NASA Contractor Report 3780

Computer Program for Prediction of the Deposition of Material Released From Fixed and Rotary Wing Aircraft

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SUMMARY

The AGDISP code computes the motion of agricultural materials released from aircraft, predicting the mean position of the material and the position variance about the mean as a result of turbulent fluctuations. This document is the User Manual to the Mod 2.0 version of the AGDISP code.

This manual consists of nine sections. In Section 1 the dispersal dynamics formulations are reviewed, and a summary of the available background mean velocity and turbulence fields is given. In Section 2 the structure of the program, and of its companion plotting code AGPLOT and equivalent profile distribution code AGLINE, is highlighted. Section 3 contains a detailed explanation of input requirements and code outputs for AGDISP, while Section 4 contains similar information for AGPLOT, and Section 5, for AGLINE. Section 6 examines a test problem: generating the initial conditions, constructing the input deck, running AGDISP, plotting the particle trajectories with AGPLOT, and forming the equivalent distribution with AGLINE. In Section 7 a program flow chart is discussed, followed in Section 8 by a subroutine-by-subroutine description of the code. Section 9 contains details of the sample test cases, and the three Appendices identify variables used in the code.

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1. AGDISP FORMULATION, OPTIONS AND NOMENCLATURE

A Lagrangian approach is used to develop the equations of motion of discrete particles released from aircraft, and a predictor-corrector solution scheme is used to solve the resulting set of ordinary differential equations. The formulation of the particle equations, particularly the ensemble-averaging approach used to develop turbulent properties of the particle-atmospheric interaction, is detailed in Ref. 1. This section of the User Manual examines those variables and nomenclature that are a part of the AGDISP code results.

The aircraft is assumed to be in level flight near the surface, releasing particles into a (y,z) plane normal to the flight direction, x , as shown in Figure 1. The AGDISP code solves for the transport of these particles within this plane, until they deposit upon the surface or are carried aloft by wind or vortex motions. Accuracy of predictions requires accurate description of background environment (mean winds and turbulence). The need of accuracy must, however, be balanced by the requirement of computational speed and ease of calculation. Simulations need to be performed simply and repeatedly under a variety of background conditions, with minimum computer demands and setup requirements. When the need is justified, the solution for the background environment may be found by a larger, more detailed code, such as the NASA WAKE code discussed in Ref. 2. The mean velocity and turbulence profiles predicted by these codes may then be read by AGDISP to predict particle behavior. As an alternate approach the AGDISP code has been fitted with extensive simplified flow field options to permit the prediction of particle motion in a wide range of idealized background conditions. The detailed derivations of these options are included in the Technical Report (Ref. 1). In this section of the User Manual, the nomenclature needed to implement these options is discussed.

The released particles are assumed to be spherically shaped. The particle flight path as a function of time after particle release is computed as the locations (y,z) for each particle included in the simulation. The velocity of the particle is denoted by (V,W) . Gravity is downward. The particle is affected by the background environment; however, the environment is assumed to be unaffected by the presence of the particle. The interaction of the particle with the turbulence in the environment creates turbulent correlation functions for the particle position and the particle velocity, $\langle yv \rangle$ and $\langle zw \rangle$; for the particle velocity variance, $\langle vv \rangle$ and $\langle ww \rangle$; and for the particle position variance, $\langle yy \rangle$ and $\langle zz \rangle$. The square root of these last two variables gives the horizontal and vertical standard deviations of the particle motion about the mean described by y and z .

In the AGDISP code the particles are assumed to be influenced by three forces:

1. aerodynamic drag;
2. forces as a consequence of evaporation; and
3. gravity.

Inherent in the particle equations is a particle relaxation time τ_P which is essentially the e-folding time for the particle to come up to speed with the background velocity. The numerical solution of the particle equations requires the simulation time step to be a fraction of τ_P. Likewise, the evaporation model possesses a time scale τ_E during which the particle will e-fold in size due to evaporation. The evaporation model (Ref. 3) requires that a wet-bulb depression be user-specified. Fluctuations in evaporation rate are neglected in the AGDISP code. Aerodynamic drag is accounted for by using the empirical drag law of Langmuir and Blodgett (Ref. 4).

The behavior of the particles is intimately connected to the local background mean velocity and turbulence fields through which the particles are transported. The flow field options available in Mod 2.0 are the following:

<u>Fixed-Wing Fully Rolled Up Tip Vortices</u>

If roll up of trailing vorticity can be approximated as occurring immediately downstream of the wing, the mean velocity field that results may be simply characterized by the aircraft semispan, circulation and load distribution (either rectangular or triangular).

<u>Fixed-Wing Betz Roll Up</u>

Time integration of trailing vorticity rolling up into multiple discrete vortices and the influence of the increasing vortex strength and of the unrolled vortex sheet are available. The approach is based on a methodology extended from Betz (Refs. 5 and 6) and involves specifying the wing load distribution.

<u>Propeller</u>

The propeller model is an adaptation of actuator-disk theory (Ref. 7) and involves knowing the basic propeller characteristics of engine efficiency, shaft rpm, blade radius, aircraft drag coefficient, and aircraft wing planform area. Turbulence effects due to the propeller slipstream are included.

<u>Helicopter in Forward Advance</u>

The helicopter flow field is modeled partly as a skewed hover wake, following actuator-disk theory, and partly as a fully-rolled up rectangular vortex pair. The advance ratio μ ($\mu > 0$ for forward flight) is used to partition the helicopter weight between the two flow fields (see Ref. 1 for details).

Mean Background Crosswind

Atmospheric crosswind in the (y,z) plane is parameterized as a neutral logarithmic velocity profile dependent upon knowing the crosswind at a height and the surface roughness (generally characterized as 1/30 of the physical height of the surface covering).

Plant Canopy

When a plant canopy, such as a stand of fir trees, comprises the surface features, the plant areal density of the canopy may be entered into the AGDISP code. Modifications to surface roughness, turbulence and particle paths are made consistent with the canopy model of Ref. 8.

Superequilibrium Turbulence

Local background turbulence level may be simply specified by specifying the crosswind velocity, by fixing a constant value (typically one percent of the mean wind speed), or by optioning the AGDISP code to compute the turbulence field consistent with the given mean velocity field. This option solves the nonlinear, algebraic equations of superequilibrium turbulence (Ref. 9), and typically requires a doubling of the computer time needed for solution of the particle means and standard deviations.

Terrain

A nonhorizontal, level surface may be assumed.

WAKE Results

The AGDISP code has been fitted with the option of entering any externally-computed mean velocity and turbulence field, as long as the computer-generated plot file corresponds to the format specified in Section 3 of this manual.

2. AGDISP ARCHITECTURE

The AGDISP code consists of three programs: AGDISP for establishing the desired background fields and computing the particle trajectories, AGPLOT for plotting the resulting particle solutions and AGLINE for constructing an equivalent Gaussian profile distribution from the multiple-particle solution generated by AGDISP. These programs are configured as interactive programs reading their needed input data from disk files and writing output to the terminal. AGDISP reads an input file of data cards (valid cards are discussed in Section 3), types information to the terminal as the run proceeds, generates printed output in a separate file, stores particle trajectory information in a plot file for subsequent plotting, and reads WAKE plot file results from a separate data file (if invoked). AGPLOT reads the desired particle plot file and interactively questions the user to supply necessary scaling data for the plot construction. AGLINE reads the particle plot file to construct an equivalent profile distribution (compatible for entry into the FSCBG Forest Service code, Ref. 10), generating printed output and a Gaussian pattern plot. These programs have straight-line flow charts (examined in Section 7 of this manual; an overview of their construction follows in this section of the User Manual, including discussion of accuracy, program limitations, and warning messages.

The AGDISP code requires the data entry explained in Section 3. This input data is read and processed, causing termination of the program if errors are discovered or needed cards are missing. Initialization follows: particle locations and velocities, vortex strength, Betz roll up, plant canopy, WAKE plot file. The particle equations are then integrated repeatedly until one of two termination conditions occur:

1. maximum simulation time is reached; or
2. all of the particles deposit on the surface.

Each integration step in turn includes the following:

1. updating the background mean velocity and turbulence fields by the WAKE plot file, Betz roll up, vortex motion, plant canopy;
2. equation system predictor of the particle equations;
3. two equation system correctors of the particle equations; and
4. incremental file save of the particle results for subsequent plotting by AGPLOT and use by AGLINE.

Solution of the particle equations is by a modified predictor-corrector scheme (Ref. 11) employing two correctors to enhance solution accuracy. A fixed time step size is determined by the program knowing the particle and evaporation time scales τ_P and τ_E. The algorithm involved was selected to give accurate results to the particle equations without impacting computer time involved.

Nonetheless, AGDISP is flexible enough to admit a wide variety of input conditions, some of which may demand increased computer time. For these cases, "$$$ WARNING" messages will flag such events, to warn the user of cases where input conditions may require more computer time. The messages that may appear are the following:

1. SMALL PARTICLE INVOKED occurs whenever the simulation follows particles of 50 microns or less. In this case, the particle time scale can become small, and the computing needs, substantial.

2. SUPEREQUILIBRIUM TURBULENCE INVOKED occurs in those instances where the desired turbulence background solves the superequilibrium equations. This option appears to be most severe, in general doubling the computer needs of the AGDISP code.

3. EVAPORATION INVOKED occurs because the equation time step must be adjusted downward as the particles become smaller to account for evaporation effects. The comments of message 1 then apply.

4. MANY PARTICLES INVOKED occurs whenever the number of particles to be followed exceeds ten. Ten is an arbitrarily chosen number, perhaps too low, but serves to warn the user that program solution is linear; i.e., twenty particles take twice as long as ten particles.

5. LONG SIMULATION TIME INVOKED occurs whenever the maximum expected simulation time normalized by particle size exceeds a given level. This level may also be low, but it nonetheless serves the same purpose as the level in message 4.

6. WAKE PLOT FILE INVOKED is written when this option is used because the overhead associated with reading an externally constructed data file on the Langley computer system may vary greatly with the size of the data file.

The limits of the AGDISP code are the following:

1. All of the idealized background mean velocity and turbulence fields are for neutral environments.

2. The total number of particles that can be included in the simulation cannot exceed 60. The error message INCORRECT NUMBER OF PARTICLES will be invoked and AGDISP will terminate.

3. The Betz roll up cannot enter more than 100 discrete circulation values along the wing (Γ as a function of y). The error message ERROR IN CIRCULATION DATA INPUT will be invoked and AGDISP will terminate.

4. The Betz roll up procedure cannot handle more than four discrete vortices rolling up on each wing. In this case, the error message BETZ WILL ROLL UP MORE THAN 4 VORTICES will be invoked and AGDISP will terminate.

5. The plant canopy input data cannot permit more than 100 discrete entries to define the canopy vertical profile shape. The error message ERROR IN PLANT AREA DENSITY INPUT will be invoked and AGDISP will terminate.

The AGPLOT code interactively plots the AGDISP plot file contents on Tektronix 40xx terminals using the basic CDC plotting commands. Input is the desired plot file; after scanning this file AGPLOT questions the user about particle plot characteristics and sizes of axes, then plots the selected data. Following this plot, the ground deposition pattern may also be plotted, if any particles have hit the surface. The length of time needed to plot the results depends principally upon the number of particles being plotted and the amount of data to plot (which in turn depends on some of the inputs to AGDISP).

AGLINE quizzes the AGDISP plot file to compute the equivalent Gaussian distribution of the multiple-particle solution. Since the position and turbulent standard deviation of every particle in the simulation is computed by AGDISP as a function of time after particle release, the equivalent mean position and standard deviation may be determined by appropriate summation and integration at each time over all particles in the cross-section. A measure of the compatibility of the Gaussian distribution replacing the multiple-particle Gaussian distributions is made in the AGLINE code by computing a figure of merit ranging from 0 to 1. When the equivalent Gaussian no where represents the multiple-particle distributions, the figure of merit equals zero. When the equivalent Gaussian is every where identical to the multiple distribution the figure of merit is unity. The user then ultimately judges the compatibility of fit and either uses the "best fit" (the highest figure of merit) or reruns AGDISP with additional detail to improve accuracy. To aid in this compatibility assessment, a plotting package similar to AGPLOT is included in the AGLINE code to plot the multiple-particle distributions and the equivalent Gaussian pattern, one upon the other.

3. AGDISP INPUTS

This section of the AGDISP User Manual details the input cards to the code. All data entry is in free format, wherein card data is separated by commas or blank spaces. This convenience offers ease of formatting the data but requires that every data card used have all of its data elements present, even if they are zero. Unless noted below as integer values, data is entered as real numbers (with decimal points). The MKS system is used throughout.

A typical interactive procedure file for the AGDISP code is illustrated in Table 1. Here data must be present in a reader file attached to unit 4, interactive output is written to the terminal on unit 6, printed output is written to a file on unit 9, particle trajectory data results are written to a data output file on unit 8 (for later plotting by AGPLOT), and WAKE plot file data is entered on unit 10. All card input data is echoed on the terminal, improper data is flagged, and missing data cards are exposed. All data cards begin with a four-digit identification in columns 1-4, with the rest of the data in free format. The order of the cards is important and must follow ever-increasing identification numbers. The AGDISP code has been programmed to verify this order. In addition, certain available options are inconsistent with each other. The AGDISP code has been programmed to trap these inconsistencies. Unsupported cards are flagged with the message AGDISP CODE DOES NOT SUPPORT CARD NUMBER, while missing data cards are flagged with INPUT DOES NOT FULLY INITIALIZE AGDISP RUN. With free format there exists the chance that all necessary data does not appear on the appropriate card; in this case, the AGDISP code will run out of data cards before it rationalizes all of its data pointers. The error message will read INSUFFICIENT DATA BEFORE CARD following the card where data ended. This error message is perhaps the most devious because it may require a detailed examination of <u>all</u> data cards to determine the missing data point.

On the other hand, because all of the data is echoed on the terminal, error messages should be traceable in a systematic manner. A careful check should be made the first time a new case is started, and at least until the user is confident of the program input requirements. Only by looking at what the program thinks is inputted will the user be able to verify that what was inputted was correct. In almost all cases, the code makes <u>no</u> check of input validity, either signs or magnitudes. Gravity is built into the program as 9.8 m/sec^2. Every AGDISP run requires the entry, at least, of cards 0010, 0020, 0050 and 0060.

Detailed description of the available data cards follows, including the special error messages they invoke. Examples of all cards are shown in Table 2.

Card 0000 is a comment card, any number of which may be placed anywhere in the input deck. The 76 columns of comment are merely reproduced on the terminal.

Card 0010 is the program card requiring two entries. The first is the maximum time in seconds for the simulation to run, a time which will be shortened if all of the particles impact the surface before this time is reached. The other entry is the simulation plane entry (integer) configuring either a half-plane ($y > 0$) solution (a value of 1) or a full plane ($-\infty < y < +\infty$) solution (a value of 2). The full plane solution should be invoked if a crosswind, propeller or terrain exists. Single particle release without an aircraft should use the full plane value of 2. Card 0010 is a required input card.

Card 0015 is the terrain slope angle card requiring the entry of local ground slope in degrees. A positive terrain angle raises the right half of the surface as viewed in Figure 1, with the origin remaining along the initial aircraft vertical centerline. The terrain is characterized by a locally straight surface so that all of the simplified flow field options in AGDISP remain available. A full plane solution is necessary. Canopy and crosswind effects remain parallel to the tilted surface. This feature cannot be invoked with the WAKE plot file option. Card 0015 is an optional card.

Card 0020 is the aircraft characteristics card requiring six entries. The first is the mean velocity flag (integer), taking one of six values:

- 3 denotes helicopter entry;
- 2 denotes a rectangularly loaded, fully rolled up tip vortex;
- 1 denotes a triangularly loaded, fully rolled up tip vortex;
- 0 denotes Betz roll up from a given circulation pattern;
- -1 denotes WAKE plot file entry (explained under card 0050);
- -2 denotes a nonaircraft run, appropriate for single particle release.

An entry of 3 requires a 0030 card; entry of 2 or 1 requires a 0022 card; and entry of 0 requires multiple entries of 0025 cards. The second (integer) input is the crosswind flag. A value of 0 implies no crosswind; a value of 1 does, and requires a 0028 card. The third entry is the semispan of the aircraft in meters (this is also the rotor radius for a helicopter, the initial y vortex coordinate for flag = 2 and twice the initial y coordinate for flag = 1). The fourth entry is the nominal height of the aircraft wing above the surface in meters (this distance becomes the release height for single particle release, and is the assumed nominal release height for multiple particles). For fully rolled up tip vortices, this height is the initial z coordinate of the vortex centerline. For Betz roll up data this height is the z coordinate of the initial vortex sheet (assumed horizontal).

The fifth entry is the flight speed of the aircraft in m/sec. The sixth entry is the biplane configuration flag (integer) and is 0 for a single wing airplane and 1 for a biplane (with further information supplied on a 0021 card). Card 0020 is a required input card.

Card 0021 requires entry on card 0020, and specifies the biplane characteristics with three entries. The first is the vertical distance in meters from the main wing location specified on card 0020 to the biplane wing. The second entry is the semispan of the biplane wing entered as a fraction of the semispan of the main wing (if the wings were equal in length this entry would be 1.0). The third entry is the vortex strength of the biplane wing entered as a fraction of the vortex strength of the main wing (for equal strengths this entry would be 1.0).

Card 0022 requires entry on card 0020, and specifies the rectangular or triangular loading circulation value, m^2/sec, for a fully rolled up tip vortex.

Card 0025 requires entry on card 0020, and enters the Betz wing load distribution; each card consists of two entries. The first entry is the position in meters measured from the wing root monotonically towards the tip, while the second entry gives the corresponding circulation value in m^2/sec at this location. The final card is signaled by entering the last position as the negative of its actual value. This card then forces initialization of the Betz roll up procedure. This initialization (and the ensuing roll up) invokes extra printer output summarizing the roll up process. One extra, rather specific error message will be invoked if the input load distribution is not "smooth" in a sense determined by the code. In this case the error NONDISCRETE DISTRIBUTION LOCATION is displayed, suggesting that the user inspect the generated circulation derivatives for lack of monotonicity.

As the Betz roll up continues, the particles being tracked will be influenced by every-increasing strength vortices, whose positions will approach those of fully rolled up vortices. The AGDISP code includes the effect of the unrolled up sheets on the motion of the particles.

Card 0028 requires entry on card 0020, and is the crosswind card entering the three data values needed to establish the neutral crosswind velocity profile shape. The crosswind velocity is the horizontal velocity in the y direction. The first entry is the mean wind velocity in m/sec at the altitude given by the second entry, in meters, while the third entry gives the surface roughness height z_o in meters.

Card 0030 requires entry on card 0020, and is the helicopter card consisting of two entries. The first is the weight of the helicopter in N, and the second is the forward advance ratio μ, a value greater than zero. The helicopter flow field is idealized as a propeller downwash field and a rectangularly loaded, fully rolled up vortex pair.

Card 0040 is the propeller data card consisting of six entries. The first is the drag coefficient of the airplane, while the second is the planform area of the airplane in m^2. The third entry is the aircraft propeller efficiency and the fourth is the shaft rpm. The fifth is the propeller blade radius in meters and the sixth entry is the incremental distance in meters of the shaft centerline above or below the nominal release height given on card 0020 (the propeller is assumed to be at the airplane centerline, $y = 0$).

Card 0050 is the turbulence data card containing three entries. The first is an integer flag carrying one of the following values:

- -1 invokes superequilibrium turbulence;
- 0 assumes a fixed value of turbulence given on this card;
- 1, 2, 3 specifies the turbulent components in the attached WAKE plot file (invoked with a -1 entry on card 0020).

The other two entries on this card are the maximum value of the background turbulence q^2 in m^2/sec^2 (this value is incremented by the presence of a crosswind), and the maximum value of the background turbulent macroscale Λ in meters. The macroscale is assumed to be zero at the surface and to grow linearly with height up to the maximum value specified. If the inputted maximum value of Λ is sufficiently large, the macroscale will be proportional to z (the proportionality factor is 0.65) for all particle height positions. Card 0050 is a required input card.

Depending on the value of the integer flag, the AGDISP code may not use either of the other entries on this card (they must still be present, of course, even if they are set to 0.0). The integer entry on card 0050 defines the turbulent background characteristics and how AGDISP computes them. The determination of the background turbulence should not be confused with the use of a WAKE plot file (a -1 entry on card 0020). The presence of a WAKE plot file implies that the background horizontal and vertical velocity components are always found in the WAKE plot file. The integer entry on card 0050 defines whether additional background components are also present on the WAKE plot file. If a WAKE plot file is not invoked (the entry on card 0020 is something other than -1), only the -1 and 0 entries on card 0050 are admissible. The -1 entry on this card invokes the superequilibrium option, overriding the maximum value of q^2 entered on this card but using the maximum value of Λ . A 0 entry on card 0050 uses both maximum values of q^2 and Λ . When a WAKE plot file is present, the -1 entry again invokes the superequilibrium option and overrides the maximum value of q^2 ; the 0 entry uses both maximum values (in these instances, of course, the horizontal and vertical background velocities are recovered from the WAKE plot file). Entries of 1, 2 or 3 are valid only when a WAKE plot file exists. The 1 entry assumes that the WAKE plot file contains not only the horizontal and vertical background velocities but also the background turbulence q^2 . In this case, the maximum value entry for q^2 on card 0050 is overridden but the macroscale data is used. For entries of 2 or 3 the macroscale is expected to be on the WAKE plot file, and neither of the maximum values on card 0050 is used.

