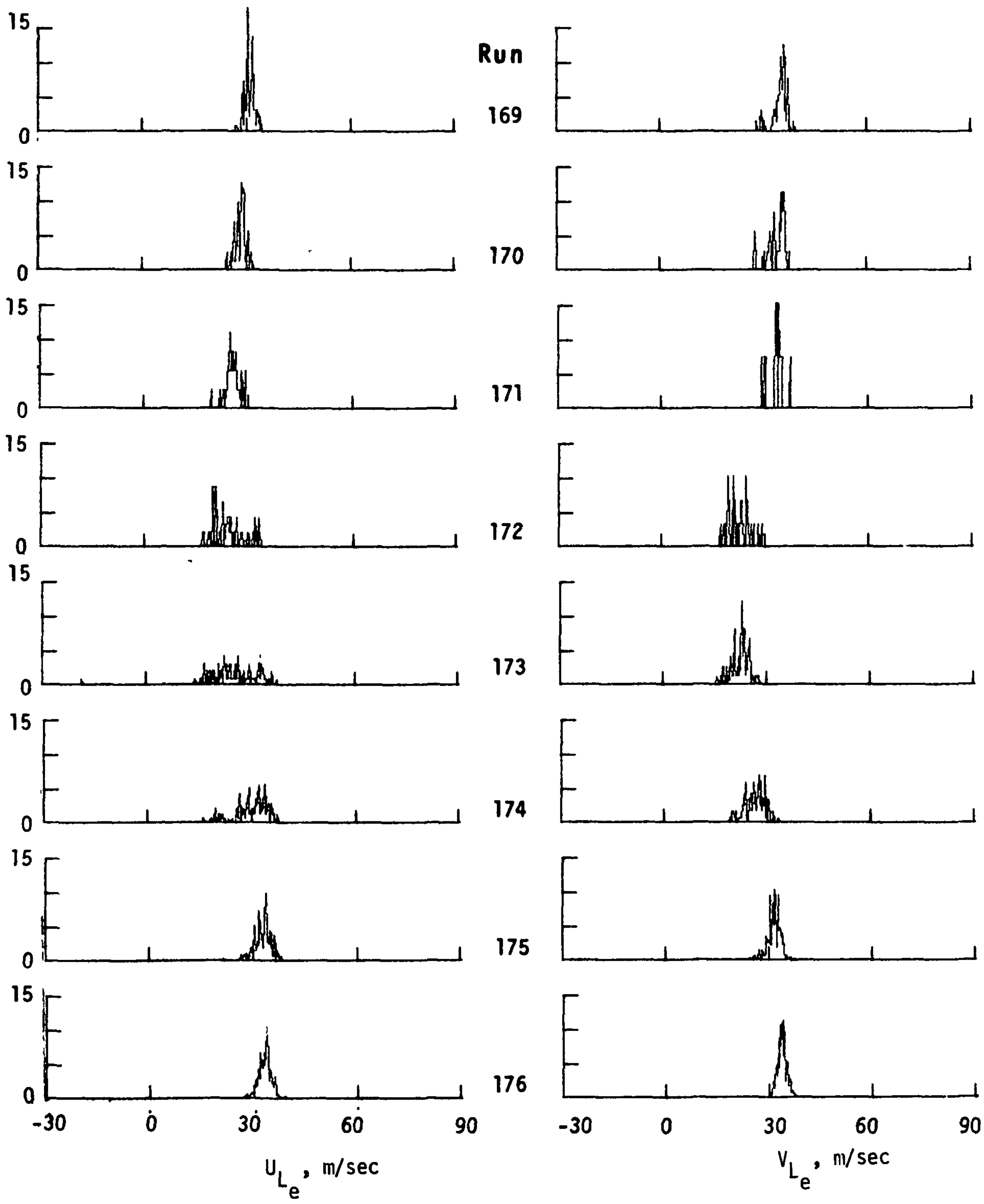



Figure B-14.- Histograms in scan at constant $x_c/c = 1.09$, $\alpha = 4.75^o$.

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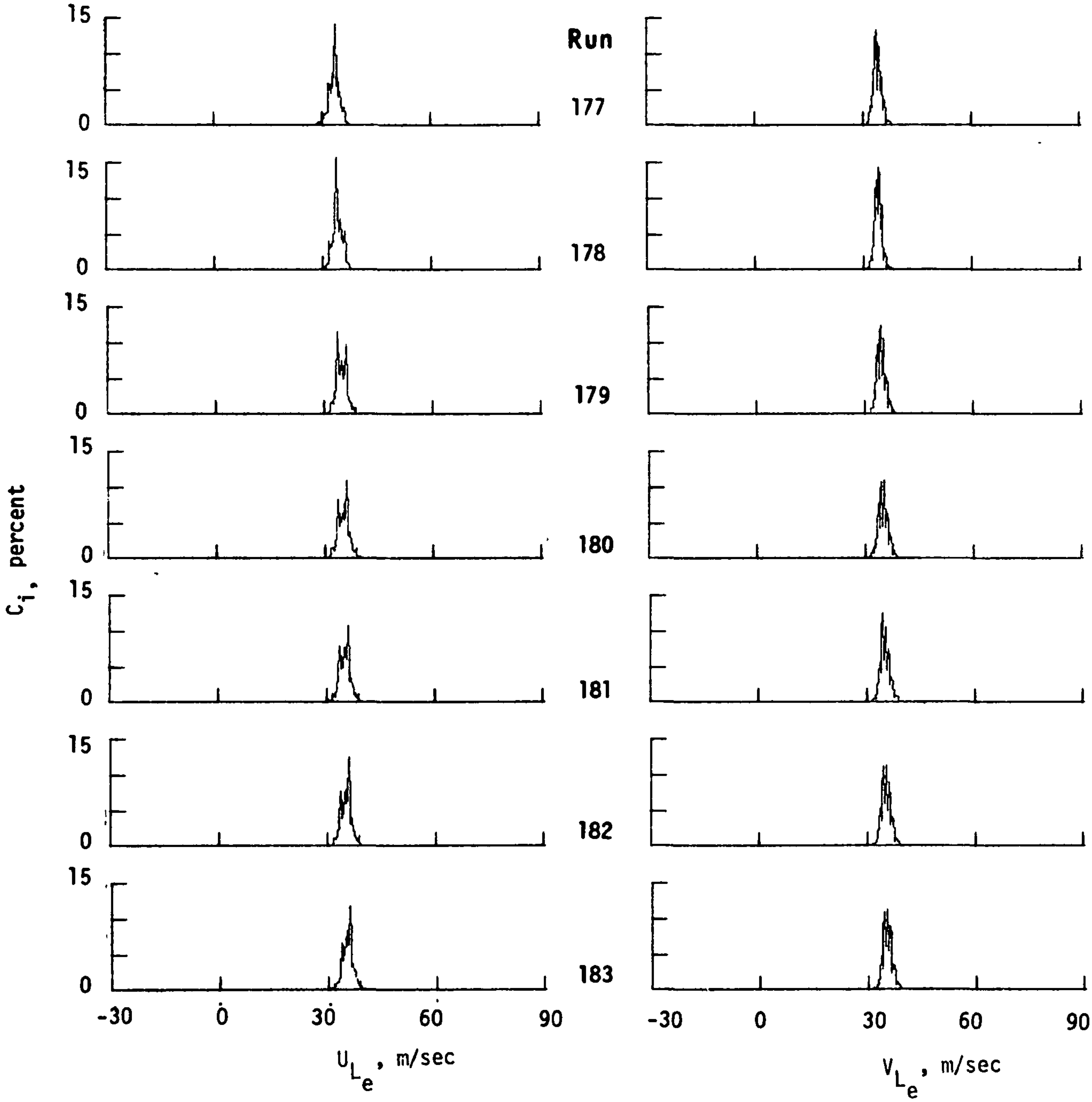


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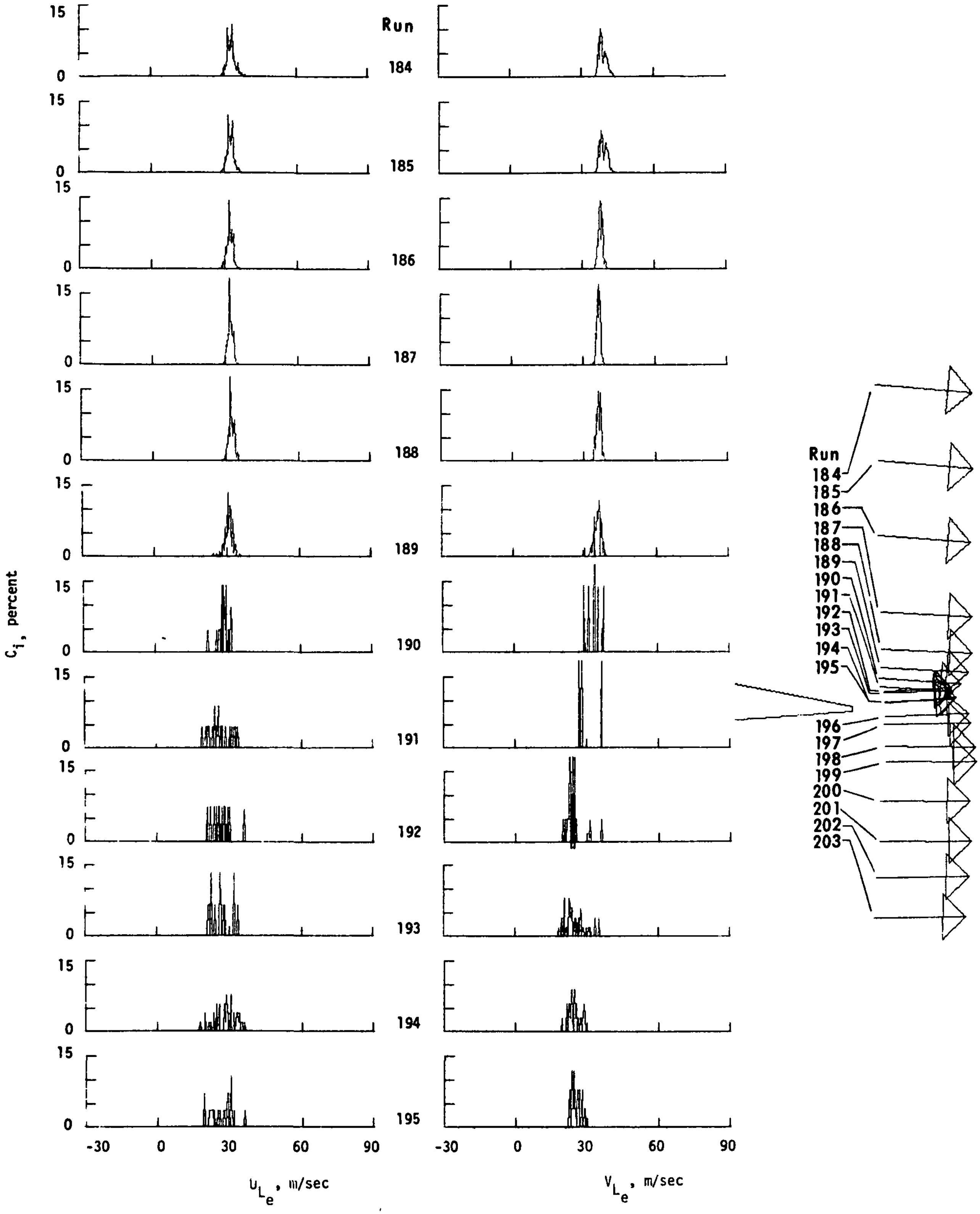
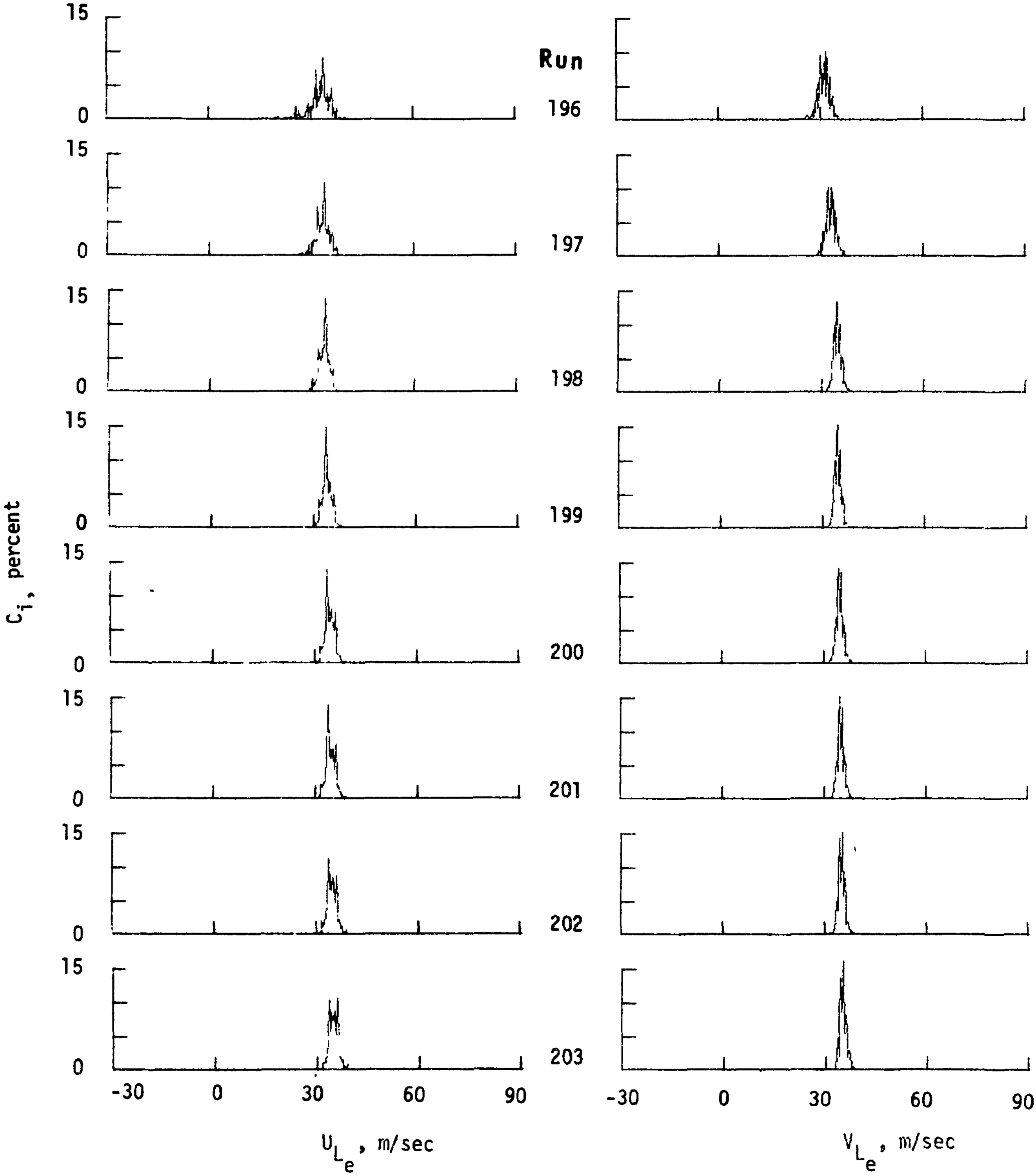