The invoking of the superequilibrium option forces the spatial solution of the superequilibrium equations using an iterative solution of a linear equation solver to determine the algebraic solution to a set of nonlinear equations. Two specific errors may arise: LINEAR SOLVER ERROR IN SUPEREQUILIBRIUM and ROOT FINDER ERROR IN SUPEREQUILIBRIUM. Either error is serious, and any code results obtained after generation of the error are suspect.

A -1 entry on card 0020 invokes the WAKE plot file and forces extra output to the printer. The WAKE plot file must be constructed as a sequential binary data file (an example is given in Section 8). Consistency of WAKE plot file contents and AGDISP input data is checked, with errors invoking WAKE PLOT FILE VARIABLE ERROR. The WAKE plot file configuration must be one of the following:

1. If the turbulence is superequilibrium (the turbulence flag is -1), the plot file variable list must consist of the cross-plane velocities V and W (two variables); the turbulence components are determined from superequilibrium, and the macroscale is computed algebraically using the data on card 0050.

2. If the turbulence is fixed at a specified value (the turbulence flag is 0), the turbulent components are assumed isotropic, the macroscale is computed algebraically, and the plot file variable list must contain only V and W (two variables).

3. If the turbulence flag is 1, the WAKE plot file must additionaly contain q^2 (three variables), with the turbulent components assumed isotropic and the macroscale computed algebraically.

4. If the turbulence flag is 2, the WAKE plot file must additionally contain Λ (four variables), with the turbulent components assumed isotropic.

5. If the turbulence flag is 3, the WAKE plot file contains all of the data needed to specify the mean velocity and turbulent background profiles, (six variables): V , W , q^2 , Λ , $\langle vv \rangle$ and $\langle ww \rangle$.

The first nineteen words of the WAKE plot file are a comment header field. The next integer entry gives the number of variables stored in the WAKE plot file (2, 3, 4 or 6 as explained above). This number must be consistent with what AGDISP expects. Following this integer is a header field of length equal to the number of variables. The next integer on the WAKE plot file is the number of y (or horizontal) mesh points in the plot file, followed by these mesh values in meters. The next integer is the number of z (or vertical) mesh points, followed by these mesh values, again in meters. The code restricts these entries to 16 or less. Larger values invoke WAKE PLOT FILE MESH OUT OF RANGE.

The profile data follows. Each time slot repeats the same pattern. It begins by a single word which is the time saved in seconds. A negative time denotes end-of data. The data for each variable on the file (specified in the order above) follows, by giving all of the y values of the first variable at the first z position, then all of the y values of the first variable at the second z position, on to the last z position; then on to all of the y values of the second variable at the first z position, etc., until the values of all of the variables at all of the y and z positions have been given. The next time value follows, repeated to the end of the plot file. Velocities are in m/sec, scales in meters, and turbulence in m^2/sec^2. The warning message WAKE PLOT FILE EXTRAPOLATION is output the first time spatial extrapolation must be used by the AGDISP code during interpolation for the variables contained on the WAKE plot file. For times beyond the entries in the WAKE plot file, the spatial profiles nearest in time to the time being solved in AGDISP will be used.

Before integrating the particle equations, AGDISP reads the entire WAKE plot file through to the negative end-of-data. If the file is constructed incorrectly, the error message PREMATURE END OF WAKE PLOT FILE REACHED is invoked, and AGDISP terminates.

Card 0055 enters the canopy plant area profile; each card consists of two entries. The first entry is the z position in meters beginning at the surface and increasing monotonically to the top of the canopy. The second entry is the value of the plant area density (m^2/m^3) corresponding to the z location. The final card 0055 is signaled by entering the last z position as the negative of its actual value. This card entry then initializes the canopy calculation, computing the displacement thickness of the canopy, forcing modification to the crosswind velocity and turbulence within the canopy. During the AGDISP run, the trajectories of the aircraft vortices will be altered upon entering the canopy.

Card 0060 is the particle data card, containing six entries. The first entry is the integer number of particles to be followed in the half-plane ($y \geq 0$); the second entry (integer) is equal to 1 if a particle is to be released at the centerline of the aircraft ($y = 0$); otherwise 0. Thus, a half-plane solution will track total particles equal to the sum of these two integers; a full-plane solution will track total particles equal to the sum of twice the first integer plus the second integer. Additionally, if these two integers are entered positive, AGDISP will position the particles uniformly along the wing (for a first integer entry of 1, the particle will be positioned at 1/2 the semispan; for a first integer entry of 2, the particles will be positioned at 1/3 and 2/3 the semi-span, etc.). If these two integers are entered negative, AGDISP will expect sufficient 0061 cards in the input deck to initialize all of the particles. For both integers equal to zero, AGDISP assumes a single particle release at the centerline position.

The third entry is the vertical position in meters off-setting the particle release point from the height of the wing given on card 0020. The fourth entry is the diameter in microns of the released particles (only one particle size can be released during any one run of AGDISP). The fifth entry is the specific gravity of the released particle. The sixth entry is the (integer) evaporation flag, set to 0 for no evaporation or 1 when evaporation is invoked. Evaporation requires the entry of card 0065. Card 0060 is a required input card.

Cards 0061 require entry on card 0060, and are the discrete particle location entry cards. Each card contains two entries. There must be enough 0061 cards to satisfy the requirements of the 0060 card. If a full-plane solution is invoked all particle locations must be specified. If a particle is released along the centerline, that particle must be the last card 0061 for purposes of computing the ground deposition correctly. The first entry is the y value in meters along the wing, while the second entry is the vertical position in meters off-setting the particle release point from the height of the wing given on card 0020. The vertical position off-set on card 0060 is disregarded. Discrete particle locations allow for fine tuning of nozzle locations, and are necessary if nozzles are not uniformly distributed along the wing or if the spray boom is not parallel to the surface.

Card 0062 is the particle initial condition data card, and consists of four entries: the initial horizontal velocity in m/sec; the initial vertical velocity in m/sec; the initial spatial variance of the particle path in m^2; and the initial velocity variance of the particle in m^2/sec^2. This card is optional; all initial conditions are set to zero unless modified by card 0062.

Card 0065 requires entry on card 0060, and is the evaporation data card, consisting of two entries; the wet bulb temperature difference in deg. C, and the particle diameter in microns, below which the user considers evaporation to have ceased. This latter number is important because the smaller the particle becomes, the smaller the step size must be to maintain numerical accuracy in solving the particle equations.

This completes the input discussion to the AGDISP code. The calculation is then performed, with periodic output to the printer of the particle positions, variances, and turbulent correlations. When a particle intersects the surface, it is no longer computed, and, therefore, its location is no longer printed. At the end of the run, the surface impact statistics are summarized and the deposition fraction (the mass fraction of particles released that have reached the ground in the desired simulation time) is computed.

4. AGPLOT INPUTS

The AGPLOT program may be invoked to plot the resulting trajectories and deposition pattern. The code asks questions of the user in the interactive environment, and with this information processes the data and plots the results. Again, entry is in free format. A typical procedure file for AGPLOT is shown in Table 3. Here the particle trajectory data file (constructed by an AGDISP run) is attached to unit 8, interactive output is written to the terminal on unit 6, and a system graphics library is accessed to resolve the external plotting subroutine calls. All graphics output is displayed on the terminal. The line-by-line questions asked by AGPLOT are the following:

ENTER TERMINAL DESIGNATION requires the entry of -1, 0, 1 or 2. Entries of -1 and 0 pertain to a Tektronix 4025, with -1 producing a horizontal plot (the surface $z = 0$ is horizontal on the screen) and 0 producing a vertical plot (the surface $z = 0$ is vertical on the right edge of the screen). The entry of 1 or 2 pertains to a Tektronix 401x and invokes a horizontal plot using CDC graphic software (a response of 2 does not produce a hard copy). In all cases the plot fills the screen.

The desired AGDISP data file is then read, and the input cards used to generate the results are typed on the screen to serve as verification before plotting.

FULL PLANE PLOT is asked whenever the AGDISP run was a half-plane run. Response is YES or NO. No such request is necessary when a full-plane calculation is being plotted.

ENTER Y SCALE MIN, Y SCALE MAX, Y SCALE DELTA asks for the horizontal scale information (in meters); at what y position the scale starts, at what y position the scale ends, and the scale increment at which to place tick marks. The AGPLOT code has a scale checking routine and will invoke a warning message whenever the scale delta is not an integer fraction of the overall scale size. Also, three errors will be trapped: MAX SCALE LESS THAN MIN SCALE: SCALE DELTA LESS THAN ZERO; and TOO MANY SCALE DIVISIONS whenever more than ten tick marks are required.

PLOT PARTICLE MEANS requests YES if the mean position of the particles are to be plotted; NO if they are not. The particle mean trajectories are plotted as solid lines.

PLOT PARTICLE STANDARD DEVIATIONS requests YES if the turbulence standard deviations of the particle positions are to be plotted about the mean; NO if they are not. If neither means nor deviations is requested, the code will move down to the questions on ground dispersal pattern. The particle standard deviations are plotted as dashed lines.

TAG LOCATION AT TIME INCREMENTS requests whether the particle mean positions should be tagged (by a +) at uniform time increments during the simulation. The size of the + is scaled by the size of the particle standard deviation at the (y,z) position of the +. If the response is YES, the code will further ask ENTER TAG TIME INCREMENT as incremental seconds between tags. If the original response is NO, no further information is requested.

ENTER Z SCALE MIN, Z SCALE MAX, Z SCALE DELTA requests the vertical scale data of minimum value, maximum value, and tick increment in meters. With the input of this data, all necessary information is available to plot the trajectory data. Before plotting, though, one further question is asked:

PLOT SCALE INCREMENTS EQUAL asks whether the y and z scales should be plotted in a one-to-one ratio on the terminal. This option makes sense only if visual advantage exists in presenting a more physically correct picture of the trajectory pattern. After response to this question, the AGPLOT code will plot the desired trajectories and invoke a copy of the screen. It will then move on to plotting the ground deposition pattern.

PLOT GROUND DEPOSITION PATTERN asks whether the deposition pattern is desired. If the answer is NO, the AGPLOT code will terminate. If YES, the deposition pattern will be computed using Gaussians whose magnitudes are consistent with the size of the particle on impact, whose center location corresponds to the y position of the mean as the particle impacted the surface, and whose standard deviation is equal to the standard deviation of the particle just before impact. If none of the particles have hit the ground, the message NO GROUND DEPOSITION is typed, and the AGPLOT code will terminate. Otherwise the code will type: ENTER G SCALE MIN, G SCALE MAX, G SCALE DELTA to request the deposition scale values of minimum, maximum and increment. After this the deposition pattern is plotted and copied. The AGPLOT code then terminates.

5. AGLINE INPUTS

The AGLINE program is invoked by using a procedure file similar to the one illustrated in Table 4. Program input data comes from terminal response by the user and trajectory data from the AGDISP plot file on unit 8. A printer output file is constructed on unit 9 to document the analysis of the plot file and all final results. The desired configuration position is plotted on the terminal. The AGLINE code requests and actions are the following:

ENTER TERMINAL DESIGNATION requires the entry of -1, 0, 1 or 2. Entries of -1 and 0 pertain to a Tektronix 4025 (horizontal and vertical plots, respectively), while the 1 and 2 entries pertain to Tektronix 401X terminals (a response of 2 does not produce a hard copy).

The inputted AGDISP plot file is then processed. The input data deck used to generate the results are typed on the screen to serve as verification before plotting. Equivalent Gaussian calculations are made for every time on the plot file; the mean position, standard deviation and figure of merit are written to the printer output file. All times on the plot file are given a monotonically increasing sequence number. The critical sequence numbers, the time associated with each of them and their respective figure of merit are typed to the screen whenever:

1. the first sequence number is reached;
2. the last sequence number is reached;
3. the figure of merit reaches a local minimum;
4. the figure of merit reaches a local maximum or
5. a particle first comes within a standard deviation of the ground.

After processing the entire plot file and displaying the above summary data, the AGLINE code requests:

ENTER DESIRED SEQUENCE NUMBER to select the sequence position in the plot file at which to display the equivalent Gaussian. If a specific figure of merit is desired the appropriate response is 0 in which case the code will request:

ENTER DESIRED FIGURE OF MERIT will cause the code to seek the <u>first</u> occurrance of the entered figure of merit. If the entered value cannot be found the error message DESIRED FIGURE OF MERIT NOT FOUND will be invoked and AGLINE will terminate. Otherwise the search will be successful and the equivalent Gaussian data will be written to the printer output file. If the equivalent Gaussian vertical standard deviation places the vertical mean into contact with the surface the warning message GROUND ENCOUNTER BY EQUIVALENT GAUSSIAN will be typed to the screen.

The particle and equivalent Gaussian distributions are now plotted. Consistent with the AGPLOT procedures AGLINE will ask:

ENTER Y SCALE MIN, Y SCALE MAX, Y SCALE DELTA for horizontal scale information (in meters); at what y position the scale starts, at what y position the scale ends, and the scale increment at which to place tick marks.

ENTER Z SCALE MIN, Z SCALE MAX, Z SCALE DELTA for vertical scale data of minimum value, maximum value, and tick increments in meters. With the input of this data, all necessary information is available to plot the distribution data. Before plotting, though, one further question is asked:

PLOT SCALE INCREMENTS EQUAL asks whether the y and z scales should be plotted in a one-to-one ratio on the terminal. After response to this question, the AGLINE code will plot the Gaussian distribution and invoke a copy of the screen.

The resulting plot represents each multiple-particle distribution as dashed lines and the single equivalent distribution as solid lines. Around each center position normalized contour lines are plotted at one-eighth, one-fourth, one-half, one and two times the standard deviation.

6. EXAMPLE TEST CASE

This section of the User Manual illustrates the use of the AGDISP code by presenting an example test case. The following problem is posed (see Figure 2 for a schematic).

A single-wing aircraft weighing 17300 N and flying at 35 m/sec is dispersing 150 micron water droplets from four locations on a spray boom positioned beneath the wing 3 meters above the surface. The wing has a chord of 1.5 meters and a semispan of 6 meters, with a slight dihedral such that the rectangular wing loading rolls up a tip vortex with a vertical centerline 0.75 meters above the level of the spray boom. The spray nozzles are located at -3.0, 0.5, 2.6 and 4.8 meters measured from the airplane centerline.

Complicating the wake of the airplane is the presence of its propeller, located one meter above the spray boom level, with a blade radius of 1.5 meters and an efficiency of 0.8 at a rated speed of 500 rpms. For convenience, the drag coefficient of the airplane will be taken to be 0.1. The airplane is in straight and level flight with a slight crosswind blowing from left to right at a velocity of 2 m/sec at 5 meters (nearby instrumented tower data). The ground cover will be assumed to have a roughness of 2 centimeters.

The above problem definition is sufficient to generate initial conditions to the AGDISP code. The input data cards are constructed using the documentation in Section 3, and become the following.

The simulation time will be taken to be 10 seconds, enough time to allow ground impact of the three inboard particles (the fourth particle will probably be "trapped" in the tip vortex and carried left-to-right). The presence of the crosswind and propeller require a full-plane solution. Thus, card 0010 will read:

```
0010  10.0  2
```

Rectangular wing loading will be assumed; hence the velocity flag is 2, requiring the entry of a 0022 card. A crosswind requires a 0028 card. The semispan of the airplane is 6 meters; the height of the fully rolled up tip vortex is 3.75 meters above the surface; the flight speed of the airplane is 35 m/sec; and the airplane is a single wing. Thus, card 0020 will read:

```
0020  2  1  6.0  3.75  35.0  0
```

The rectangularly loaded wing will have a tip circulation determined by the formula $\Gamma = L/2s\rho U$ where L is the weight of the airplane, s is the semispan, ρ is the air density and U is the flight speed. For standard atmospheric air $\rho = 1.2266$ kg/m^3 and Γ becomes 33.6 m^2/sec. Thus, card 0022 will read:

```
0022  33.6
```

The crosswind velocity is 2 m/sec at a height of 5 meters, with a surface roughness of 0.02 meters. Thus, card 0028 will read:

0028 2.0 5.0 0.02

The drag coefficient is assumed to be 0.1; the propeller efficiency is 0.8 at 500 rpms; and the propeller radius is 1.5 meters. The planform area of the wing is equal to the span times the chord length, or 18 m^2. The propeller centerline is one meter above the spray boom but only 0.25 meters above the height given on card 0020. Thus card 0040 will read:

0040 0.1 18.0 0.8 500.0 1.5 0.25

The assumption will be made that the crosswind determines the background turbulence level, constant for all points in space; with the entry of 0.0 for the fixed turbulence level, the code will add the level generated by the crosswind. The assumption will also be made that the turbulent macroscale is linear with height; entering a large maximum value will ensure this linearity. Thus, card 0050 will read:

0050 0 0.0 30.0

Four particles are to be user-specified and released into a full-plane simulation. Thus, the first two entries on this card are -2 and 0 (no particle is at the centerline). The code will then expect four 0061 cards. The vertical release position is disregarded because the points are user-specified (if they were uniformly placed by the code, the entry would be -0.75 meters to recover the 3 meter height of the spray boom). The particles are 150 microns in diameter with a specific gravity of 1.0 without evaporation. Thus, card 0060 will read:

0060 -2 0 0.0 150.0 1.0 0

Four 0061 cards are expected, recording the four y positions of the particles and the proper location of the spray boom relative to the surface. These cards will read:

```
0061    -3.0  -0.75
0061     0.5  -0.75
0061     2.6  -0.75
0061     4.8  -0.75
```

The AGDISP code can now be run. The terminal output for this example is shown in Figure 3 and the first and last pages of the printer output are shown in Figure 4. Plotting vertically on a Tektronix 4025 with convenient scales to include the particle mean trajectories and standard deviations gives the trajectory plot in Figure 5 and the deposition plot in Figure 6. Invoking AGLINE for the maximum figure-of-merit value results in the distribution plot shown in Figure 7.

7. AGDISP FLOW CHART

The AGDISP, AGPLOT and AGLINE codes consist of mainline sections that process user-supplied input data and data file information, initializing the program fields and output files. From these main routines, subroutines are called to provide specific information pertinent to the solution of the particle equations. The simplified models for particle time scale, evaporation time scale, particle-turbulence correlation, etc., are placed in separate subroutines for ease of modification. This section of the User Manual examines the flow charts to these three codes.

The AGDISP code is configured to run interactively on the Langley computer, with a size under 60K octal words. Input comes from a card reader file on unit 4, with terminal output written on unit 6, and printer output written on unit 9. The code generates a trajectory plot file on unit 8, to be used subsequently by the AGPLOT code. When an externally-computed fluid-turbulence field is supplied by the user, this data file is entered into the AGDISP code on unit 10. The unit 8 and unit 10 data files are binary.

The AGPLOT code is also configured to execute interactively, with a size under 50K octal words. All input data is entered by the user at the terminal on unit 5, and all output is written on the terminal in graphical form on unit 6. Only Tektronix and Langley computer center graphics are available. The data file generated by AGDISP serves as the input data file for AGPLOT; this file is entered on unit 8.

The AGLINE code executes interactively, with a size also under 50K octal words. Input data is entered by the user at the terminal on unit 5, with trajectory data from the AGDISP plot file on unit 8. Terminal output is written on unit 6 and printer output on unit 9.

The flow charts for the AGDISP, AGPLOT and AGLINE codes are given in Figures 8, 9 and 10, respectively. These charts attempt to show the overall details of the respective codes, indicating what each subroutine does; and supplementing the discussion of Section 8. Procedure files used to execute these programs are illustrated in Tables 1, 3 and 4.

8. AGDISP SUBROUTINES

This section of the User Manual examines the code comprising each subroutine in the AGDISP, AGPLOT and AGLINE computer programs. While Figures 8, 9 and 10 give an overview of the operation of the programs, this section is intended to summarize the contents of the code. The routines are examined in alphabetical order.

AGDISP is the mainline program computing particle motion by a Lagrangian technique. Most of the details of AGDISP are covered earlier in the User Manual, including data card entry, verification, initialization and calculation. Each data card has its own section in AGDISP wherein valid data entry is checked and initialization is performed. Card order is important, and is maintained by a series of error flags L20, L22, L25, etc. Free-format entry demands that all data cards contain the appropriate data; otherwise, an error will be trapped. Inadvertently reaching the end of the data deck also generates an error. All input cards generate output onto the terminal. After completing the input, any possible warning conditions are flagged before selecting the integration step size equal to one-half the particle time constant (this time step may be smaller if evaporation is included in the calculation). Also, the code has been configured to adjust the output frequency such that line printer output occurs approximately every one-tenth second of simulated time. Integration is then performed, after which the final particle ground deposition is computed, taking evaporation into account, and the input card deck is written to the generated plot file for typing back to the user when plotting the trajectories and deposition with AGPLOT.

AGBZD evaluates the derivatives for the time-dependent solution of the Betz roll up methodology found in Ref. 1. The input parameters are the present values of the variables, the derivatives (to be computed), the starting pointer, maximum pointer, end pointer and total entry pointer of the rolling up vortex circulation distribution. The variables are R, the radius of the vortex core, and Γ, the circulation of the vortex. At $t = 0$, R is zero and the singularity is treated by taking the appropriate limit (see Ref. 1).

AGBZG initializes the Betz roll up procedure using the user-inputted circulation distribution stored in common block BETZ. The first section of the subroutine computes the spatial derivative $d\Gamma/dy$ of the circulation Γ and sets a noise level of 0.5% of peak derivative value. The circulation distribution is then reexamined to locate where $d\Gamma/dy$ is maximum (these become positions where vortices start rolling up) and where $d\Gamma/dy$ is minimum (these become the end positions of the vortex circulation patterns). The noise level is used here to correct for slightly nonuniform data (a frequent occurrence when discrete data is entered). The circulation pointers to start, maximum and end for up to four vortices are then set (more than four vortices invoke an error exit from AGDISP). The initialization is completed by evaluating the derivatives at zero time and initializing all of the parameters pointing in the AGDISP code to vortex center location, strength, canopy effect and unrolled sheet effect. The code then establishes a vortex-dependent time step DTV vector based on 1% of the rollup time constant $\tau_R = 2\pi R_{max}^2/\Gamma_{max}$.

AGBZI integrates the Betz equations across the time step DELT entered from the AGDISP code. The first section of the subroutine establishes the time step and number of steps to integrate based on the computed values of DTV and the vortices not yet rolled up completely. Each vortex is treated separately by first predicting its new values of R and Γ , then solving for the derivatives at these values and correcting the solution twice. This double correction enhances solution accuracy (Ref 11). The $\bar{y}$ centroid of the rolling up vortex is computed based upon how much circulation has rolled into the vortex by this time. The vertical centroid $\bar{z}$ is not incremented. The incremental movement of the vortex for this Betz time step is added to the current position of the vortex (this position may be influenced by the other background features incorporated in AGDISP), and fully rolled-up vortices are flagged with zero sheet strength. Lastly, the unrolled sheet lengths are determined.

AGBZQ is a Gauss-Legendre integration routine used to find the area under the inputted discrete function between inputted starting and ending points (Ref. 12).

AGBZT is a linear interpolator extracting the value of the inputted discrete function at the inputted position.

AGCOR evaluates the particle-turbulence correlations at time T , with particle time constant DTAU and turbulence time constant WTAU . The equations are a result of the assumption of a von Karman spectral distribution as described in Ref. 1. The constants XK1 , XK2 and XK3 take their limiting values whenever the two time constants are within 0.5% of each other. The correlations $\langle ux \rangle$ and $\langle uv \rangle$ are then evaluated, and these become both $\langle uy \rangle$, $\langle uz \rangle$ and $\langle uv \rangle$, $\langle uw \rangle$ respectively.

AGDEC computes the decay rate based on the particle time constant DTAU , with the effect of evaporation being a reduction of the time constant consistent with the smaller size particle. When the particle size reaches the termination size, the end-of-run flag LENDF is set. The decay rate is simply the sum of two terms, because of the simple evaporation model built into the AGDISP code. The drag law of Langmuir and Blodgett (Ref. 4) is used.

AGDIF evaluates the derivatives of the Lagrangian particle equations discussed in detail in Ref. 1. The time constant is evaluated, and the equations for each particle in the simulation are evaluated. The first and sixth elements of the vector XV are the particle position (y,z) . At this point, the mean velocity components V and W are determined, the background turbulent time constant is determined and the analytic particle turbulence correlations are computed. The equation derivatives are formed, with gravity equal to 9.8 m/sec^2.

AGINT monitors the integration of the particle equations. Initially, all particle positions are stored and initial derivatives determined. Integration then proceeds step by step to the maximum inputted time. The WAKE plot file, Betz, canopy, propeller and helicopter are updated where applicable, particle positions are predicted, derivatives evaluated, and the positions are twice corrected. Particle solutions terminate at the ground. Since the vortices move under the influence of one another and their ground images, their positions are also adjusted. Any particles that have impacted the surface are flagged and their final sizes are computed. Termination is checked for evaporation, maximum time, and ground impact; and plot save is invoked. If termination exists, transfer is returned to AGDISP; otherwise another time step is taken.

AGLQD is a linear decomposition routine transposed from the IMSL scientific subroutine package (Ref. 13), used to decompose the six-by-six matrix in the superequilibrium methodology.

AGLQS is the linear substitution routine from Ref. 13, used to evaluate the six superequilibrium unknowns.

AGMAT fills the six-by-six matrix array for the unknowns <uu> , <vv> , <ww> , <uv> , <uw> and <vw> by superequilibrium (Ref. 9) for a given value of q^2 . The linear equations are solved by AGLQD and AGLQS to determine the difference between q^2 and <uu> + <vv> + <ww> .

AGPAC computes the vortex circulation reduction resulting from interactions with a canopy. Essentially, the scrubbing of the vortex acts as a drag on the wake flow field. This drag translates into an effective vortex strength smaller than the noncanopy value. Reference 1 presents the details. In this subroutine, vortices are checked for whether they have entered the canopy; if so, an integration across the portion of the vortex interacting with the plant area density is taken, a simple time integration is performed, and the vortex strength reduction factor is computed. The reduction factors FACR and FACL modify the vortex strengths, unrolled sheet strengths, propeller swirl and helicopter effects.

AGPAD computes the displacement thickness of the plant canopy and initializes the effective circulation integrals. The displacement thickness is assumed to represent the effective surface roughness the canopy gives the atmospheric flow above it. Within the canopy, the crosswind velocity and turbulence are assumed to behave linearly with height, an approximation consistent with the numerical prediction of turbulent behavior within plant canopies (Ref. 8).

AGPRP updates the turbulence, swirl velocity and wake radius behind the propeller, using the approximations discussed in Ref. 1.

AGRTF is a modified root-finder subroutine taken from the IMSL scientific subroutine library (Ref. 13). Essentially, the routine performs higher-order interpolation to yield a solution for q^2 which agrees accurately with $\langle uu \rangle + \langle vv \rangle + \langle ww \rangle$ obtained by solving the six-by-six matrix set. The solution speed is enhanced by starting the iteration at a value of q^2 close to the answer.

AGSAV writes the step integration results from AGDISP to the plot file (the variables $\bar{y}$, $\bar{z}$, $\langle yy \rangle^{\frac{1}{2}}$, $\langle zz \rangle^{\frac{1}{2}}$) and the line printer (all variables for all nonimpacted particles).

AGSUP is the driving routine for superequilibrium. Given the four spatial derivatives in the AGDISP code (dU/dy and dU/dz are zero) and the local scale length Λ , the superequilibrium equations are iterated for the values of $\langle uu \rangle$, $\langle vv \rangle$ and $\langle ww \rangle$. The maximum gradient is used to normalize the solver, an approximate result is encountered, and then an accurate solution is found by stepping in q until a zero crossing is found by invoking the root finder AGRTF to obtain a value of q accurate to four digits or a normalized value of $q^2 - \langle uu \rangle - \langle vv \rangle - \langle ww \rangle$ within $\pm$ 0.001 m^2/sec^2 of zero. This result produces the values of turbulent energy unnormalized by Λ and the normalizing velocity gradient. Any (rare) error trap returns laminar results in an effort to reduce the impact of the background solution on the particle equations.

AGSVE computes the incremental background velocity arising from the unrolled Betz sheets. In this case, the sheets are represented by a constant circulation sheet of vorticity, and the resultant flow is analytically determined. The singularity in the vicinity of the sheet is controlled by keeping all data evaluation at a distance of 1% of the sheet length with linear falloff within 10%. As the Betz procedure continues, the sheet becomes shorter until it is finally rolled up.

AGTUR determines the turbulent scale length Λ and turbulent components q^2 , <vv> and <ww> at the position (y,z). The scale is essentially the smaller of 0.65z, the maximum inputted scale Λ_{max} , or six-tenths the distance to the nearest vortex. The turbulence comes from super-equilibrium or the fixed inputted value of q^2_{max} (modified by the propeller wake). The values will be modified if the particle position is within the canopy (a linear correction to the height of the canopy). Alternately, the scale and correlations could in all or part come from a WAKE plot file.

AGVCH examines each vortex location and propeller and helicopter centerlines and corrects for their movement in the given time step DELT

AGVEL computes the mean velocity components V and W at the position (y,z) . Each vortex, its reflecting image across $y = 0$ and their images across $z = 0$ are used to compute the overall velocity increment. The standard potential vortex velocity field $\Gamma/2\pi r$, producing a velocity normal to the radius vector, is broken into its (y,z) components and modified by FACR and FACL for the presence of a canopy. The unrolled sheet effect (with image sheets) is added, as are the helicopter, propeller and mean crosswind modified by the canopy. Alternately, the WAKE plot file is quizzed to return the appropriate velocity components.

AGWKI linearly interpolates the data array read from the WAKE plot file for the variable desired (V , W , q^2 , Λ , <vv> or <ww>) at the position (y,z) . A warning message is written the first time spatial extrapolation beyond the WAKE plot file grid coordinate is invoked, even though extrapolation may continue indefinitely thereafter.

AGWKR recovers the WAKE plot file data for the desired time T . Interpolation between time steps is performed every one-tenth of the interval; otherwise the data arrays in common block WAKE are not updated. The file is rewound, the initial data skipped, and the pertinent time step bracketed. Linear interpolation is then performed, and the next time check is computed. When the end of the WAKE plot file is reached, the last time entry data is used for the duration of the AGDISP run.

AGWKS processes the WAKE plot file header information. The file is binary and is read using sequential reads. The plot file comment of nineteen words is followed by the number of variables, a list of the variable names, the number of y data points, the values of the y mesh, the number of z data points and the values of the z mesh. Thereafter the data consists of a time entry followed by all y data values for each z mesh row for each variable. The structure of the WAKE plot file used in test case #5 is shown in Figure 11, where the binary information has been printed. Details are given in Section 3.

AGPLOT is the mainline program for plotting the results from AGDISP , quizzing the interactive user about the details of the desired plots and plotting the trajectory pattern and ground deposition.

AGCHK verifies the appropriateness of the scaling information requested by AGPLOT of the interactive user. Thus, the scale must be monotonically increasing with a positive spacing between scale marks and an integer number of scale marks, not to exceed ten.

AGDRW translates the data to be plotted into the graphical grid point coordinates representing the data, given the mesh sizes to be plotted on the screen. This transformed data is plotted by a call to AGMDL .

AGGRD computes the ground deposition pattern, quizzes the user for plot scale information, and plots the resulting distribution. Each impacting particle in the AGDISP simulation hits the surface at a known $\bar{y}$ position with a known variance <yy> . Adding all particle locations with their known impact sizes produces the deposition pattern along the surface. The scales are established and the curve is plotted.

AGMDL plots the graphical screen data points, either directly for Tektronix 4025 or with CDC plotting routines for Tektronix 4010 and 4014.

AGPLT is the plotting subroutine that uses either Tektronix 4025 or CDC graphics calls to perform the actual plotting of trajectory data. The screen is first cleared; then axes are established and plotted and a wing schematic is drawn if appropriate. The plot file is read so that nine points are plotted at a time, drawing the mean particle paths (including the image if desired) the standard deviation paths and tag markers at the desired intervals. At the conclusion of the plot, the screen is copied.

AGSPD uses the time dependent values of $\bar{y}$, $\bar{z}$, $\langle yy\rangle^{\frac{1}{2}}$ and $\langle zz\rangle^{\frac{1}{2}}$ to determine the plotting coordinates of the particle standard deviation. The deviation is found normal to the instantaneous particle direction, and the coordinates are adjusted accordingly.

Simple FORTRAN WRITES are needed to cue the Tektronix 4025 to construct a graphics area, write into it and produce a printed copy of the screen. The default character is the exclamation mark (!) and the useful graphics commands are the following:

BEL - rings the terminal bell (signals end-of-plot).

GRA - establishes a graphics area.

HCO - invokes a copy of the screen.

LIN - sets the line segment character (1 is solid, 3 is dashed).

MON - transfers command response to the terminal monitor space.

RDO - positions the workspace.

VEC - draws line segments in the workspace.

WOR - establishes a terminal workspace and transfers command response to it.

For the Tektronix 4010 and 4014 subroutine calls must be made using the CDC-Langley software to accomplish the graphics. The subroutines invoked by AGPLOT are the following:

BELL - rings the terminal bell.

DRASE - erases the screen, returns to character mode and sets the cursor to the home position (upper left hand corner).

DRWABS - draws a solid line from the current cursor position to the screen coordinate supplied.

DSHABS - draws a dashed line (with defined characteristics) from the current cursor position to the screen coordinate supplied.

HDCOPY - invokes a copy of the screen.

MOVABS - moves the cursor from wherever it is to the screen coordinate supplied (no line is drawn).

PSEUDO - erases the screen, establishes a plotting buffer, enters graph mode and positions the cursor at (0,0).

TSEND - flushes the plotting buffer, thereby finishing the current plot.

AGLINE is the mainline program for interpreting the AGDISP plot file to construct an equivalent Gaussian profile distribution from the multiple-particle solution, compatible with the FSCBG code (Ref. 10). Three passes are made through the plot file. The first locates the AGDISP input data cards (at the end of the file) and displays them on the screen. The second pass computes the equivalent Gaussian profile distribution and figure-of-merit given the multiple-particle solution at every saved time in the plot file. The third pass locates the desired sequence number or figure-of-merit and plots the final distributions.

AGCHK verifies the appropriateness of the scaling information for AGLINE as it does for AGPLOT.

AGDRW translates the data to be plotted into grid coordinates as for AGPLOT.

AGELP sets up the plots of particle isopleths at one-eighth, one-fourth, one-half, one and twice the standard deviation.

AGEQD computes the equivalent Gaussian distribution of the multiple-particle solution (including the particle solution on the other half of a half-plane solution). The mean horizontal and vertical positions and standard deviations are summed over all particles in the solution plane.

AGMDL plots the graphical screen data as for AGPLOT.

AGPLT is the plotting subroutine, working similar to the AGPLT subroutine in AGPLOT, plotting the particle and equivalent distributions and copying the screen.

9. AGDISP TEST CASES

Six test cases are included in the User Manual to illustrate the variety of data entry available with AGDISP. These examples are included to demonstrate the structure of the input card deck and the data entry requirements of each type of data card and option. They are not meant to suggest that certain options go with certain other options, nor are all options covered. For example, only one WAKE plot file run is shown, in this case for a plot file containing V, W and q^2 with Λ and <vv> and <ww> determined algebraically. Extension to more complete files has been demonstrated but is not included.

The six examples are meant to illustrate the following features:

1. A rectangularly loaded wing, with fixed background turbulence, full plane results with code-determined particle positions, including a centerline data point and a propeller.

2. A rectangularly loaded biplane wing, with superequilibrium invoked, half-plane results with code-determined particle positions, no centerline data point, with evaporation.

3. Circulation loading with Betz, a canopy, half-plane with fixed turbulence and the particles user-inputted.

4. A single particle release into a crosswind, fixed turbulence in a full plane.

5. A WAKE plot file background condition for particles user-inputted in a full-plane configuration.

6. A helicopter input for a fixed turbulence background with code-determined particle positions in a half-plane simulation.

The simulation time is kept short since the essential features of the input data decks and the general character of the evolving solution are what are sought here. Each test case makes use of the documentation in Section 3 to construct the input decks. Figures 12-17 illustrate the six test cases. Each figure is a reproduction of the terminal output (showing the reproduction of the input deck and the AGDISP echo responses) and the first and last output pages (showing the final time step for the nonimpacted particles and giving the deposition information). An example of plotted particle and standard deviation results and the corresponding ground deposition plot may be found for the example test case in Section 6.

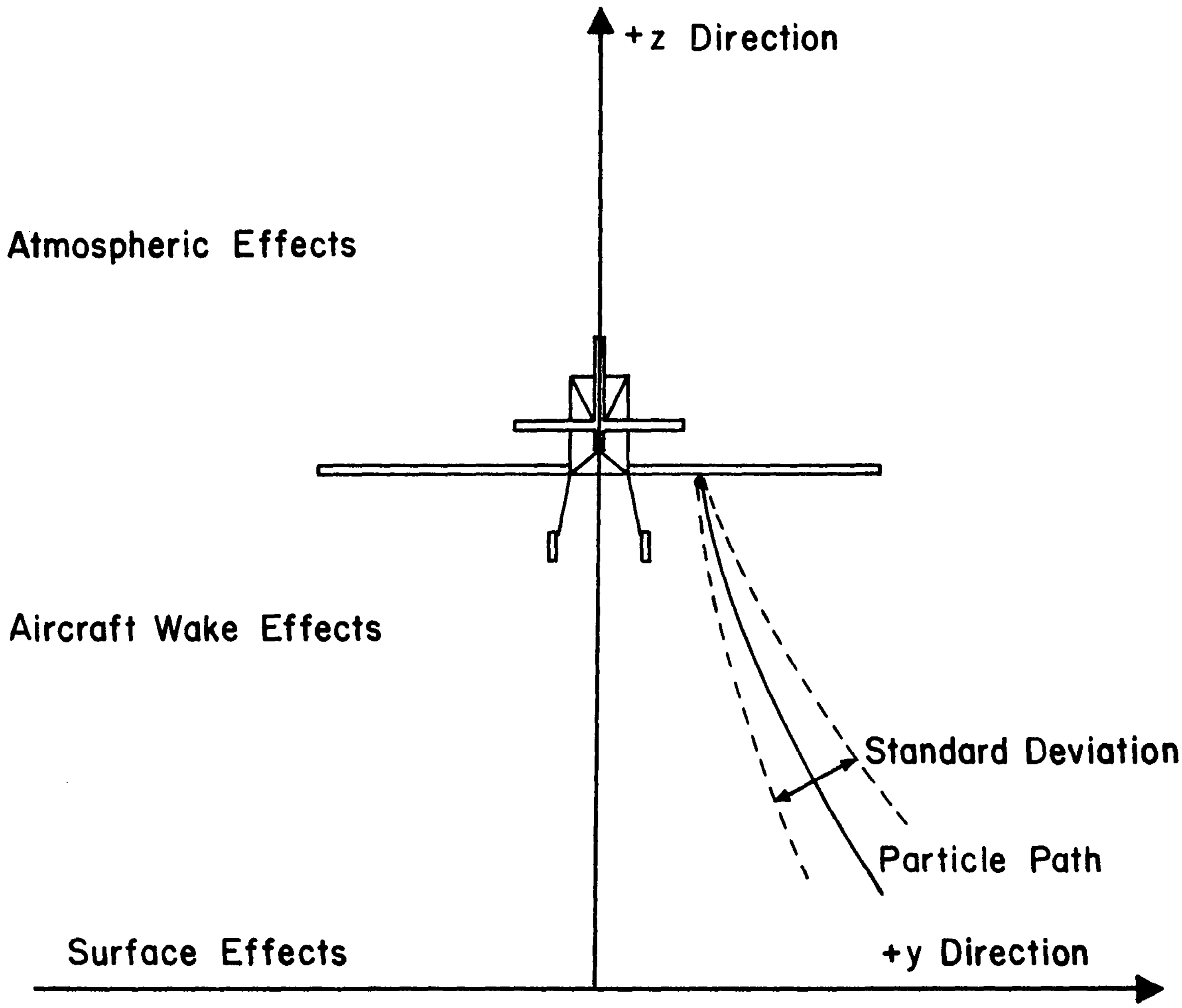

Figure 1. Schematic of the calculation plane of the AGDISP code. The aircraft is assumed in level flight into the figure (+x direction)

TABLE 1

Typical AGDISP Interactive Procedure File

Command Line	Description
MAP,OFF.	Linkage editor load map output is disabled.
ASSIGN,MS,OUTPUT.	Program underflows are written to the file OUTPUT. By assigning OUTPUT to mass storage, these warning messages are suppressed.
ASSIGN,TT,TAPE6.	AGDISP writes all interactive output to unit number 6. This unit is assigned to the time-sharing terminal and the output appears on the screen.
GET,TAPE4=INPUT0.	AGDISP reads all input data cards from unit number 4. This unit is equated to the default input file name INPUT0 and is retrieved from the permanent directory as the local file TAPE4.
GET,TAPE10=WAKE0.	AGDISP reads wake plot file input data from unit number 10. This unit is equated to the default wake file name WAKE0 and is retrieved from the permanent directory as the local file TAPE10. NOTE: This GET is issued only when the wake plot file code option is invoked.
GET,OBDISP.	The AGDISP object module OBDISP is retrieved from the permanent directory.
OBDISP.	Load and execute the AGDISP object module.
REWIND,TAPE8,TAPE9.	Output written by AGDISP to unit numbers 8 and 9 are positioned at their initial records.
REPLACE,TAPE8=PLOT0.	AGDISP writes trajectory plot file data results to unit number 8. This unit is equated to the default plot file name PLOT0 and transferred from the local directory to the permanent directory, overwriting existing data.
REPLACE,TAPE9=OUTPUT0.	AGDISP writes printer output data results to unit number 9. This unit is equated to the default output file name OUTPUT0 and transferred from the local directory to the permanent directory, overwriting existing data.