Figure B-15.- Histograms in scan at constant $x_c/c = 1.13$, $\alpha = 4.75^o$.

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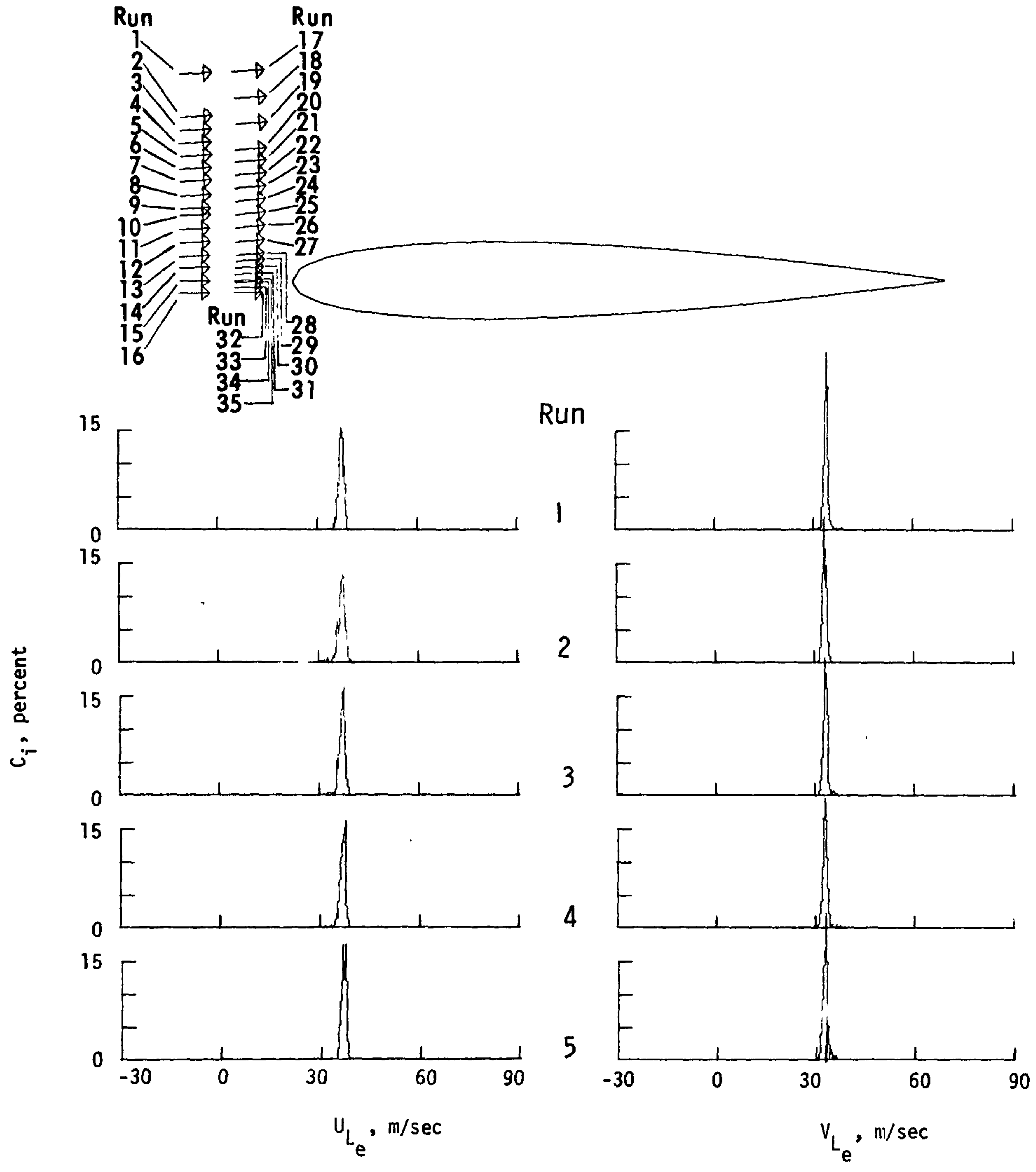
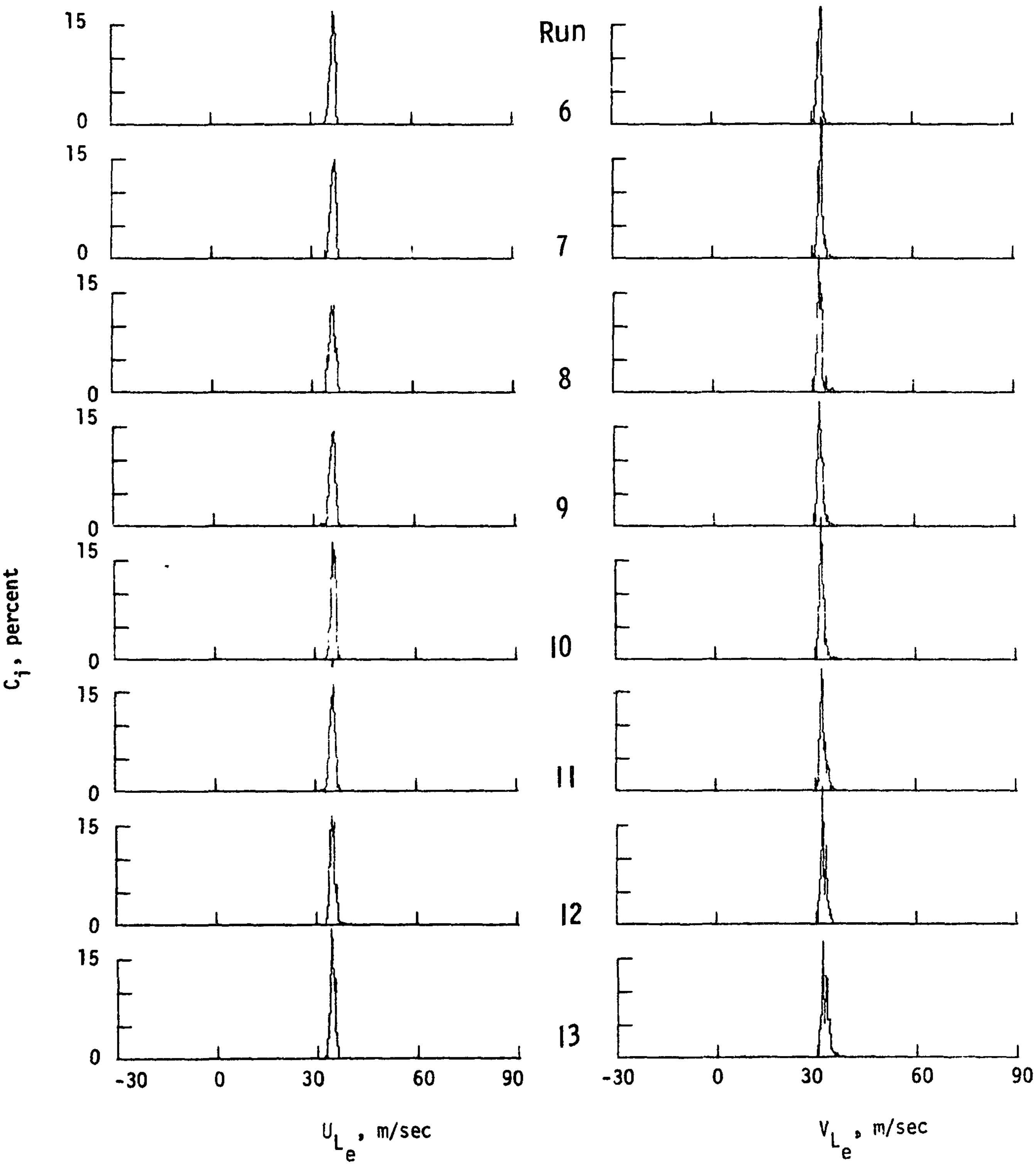



Figure B-16.- Histograms in scan at constant $x_c/c$ = -0.17 and -0.09, $\alpha$ = 0.6°.

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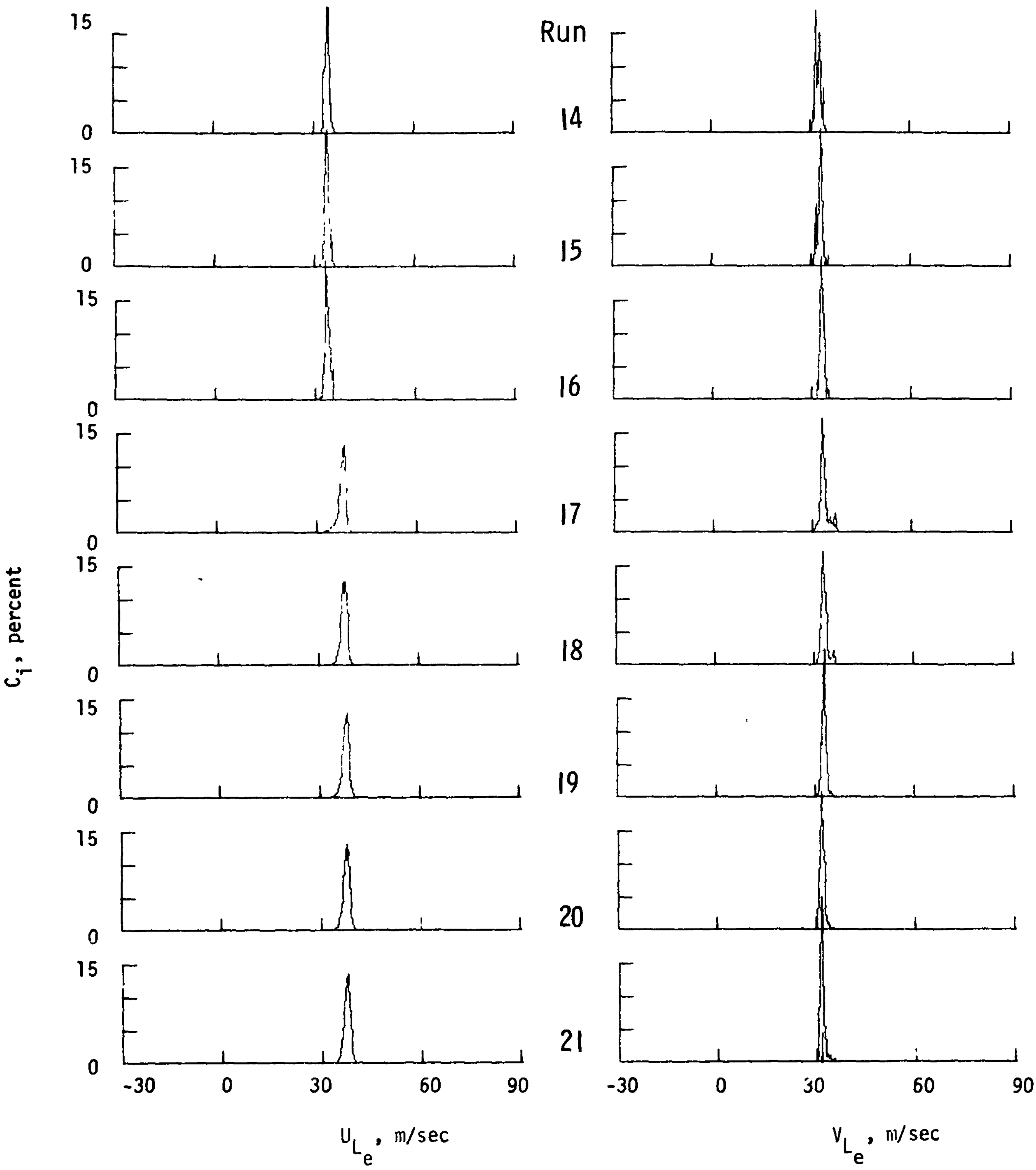