TABLE 2

Example Card Input to AGDISP

```
0000  card  0010  is the program data card
0010  10.0  1
0000  card  0015  is the terrain slope card
0015  0.0
0000  card  0020  is the aircraft characteristics data card
0020  2  0  6.5  4.0  35.0  1
0000  card  0021  is the biplane data card
0021  2.0  0.8  0.6
0000  card  0022  specifies vortex circulation
0022  25.0
0000  card  0025  specifies Betz wing circulation data
0025    0.0  10.0
0025    2.0  10.0
0025    3.0  20.0
0025    4.0  15.0
0025   -5.0   0.0
0000  card  0028  is the cross wind velocity data card
0028  3.0  3.0  0.01
0000  card  0030  is the helicopter data card
0030  15000.0  0.05
0000  card  0040  is the propeller data card
0040  0.1  16.0  0.8  500.0  2.0  0.75
0000  card  0050  is the turbulence data card
0050  0  1.0  30.0
0000  card  0055  specifies the canopy profile data
0055    0.0  0.05
0055    0.3  0.1
0055    0.7  0.3
0055   -1.5  0.0
0000  card  0060  is the particle data card
0060  -3  -1  0.0  100.0  1.0  1
0000  card  0061  enters discrete particle locations
0061   1.0  0.0
0061   2.5  0.0
0061   4.0  0.0
0061   0.0  0.0
0000  card  0062  provides particle initial conditions
0062  0.0  -0.5  0.5  0.0
0000  card  0065  is the evaporation data card
0065  5.0  50.0
```

TABLE 3

Typical AGPLOT Interactive Procedure File

Command Line	Description
MAP,OFF.	Linkage editor load map output is disabled.
ASSIGN,MS,OUTPUT.	Program underflows are written to the file OUTPUT. By assigning OUTPUT to mass storage, these warning messages are suppressed.
ASSIGN,TT,TAPE6.	AGPLOT writes all interactive output to unit number 6. This unit is assigned to the time-sharing terminal and the output appears on the screen.
GET,TAPE8=PLOTO.	AGPLOT reads all trajectory plot data from unit number 8. This unit is equated to the default trajectory plot file name PLOTO and is retrieved from the permanent directory as the local file TAPE8.
ATTACH(LIBFTEK/UN=LIBRARY)	To write graphics data to the Tektronix 401x, basic system plotting subroutines called by AGPLOT must be made available to the linkage editor. These routines are located within the system library LIBFTEK, and this library is made a local library.
GET,OBPLOT.	The AGPLOT object module OBPLOT is retrieved from the permanent directory.
LDSET(LIB=LIBFTEK)	The linkage editor is instructed to search LIBFTEK for the graphics subroutines (BELL, DRASE, DRWABS, DSHABS, HDCOPY, MOVABS, PSEUDO, and TSEND).
OBPLOT.	Load and execute the AGPLOT object module.

TABLE 4

Typical AGLINE Interactive Procedure File

Command Line	Description
MAP,OFF.	Linkage editor load map output is disabled.
ASSIGN,MS,OUTPUT.	Program underflows are written to the file OUTPUT. By assigning OUTPUT to mass storage, these warning messages are suppressed.
ASSIGN,TT,TAPE6.	AGLINE writes all interactive output to unit number 6. This unit is assigned to the time-sharing terminal and the output appears on the screen.
GET,TAPE8=PLOTO.	AGLINE reads all trajectory plot data from unit number 8. This unit is equated to the default trajectory plot file name PLOTO and is retrieved from the permanent directory as the local file TAPE8.
ATTACH(LIBFTEK/UN=LIBRARY)	To write graphics data to the Tektronix 401x, basic system plotting subroutines called by AGLINE must be made available to the linkage editor. These routines are located within the system library LIBFTEK, and this library is made a local library.
GET,OBLINE.	The AGLINE object module OBLINE is retrieved from the permanent directory.
LDSET(LIB=LIBFTEK)	The linkage editor is instructed to search LIBFTEK for the graphics subroutines (BELL, DRASE, DRWABS, DSHABS, HDCOPY, MOVABS, PSEUDO, and TSEND).
OBLINE.	Load and execute the AGLINE object module.
REWIND,TAPE9.	Output written by AGLINE to unit number 9 is positioned at its initial record.
REPLACE,TAPE9=OUTPUTO.	AGLINE writes printer output data results to unit number 9. This unit is equated to the default output file name OUTPUTO and transferred from the local directory to the permanent directory, overwriting existing data.

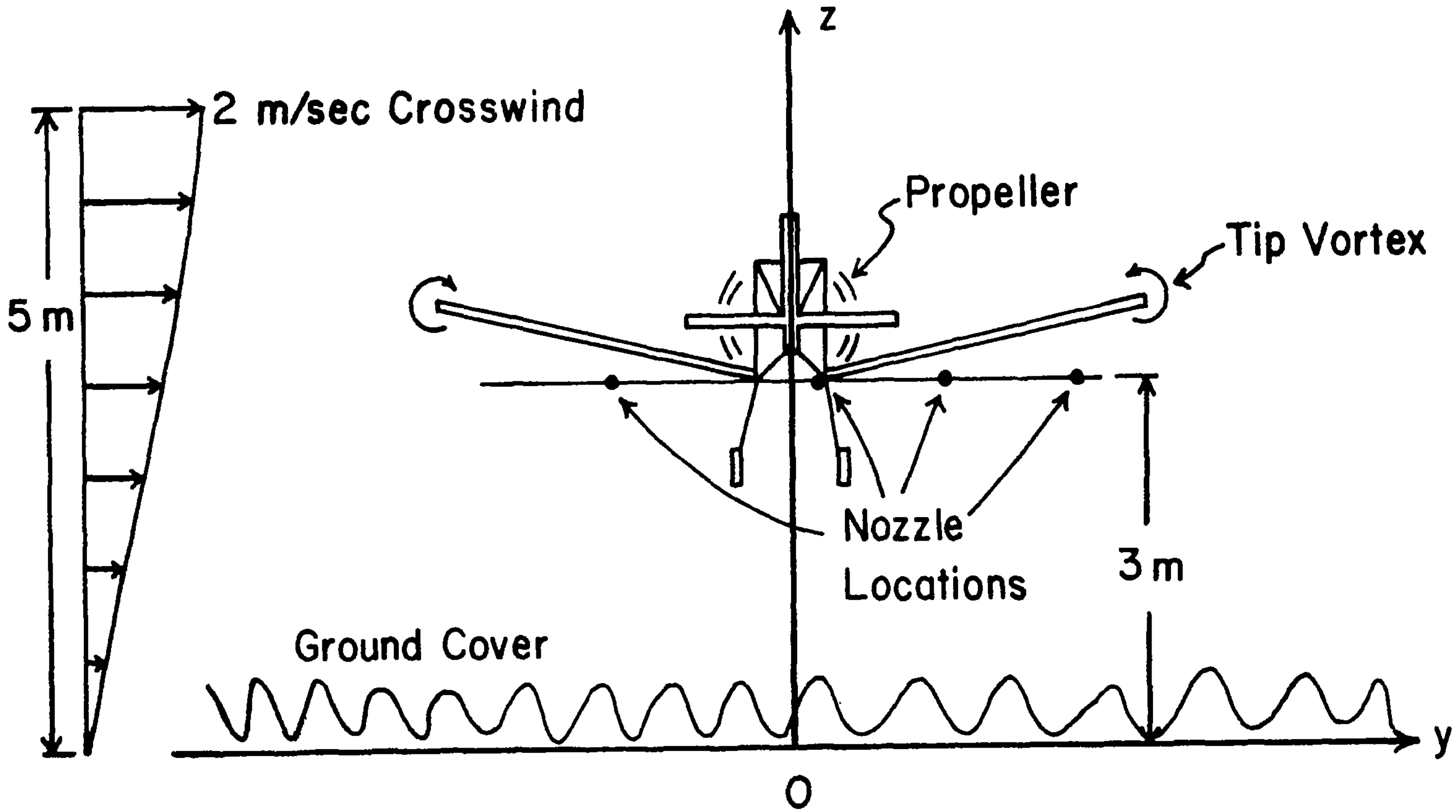

Figure 2. Airplane configuration for the example test case of Section 6.

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

  1: 0000  EXAMPLE TEST CASE
  2: 0010  10.0  2
  3: 0020  2  1  6.0  3.75  35.0  0
  4: 0022  33.6
  5: 0028  2.0  5.0  0.02
  6: 0040  0.1  18.0  0.8  500.0  1.5  0.25
  7: 0050  0  0.0  30.0
  8: 0060  -2  0  0.0  150.0  1.0  0
  9: 0061  -3.0  -0.75
 10: 0061   0.5  -0.75
 11: 0061   2.6  -0.75
 12: 0061   4.8  -0.75

FULL-PLANE CALCULATION
AIRCRAFT SEMI-SPAN/DISK RADIUS:  0.60000E+01 M
                  FLIGHT SPEED:  0.35000E+02 M/SEC
NOMINAL RELEASE HEIGHT:  0.37500E+01 M
RECTANGULARLY LOADED WING WITH GAMMA:  0.33600E+02 M**2/SEC
CROSS-WIND VELOCITY:  0.20000E+01 M/SEC
                  Z:  0.50000E+01 M
                 Z0:  0.20000E-01 M
PROPELLER HUB HEIGHT:  0.25000E+00 M
              RADIUS:  0.15000E+01 M
      SWIRL VELOCITY:  0.46835E+01 M/SEC
          TURBULENCE:  0.31810E+01 (M/SEC)**2
TURBULENCE FIXED VALUE:  0.11071E+00 (M/SEC)**2
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
TOTAL NUMBER OF PARTICLES:  4
                 DIAMETER:  0.15000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
INITIAL TIME STEP:  0.35100E-01 SEC
MAXIMUM TIME:  0.10000E+02 SEC

TIME:  0.3866E+00 SEC
TIME:  0.8143E+00 SEC
TIME:  0.1261E+01 SEC
TIME:  0.1713E+01 SEC
TIME:  0.2168E+01 SEC
TIME:  0.2627E+01 SEC
TIME:  0.3032E+01 SEC
TIME:  0.3362E+01 SEC
TIME:  0.3691E+01 SEC
TIME:  0.4020E+01 SEC
TIME:  0.4349E+01 SEC
TIME:  0.4679E+01 SEC
TIME:  0.5008E+01 SEC
TIME:  0.5337E+01 SEC
TIME:  0.5666E+01 SEC
TIME:  0.5995E+01 SEC
TIME:  0.6325E+01 SEC
TIME:  0.6654E+01 SEC
TIME:  0.6983E+01 SEC
TIME:  0.7312E+01 SEC
TIME:  0.7641E+01 SEC
TIME:  0.7971E+01 SEC
TIME:  0.8300E+01 SEC
TIME:  0.8629E+01 SEC
TIME:  0.8958E+01 SEC
TIME:  0.9287E+01 SEC
TIME:  0.9617E+01 SEC
TIME:  0.9946E+01 SEC

INTEGRATION COMPLETE

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 3. Terminal output from the AGDISP run of the Example Test Case constructed in Section 6.

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

INPUT DATA DECK:

  1: 0000   EXAMPLE TEST CASE
  2: 0010   10.0  2
  3: 0020   2  1  6.0  3.75  35.0  0
  4: 0022   33.6
  5: 0028   2.0  5.0  0.02
  6: 0040   0.1  18.0  0.8  500.0  1.5  0.25
  7: 0050   0  0.0  30.0
  8: 0060   -2  0  0.0  150.0  1.0  0
  9: 0061   -3.0  -0.75
 10: 0061    0.5  -0.75
 11: 0061    2.6  -0.75
 12: 0061    4.8  -0.75


TIME:  0.0        SEC
    #       Y           V          YY          YV          VV           Z           W          ZZ          ZW          WW
    1 -0.3000E+01  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
    2  0.5000E+00  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
    3  0.2600E+01  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
    4  0.4800E+01  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0

TIME:  0.2188E-01 SEC
    #       Y           V          YY          YV          VV           Z           W          ZZ          ZW          WW
    1 -0.2994E+01  0.5131E+00  0.8001E-03  0.3463E-01  0.2888E-03  0.2989E+01 -0.9291E+00  0.8001E-03  0.3463E-01  0.2888E-03
    2  0.4928E+00 -0.6133E+00  0.1540E-01  0.6522E+00  0.1654E-01  0.2983E+01 -0.1467E+01  0.1540E-01  0.6522E+00  0.1654E-01
    3  0.2615E+01  0.1288E+01  0.6658E-03  0.2800E-01  0.7031E-03  0.2989E+01 -0.9077E+00  0.6658E-03  0.2800E-01  0.7031E-03
    4  0.4832E+01  0.2759E+01  0.2094E-03  0.7865E-02  0.2086E-02  0.2975E+01 -0.2159E+01  0.2094E-03  0.7865E-02  0.2086E-02

TIME:  0.5447E-01 SEC
    #       Y           V          YY          YV          VV           Z           W          ZZ          ZW          WW
    1 -0.2972E+01  0.7969E+00  0.5587E-02  0.1066E+00  0.6295E-02  0.2949E+01 -0.1517E+01  0.5587E-02  0.1066E+00  0.6295E-02
    2  0.4684E+00 -0.8752E+00  0.9142E-01  0.1616E+01  0.1802E+00  0.2923E+01 -0.2130E+01  0.9142E-01  0.1616E+01  0.1802E+00
    3  0.2668E+01  0.1953E+01  0.4348E-02  0.7801E-01  0.8668E-02  0.2951E+01 -0.1421E+01  0.4348E-02  0.7801E-01  0.8668E-02
    4  0.4940E+01  0.3869E+01  0.1387E-02  0.2366E-01  0.1189E-01  0.2891E+01 -0.2972E+01  0.1387E-02  0.2366E-01  0.1189E-01

TIME:  0.9660E-01 SEC
    #       Y           V          YY          YV          VV           Z           W          ZZ          ZW          WW
    1 -0.2936E+01  0.9122E+00  0.1916E-01  0.2110E+00  0.1625E-01  0.2878E+01 -0.1839E+01  0.1916E-01  0.2110E+00  0.1625E-01
    2  0.4292E+00 -0.9848E+00  0.2541E+00  0.2224E+01  0.4691E+00  0.2830E+01 -0.2258E+01  0.2541E+00  0.2224E+01  0.4691E+00
    3  0.2757E+01  0.2252E+01  0.1424E-01  0.1498E+00  0.1945E-01  0.2886E+01 -0.1677E+01  0.1424E-01  0.1498E+00  0.1945E-01
    4  0.5114E+01  0.4422E+01  0.4490E-02  0.4672E-01  0.2224E-01  0.2761E+01 -0.3165E+01  0.4490E-02  0.4672E-01  0.2224E-01

TIME:  0.1392E+00 SEC
    #       Y           V          YY          YV          VV           Z           W          ZZ          ZW          WW
    1 -0.2897E+01  0.9319E+00  0.3695E-01  0.2130E+00  0.2721E-01  0.2797E+01 -0.1950E+01  0.3695E-01  0.2130E+00  0.2721E-01
    2  0.3864E+00 -0.1019E+01  0.4312E+00  0.2005E+01  0.7427E+00  0.2739E+01 -0.2024E+01  0.4312E+00  0.2005E+01  0.7427E+00
    3  0.2856E+01  0.2378E+01  0.2806E-01  0.1755E+00  0.2835E-01  0.2812E+01 -0.1760E+01  0.2806E-01  0.1755E+00  0.2835E-01
    4  0.5310E+01  0.4774E+01  0.8767E-02  0.5435E-01  0.2996E-01  0.2629E+01 -0.3028E+01  0.8767E-02  0.5435E-01  0.2996E-01
```

Figure 4a. First page of printer output for the Example Test Case of Section 6.

```
TIME:  0.9748E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1006E+02  0.6231E-02  0.6137E+01  0.1614E-01  0.6951E-01  0.3789E+00 -0.1751E+00  0.6137E+01  0.1614E-01  0.6951E-01
  4   0.3424E+02  0.2769E+01  0.9293E+00  0.4723E-01  0.3590E-01  0.2221E+01  0.4724E+00  0.9293E+00  0.4723E-01  0.3590E-01

TIME:  0.9781E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1006E+02 -0.1164E-01  0.6138E+01  0.1587E-01  0.6921E-01  0.3732E+00 -0.1727E+00  0.6138E+01  0.1587E-01  0.6921E-01
  4   0.3433E+02  0.2764E+01  0.9324E+00  0.4758E-01  0.3590E-01  0.2237E+01  0.4755E+00  0.9324E+00  0.4758E-01  0.3590E-01

TIME:  0.9814E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1006E+02 -0.2985E-01  0.6139E+01  0.1560E-01  0.6890E-01  0.3676E+00 -0.1703E+00  0.6139E+01  0.1560E-01  0.6890E-01
  4   0.3442E+02  0.2759E+01  0.9356E+00  0.4794E-01  0.3591E-01  0.2252E+01  0.4786E+00  0.9356E+00  0.4794E-01  0.3591E-01

TIME:  0.9847E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1006E+02 -0.4839E-01  0.6140E+01  0.1534E-01  0.6860E-01  0.3620E+00 -0.1678E+00  0.6140E+01  0.1534E-01  0.6860E-01
  4   0.3451E+02  0.2754E+01  0.9388E+00  0.4830E-01  0.3592E-01  0.2268E+01  0.4818E+00  0.9388E+00  0.4830E-01  0.3592E-01

TIME:  0.9880E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1005E+02 -0.6729E-01  0.6141E+01  0.1508E-01  0.6829E-01  0.3565E+00 -0.1654E+00  0.6141E+01  0.1508E-01  0.6829E-01
  4   0.3460E+02  0.2749E+01  0.9420E+00  0.4866E-01  0.3592E-01  0.2284E+01  0.4850E+00  0.9420E+00  0.4866E-01  0.3592E-01

TIME:  0.9913E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1005E+02 -0.8655E-01  0.6142E+01  0.1482E-01  0.6799E-01  0.3511E+00 -0.1629E+00  0.6142E+01  0.1482E-01  0.6799E-01
  4   0.3469E+02  0.2745E+01  0.9452E+00  0.4903E-01  0.3593E-01  0.2300E+01  0.4882E+00  0.9452E+00  0.4903E-01  0.3593E-01

TIME:  0.9946E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1005E+02 -0.1062E+00  0.6143E+01  0.1457E-01  0.6768E-01  0.3458E+00 -0.1604E+00  0.6143E+01  0.1457E-01  0.6768E-01
  4   0.3478E+02  0.2740E+01  0.9484E+00  0.4940E-01  0.3594E-01  0.2316E+01  0.4915E+00  0.9484E+00  0.4940E-01  0.3594E-01

TIME:  0.9979E+01 SEC
  #        Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  2   0.1004E+02 -0.1262E+00  0.6144E+01  0.1433E-01  0.6737E-01  0.3405E+00 -0.1579E+00  0.6144E+01  0.1433E-01  0.6737E-01
  4   0.3487E+02  0.2735E+01  0.9517E+00  0.4977E-01  0.3594E-01  0.2333E+01  0.4948E+00  0.9517E+00  0.4977E-01  0.3594E-01

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
  #       DR         TIME         Y          YY
  1   0.1000E+01  0.3460E+01 -0.5427E+01  0.2979E+00
  2   0.0
  3   0.1000E+01  0.2901E+01  0.9934E+01  0.3039E+00
  4   0.0
                     SEC          M         M**2

DEPOSITION FRACTION:  0.5000E+00

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 4b. Last page of printer output for the Example Test Case of Section 6.

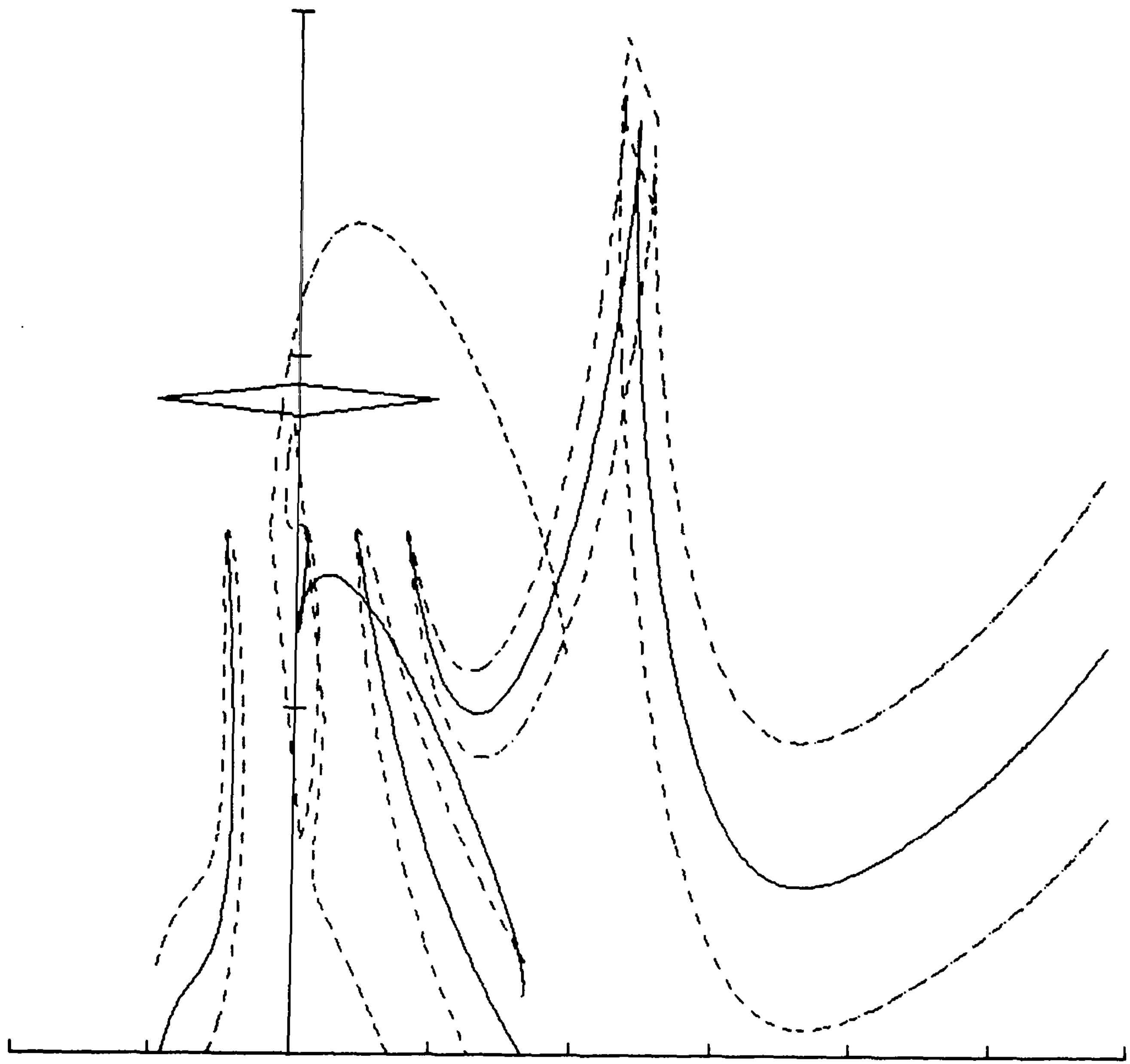

Figure 5. Trajectory plot of the particle means and standard deviations for the Example Test Case of Section 6.

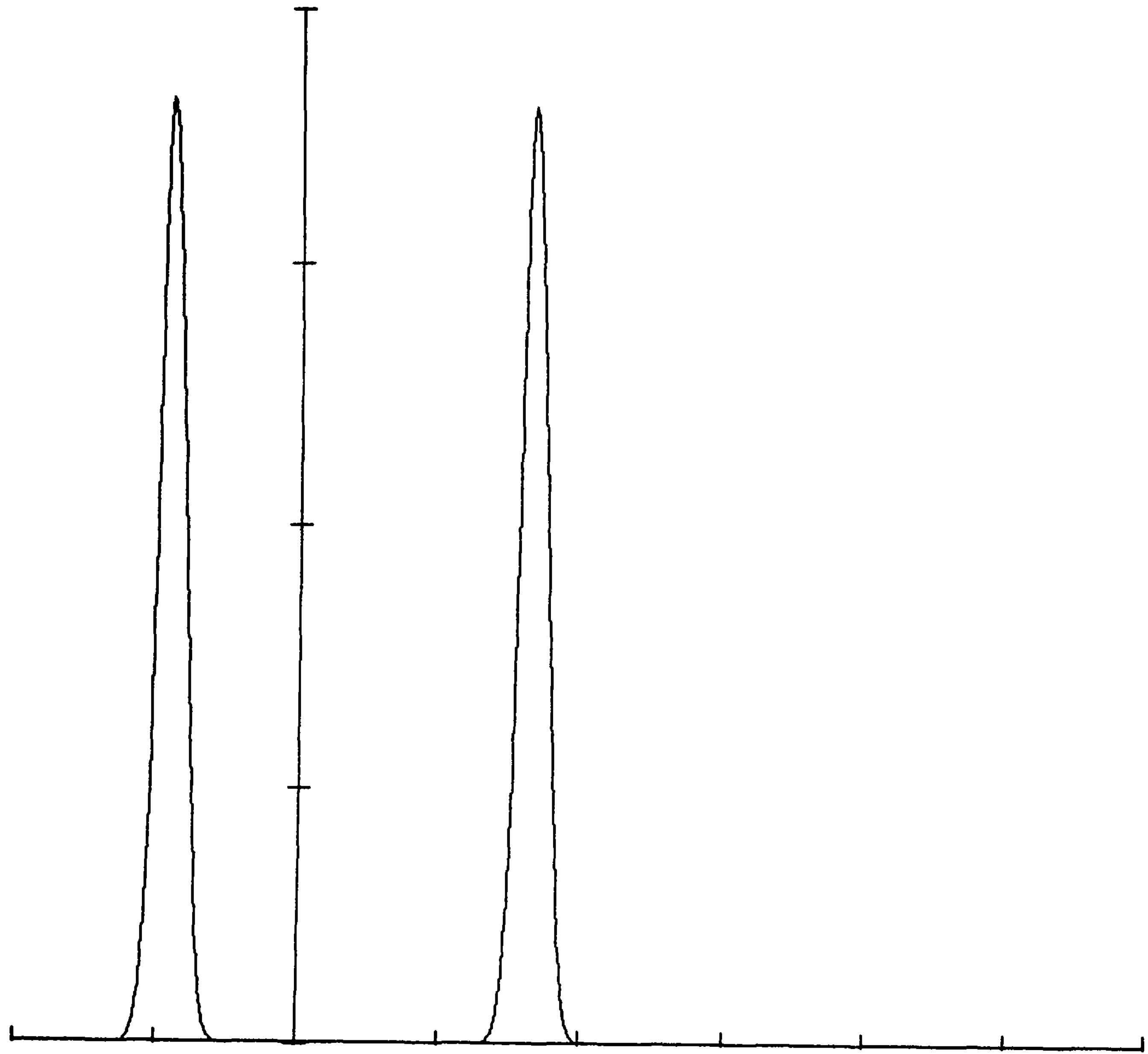

Figure 6. Ground deposition pattern for the Example Test Case of Section 6.

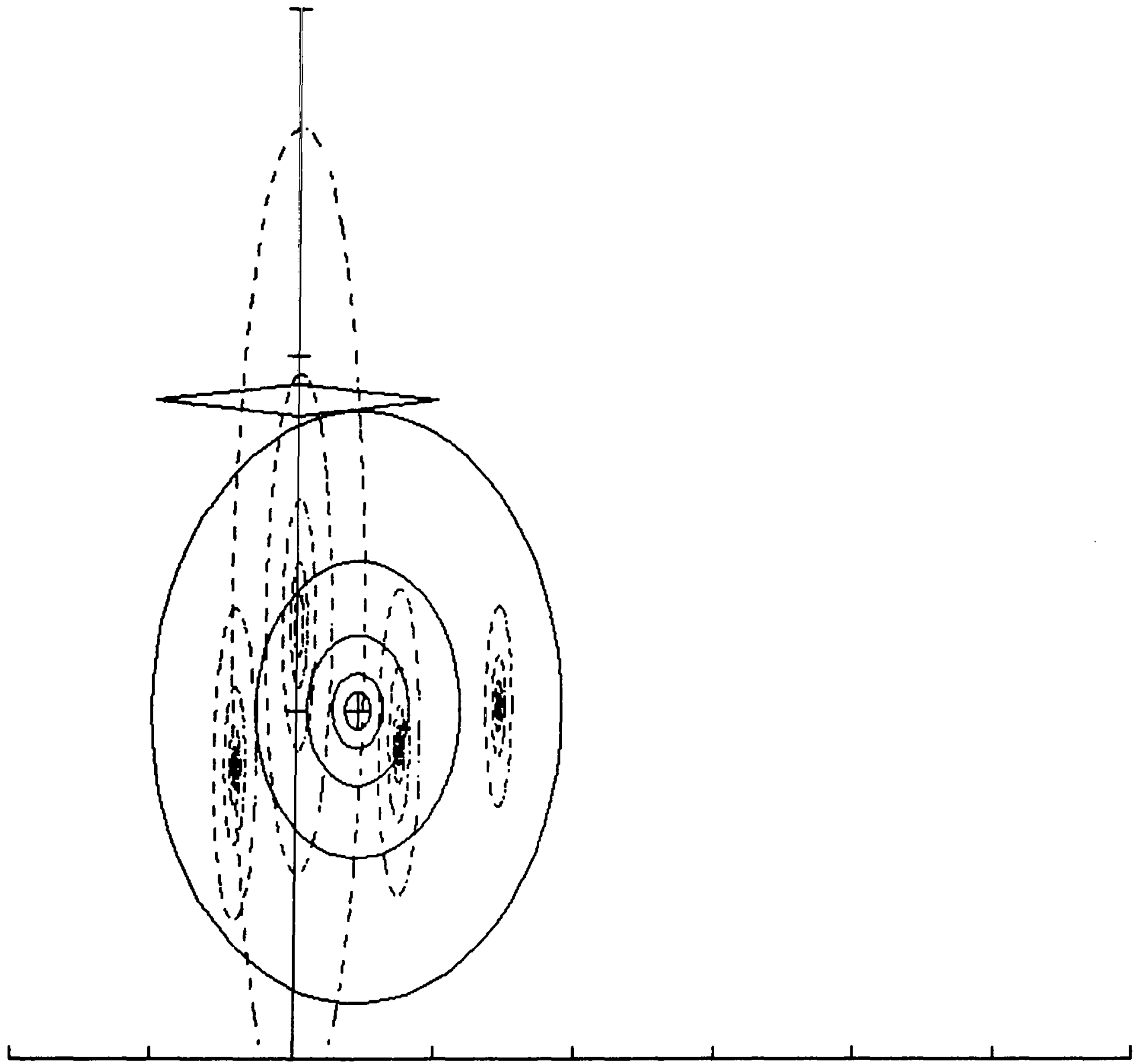

Figure 7. Equivalent Gaussian distribution at maximum figure-of-merit for the Example Test Case of Section 6.

START — AGDISP

PROCESS ALL INPUT DATA CARDS

0000	COMMENT CARD	
0010	PROGRAM CARD	
0015	TERRAIN CARD	
0020	AIRCRAFT CHARACTERISTICS CARD	
0021	BIPLANE CHARACTERISTICS CARD	
0022	AIRPLANE WING LOADING CARD	
0025	BETZ ROLLUP CARDS	
	BETZ INITIALIZER:	
	EVALUATE LOAD DISTRIBUTION	AGBZG
	INITIALIZE TIME-DEPENDENT EQNS	AGBZD
	GAUSS-LEGENDRE QUADRATURE	AGBZQ
	TABLE INTERPOLATOR	AGBZT
0028	CROSSWIND CARD	
0030	HELICOPTER CARD	
0040	PROPELLER CARD	
0050	TURBULENCE CARD	
	WAKE PLOT FILE INITIALIZER:	
	EXTRACT INITIAL DATA ON FILE	AGWKS
	DETERMINE INITIAL SPATIAL DATA	AGWKR
0055	CANOPY CARDS	
	CANOPY INITIALIZER:	
	COMPUTE CANOPY HEIGHT & EFFECTIVE ROUGHNESS	AGPAD
0060	PARTICLE CARD	
0061	PARTICLE LOCATION CARDS	
0062	PARTICLE INITIAL CONDITION CARD	
0065	EVAPORATION CARD	

END OF INPUT DATA

A

Figure 8. AGDISP program flow chart

A	
ESTABLISH TIME STEP	AGDEC
DISK SAVE OF INITIAL CONDITIONS	AGSAV
INITIALIZE DIFFERENTIAL EQUATIONS	AGDIF
B	
INCREMENT TIME TO INTEGRATE	
EQUATION INTEGRATION:	AGINT
WAKE PLOT FILE CHECK TO REREAD PLOT FILE & POSITION TO CURRENT TIME	AGWRK
BETZ INTEGRATION:	AGBZI
COMPUTE STEPSIZE	
LOOP ON NUMBER OF VORTICES	
PREDICTOR	
EVALUATE BETZ DERIVATIVES	AGBZD
CORRECTORS (2)	
COMPUTE VORTEX LOCATIONS & STRENGTHS	
CANOPY CHECK TO MODIFY VORTEX STRENGTH FOR PORTION IN CANOPY	AGPAC
PROPELLOR UPDATE	AGPRP
PARTICLE EQUATIONS PREDICTOR	
B	
PARTICLE EQUATION CORRECTORS	
UPDATE VORTEX LOCATIONS	AGVCH
CHECK GROUND IMPACT	AGVEL
CHECK PARTICLE EVAPORATION LIMIT	
CHECK MAXIMUM TIME LIMIT	
CHECK DISK SAVE OF CURRENT DATA	AGSAV
CHECK TERMINATION	
STORE INPUT DATA	
END	

Figure 8. (Cont'd)

B

EVALUATE PARTICLE EQUATIONS DERIVATIVES	AGDIF
EVALUATE PARTICLE TIME CONSTANT	AGDEC
EXAMINE EACH PARTICLE	
DETERMINE VELOCITY:	AGVEL
VORTICES	
BETZ UNROLLED SHEETS	AGSVE
CROSSWIND	
HELICOPTER	
PROPELLER	
WAKE PLOT FILE INTERPOLATION	AGWKI
DETERMINE TURBULENCE AND SCALE:	AGTUR
FIXED VALUES	
WAKE PLOT FILE INTERPOLATION	AGWKI
CANOPY	
PROPELLER	
SUPEREQUILIBRIUM	
ROOT FINDER ITERATION FOR CONSISTANT q^2	AGRTF
COMPUTE TURBULENT COMPONENTS IN 6X6 MATRIX	AGMAT
LINEAR DECOMPOSITION	AGLOD
LINEAR SUBSTITUTION	AGLQS
COMPUTE ANALYTIC CORRELATIONS WITH ATMOSPHERE	AGCOR

EVALUATE DERIVATIVE FOR
1 y POSITION
2 v VELOCITY
3 <yy> VARIANCE
4 <uv> CORRELATION
5 <vv> VARIANCE
6 z POSITION
7 w VELOCITY
8 <zz> VARIANCE
9 <zw> CORRELATION
10 <ww> VARIANCE

RETURN

Figure 8. (Cont'd)

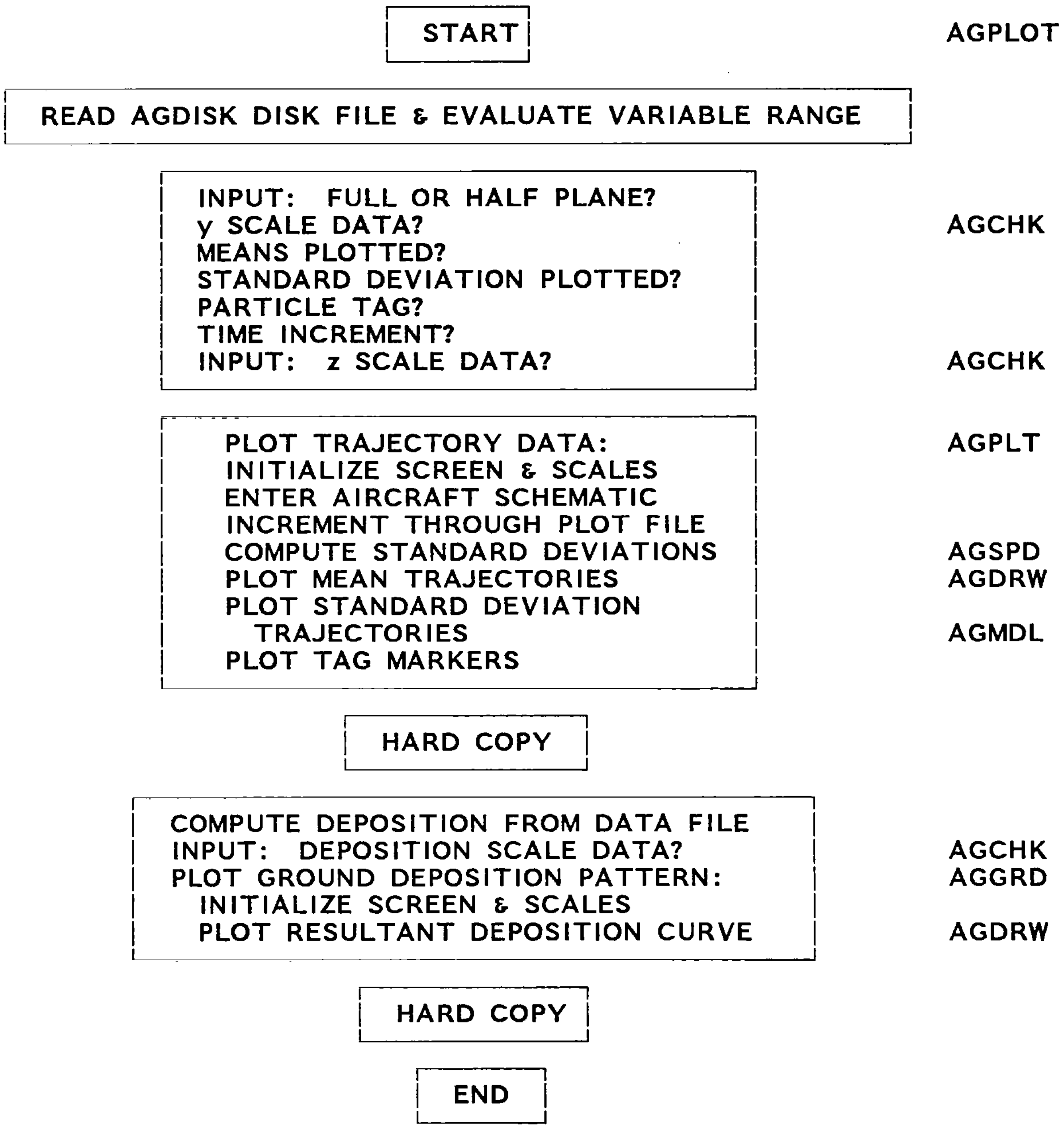

Figure 9. AGPLOT program flow chart

START	AGLINE
READ ADGISP DISK FILE TO LOCATE CASE CARDS	
READ AGDISP DISK FILE TO COMPUTE EQUIVALENT GAUSSIAN DISTRIBUTION AND FIGURE-OF-MERIT FOR ALL ENTRIES IN DISK FILE	
INPUT: SEQUENCE NUMBER OR FIGURE-OF-MERIT?	
READ AGDISP DISK FILE TO FIND DESIRED POSITION	
INPUT: y SCALE DATA? INPUT: z SCALE DATA?	AGCHK AGCHK
PLOT DISTRIBUTIONS: INITIALIZE SCREEN & SCALES ENTER AIRCRAFT SCHEMATIC PLOT PARTICLE PROFILES (DASHED) PLOT EQUIVALENCE PROFILES (SOLID)	AGPLT AGELP AGDRW AGMDL
HARD COPY	
END	

Figure 10. AGLINE program flow chart

Record Contents			Description
TEST WITH VELOCITIES AND QQ			WAKE plot file header record - 76 characters long.
3			Number of variables in plot file - the maximum number is six: horizontal and vertical velocities V and W in m/sec; turbulence QQ in (m/sec)**2; turbulent macroscale SL in m; and horizontal and vertical turbulence components VV and WW in (m/sec)**2.
V W QQ			Descriptive titles of the variables - three in this case - 4 characters per title. Verification of number of variables in plot file with flags in the AGDISP input data deck is made.
3			Number of Y (horizontal) data points in plot file - 16 is the maximum permitted.
0.0	20.0	40.0	The three Y position values in meters. If there are more Y values, they go here also.
3			Number of Z (vertical) data points in plot file - 16 is the maximum permitted.
0.0	20.0	40.0	The three Z position values in meters. If there are more Z values, they go here also.
0.0			The first time in the plot file: 0.0 seconds.
0.0	20.0	40.0	The values of the first variable (V) for the first Z position (0.0) for all Y positions in the file. Additional values of V go here if there are more Y positions.
0.0	20.0	40.0	The values of V for the second Z position (20.0) for all Y positions in the file.
0.0	20.0	40.0	The values of V for the third Z position (40.0) for all Y positions in the file. Additional values of V for additional Z positions go here if there are more Z positions.
0.0	0.0	0.0	The values of the second variable (W) for the first Z position for all Y positions.
-20.0	-20.0	-20.0	The values of W for the second Z position for all Y positions.
-40.0	-40.0	-40.0	The values of W for the third Z position for all Y positions. Additional values of W go here for additional Z positions.