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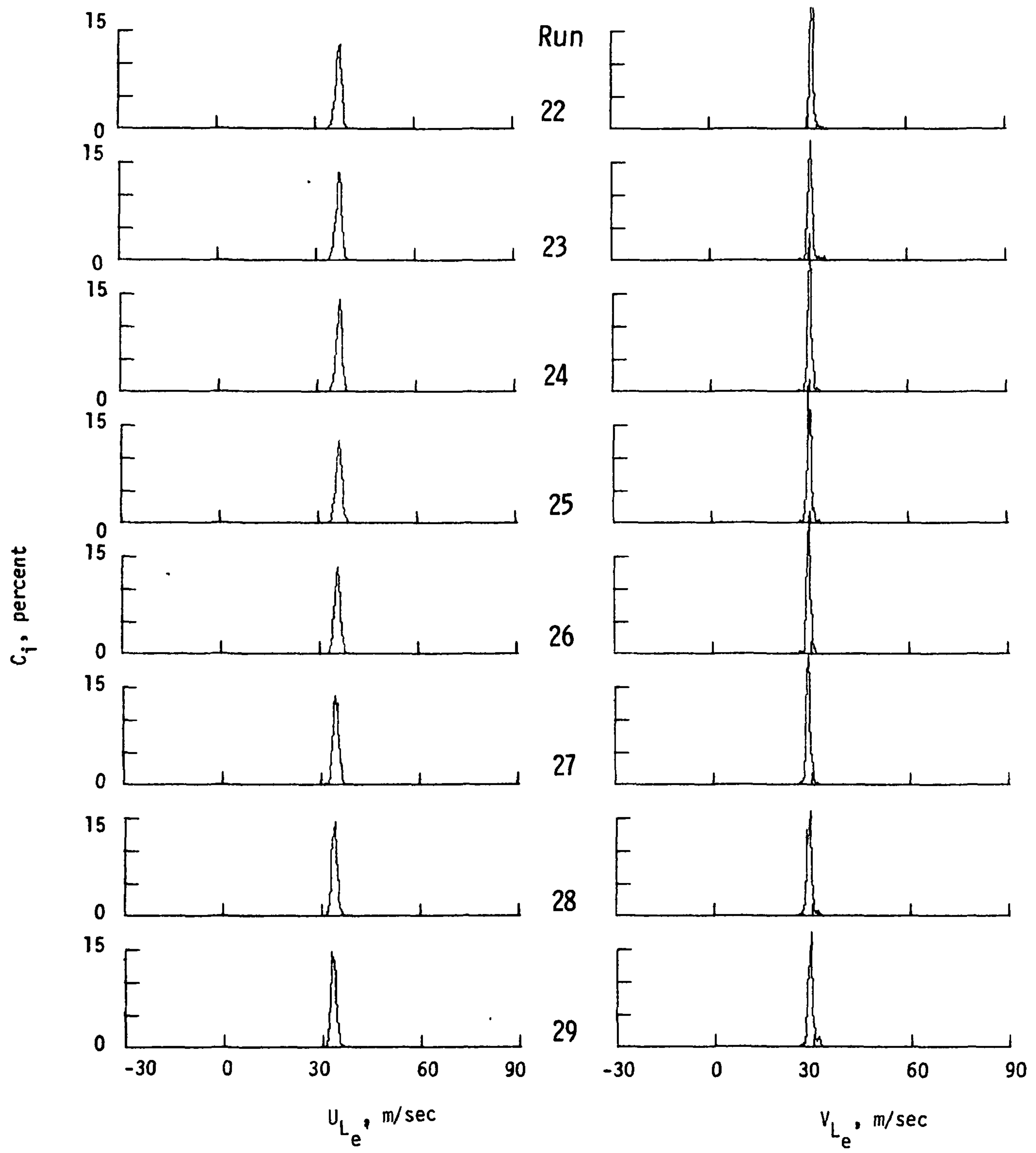


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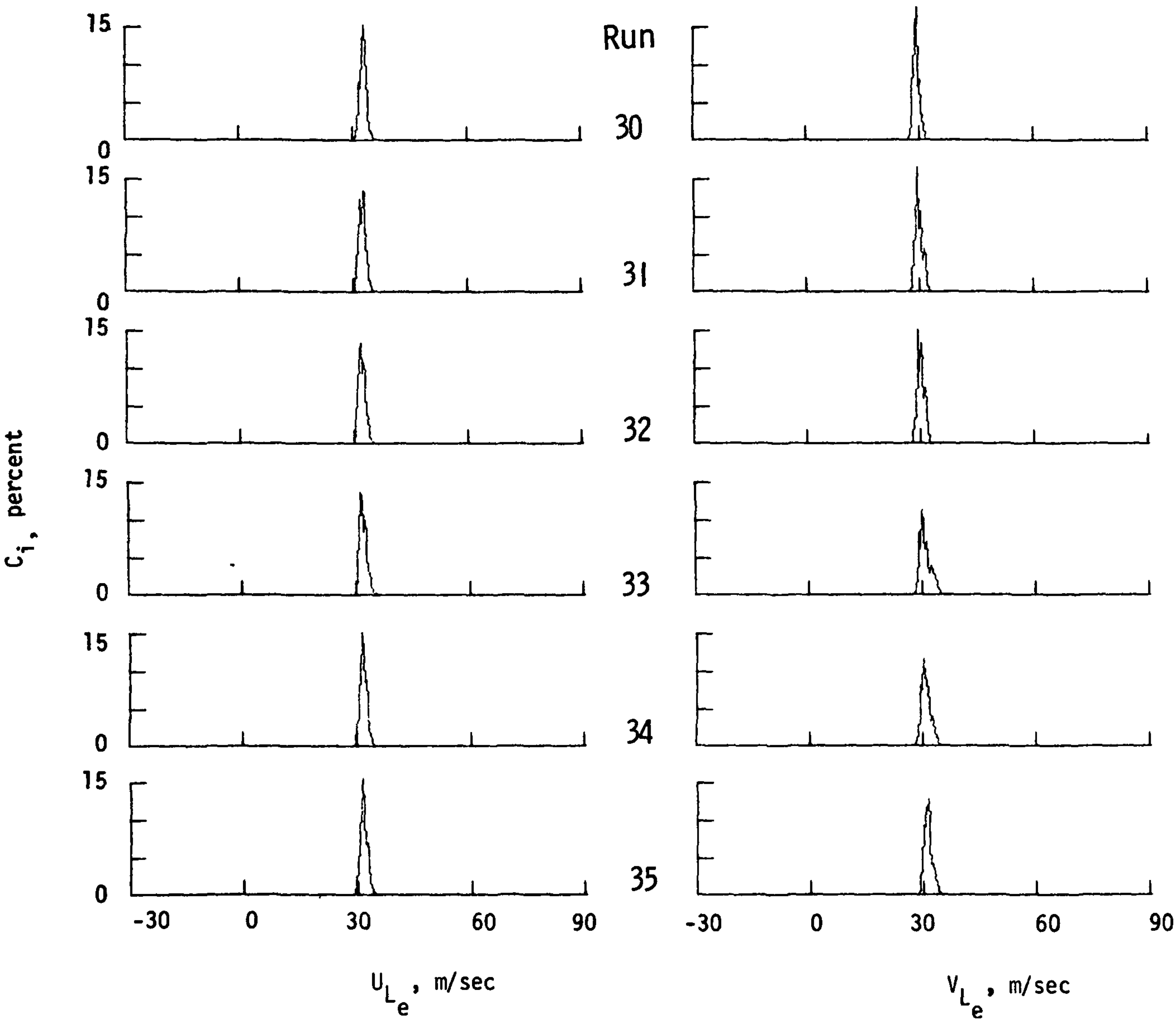