Figure 11. Structure of the WAKE plot file used in test case #5

1.0	1.0	1.0	The values of the third variable (QQ) for the first Z position for all Y positions.
1.0	1.0	1.0	The values of QQ for the second Z position for all Y positions.
1.0	1.0	1.0	The values of QQ for the third Z position for all Y positions. Additional values of QQ go here for additional Z positions.
			Additional variable data (for SL, VV and WW) follow the same pattern and go here if applicable.
2.0			The second time in the plot file: 2.0 seconds.
0.0	10.0	20.0	The V data corresponding to the second time.
0.0	10.0	20.0	
0.0	10.0	20.0	
0.0	0.0	0.0	The W data corresponding to the second time.
-10.0	-10.0	-10.0	
-20.0	-20.0	-20.0	
0.05	0.05	0.05	The QQ data corresponding to the second time.
0.05	0.05	0.05	
0.05	0.05	0.05	
			Additional variable data go here if applicable.
5.0			The third time in the plot file: 5.0 seconds.
0.0	4.0	8.0	The V data corresponding to the third time.
0.0	4.0	8.0	
0.0	4.0	8.0	
0.0	0.0	0.0	The W data corresponding to the third time.
-4.0	-4.0	-4.0	
-8.0	-8.0	-8.0	
0.02	0.02	0.02	The QQ data corresponding to the third time.
0.02	0.02	0.02	
0.02	0.02	0.02	
			Additional variable data go here if applicable.
			Additional times and variable data go here if applicable, repeating the pattern established above.
-1.0			The WAKE plot file termination signal, a negative time.

Figure 11. (Cont'd)

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

  1: 0000  AGDISP TEST CASE # 1
  2: 0010  10.0  2
  3: 0020  2  0  6.5  4.0  35.0  0
  4: 0022  25.0
  5: 0040  0.1  16.0  0.8  500.0  2.0  0.75
  6: 0050  0  1.0  30.0
  7: 0060  3  1  0.0  100.0  1.0  0

FULL-PLANE CALCULATION
AIRCRAFT SEMI-SPAN/DISK RADIUS:  0.65000E+01 M
                  FLIGHT SPEED:  0.35000E+02 M/SEC
NOMINAL RELEASE HEIGHT:  0.40000E+01 M
RECTANGULARLY LOADED WING WITH GAMMA:  0.25000E+02 M**2/SEC
PROPELLER HUB HEIGHT:  0.75000E+00 M
              RADIUS:  0.20000E+01 M
      SWIRL VELOCITY:  0.18060E+01 M/SEC
          TURBULENCE:  0.84092E+00 (M/SEC)**2
TURBULENCE FIXED VALUE:  0.10000E+01 (M/SEC)**2
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
TOTAL NUMBER OF PARTICLES:  7
                 DIAMETER:  0.10000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
INITIAL TIME STEP:  0.15600E-01 SEC
MAXIMUM TIME:  0.10000E+02 SEC

TIME:  0.7066E+00 SEC
TIME:  0.1422E+01 SEC
TIME:  0.2148E+01 SEC
TIME:  0.2881E+01 SEC
TIME:  0.3615E+01 SEC
TIME:  0.4349E+01 SEC
TIME:  0.5084E+01 SEC
TIME:  0.5820E+01 SEC
TIME:  0.6491E+01 SEC
TIME:  0.7024E+01 SEC
TIME:  0.7557E+01 SEC
TIME:  0.8089E+01 SEC
TIME:  0.8622E+01 SEC
TIME:  0.9154E+01 SEC
TIME:  0.9687E+01 SEC

INTEGRATION COMPLETE

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 12a. AGDISP test case #1 terminal output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

INPUT DATA DECK:

  1: 0000   AGDISP TEST CASE # 1
  2: 0010   10.0  2
  3: 0020   2  0  6.5  4.0  35.0  0
  4: 0022   25.0
  5: 0040   0.1  16.0  0.8  500.0  2.0  0.75
  6: 0050   0  1.0  30.0
  7: 0060   3  1  0.0  100.0  1.0  0


TIME:  0.0        SEC
   #      Y          V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.1625E+01  0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0
   2  0.3250E+01  0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0
   3  0.4875E+01  0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0
   4 -0.1625E+01  0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0
   5 -0.3250E+01  0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0
   6 -0.4875E+01  0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0
   7  0.0         0.0         0.0         0.0         0.0         0.4000E+01  0.0         0.0         0.0         0.0

TIME:  0.6021E-01 SEC
   #      Y          V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.1601E+01 -0.5409E+00  0.1902E+00  0.3008E+01  0.3625E+00  0.3894E+01 -0.2361E+01  0.1902E+00  0.3008E+01  0.3625E+00
   2  0.3259E+01  0.2217E+00  0.1123E+00  0.1708E+01  0.1921E+00  0.3942E+01 -0.1359E+01  0.1123E+00  0.1708E+01  0.1921E+00
   3  0.4890E+01  0.3908E+00  0.4508E-01  0.7543E+00  0.2034E+00  0.3886E+01 -0.2566E+01  0.4508E-01  0.7543E+00  0.2034E+00
   4 -0.1656E+01 -0.7059E+00  0.1962E+00  0.2665E+01  0.4093E+00  0.4016E+01  0.3571E+00  0.1962E+00  0.2665E+01  0.4093E+00
   5 -0.3259E+01 -0.2217E+00  0.1123E+00  0.1708E+01  0.1921E+00  0.3942E+01 -0.1359E+01  0.1123E+00  0.1708E+01  0.1921E+00
   6 -0.4890E+01 -0.3908E+00  0.4508E-01  0.7543E+00  0.2034E+00  0.3886E+01 -0.2566E+01  0.4508E-01  0.7543E+00  0.2034E+00
   7 -0.2641E-01 -0.6143E+00  0.2221E+00  0.3068E+01  0.3707E+00  0.3962E+01 -0.8983E+00  0.2221E+00  0.3068E+01  0.3707E+00

TIME:  0.1333E+00 SEC
   #      Y          V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.1558E+01 -0.6146E+00  0.6279E+00  0.2819E+01  0.5801E+00  0.3720E+01 -0.2360E+01  0.6279E+00  0.2819E+01  0.5801E+00
   2  0.3278E+01  0.2721E+00  0.3554E+00  0.1585E+01  0.3250E+00  0.3839E+01 -0.1435E+01  0.3554E+00  0.1585E+01  0.3250E+00
   3  0.4929E+01  0.6710E+00  0.1587E+00  0.7456E+00  0.3219E+00  0.3693E+01 -0.2642E+01  0.1587E+00  0.7456E+00  0.3219E+00
   4 -0.1707E+01 -0.6564E+00  0.6309E+00  0.3091E+01  0.5782E+00  0.4042E+01  0.3437E+00  0.6309E+00  0.3091E+01  0.5782E+00
   5 -0.3278E+01 -0.2721E+00  0.3554E+00  0.1585E+01  0.3250E+00  0.3839E+01 -0.1435E+01  0.3554E+00  0.1585E+01  0.3250E+00
   6 -0.4929E+01 -0.6710E+00  0.1587E+00  0.7456E+00  0.3219E+00  0.3693E+01 -0.2642E+01  0.1587E+00  0.7456E+00  0.3219E+00
   7 -0.7295E-01 -0.6413E+00  0.6712E+00  0.2980E+01  0.5792E+00  0.3895E+01 -0.9128E+00  0.6712E+00  0.2980E+01  0.5792E+00

TIME:  0.2055E+00 SEC
   #      Y          V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.1512E+01 -0.6602E+00  0.1014E+01  0.2561E+01  0.5756E+00  0.3554E+01 -0.2241E+01  0.1014E+01  0.2561E+01  0.5756E+00
   2  0.3299E+01  0.3103E+00  0.5791E+00  0.1529E+01  0.3292E+00  0.3736E+01 -0.1422E+01  0.5791E+00  0.1529E+01  0.3292E+00
   3  0.4987E+01  0.9453E+00  0.2625E+00  0.7011E+00  0.3254E+00  0.3505E+01 -0.2564E+01  0.2625E+00  0.7011E+00  0.3254E+00
   4 -0.1751E+01 -0.5699E+00  0.1076E+01  0.3060E+01  0.5765E+00  0.4066E+01  0.3190E+00  0.1076E+01  0.3060E+01  0.5765E+00
   5 -0.3299E+01 -0.3103E+00  0.5791E+00  0.1529E+01  0.3292E+00  0.3736E+01 -0.1422E+01  0.5791E+00  0.1529E+01  0.3292E+00
   6 -0.4987E+01 -0.9453E+00  0.2625E+00  0.7011E+00  0.3254E+00  0.3505E+01 -0.2564E+01  0.2625E+00  0.7011E+00  0.3254E+00
   7 -0.1188E+00 -0.6277E+00  0.1089E+01  0.2825E+01  0.5761E+00  0.3831E+01 -0.8686E+00  0.1089E+01  0.2825E+01  0.5761E+00
```

Figure 12b. AGDISP test case #1, first full page of printer output

```
    4 -0.1859E+01 -0.9016E-01  0.2294E+02  0.3394E+00  0.3586E+00  0.1786E+01 -0.2059E+00  0.2294E+02  0.3394E+00  0.3586E+00
    6 -0.1341E+02 -0.9441E+00  0.8634E+01  0.4644E+00  0.3288E+00  0.2763E+01  0.9129E+00  0.8634E+01  0.4644E+00  0.3288E+00
    7 -0.2969E+01 -0.2333E+00  0.1522E+02  0.2525E+00  0.3563E+00  0.1341E+01 -0.8808E-01  0.1522E+02  0.2525E+00  0.3563E+00

TIME:  0.9794E+01  SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1 -0.3770E+01 -0.3806E+00  0.7917E+01  0.1461E+00  0.3495E+00  0.7790E+00  0.2576E-01  0.7917E+01  0.1461E+00  0.3495E+00
    3  0.1346E+02  0.9114E+00  0.8684E+01  0.4655E+00  0.3288E+00  0.2812E+01  0.9190E+00  0.8684E+01  0.4655E+00  0.3288E+00
    4 -0.1864E+01 -0.9065E-01  0.2298E+02  0.3370E+00  0.3584E+00  0.1775E+01 -0.2047E+00  0.2298E+02  0.3370E+00  0.3584E+00
    6 -0.1346E+02 -0.9114E+00  0.8684E+01  0.4655E+00  0.3288E+00  0.2812E+01  0.9190E+00  0.8684E+01  0.4655E+00  0.3288E+00
    7 -0.2982E+01 -0.2329E+00  0.1525E+02  0.2516E+00  0.3561E+00  0.1337E+01 -0.8742E-01  0.1525E+02  0.2516E+00  0.3561E+00

TIME:  0.9847E+01  SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1 -0.3790E+01 -0.3797E+00  0.7932E+01  0.1463E+00  0.3494E+00  0.7803E+00  0.2578E-01  0.7932E+01  0.1463E+00  0.3494E+00
    3  0.1351E+02  0.8791E+00  0.8734E+01  0.4665E+00  0.3288E+00  0.2861E+01  0.9250E+00  0.8734E+01  0.4665E+00  0.3288E+00
    4 -0.1869E+01 -0.9113E-01  0.2302E+02  0.3347E+00  0.3582E+00  0.1764E+01 -0.2036E+00  0.2302E+02  0.3347E+00  0.3582E+00
    6 -0.1351E+02 -0.8791E+00  0.8734E+01  0.4665E+00  0.3288E+00  0.2861E+01  0.9250E+00  0.8734E+01  0.4665E+00  0.3288E+00
    7 -0.2994E+01 -0.2326E+00  0.1528E+02  0.2506E+00  0.3559E+00  0.1332E+01 -0.8677E-01  0.1528E+02  0.2506E+00  0.3559E+00

TIME:  0.9900E+01  SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1 -0.3810E+01 -0.3788E+00  0.7948E+01  0.1465E+00  0.3492E+00  0.7817E+00  0.2581E-01  0.7948E+01  0.1465E+00  0.3492E+00
    3  0.1356E+02  0.8474E+00  0.8783E+01  0.4674E+00  0.3288E+00  0.2911E+01  0.9309E+00  0.8783E+01  0.4674E+00  0.3288E+00
    4 -0.1874E+01 -0.9159E-01  0.2305E+02  0.3323E+00  0.3580E+00  0.1753E+01 -0.2025E+00  0.2305E+02  0.3323E+00  0.3580E+00
    6 -0.1356E+02 -0.8474E+00  0.8783E+01  0.4674E+00  0.3288E+00  0.2911E+01  0.9309E+00  0.8783E+01  0.4674E+00  0.3288E+00
    7 -0.3006E+01 -0.2322E+00  0.1530E+02  0.2496E+00  0.3557E+00  0.1327E+01 -0.8613E-01  0.1530E+02  0.2496E+00  0.3557E+00

TIME:  0.9953E+01  SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1 -0.3830E+01 -0.3779E+00  0.7963E+01  0.1467E+00  0.3491E+00  0.7831E+00  0.2583E-01  0.7963E+01  0.1467E+00  0.3491E+00
    3  0.1360E+02  0.8160E+00  0.8833E+01  0.4681E+00  0.3288E+00  0.2960E+01  0.9365E+00  0.8833E+01  0.4681E+00  0.3288E+00
    4 -0.1878E+01 -0.9205E-01  0.2309E+02  0.3300E+00  0.3578E+00  0.1743E+01 -0.2014E+00  0.2309E+02  0.3300E+00  0.3578E+00
    6 -0.1360E+02 -0.8160E+00  0.8833E+01  0.4681E+00  0.3288E+00  0.2960E+01  0.9365E+00  0.8833E+01  0.4681E+00  0.3288E+00
    7 -0.3019E+01 -0.2318E+00  0.1533E+02  0.2486E+00  0.3555E+00  0.1323E+01 -0.8549E-01  0.1533E+02  0.2486E+00  0.3555E+00

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
    #     DR          TIME          Y           YY
    1  0.0
    2  0.1000E+01  0.6323E+01  0.1188E+02  0.5369E+01
    3  0.0
    4  0.0
    5  0.1000E+01  0.6323E+01 -0.1188E+02  0.5369E+01
    6  0.0
    7  0.0
                    SEC           M           M**2

DEPOSITION FRACTION:  0.2857E+00

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 12c. AGDISP test case #1, last full page of printer output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

  1: 0000  AGDISP TEST CASE # 2
  2: 0010  2.0  1
  3: 0020  2  0  5.5  4.0  25.0  1
  4: 0021  1.5  1.0  1.0
  5: 0022  20.0
  6: 0050  -1  0.0  30.0
  7: 0060  4  0  0.0  100.0  1.0  1
  8: 0065  5.0  50.0

HALF-PLANE CALCULATION
AIRCRAFT SEMI-SPAN/DISK RADIUS:  0.55000E+01 M
                  FLIGHT SPEED:  0.25000E+02 M/SEC
NOMINAL RELEASE HEIGHT:  0.40000E+01 M
BIPLANE INCREMENTAL HEIGHT:  0.15000E+01 M
             SPAN FRACTION:  0.10000E+01
            GAMMA FRACTION:  0.10000E+01
RECTANGULARLY LOADED WING WITH GAMMA:  0.20000E+02 M**2/SEC
TURBULENCE FROM SUPEREQUILIBRIUM
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
TOTAL NUMBER OF PARTICLES:  4
                 DIAMETER:  0.10000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
EVAPORATION TEMPERATURE:  0.50000E+01 DEG C
        CUTOFF DIAMETER:  0.50000E+02 MICRONS
$$$ WARNING: SUPEREQUILIBRIUM TURBULENCE INVOKED
$$$ WARNING: EVAPORATION INVOKED
INITIAL TIME STEP:  0.15600E-01 SEC
MAXIMUM TIME:  0.20000E+01 SEC

TIME:  0.6592E+00 SEC
TIME:  0.1344E+01 SEC

INTEGRATION COMPLETE

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 13a. AGDISP test case #2 terminal output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

INPUT DATA DECK:

  1: 0000  AGDISP TEST CASE # 2
  2: 0010  2.0  1
  3: 0020  2  0  5.5  4.0  25.0  1
  4: 0021  1.5  1.0  1.0
  5: 0022  20.0
  6: 0050  -1  0.0  30.0
  7: 0060  4  0  0.0  100.0  1.0  1
  8: 0065  5.0  50.0


TIME:  0.0         SEC
   #     Y          V            YY           YV           VV           Z           W            ZZ           ZW           WW
   1  0.1100E+01  0.0          0.0          0.0          0.0          0.4000E+01  0.0          0.0          0.0          0.0
   2  0.2200E+01  0.0          0.0          0.0          0.0          0.4000E+01  0.0          0.0          0.0          0.0
   3  0.3300E+01  0.0          0.0          0.0          0.0          0.4000E+01  0.0          0.0          0.0          0.0
   4  0.4400E+01  0.0          0.0          0.0          0.0          0.4000E+01  0.0          0.0          0.0          0.0

TIME:  0.5287E-01 SEC
   #     Y          V            YY           YV           VV           Z           W            ZZ           ZW           WW
   1  0.1108E+01  0.2225E+00  0.0          0.0          0.0          0.3936E+01 -0.1730E+01  0.0          0.0          0.0
   2  0.2219E+01  0.4983E+00  0.0          0.0          0.0          0.3924E+01 -0.2016E+01  0.0          0.0          0.0
   3  0.3335E+01  0.9445E+00  0.0          0.0          0.0          0.3899E+01 -0.2609E+01  0.0          0.0          0.0
   4  0.4471E+01  0.1915E+01  0.0          0.0          0.0          0.3840E+01 -0.3932E+01  0.0          0.0          0.0

TIME:  0.1206E+00 SEC
   #     Y          V            YY           YV           VV           Z           W            ZZ           ZW           WW
   1  0.1125E+01  0.2686E+00  0.0          0.0          0.0          0.3812E+01 -0.1846E+01  0.0          0.0          0.0
   2  0.2256E+01  0.6102E+00  0.0          0.0          0.0          0.3781E+01 -0.2126E+01  0.0          0.0          0.0
   3  0.3408E+01  0.1194E+01  0.0          0.0          0.0          0.3718E+01 -0.2659E+01  0.0          0.0          0.0
   4  0.4626E+01  0.2608E+01  0.5025E-02  0.3557E+00  0.1312E+01  0.3582E+01 -0.3561E+01  0.1560E-01  0.1104E+01  0.4071E+01

TIME:  0.1869E+00 SEC
   #     Y          V            YY           YV           VV           Z           W            ZZ           ZW           WW
   1  0.1144E+01  0.2989E+00  0.2106E+00  0.3216E+01  0.1370E+01  0.3691E+01 -0.1813E+01  0.6398E+00  0.9841E+01  0.4204E+01
   2  0.2300E+01  0.6930E+00  0.0          0.0          0.0          0.3642E+01 -0.2076E+01  0.0          0.0          0.0
   3  0.3494E+01  0.1399E+01  0.9757E-02  0.6871E+00  0.1017E+01  0.3546E+01 -0.2523E+01  0.2973E-01  0.2094E+01  0.3100E+01
   4  0.4815E+01  0.3078E+01  0.1774E+00  0.1606E+01  0.4476E+01  0.3367E+01 -0.2942E+01  0.5954E+00  0.5722E+01  0.1634E+02

TIME:  0.2535E+00 SEC
   #     Y          V            YY           YV           VV           Z           W            ZZ           ZW           WW
   1  0.1165E+01  0.3277E+00  0.6675E+00  0.3474E+01  0.1368E+01  0.3571E+01 -0.1779E+01  0.2059E+01  0.1095E+02  0.4334E+01
   2  0.2348E+01  0.7737E+00  0.0          0.0          0.0          0.3506E+01 -0.2025E+01  0.0          0.0          0.0
   3  0.3594E+01  0.1595E+01  0.3580E+00  0.3269E+01  0.3732E+01  0.3383E+01 -0.2381E+01  0.1139E+01  0.1081E+02  0.1253E+02
   4  0.5031E+01  0.3384E+01  0.3868E+00  0.1555E+01  0.4141E+01  0.3191E+01 -0.2333E+01  0.1360E+01  0.5652E+01  0.1496E+02

TIME:  0.3204E+00 SEC
   #     Y          V            YY           YV           VV           Z           W            ZZ           ZW           WW
   1  0.1188E+01  0.3557E+00  0.1122E+01  0.3306E+01  0.1393E+01  0.3453E+01 -0.1748E+01  0.3508E+01  0.1067E+02  0.4512E+01
   2  0.2403E+01  0.8538E+00  0.9056E-01  0.2672E+01  0.2500E+01  0.3372E+01 -0.1980E+01  0.2752E+00  0.8149E+01  0.7626E+01
   3  0.3707E+01  0.1787E+01  0.7729E+00  0.2891E+01  0.3380E+01  0.3228E+01 -0.2240E+01  0.2568E+01  0.1034E+02  0.1226E+02
   4  0.5264E+01  0.3564E+01  0.5832E+00  0.8295E+00  0.1339E+01  0.3055E+01 -0.1760E+01  0.2035E+01  0.2703E+01  0.4142E+01
```

Figure 13b. AGDISP test case #2, first full page of printer output

```
   1  0.1894E+01  0.7419E+00  0.5185E+01  0.4651E+00  0.4485E+00  0.1682E+01 -0.9837E+00  0.1725E+02  0.1695E+01  0.1635E+01
   2  0.4271E+01  0.1960E+01  0.4818E+01  0.3738E+00  0.4979E+00  0.1409E+01 -0.9191E+00  0.1654E+02  0.1373E+01  0.1824E+01
   3  0.7707E+01  0.2966E+01  0.2343E+01  0.2930E+01  0.1102E+02  0.2383E+01  0.8836E+00  0.7657E+01  0.9449E+00  0.3548E+01
   4  0.8087E+01 -0.4601E+00  0.3528E+01  0.3859E-11  0.0         0.4677E+01  0.2842E+01  0.2995E+01  0.1216E-11  0.0

TIME:  0.1683E+01 SEC
   #     Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.1945E+01  0.7722E+00  0.5246E+01  0.4214E+00  0.4274E+00  0.1616E+01 -0.9617E+00  0.1747E+02  0.1539E+01  0.1561E+01
   2  0.4407E+01  0.2037E+01  0.4866E+01  0.3280E+00  0.4418E+00  0.1349E+01 -0.8637E+00  0.1671E+02  0.1182E+01  0.1586E+01
   3  0.7902E+01  0.2789E+01  0.2813E+01  0.3736E+01  0.1028E+02  0.2446E+01  0.9551E+00  0.7803E+01  0.1123E+01  0.3051E+01
   4  0.8041E+01 -0.9027E+00  0.3528E+01  0.1473E-12  0.0         0.4871E+01  0.2847E+01  0.2995E+01  0.4643E-13  0.0

TIME:  0.1751E+01 SEC
   #     Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.1999E+01  0.8031E+00  0.5300E+01  0.3817E+00  0.4073E+00  0.1551E+01 -0.9411E+00  0.1767E+02  0.1395E+01  0.1489E+01
   2  0.4548E+01  0.2121E+01  0.4908E+01  0.2906E+00  0.3970E+00  0.1292E+01 -0.8112E+00  0.1686E+02  0.1020E+01  0.1385E+01
   3  0.8086E+01  0.2611E+01  0.3335E+01  0.3948E+01  0.9970E+01  0.2513E+01  0.1013E+01  0.7956E+01  0.1118E+01  0.2795E+01
   4  0.7964E+01 -0.1388E+01  0.3585E+01  0.8405E+00  0.6310E+01  0.5062E+01  0.2788E+01  0.3178E+01  0.2763E+01  0.2099E+02

TIME:  0.1819E+01 SEC
   #     Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.2055E+01  0.8340E+00  0.5350E+01  0.3451E+00  0.3873E+00  0.1488E+01 -0.9211E+00  0.1785E+02  0.1262E+01  0.1416E+01
   2  0.4695E+01  0.2210E+01  0.4945E+01  0.2602E+00  0.3614E+00  0.1238E+01 -0.7610E+00  0.1699E+02  0.8806E+00  0.1214E+01
   3  0.8258E+01  0.2438E+01  0.3887E+01  0.4144E+01  0.9658E+01  0.2583E+01  0.1060E+01  0.8108E+01  0.1128E+01  0.2615E+01
   4  0.7851E+01 -0.1917E+01  0.3704E+01  0.8695E+00  0.5981E+01  0.5248E+01  0.2641E+01  0.3593E+01  0.3171E+01  0.2218E+02

TIME:  0.1887E+01 SEC
   #     Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.2112E+01  0.8640E+00  0.5394E+01  0.3112E+00  0.3667E+00  0.1426E+01 -0.9008E+00  0.1801E+02  0.1138E+01  0.1340E+01
   2  0.4849E+01  0.2303E+01  0.4979E+01  0.2357E+00  0.3333E+00  0.1188E+01 -0.7129E+00  0.1710E+02  0.7617E+00  0.1068E+01
   3  0.8418E+01  0.2271E+01  0.4465E+01  0.4344E+01  0.9379E+01  0.2657E+01  0.1099E+01  0.8264E+01  0.1166E+01  0.2513E+01
   4  0.7701E+01 -0.2482E+01  0.3822E+01  0.8751E+00  0.6615E+01  0.5419E+01  0.2375E+01  0.4026E+01  0.3160E+01  0.2362E+02

TIME:  0.1955E+01 SEC
   #     Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
   1  0.2172E+01  0.8922E+00  0.5434E+01  0.2797E+00  0.3450E+00  0.1365E+01 -0.8797E+00  0.1816E+02  0.1021E+01  0.1260E+01
   2  0.5009E+01  0.2398E+01  0.5009E+01  0.1770E+00  0.2343E+00  0.1141E+01 -0.6666E+00  0.1719E+02  0.5436E+00  0.7112E+00
   3  0.8567E+01  0.2113E+01  0.5070E+01  0.4546E+01  0.9152E+01  0.2733E+01  0.1132E+01  0.8427E+01  0.1233E+01  0.2489E+01
   4  0.7513E+01 -0.3062E+01  0.3939E+01  0.5144E+00  0.2517E+01  0.5568E+01  0.1956E+01  0.4420E+01  0.1642E+01  0.7556E+01

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
   #     DR          TIME          Y              YY
   1  0.0
   2  0.0
   3  0.0
   4  0.0
                     SEC           M              M**2

DEPOSITION FRACTION:  0.0

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 13c. AGDISP test case #2, last full page of printer output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

  1: 0000  AGDISP TEST CASE # 3
  2: 0010  10.0  1
  3: 0020  0  0  6.16  3.0  30.0  0
  4: 0025    0.0     8.764
  5: 0025    1.733   8.764
  6: 0025    1.959  10.149                TIME:  0.6315E+00 SEC
  7: 0025    2.185  11.487                TIME:  0.1324E+01 SEC
  8: 0025    2.412  12.723                TIME:  0.2055E+01 SEC
  9: 0025    2.638  13.848                TIME:  0.2786E+01 SEC
 10: 0025    2.865  14.870                TIME:  0.3487E+01 SEC
 11: 0025    3.091  15.827                TIME:  0.4209E+01 SEC
 12: 0025    3.318  16.719                TIME:  0.4940E+01 SEC
 13: 0025    3.544  17.519                TIME:  0.5666E+01 SEC
 14: 0025    3.770  18.216                TIME:  0.6398E+01 SEC
 15: 0025    3.997  18.968                TIME:  0.7132E+01 SEC
 16: 0025    4.223  19.740                TIME:  0.7856E+01 SEC
 17: 0025    4.450  20.511                TIME:  0.8574E+01 SEC
 18: 0025    4.676  21.180                TIME:  0.9294E+01 SEC
 19: 0025    4.903  21.664
 20: 0025    5.129  21.859                INTEGRATION COMPLETE
 21: 0025    5.356  21.357
 22: 0025    5.582  19.591                NASA AGDISP (MOD 2.0) PROGRAM END
 23: 0025    5.809  16.171
 24: 0025    6.035  10.827
 25: 0025   -6.160   0.0
 26: 0050  0  1.0  30.0
 27: 0055    0.0  0.05
 28: 0055    0.3  0.1
 29: 0055    0.7  0.3
 30: 0055   -1.5  0.0
 31: 0060  -4  0  0.0  100.0  1.0  0
 32: 0061    1.0  0.0
 33: 0061    2.5  0.0
 34: 0061    4.0  0.0
 35: 0061    5.0  0.0

HALF-PLANE CALCULATION
AIRCRAFT SEMI-SPAN/DISK RADIUS:  0.61600E+01 M
                    FLIGHT SPEED:  0.30000E+02 M/SEC
NOMINAL RELEASE HEIGHT:  0.30000E+01 M
BETZ ROLL UP INVOKED, MAXIMUM ENTRIES:  22
TURBULENCE FIXED VALUE:  0.10000E+01 (M/SEC)**2
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
CANOPY INVOKED, MAXIMUM ENTRIES:   4
PLANT AREA DENSITY HEIGHT:  0.15000E+01 M
   DISPLACEMENT THICKNESS:  0.73031E+00 M
TOTAL NUMBER OF PARTICLES:  4
                 DIAMETER:  0.10000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
INITIAL TIME STEP:  0.15600E-01 SEC
MAXIMUM TIME:  0.10000E+02 SEC
```

Figure 14a. AGDISP test case #3 terminal output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

INPUT DATA DECK:

  1: 0000  AGDISP TEST CASE # 3
  2: 0010  10.0  1
  3: 0020  0  0  6.16  3.0  30.0  0
  4: 0025    0.0     8.764
  5: 0025    1.733   8.764
  6: 0025    1.959  10.149
  7: 0025    2.185  11.487
  8: 0025    2.412  12.723
  9: 0025    2.638  13.848
 10: 0025    2.865  14.870
 11: 0025    3.091  15.827
 12: 0025    3.318  16.719
 13: 0025    3.544  17.519
 14: 0025    3.770  18.216
 15: 0025    3.997  18.968
 16: 0025    4.223  19.740
 17: 0025    4.450  20.511
 18: 0025    4.676  21.180
 19: 0025    4.903  21.664
 20: 0025    5.129  21.859
 21: 0025    5.356  21.357
 22: 0025    5.582  19.591
 23: 0025    5.809  16.171
 24: 0025    6.035  10.827
 25: 0025   -6.160   0.0
 26: 0050  0  1.0  30.0
 27: 0055    0.0  0.05
 28: 0055    0.3  0.1
 29: 0055    0.7  0.3
 30: 0055   -1.5  0.0
 31: 0060  -4  0  0.0  100.0  1.0  0
 32: 0061    1.0  0.0
 33: 0061    2.5  0.0
 34: 0061    4.0  0.0
 35: 0061    5.0  0.0


BETZ ROLL UP INITIALIZATION:
  N        Y              GAMMA           DERIV
  1   0.0             0.876400E+01   0.0             MN
  2   0.173300E+01    0.876400E+01   0.542134E+01
  3   0.195900E+01    0.101490E+02   0.602432E+01    MX
  4   0.218500E+01    0.114870E+02   0.568317E+01
  5   0.241200E+01    0.127230E+02   0.521091E+01
  6   0.263800E+01    0.138480E+02   0.474057E+01
  7   0.286500E+01    0.148700E+02   0.436807E+01
  8   0.309100E+01    0.158270E+02   0.408234E+01
  9   0.331800E+01    0.167190E+02   0.373424E+01
 10   0.354400E+01    0.175190E+02   0.331197E+01
 11   0.377000E+01    0.182160E+02   0.319820E+01
 12   0.399700E+01    0.189680E+02   0.336449E+01
```

Figure 14b. AGDISP test case #3, first full page of printer output

```
    4  0.1290E+02  0.2223E+01  0.4870E+01  0.7870E-01  0.1618E+00  0.7620E+00  0.4676E+00  0.4870E+01  0.7870E-01  0.1618E+00

TIME:  0.9294E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1306E+02  0.2105E+01  0.4882E+01  0.8535E-01  0.1693E+00  0.7965E+00  0.4897E+00  0.4882E+01  0.8535E-01  0.1693E+00

TIME:  0.9366E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1320E+02  0.1997E+01  0.4894E+01  0.9246E-01  0.1772E+00  0.8324E+00  0.5075E+00  0.4894E+01  0.9246E-01  0.1772E+00

TIME:  0.9438E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1334E+02  0.1898E+01  0.4908E+01  0.1000E+00  0.1853E+00  0.8695E+00  0.5222E+00  0.4908E+01  0.1000E+00  0.1853E+00

TIME:  0.9510E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1348E+02  0.1808E+01  0.4923E+01  0.1080E+00  0.1937E+00  0.9076E+00  0.5347E+00  0.4923E+01  0.1080E+00  0.1937E+00

TIME:  0.9582E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1361E+02  0.1726E+01  0.4939E+01  0.1163E+00  0.2022E+00  0.9465E+00  0.5455E+00  0.4939E+01  0.1163E+00  0.2022E+00

TIME:  0.9654E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1373E+02  0.1650E+01  0.4957E+01  0.1250E+00  0.2109E+00  0.9861E+00  0.5553E+00  0.4957E+01  0.1250E+00  0.2109E+00

TIME:  0.9726E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1384E+02  0.1580E+01  0.4975E+01  0.1341E+00  0.2198E+00  0.1026E+01  0.5643E+00  0.4975E+01  0.1341E+00  0.2198E+00

TIME:  0.9798E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1395E+02  0.1516E+01  0.4995E+01  0.1436E+00  0.2288E+00  0.1067E+01  0.5729E+00  0.4995E+01  0.1436E+00  0.2288E+00

TIME:  0.9870E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1406E+02  0.1456E+01  0.5017E+01  0.1535E+00  0.2379E+00  0.1109E+01  0.5813E+00  0.5017E+01  0.1535E+00  0.2379E+00

TIME:  0.9942E+01 SEC
    #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    4  0.1416E+02  0.1400E+01  0.5040E+01  0.1638E+00  0.2472E+00  0.1151E+01  0.5896E+00  0.5040E+01  0.1638E+00  0.2472E+00

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
    #      DR          TIME        Y           YY
    1  0.1000E+01  0.9270E+01  0.2091E+01  0.6375E+01
    2  0.1000E+01  0.8168E+01  0.4592E+01  0.4206E+01
    3  0.1000E+01  0.7303E+01  0.4230E+01  0.3465E+01
    4  0.0
                      SEC          M          M**2

DEPOSITION FRACTION:  0.7500E+00

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 14c. AGDISP test case #3, last full page of printer output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

   1: 0000  AGDISP TEST CASE # 4
   2: 0010  10.0  2
   3: 0020  -2  1  0.0  2.0  0.0  0
   4: 0028  3.0  3.0  0.01
   5: 0050  0  0.0  30.0
   6: 0060  0  0  0.0  100.0  1.0  0

FULL-PLANE CALCULATION
NOMINAL RELEASE HEIGHT:  0.20000E+01 M
CROSS-WIND VELOCITY:  0.30000E+01 M/SEC
                   Z:  0.30000E+01 M
                  Z0:  0.10000E-01 M
TURBULENCE FIXED VALUE:  0.23349E+00 (M/SEC)**2
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
TOTAL NUMBER OF PARTICLES:  1
                  DIAMETER:  0.10000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
INITIAL TIME STEP:  0.15600E-01 SEC
MAXIMUM TIME:  0.10000E+02 SEC

TIME:  0.7204E+00 SEC
TIME:  0.1457E+01 SEC
TIME:  0.2193E+01 SEC
TIME:  0.2929E+01 SEC
TIME:  0.3666E+01 SEC
TIME:  0.4402E+01 SEC
TIME:  0.5138E+01 SEC
TIME:  0.5875E+01 SEC
TIME:  0.6611E+01 SEC
TIME:  0.7347E+01 SEC
TIME:  0.8083E+01 SEC

INTEGRATION COMPLETE

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 15a. AGDISP test case #4 terminal output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

INPUT DATA DECK:

  1: 0000  AGDISP TEST CASE # 4
  2: 0010  10.0  2
  3: 0020  -2  1  0.0  2.0  0.0  0
  4: 0028  3.0  3.0  0.01
  5: 0050  0  0.0  30.0
  6: 0060  0  0  0.0  100.0  1.0  0


TIME:  0.0        SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.0         0.0         0.0         0.0         0.0         0.2000E+01  0.0         0.0         0.0         0.0

TIME:  0.5748E-01 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.1144E+00  0.2667E+01  0.1369E-01  0.2432E+00  0.5189E-01  0.1992E+01 -0.2081E+00  0.1369E-01  0.2432E+00  0.5189E-01

TIME:  0.1313E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.3171E+00  0.2778E+01  0.6075E-01  0.3463E+00  0.7563E-01  0.1975E+01 -0.2397E+00  0.6075E-01  0.3463E+00  0.7563E-01

TIME:  0.2049E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.5218E+00  0.2778E+01  0.1113E+00  0.3397E+00  0.7683E-01  0.1958E+01 -0.2405E+00  0.1113E+00  0.3397E+00  0.7683E-01

TIME:  0.2786E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.7262E+00  0.2773E+01  0.1607E+00  0.3311E+00  0.7688E-01  0.1940E+01 -0.2405E+00  0.1607E+00  0.3311E+00  0.7688E-01

TIME:  0.3522E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.9302E+00  0.2769E+01  0.2089E+00  0.3228E+00  0.7687E-01  0.1922E+01 -0.2405E+00  0.2089E+00  0.3228E+00  0.7687E-01

TIME:  0.4258E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.1134E+01  0.2764E+01  0.2558E+00  0.3145E+00  0.7687E-01  0.1904E+01 -0.2405E+00  0.2558E+00  0.3145E+00  0.7687E-01

TIME:  0.4995E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.1337E+01  0.2759E+01  0.3015E+00  0.3064E+00  0.7686E-01  0.1887E+01 -0.2405E+00  0.3015E+00  0.3064E+00  0.7686E-01

TIME:  0.5731E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.1540E+01  0.2754E+01  0.3461E+00  0.2985E+00  0.7685E-01  0.1869E+01 -0.2405E+00  0.3461E+00  0.2985E+00  0.7685E-01

TIME:  0.6467E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.1743E+01  0.2749E+01  0.3894E+00  0.2906E+00  0.7684E-01  0.1851E+01 -0.2405E+00  0.3894E+00  0.2906E+00  0.7684E-01

TIME:  0.7204E+00 SEC
    #    Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
    1  0.1945E+01  0.2744E+01  0.4317E+00  0.2829E+00  0.7683E-01  0.1834E+01 -0.2405E+00  0.4317E+00  0.2829E+00  0.7683E-01
```