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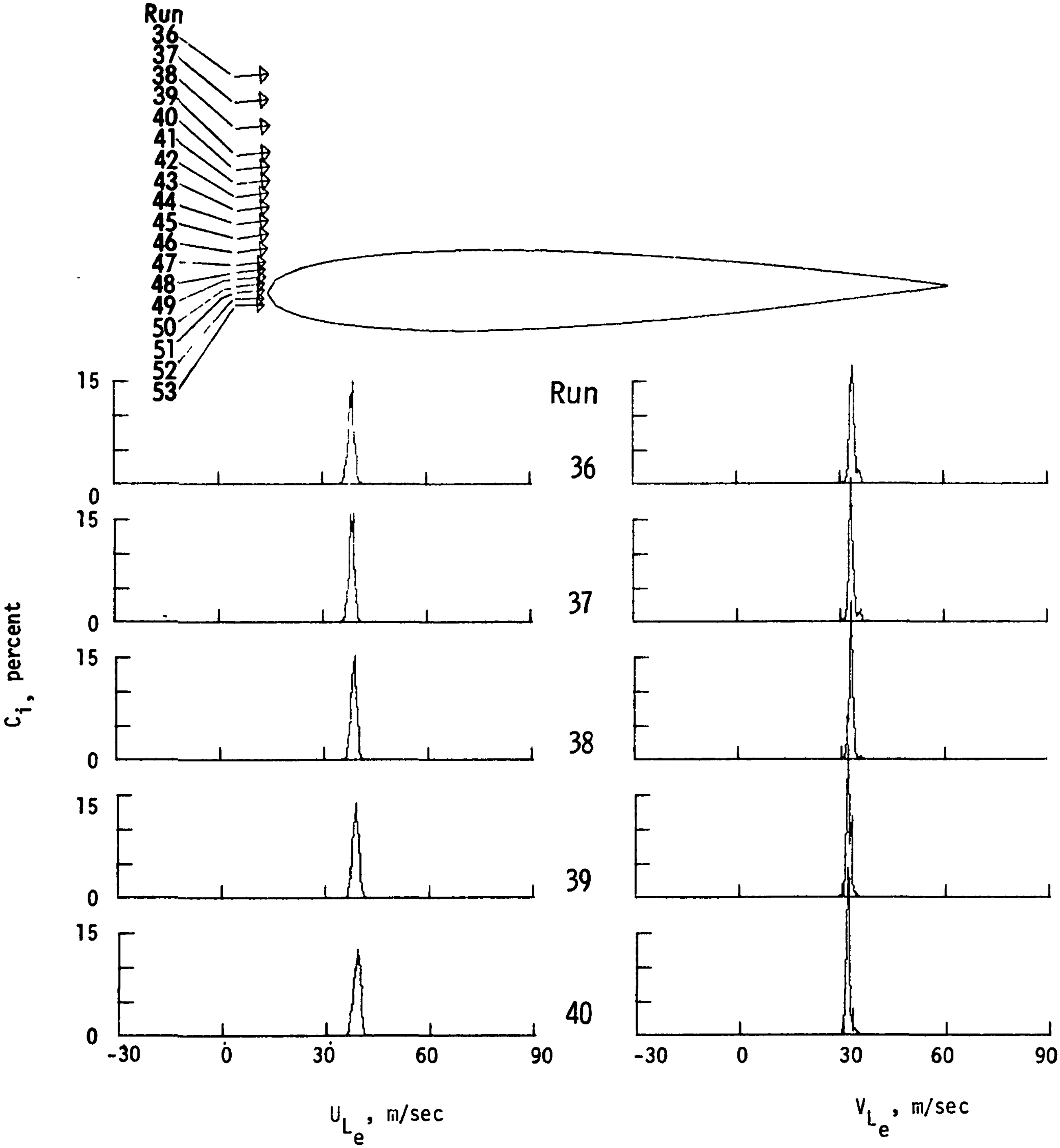
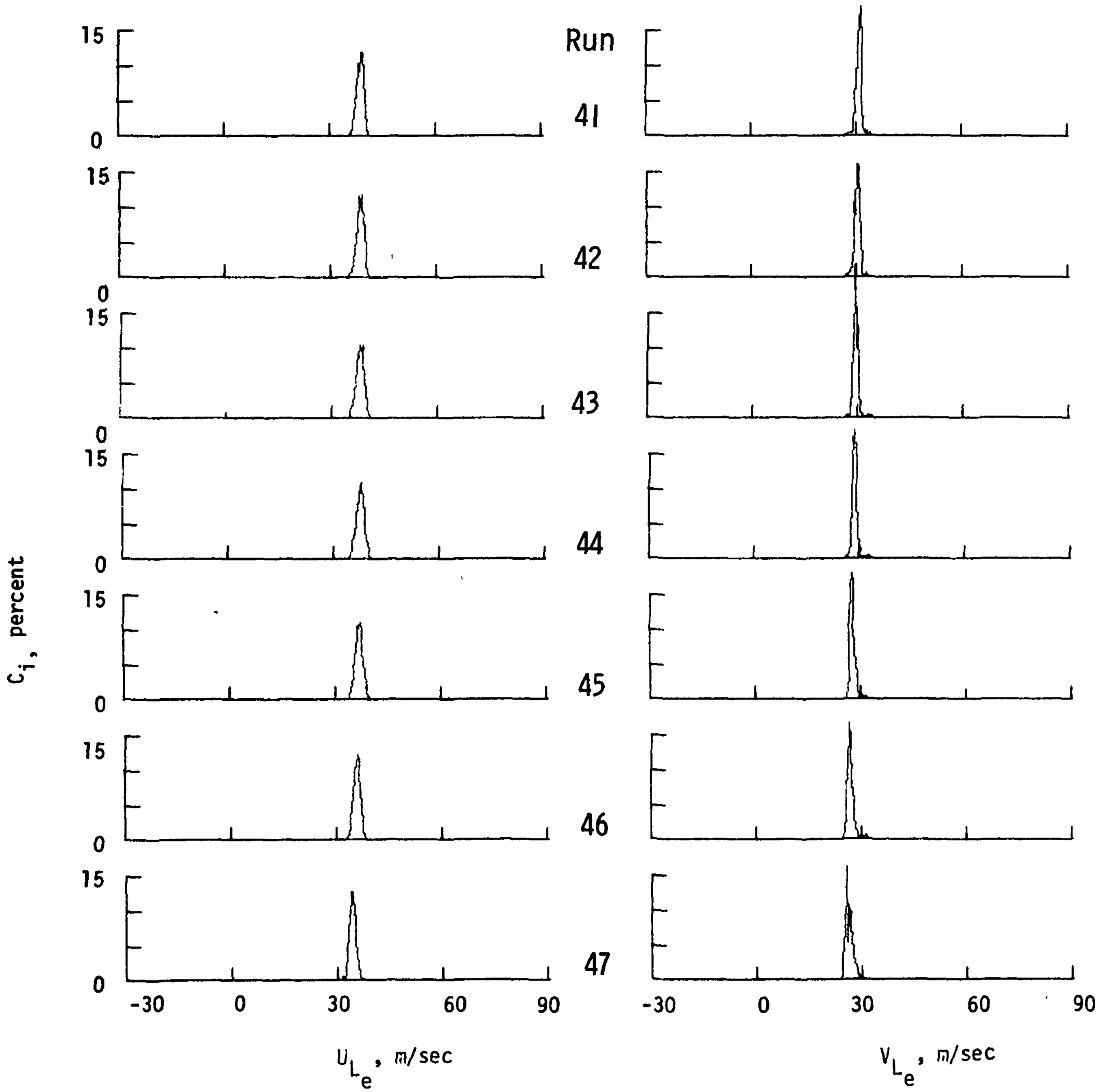



Figure B-17.- Histograms in scan at constant $x_c/c = -0.05$, $\alpha = 0.6^{o}$.

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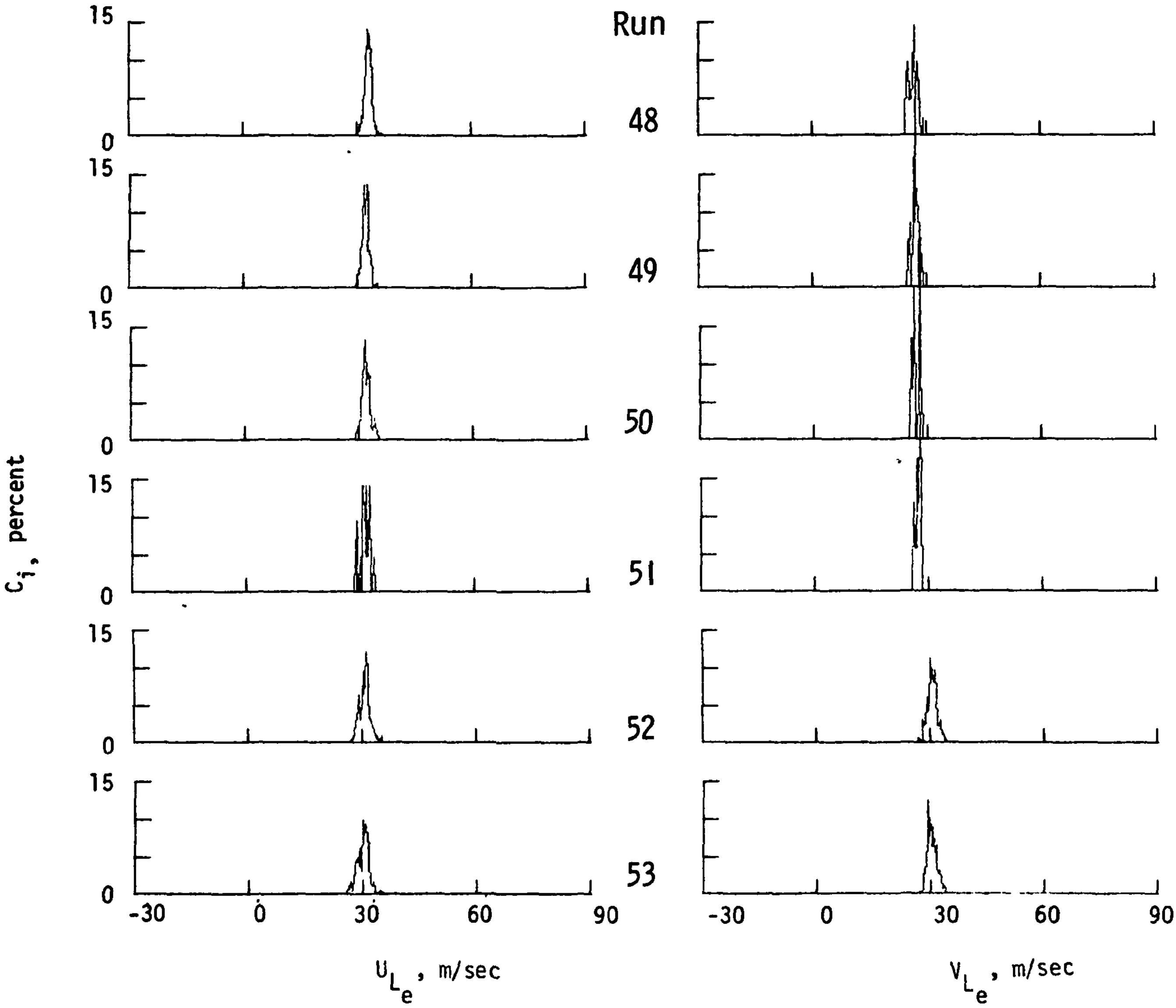


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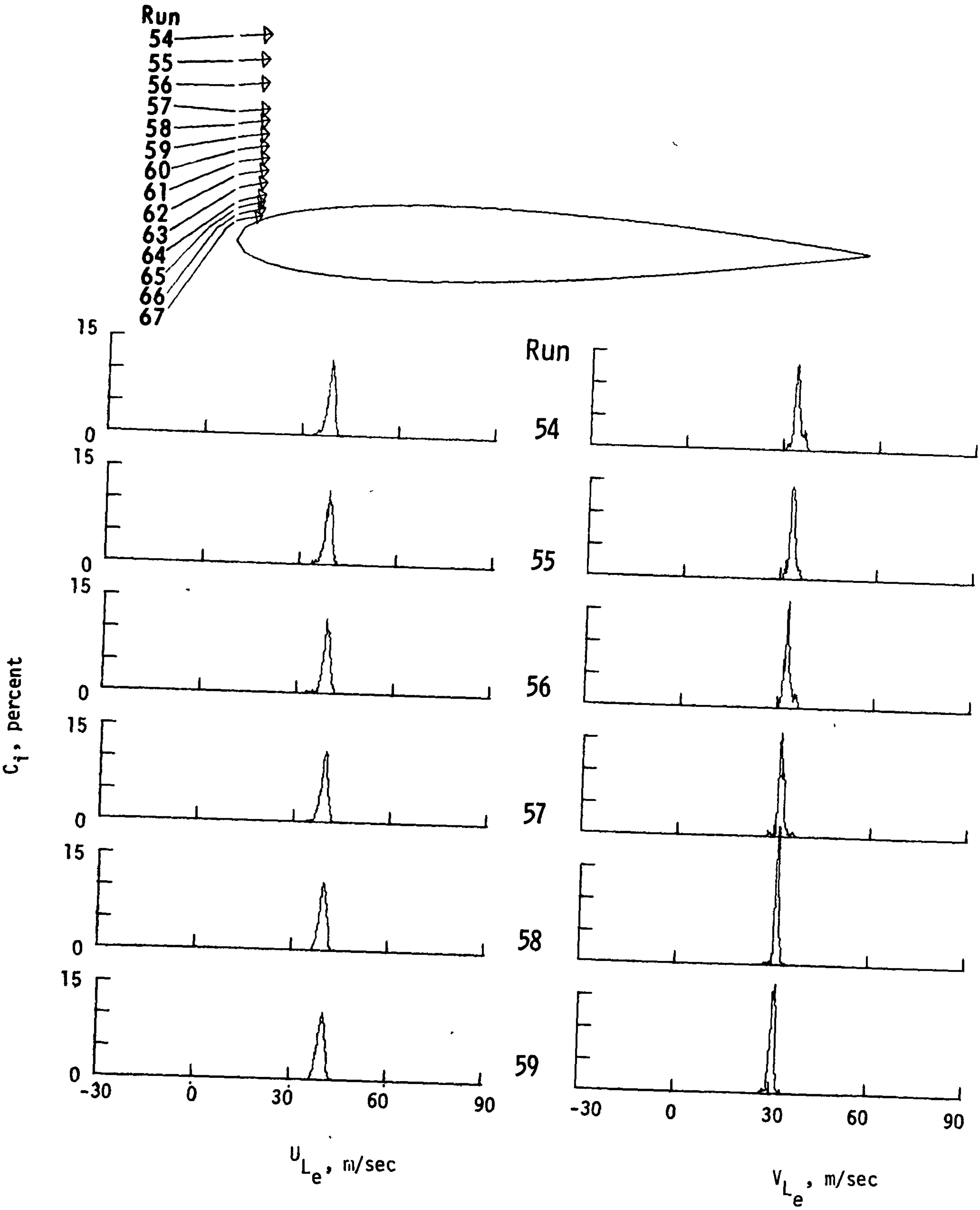
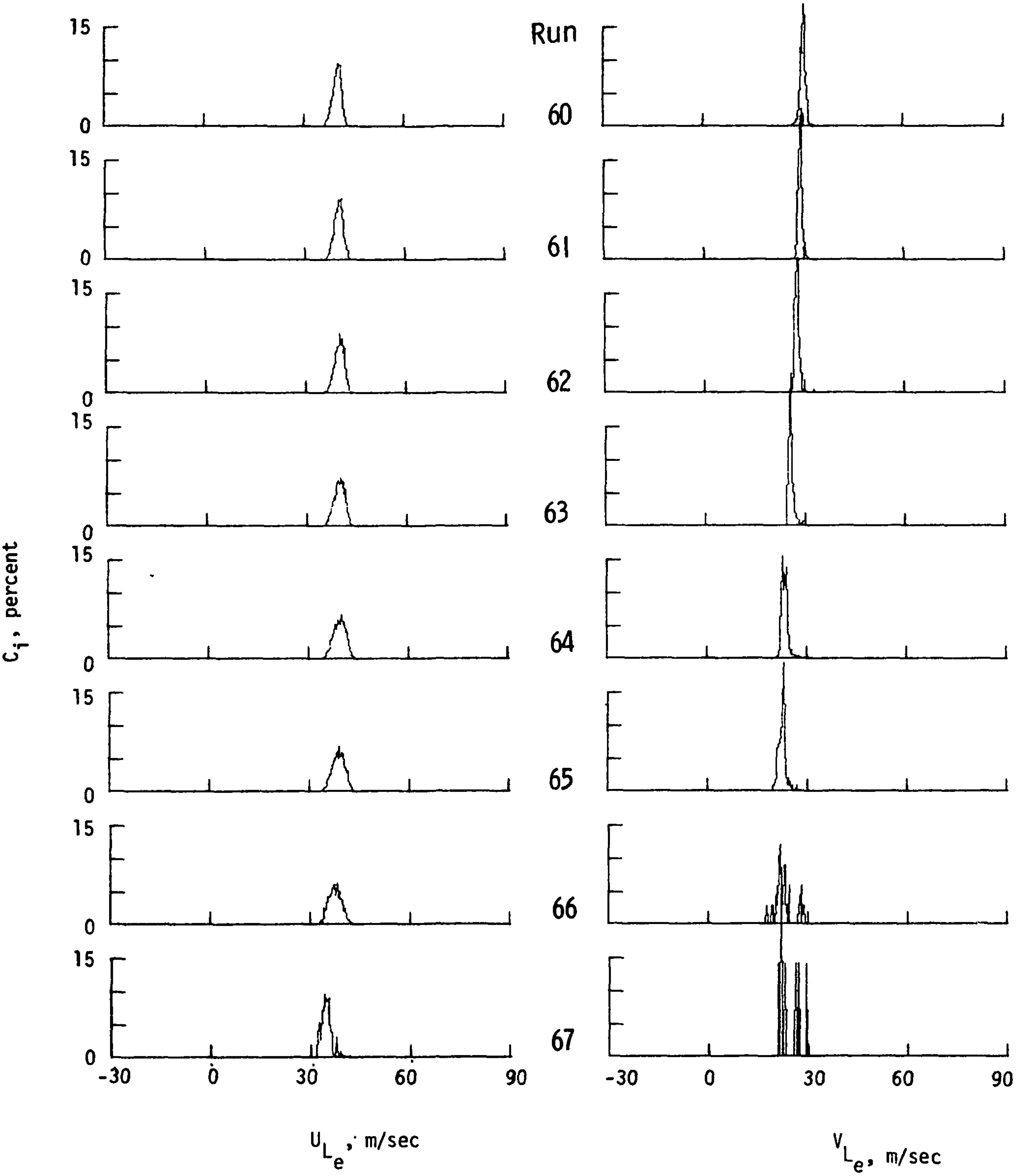



Figure B-18.- Histograms in scan at constant $x_c/c = 0$, $\alpha = 0.6^o$.

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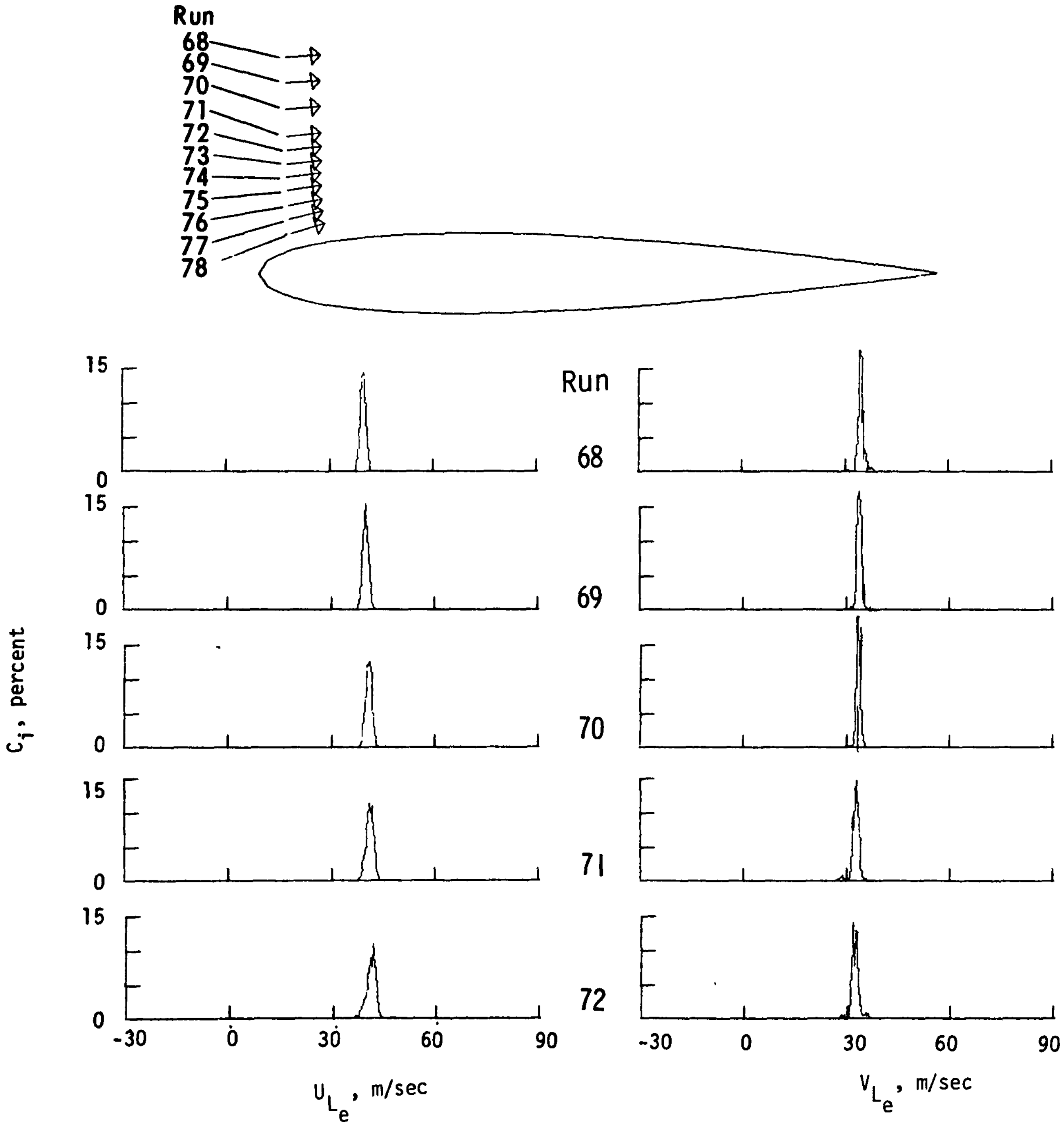
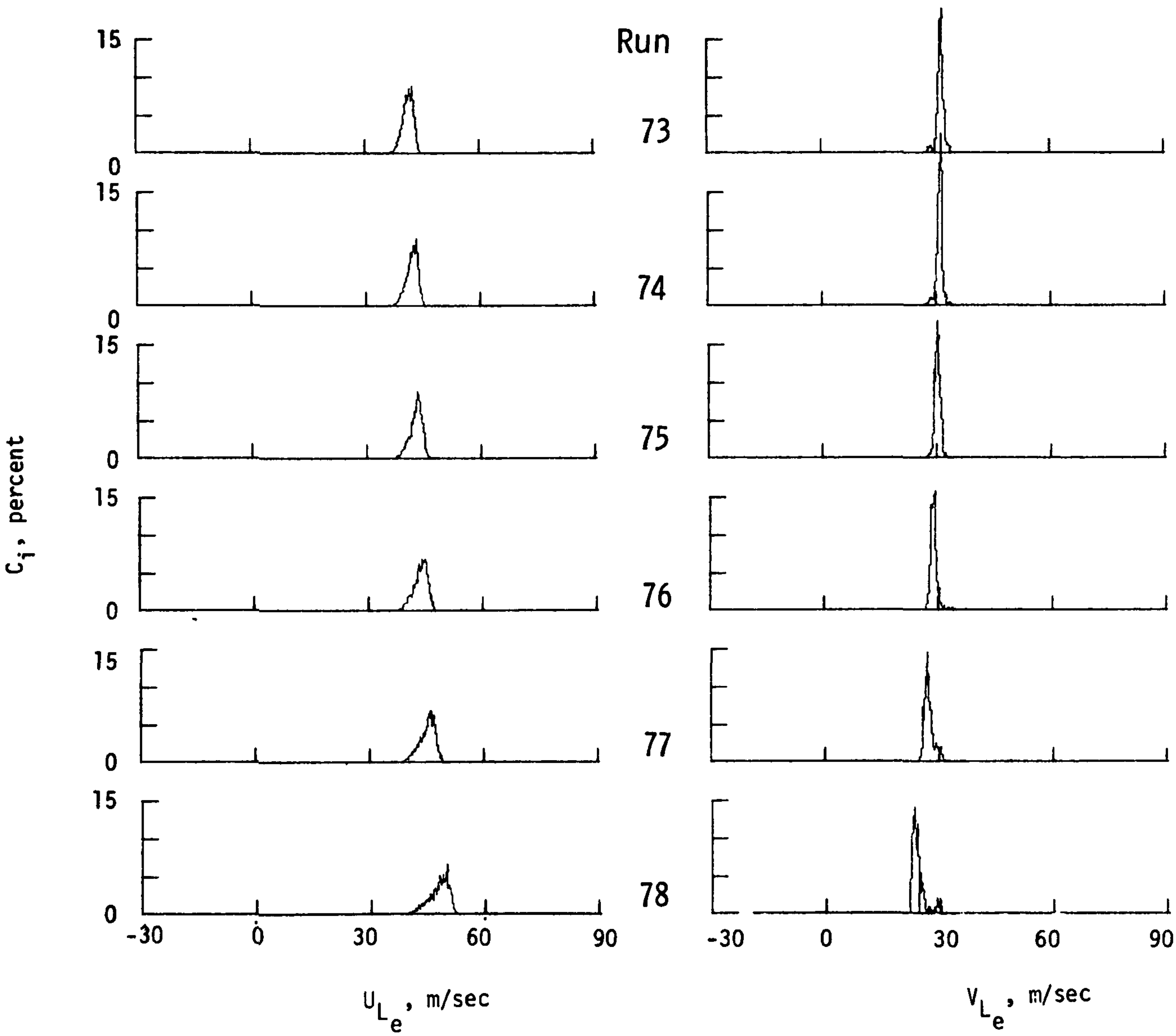



Figure B-19.- Histograms in scan at constant $x_c/c = 0.04$, $\alpha = 0.6^{\circ}$.

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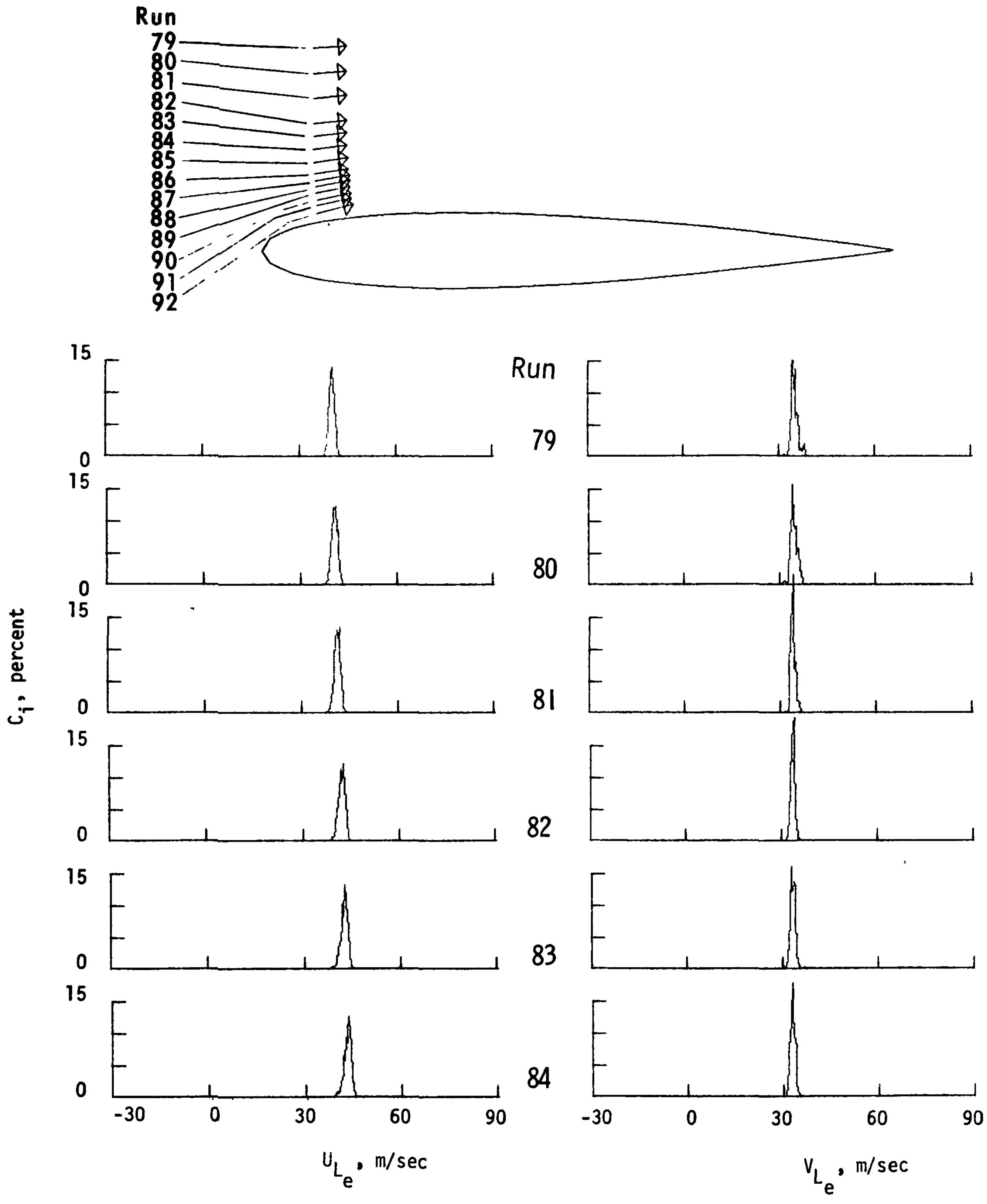
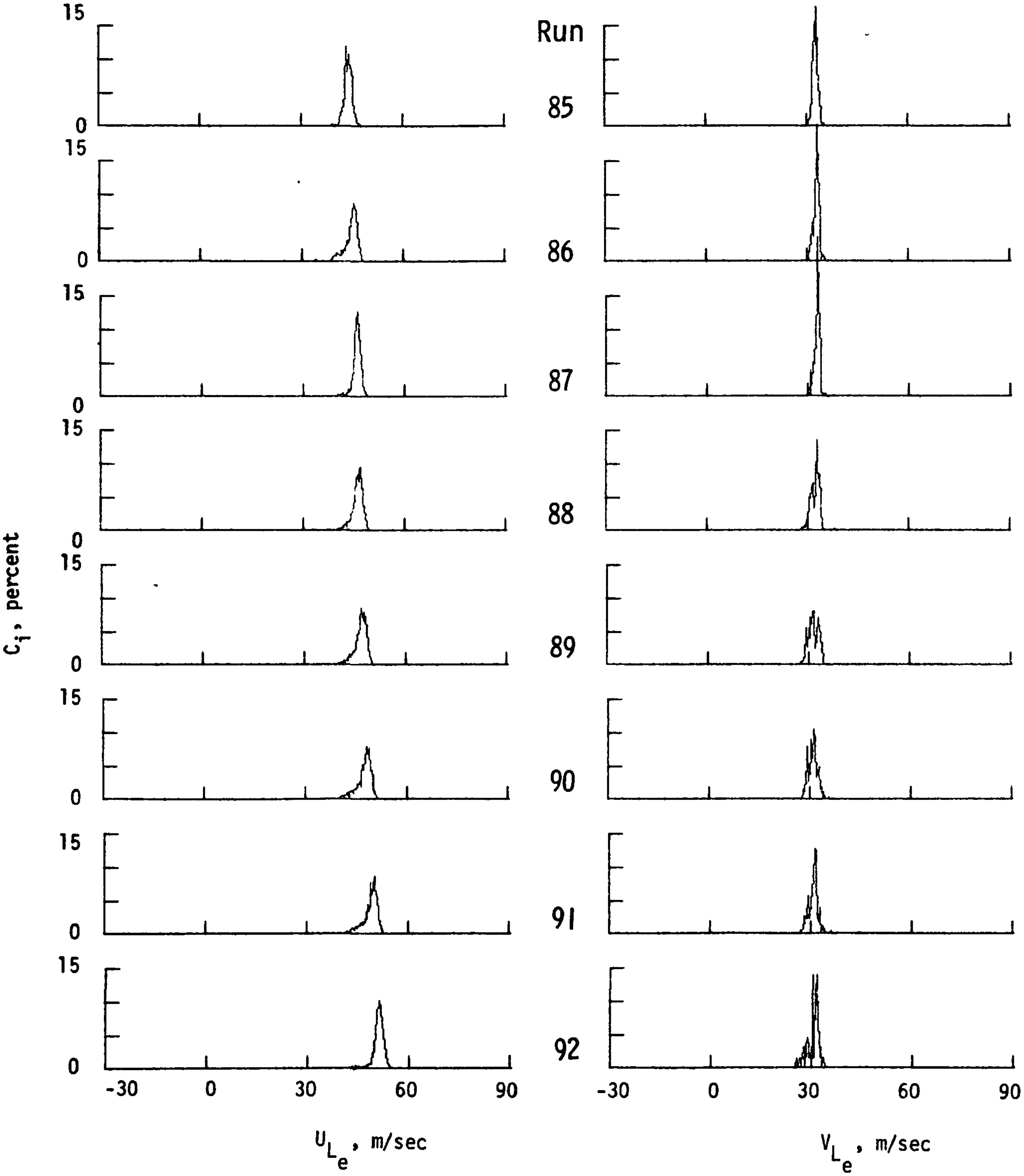



Figure B-20.- Histograms in scan at constant $x_c/c = 0.08$, $\alpha = 0.6^o$.

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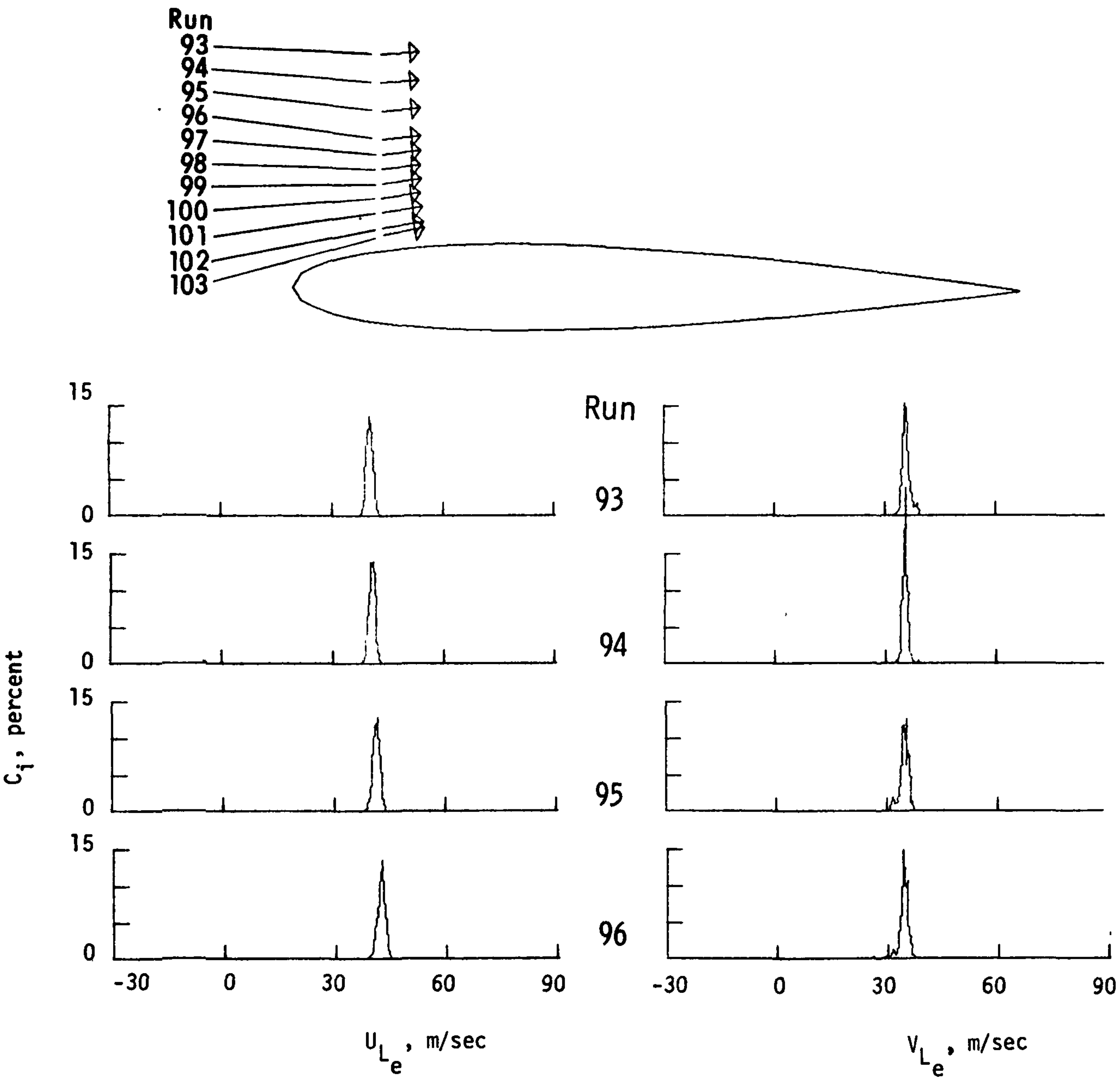
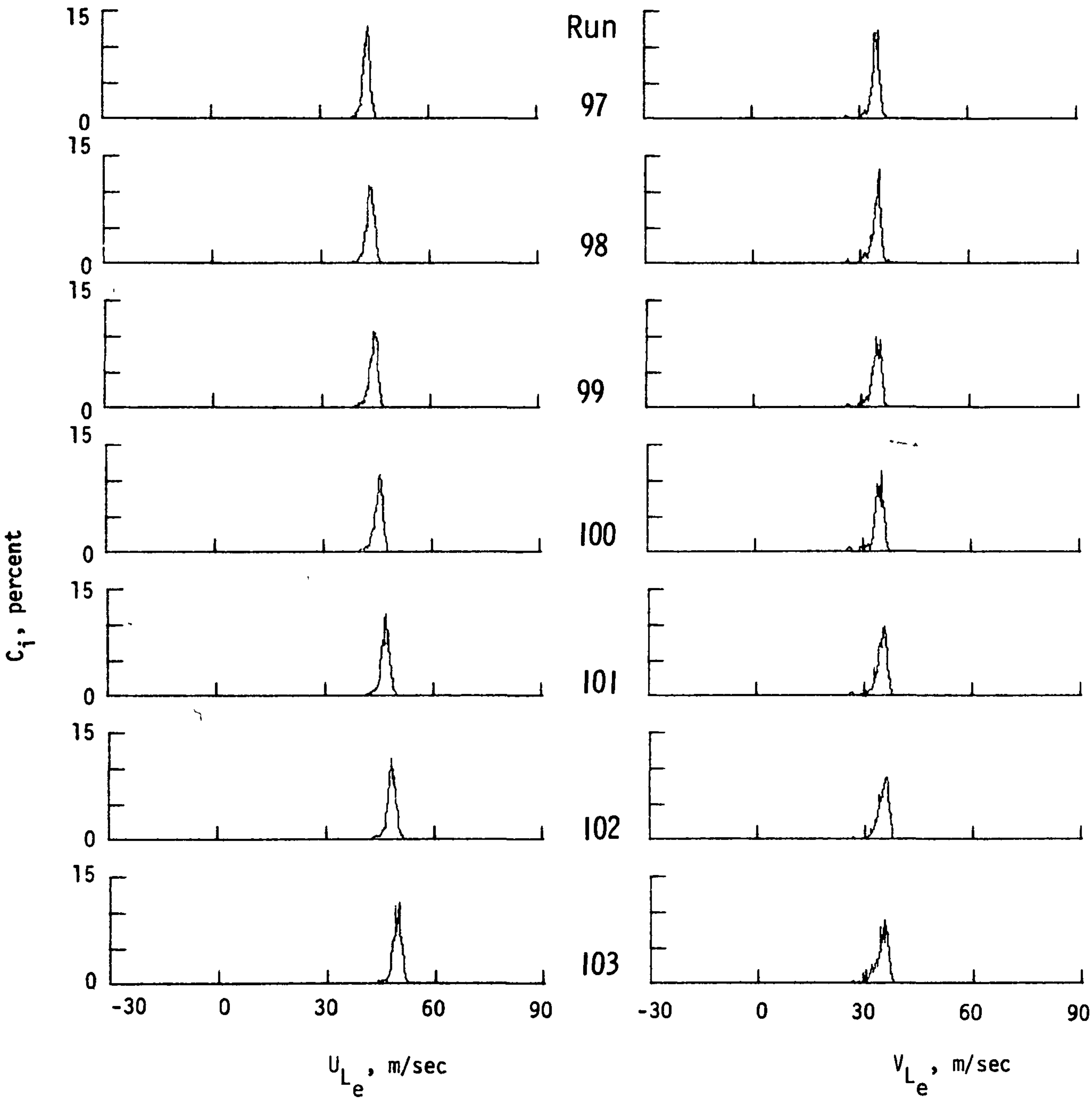



Figure B-21.- Histograms in scan at constant $x_c/c = 0.12$, $\alpha = 0.6^o$.

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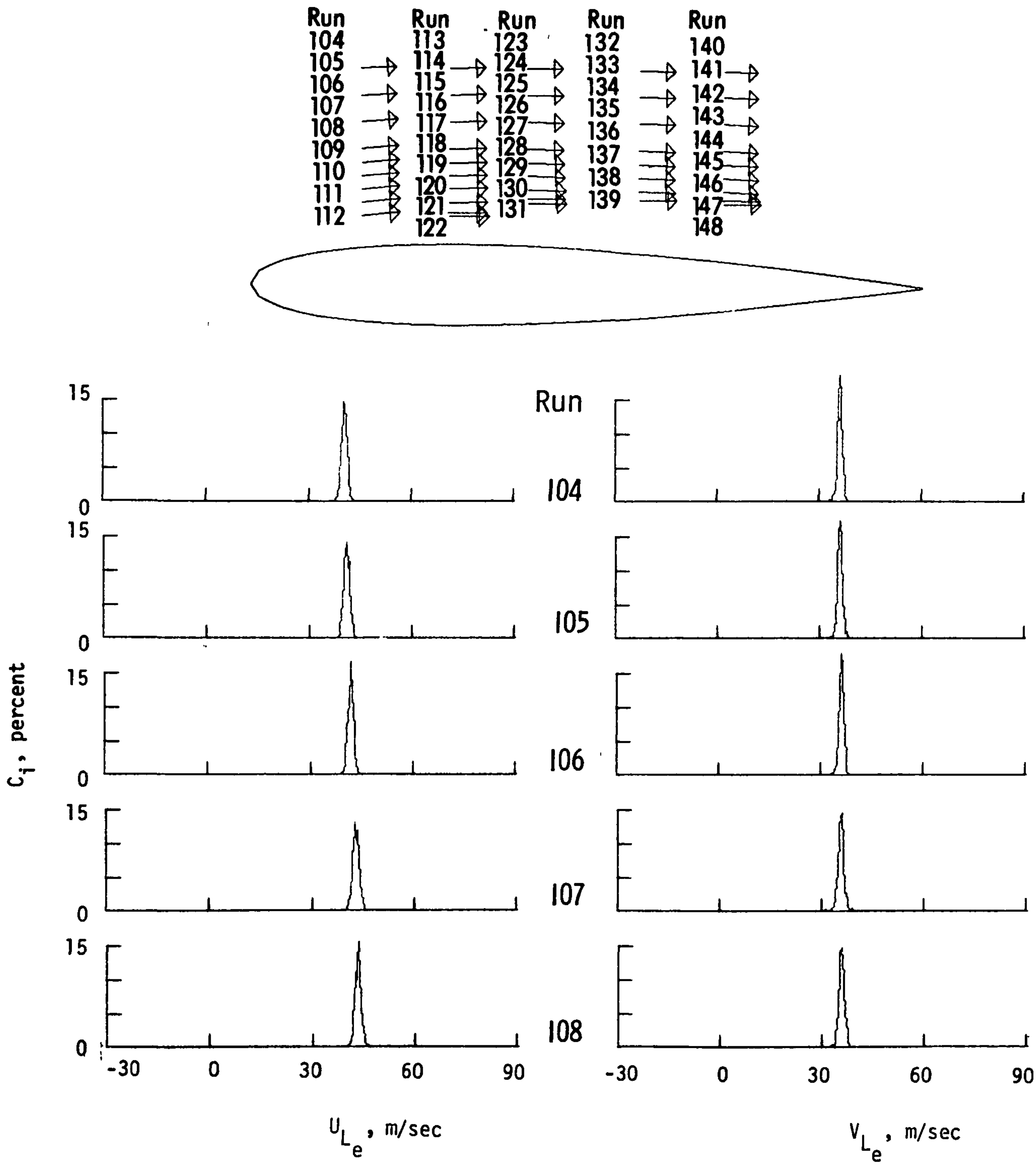
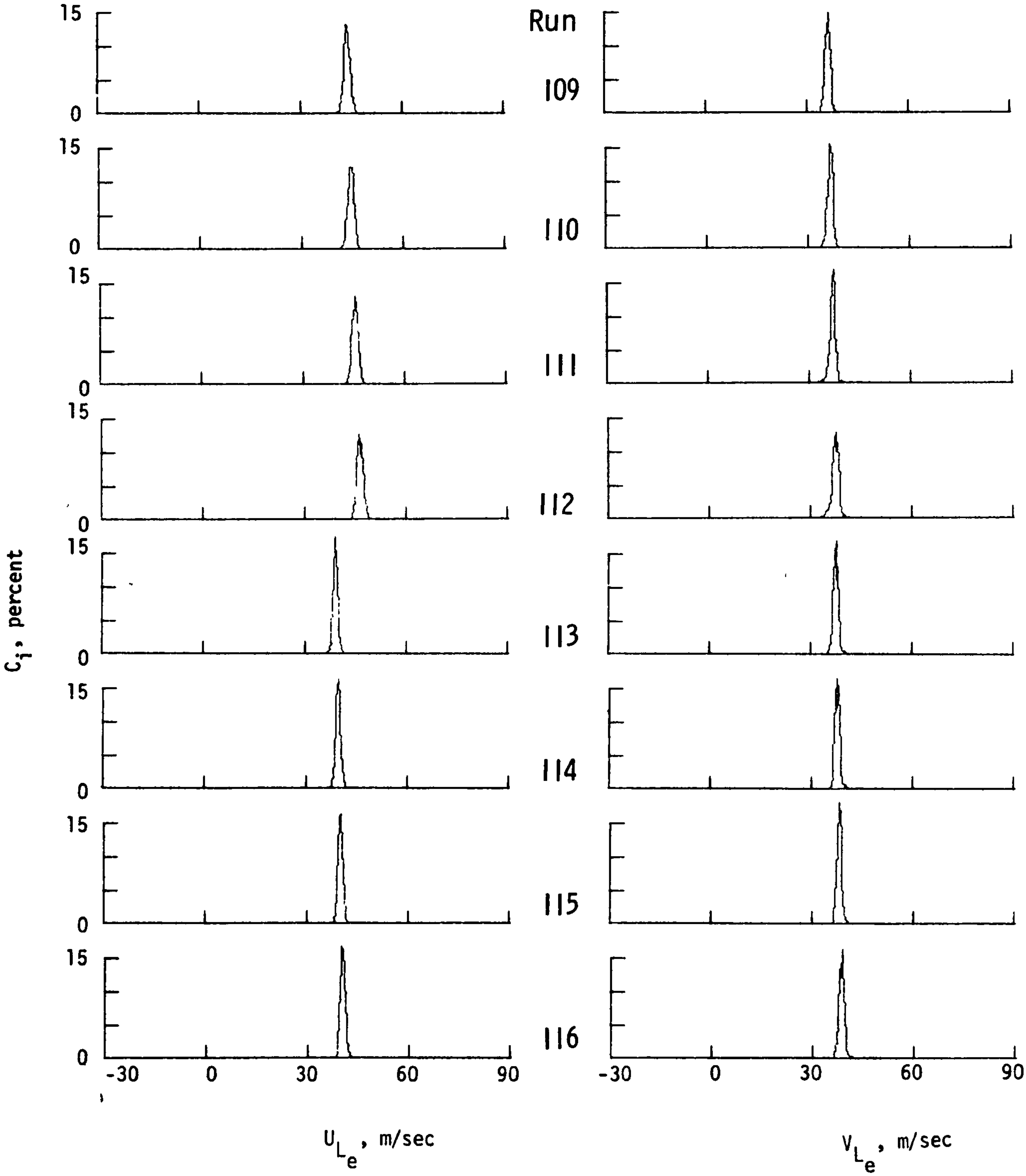



Figure B-22.- Histograms in scan at constant $x_c/c$ = 0.16, 0.29, 0.41, 0.58, and 0.70, $\alpha = 0.6^o$.

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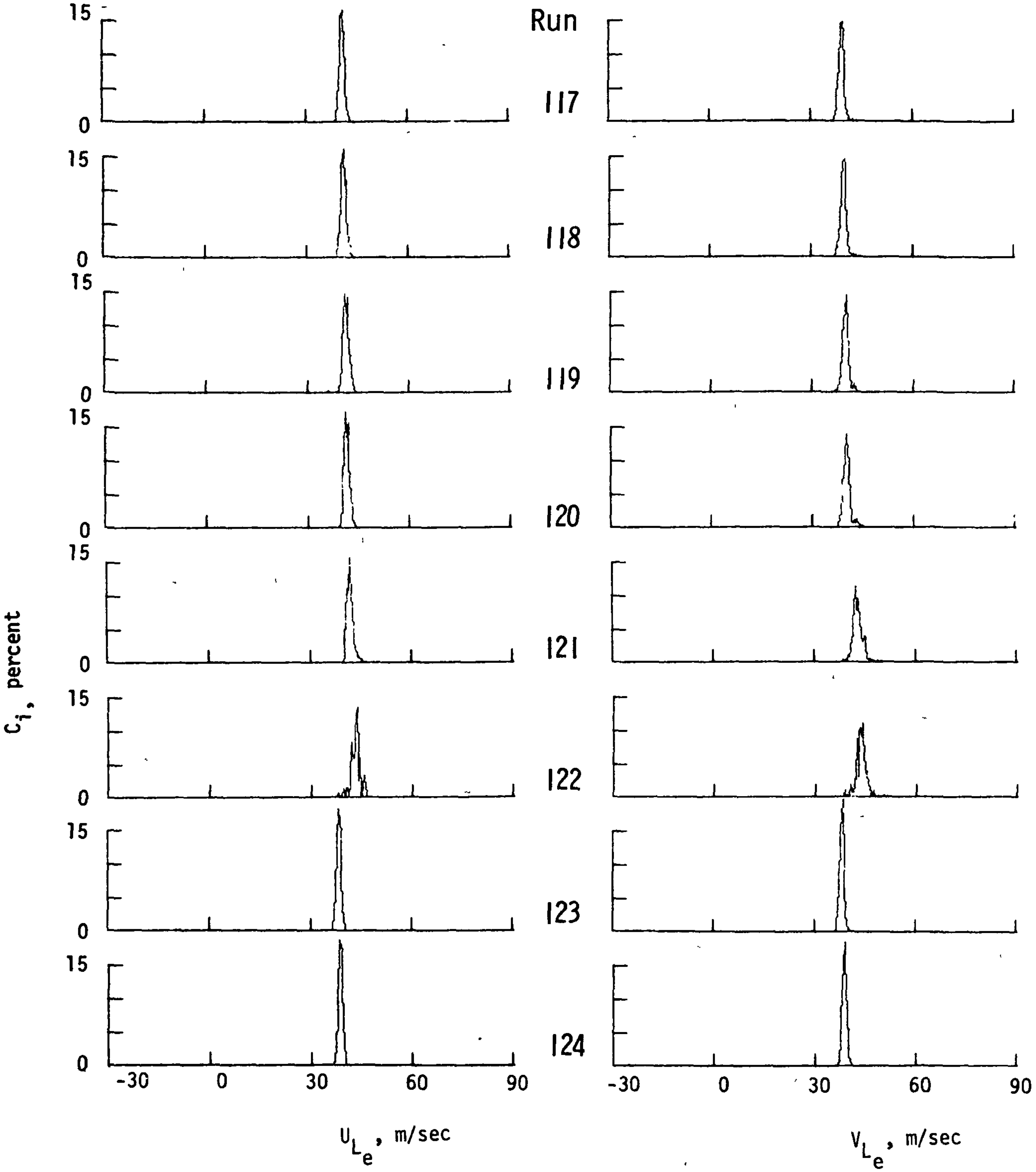


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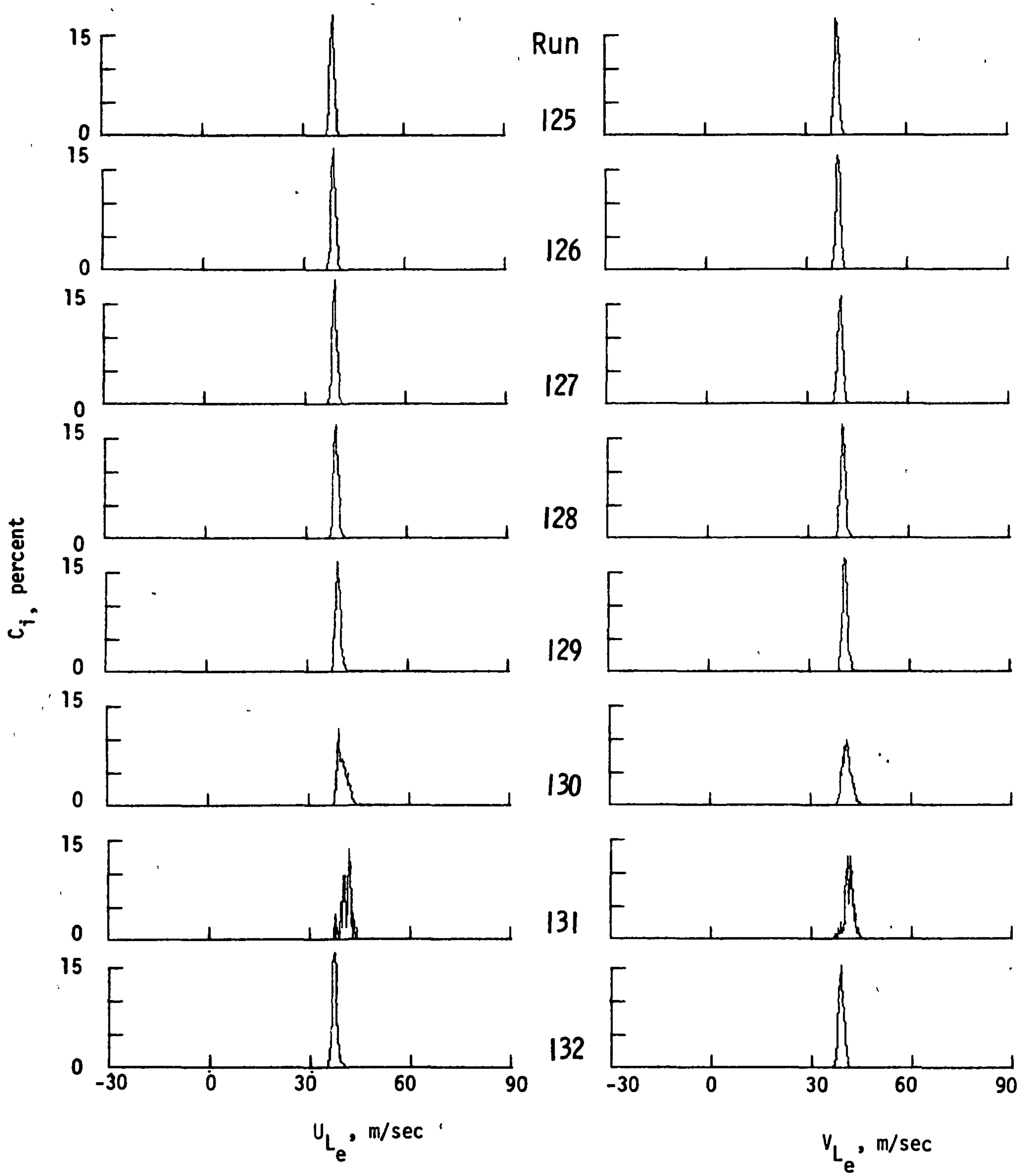


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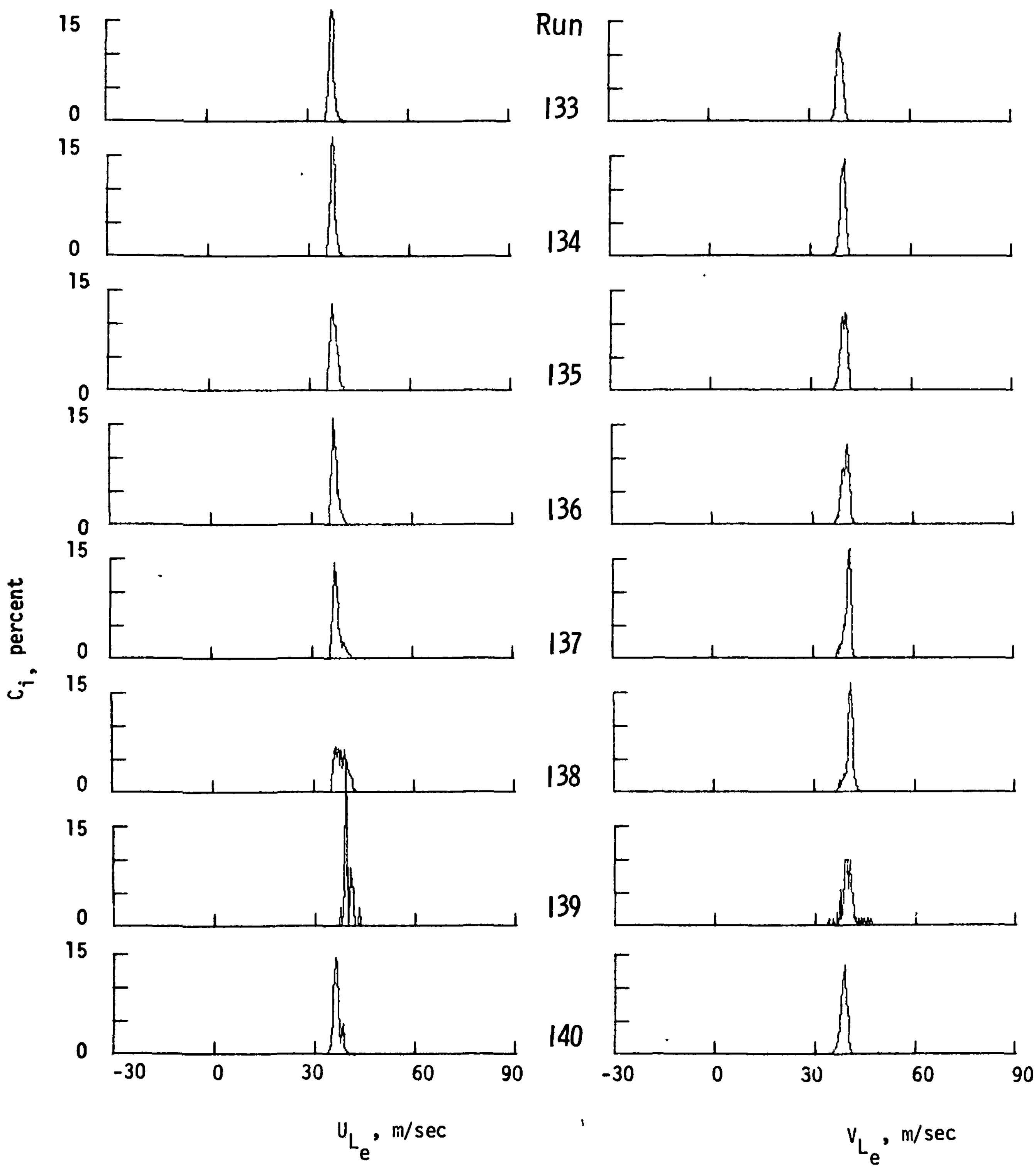


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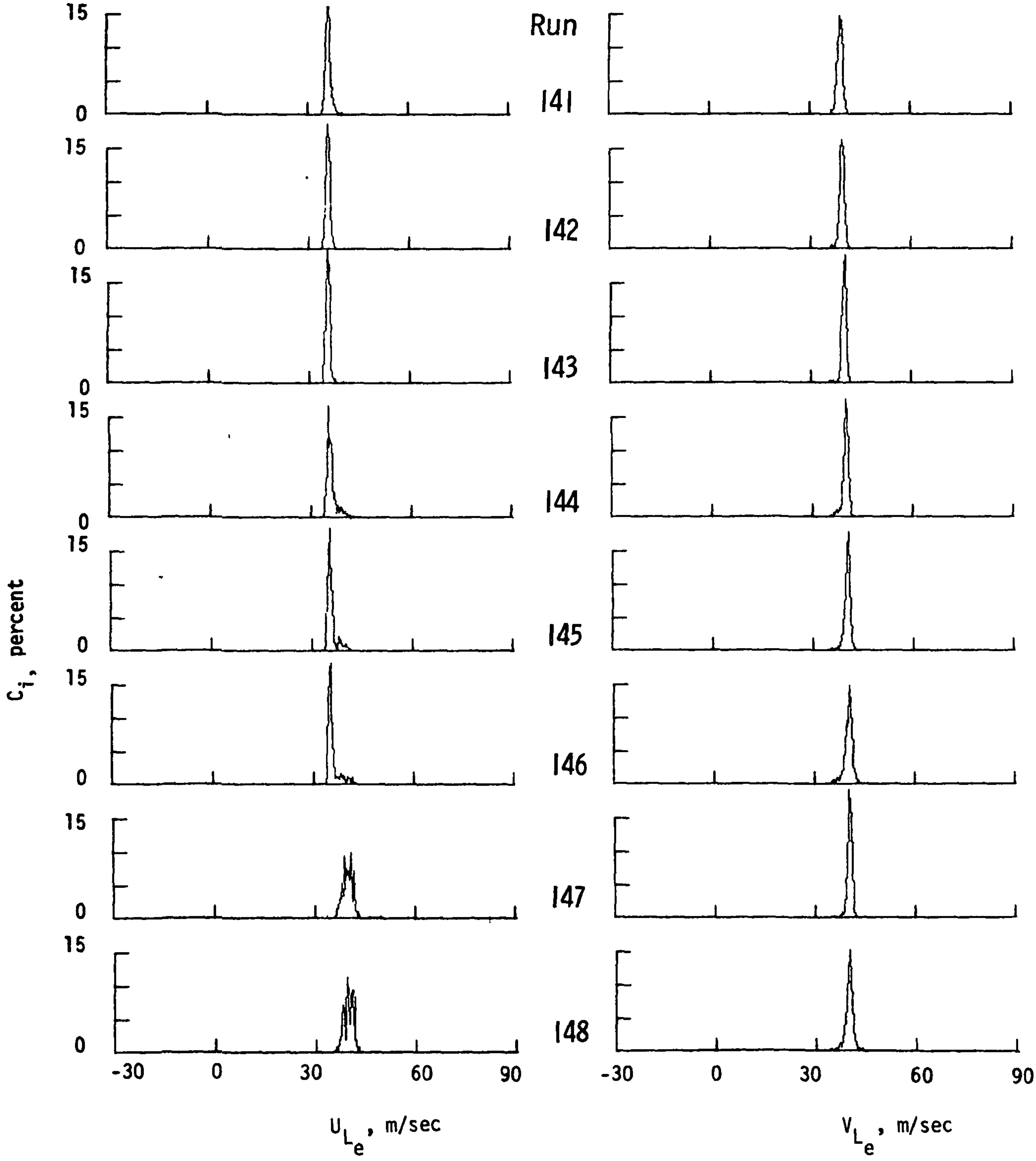


Figure B-22.- Concluded.

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16 Abstract

An investigation has been conducted in the Langley V/STOL tunnel with a laser velocimeter to obtain measurements of airflow velocities around a wing at low angles of attack (0.6° and 4.75°). The applicability of the laser velocimeter technique for this purpose in the V/STOL tunnel was demonstrated in this investigation with measurement precision bias calculated at -1.33 percent to 0.91 percent and a random uncertainty calculated at ±0.47 percent. Free-stream measurements were obtained with this device and compared with velocity calculations from pitot-static probe data taken near the laser velocimeter measurement location. The two measurements were in agreement to within 1 percent. Velocity measurement results about the centerline at 0.6° angle of attack were typically those expected. At 4.75°, the velocity measurements indicated that a short laminar separation bubble existed near the leading with with an oscillating shear layer.

17 Key Words (Suggested by Author(s))
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