Figure 15b. AGDISP test case #4, first full page of printer output

```
TIME:  0.7568E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1811E+02 0.1580E+01 0.1745E+01 0.1151E-01 0.6899E-01 0.1862E+00 -0.2405E+00 0.1745E+01 0.1151E-01 0.6899E-01

TIME:  0.7642E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1823E+02 0.1532E+01 0.1746E+01 0.1045E-01 0.6818E-01 0.1685E+00 -0.2405E+00 0.1746E+01 0.1045E-01 0.6818E-01

TIME:  0.7715E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1834E+02 0.1479E+01 0.1748E+01 0.9386E-02 0.6720E-01 0.1508E+00 -0.2405E+00 0.1748E+01 0.9386E-02 0.6720E-01

TIME:  0.7789E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1844E+02 0.1419E+01 0.1749E+01 0.8324E-02 0.6600E-01 0.1331E+00 -0.2404E+00 0.1749E+01 0.8324E-02 0.6600E-01

TIME:  0.7862E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1855E+02 0.1353E+01 0.1750E+01 0.7262E-02 0.6451E-01 0.1154E+00 -0.2404E+00 0.1750E+01 0.7262E-02 0.6451E-01

TIME:  0.7936E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1864E+02 0.1277E+01 0.1751E+01 0.6201E-02 0.6257E-01 0.9766E-01 -0.2404E+00 0.1751E+01 0.6201E-02 0.6257E-01

TIME:  0.8010E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1873E+02 0.1187E+01 0.1752E+01 0.5141E-02 0.5998E-01 0.7998E-01 -0.2403E+00 0.1752E+01 0.5141E-02 0.5998E-01

TIME:  0.8083E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1882E+02 0.1080E+01 0.1753E+01 0.4082E-02 0.5635E-01 0.6231E-01 -0.2402E+00 0.1753E+01 0.4082E-02 0.5635E-01

TIME:  0.8157E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1889E+02 0.9445E+00 0.1753E+01 0.3026E-02 0.5086E-01 0.4467E-01 -0.2400E+00 0.1753E+01 0.3026E-02 0.5086E-01

TIME:  0.8230E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1895E+02 0.7619E+00 0.1753E+01 0.1981E-02 0.4172E-01 0.2707E-01 -0.2395E+00 0.1753E+01 0.1981E-02 0.4172E-01

TIME:  0.8303E+01 SEC
   #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1900E+02 0.4797E+00 0.1754E+01 0.9655E-03 0.2397E-01 0.9629E-02 -0.2380E+00 0.1754E+01 0.9655E-03 0.2397E-01

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
   #      DR         TIME       Y          YY
   1  0.1000E+01 0.8351E+01 0.1902E+02 0.1754E+01
                  SEC        M          M**2

DEPOSITION FRACTION:  0.1000E+01

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 15c. AGDISP test case #4, last full page of printer output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

  1: 0000  AGDISP TEST CASE # 5
  2: 0010  10.0  2
  3: 0020  -1  0  6.0  3.0  30.0  0
  4: 0050  1  0.0  30.0
  5: 0060  -3  -1  0.0  100.0  1.0  0
  6: 0061  -5.0   0.0
  7: 0061  -2.0   0.0
  8: 0061  -1.0  -0.1
  9: 0061   1.5  -0.1
 10: 0061   3.0  -0.1
 11: 0061   4.5   0.0
 12: 0061   0.0   0.0

FULL-PLANE CALCULATION
AIRCRAFT SEMI-SPAN/DISK RADIUS:  0.60000E+01 M
                  FLIGHT SPEED:  0.30000E+02 M/SEC
NOMINAL RELEASE HEIGHT:  0.30000E+01 M
VARIABLES FROM WAKE PLOT FILE: V W QQ
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
WAKE PLOT FILE TITLE:
 TEST WITH VELOCITIES AND QQ
WAKE PLOT FILE MESH SIZES: (  3 ,  3 )
    Y (M):  0.0         0.2000E+02  0.4000E+02
    Z (M):  0.0         0.2000E+02  0.4000E+02
WAKE PLOT FILE TIMES:
     0.0        SEC
     0.2000E+01 SEC
     0.5000E+01 SEC
    -0.1000E+01 SEC
TOTAL NUMBER OF PARTICLES:  7
                 DIAMETER:  0.10000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
$$$ WARNING: WAKE PLOT FILE INVOKED
INITIAL TIME STEP:  0.15600E-01 SEC
MAXIMUM TIME:  0.10000E+02 SEC

TIME:  0.6851E+00 SEC
TIME:  0.1398E+01 SEC
TIME:  0.2110E+01 SEC
TIME:  0.2828E+01 SEC

INTEGRATION COMPLETE

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 16a. AGDISP test case #5 terminal output

```
.NASA AGDISP (MOD 2.0) PROGRAM RESULTS

 INPUT DATA DECK:

   1: 0000  AGDISP TEST CASE # 5
   2: 0010  10.0  2
   3: 0020  -1  0  6.0  3.0  30.0  0
   4: 0050  1  0.0  30.0
   5: 0060  -3  -1  0.0  100.0  1.0  0
   6: 0061  -5.0   0.0
   7: 0061  -2.0   0.0
   8: 0061  -1.0  -0.1
   9: 0061   1.5  -0.1
  10: 0061   3.0  -0.1
  11: 0061   4.5   0.0
  12: 0061   0.0   0.0

 WAKE PLOT FILE ACCESS:   0.0        SEC
 WAKE PLOT FILE ACCESS:   0.2000E+01 SEC

 TIME:  0.0        SEC
     #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
     1 -0.5000E+01  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
     2 -0.2000E+01  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
     3 -0.1000E+01  0.0         0.0         0.0         0.0         0.2900E+01  0.0         0.0         0.0         0.0
     4  0.1500E+01  0.0         0.0         0.0         0.0         0.2900E+01  0.0         0.0         0.0         0.0
     5  0.3000E+01  0.0         0.0         0.0         0.0         0.2900E+01  0.0         0.0         0.0         0.0
     6  0.4500E+01  0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
     7  0.0         0.0         0.0         0.0         0.0         0.3000E+01  0.0         0.0         0.0         0.0
 *** WARNING: 1ST WAKE PLOT FILE EXTRAPOLATION ( -0.5000E+01 ,  0.3000E+01 ) M

 TIME:  0.4811E-01 SEC
     #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
     1 -0.5176E+01 -0.4874E+01  0.3874E-01  0.8230E+00  0.2028E+00  0.2891E+01 -0.2992E+01  0.3874E-01  0.8230E+00  0.2028E+00
     2 -0.2066E+01 -0.1900E+01  0.4790E-01  0.1034E+01  0.1792E+00  0.2896E+01 -0.2942E+01  0.4790E-01  0.1034E+01  0.1792E+00
     3 -0.1033E+01 -0.9395E+00  0.5072E-01  0.1117E+01  0.1674E+00  0.2801E+01 -0.2831E+01  0.5072E-01  0.1117E+01  0.1674E+00
     4  0.1549E+01  0.1416E+01  0.4865E-01  0.1057E+01  0.1733E+00  0.2800E+01 -0.2839E+01  0.4865E-01  0.1057E+01  0.1733E+00
     5  0.3102E+01  0.2876E+01  0.4275E-01  0.9105E+00  0.1888E+00  0.2798E+01 -0.2867E+01  0.4275E-01  0.9105E+00  0.1888E+00
     6  0.4657E+01  0.4371E+01  0.3983E-01  0.8464E+00  0.2000E+00  0.2891E+01 -0.2985E+01  0.3983E-01  0.8464E+00  0.2000E+00
     7  0.0         0.0         0.5432E-01  0.1247E+01  0.1567E+00  0.2898E+01 -0.2917E+01  0.5432E-01  0.1247E+01  0.1567E+00

 TIME:  0.1191E+00 SEC
     #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
     1 -0.5544E+01 -0.5413E+01  0.2027E+00  0.1242E+01  0.3215E+00  0.2676E+01 -0.2971E+01  0.2027E+00  0.1242E+01  0.3215E+00
     2 -0.2212E+01 -0.2156E+01  0.2356E+00  0.1325E+01  0.3214E+00  0.2682E+01 -0.2979E+01  0.2356E+00  0.1325E+01  0.3214E+00
     3 -0.1105E+01 -0.1076E+01  0.2441E+00  0.1312E+01  0.3214E+00  0.2594E+01 -0.2889E+01  0.2441E+00  0.1312E+01  0.3214E+00
     4  0.1658E+01  0.1616E+01  0.2358E+00  0.1297E+01  0.3213E+00  0.2593E+01 -0.2888E+01  0.2358E+00  0.1297E+01  0.3213E+00
     5  0.3321E+01  0.3239E+01  0.2145E+00  0.1253E+01  0.3211E+00  0.2590E+01 -0.2885E+01  0.2145E+00  0.1253E+01  0.3211E+00
     6  0.4988E+01  0.4869E+01  0.2067E+00  0.1255E+01  0.3214E+00  0.2677E+01 -0.2972E+01  0.2067E+00  0.1255E+01  0.3214E+00
     7  0.0         0.0         0.2643E+00  0.1376E+01  0.3221E+00  0.2685E+01 -0.2982E+01  0.2643E+00  0.1376E+01  0.3221E+00

 TIME:  0.1896E+00 SEC
     #      Y           V           YY          YV          VV          Z           W           ZZ          ZW          WW
     1 -0.5940E+01 -0.5806E+01  0.3697E+00  0.1126E+01  0.3280E+00  0.2474E+01 -0.2770E+01  0.3697E+00  0.1126E+01  0.3280E+00
     2 -0.2370E+01 -0.2316E+01  0.4100E+00  0.1166E+01  0.3281E+00  0.2479E+01 -0.2779E+01  0.4100E+00  0.1166E+01  0.3281E+00
```

Figure 16b. AGDISP test case #5, first full page of printer output

```
TIME:  0.2900E+01 SEC
 #      Y           V          YY          YV          VV          Z           W          ZZ          ZW          WW
 1 -0.3474E+02 -0.1492E+02  0.1616E+01  0.5751E-02  0.9867E-01  0.6233E-01 -0.2606E+00  0.1616E+01  0.5751E-02  0.9867E-01
 2 -0.1386E+02 -0.5956E+01  0.1717E+01  0.5913E-02  0.9699E-01  0.5673E-01 -0.2654E+00  0.1717E+01  0.5913E-02  0.9699E-01
 3 -0.6922E+01 -0.2975E+01  0.1675E+01  0.4696E-02  0.8769E-01  0.4227E-01 -0.2607E+00  0.1675E+01  0.4696E-02  0.8769E-01
 4  0.1039E+02  0.4464E+01  0.1662E+01  0.4678E-02  0.8789E-01  0.4268E-01 -0.2602E+00  0.1662E+01  0.4678E-02  0.8789E-01
 5  0.2080E+02  0.8940E+01  0.1615E+01  0.4632E-02  0.8878E-01  0.4470E-01 -0.2578E+00  0.1615E+01  0.4632E-02  0.8878E-01
 6  0.3125E+02  0.1343E+02  0.1633E+01  0.5770E-02  0.9829E-01  0.6118E-01 -0.2613E+00  0.1633E+01  0.5770E-02  0.9829E-01
 7  0.0         0.0         0.1763E+01  0.6011E-02  0.9657E-01  0.5544E-01 -0.2672E+00  0.1763E+01  0.6011E-02  0.9657E-01

TIME:  0.2971E+01 SEC
 #      Y           V          YY          YV          VV          Z           W          ZZ          ZW          WW
 1 -0.3576E+02 -0.1455E+02  0.1616E+01  0.4476E-02  0.8531E-01  0.4443E-01 -0.2582E+00  0.1616E+01  0.4476E-02  0.8531E-01
 2 -0.1427E+02 -0.5806E+01  0.1717E+01  0.4140E-02  0.8063E-01  0.3847E-01 -0.2581E+00  0.1717E+01  0.4140E-02  0.8063E-01
 3 -0.7126E+01 -0.2900E+01  0.1676E+01  0.2894E-02  0.6567E-01  0.2430E-01 -0.2526E+00  0.1676E+01  0.2894E-02  0.6567E-01
 4  0.1069E+02  0.4352E+01  0.1662E+01  0.2919E-02  0.6629E-01  0.2475E-01 -0.2526E+00  0.1662E+01  0.2919E-02  0.6629E-01
 5  0.2142E+02  0.8716E+01  0.1616E+01  0.3050E-02  0.6915E-01  0.2696E-01 -0.2526E+00  0.1616E+01  0.3050E-02  0.6915E-01
 6  0.3217E+02  0.1309E+02  0.1634E+01  0.4407E-02  0.8445E-01  0.4323E-01 -0.2582E+00  0.1634E+01  0.4407E-02  0.8445E-01
 7  0.0         0.0         0.1764E+01  0.4068E-02  0.7933E-01  0.3704E-01 -0.2581E+00  0.1764E+01  0.4068E-02  0.7933E-01

TIME:  0.3043E+01 SEC
 #      Y           V          YY          YV          VV          Z           W          ZZ          ZW          WW
 1 -0.3682E+02 -0.1495E+02  0.1617E+01  0.2846E-02  0.6595E-01  0.2608E-01 -0.2491E+00  0.1617E+01  0.2846E-02  0.6595E-01
 2 -0.1469E+02 -0.5965E+01  0.1718E+01  0.2481E-02  0.5928E-01  0.2008E-01 -0.2503E+00  0.1718E+01  0.2481E-02  0.5928E-01
 3 -0.7339E+01 -0.2980E+01  0.1676E+01  0.1291E-02  0.3079E-01  0.6295E-02 -0.2451E+00  0.1676E+01  0.1291E-02  0.3079E-01
 4  0.1101E+02  0.4471E+01  0.1662E+01  0.1324E-02  0.3194E-01  0.6748E-02 -0.2451E+00  0.1662E+01  0.1324E-02  0.3194E-01
 5  0.2205E+02  0.8955E+01  0.1616E+01  0.1484E-02  0.3715E-01  0.8963E-02 -0.2447E+00  0.1616E+01  0.1484E-02  0.3715E-01
 6  0.3313E+02  0.1345E+02  0.1634E+01  0.2777E-02  0.6476E-01  0.2487E-01 -0.2494E+00  0.1634E+01  0.2777E-02  0.6476E-01
 7  0.0         0.0         0.1764E+01  0.2384E-02  0.5734E-01  0.1864E-01 -0.2504E+00  0.1764E+01  0.2384E-02  0.5734E-01

TIME:  0.3115E+01 SEC
 #      Y           V          YY          YV          VV          Z           W          ZZ          ZW          WW
 1 -0.3792E+02 -0.1540E+02  0.1617E+01  0.1353E-02  0.3462E-01  0.8405E-02 -0.2413E+00  0.1617E+01  0.1353E-02  0.3462E-01
 2 -0.1513E+02 -0.6141E+01  0.1718E+01  0.9363E-03  0.1862E-01  0.2312E-02 -0.2428E+00  0.1718E+01  0.9363E-03  0.1862E-01
 6  0.3411E+02  0.1385E+02  0.1635E+01  0.1272E-02  0.3180E-01  0.7174E-02 -0.2416E+00  0.1635E+01  0.1272E-02  0.3180E-01
 7  0.0         0.0         0.1764E+01  0.8285E-03  0.1397E-01  0.8555E-03 -0.2431E+00  0.1764E+01  0.8285E-03  0.1397E-01

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
 #     DR          TIME         Y           YY
 1  0.1000E+01  0.3151E+01 -0.3846E+02  0.1617E+01
 2  0.1000E+01  0.3127E+01 -0.1519E+02  0.1718E+01
 3  0.1000E+01  0.3079E+01 -0.7416E+01  0.1676E+01
 4  0.1000E+01  0.3079E+01  0.1114E+02  0.1662E+01
 5  0.1000E+01  0.3091E+01  0.2239E+02  0.1616E+01
 6  0.1000E+01  0.3151E+01  0.3453E+02  0.1635E+01
 7  0.1000E+01  0.3127E+01  0.0         0.1764E+01
                   SEC          M          M**2

DEPOSITION FRACTION:  0.1000E+01

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 16c. AGDISP test case #5, last full page of printer output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

  1: 0000  AGDISP TEST CASE # 6
  2: 0010  10.0  1
  3: 0020  3  0  8.0  6.0  30.0  0
  4: 0030  15000.0  0.05
  5: 0050  0  1.0  30.0
  6: 0060  6  0  -1.0  100.0  1.0  0

HALF-PLANE CALCULATION
AIRCRAFT SEMI-SPAN/DISK RADIUS:  0.80000E+01 M
                  FLIGHT SPEED:  0.30000E+02 M/SEC
NOMINAL RELEASE HEIGHT:  0.60000E+01 M
HELICOPTER FORWARD ADVANCE:  0.50000E-01
         DOWNWASH VELOCITY:  0.53750E+01 M/SEC
           EFFECTIVE GAMMA:  0.12738E+01 M**2/SEC
TURBULENCE FIXED VALUE:  0.10000E+01 (M/SEC)**2
SCALE LENGTH MAXIMUM VALUE:  0.30000E+02 M
TOTAL NUMBER OF PARTICLES:  6
                 DIAMETER:  0.10000E+03 MICRONS
         SPECIFIC GRAVITY:  0.10000E+01
INITIAL TIME STEP:  0.15600E-01 SEC
MAXIMUM TIME:  0.10000E+02 SEC

TIME:  0.6901E+00 SEC
TIME:  0.1412E+01 SEC
TIME:  0.2140E+01 SEC
TIME:  0.2872E+01 SEC

INTEGRATION COMPLETE

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 17a. AGDISP test case #6 terminal output

```
NASA AGDISP (MOD 2.0) PROGRAM RESULTS

INPUT DATA DECK:

  1: 0000  AGDISP TEST CASE # 6
  2: 0010  10.0  1
  3: 0020  3  0  8.0  6.0  30.0  0
  4: 0030  15000.0  0.05
  5: 0050  0  1.0  30.0
  6: 0060  6  0  -1.0  100.0  1.0  0

TIME:  0.0        SEC
   #     Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1143E+01  0.0        0.0        0.0        0.0        0.5000E+01  0.0        0.0        0.0        0.0
   2  0.2286E+01  0.0        0.0        0.0        0.0        0.5000E+01  0.0        0.0        0.0        0.0
   3  0.3429E+01  0.0        0.0        0.0        0.0        0.5000E+01  0.0        0.0        0.0        0.0
   4  0.4571E+01  0.0        0.0        0.0        0.0        0.5000E+01  0.0        0.0        0.0        0.0
   5  0.5714E+01  0.0        0.0        0.0        0.0        0.5000E+01  0.0        0.0        0.0        0.0
   6  0.6857E+01  0.0        0.0        0.0        0.0        0.5000E+01  0.0        0.0        0.0        0.0

TIME:  0.5078E-01 SEC
   #     Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1158E+01  0.4012E+00  0.9014E-01  0.2000E+01  0.1808E+00  0.4831E+01 -0.4399E+01  0.9014E-01  0.2000E+01  0.1808E+00
   2  0.2316E+01  0.8041E+00  0.8884E-01  0.1940E+01  0.1844E+00  0.4831E+01 -0.4405E+01  0.8884E-01  0.1940E+01  0.1844E+00
   3  0.3474E+01  0.1210E+01  0.7623E-01  0.1656E+01  0.1880E+00  0.4830E+01 -0.4415E+01  0.7623E-01  0.1656E+01  0.1880E+00
   4  0.4633E+01  0.1622E+01  0.5664E-01  0.1215E+01  0.1916E+00  0.4829E+01 -0.4432E+01  0.5664E-01  0.1215E+01  0.1916E+00
   5  0.5792E+01  0.2046E+01  0.3841E-01  0.8156E+00  0.1949E+00  0.4828E+01 -0.4456E+01  0.3841E-01  0.8156E+00  0.1949E+00
   6  0.6952E+01  0.2510E+01  0.2282E-01  0.4840E+00  0.1978E+00  0.4826E+01 -0.4482E+01  0.2282E-01  0.4840E+00  0.1978E+00

TIME:  0.1228E+00 SEC
   #     Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1189E+01  0.4687E+00  0.4325E+00  0.2238E+01  0.3252E+00  0.4510E+01 -0.4390E+01  0.4325E+00  0.2238E+01  0.3252E+00
   2  0.2379E+01  0.9383E+00  0.4246E+00  0.2223E+01  0.3250E+00  0.4510E+01 -0.4393E+01  0.4246E+00  0.2223E+01  0.3250E+00
   3  0.3569E+01  0.1410E+01  0.3737E+00  0.2058E+01  0.3248E+00  0.4509E+01 -0.4399E+01  0.3737E+00  0.2058E+01  0.3248E+00
   4  0.4760E+01  0.1887E+01  0.2772E+00  0.1546E+01  0.3239E+00  0.4507E+01 -0.4408E+01  0.2772E+00  0.1546E+01  0.3239E+00
   5  0.5952E+01  0.2378E+01  0.1886E+00  0.1070E+01  0.3225E+00  0.4504E+01 -0.4420E+01  0.1886E+00  0.1070E+01  0.3225E+00
   6  0.7149E+01  0.2905E+01  0.1151E+00  0.6845E+00  0.3202E+00  0.4502E+01 -0.4418E+01  0.1151E+00  0.6845E+00  0.3202E+00

TIME:  0.1929E+00 SEC
   #     Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1224E+01  0.5101E+00  0.7238E+00  0.1963E+01  0.3300E+00  0.4212E+01 -0.4123E+01  0.7238E+00  0.1963E+01  0.3300E+00
   2  0.2448E+01  0.1021E+01  0.7148E+00  0.1960E+01  0.3300E+00  0.4211E+01 -0.4126E+01  0.7148E+00  0.1960E+01  0.3300E+00
   3  0.3673E+01  0.1535E+01  0.6525E+00  0.1940E+01  0.3301E+00  0.4210E+01 -0.4131E+01  0.6525E+00  0.1940E+01  0.3301E+00
   4  0.4898E+01  0.2054E+01  0.4878E+00  0.1480E+01  0.3292E+00  0.4207E+01 -0.4138E+01  0.4878E+00  0.1480E+01  0.3292E+00
   5  0.6126E+01  0.2589E+01  0.3358E+00  0.1044E+01  0.3278E+00  0.4204E+01 -0.4145E+01  0.3358E+00  0.1044E+01  0.3278E+00
   6  0.7361E+01  0.3150E+01  0.2134E+00  0.7265E+00  0.3258E+00  0.4202E+01 -0.4127E+01  0.2134E+00  0.7265E+00  0.3258E+00

TIME:  0.2632E+00 SEC
   #     Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
   1  0.1261E+01  0.5428E+00  0.9892E+00  0.1813E+01  0.3302E+00  0.3931E+01 -0.3865E+01  0.9892E+00  0.1813E+01  0.3302E+00
   2  0.2522E+01  0.1087E+01  0.9799E+00  0.1811E+01  0.3302E+00  0.3930E+01 -0.3868E+01  0.9799E+00  0.1811E+01  0.3302E+00
   3  0.3784E+01  0.1634E+01  0.9163E+00  0.1807E+01  0.3302E+00  0.3928E+01 -0.3872E+01  0.9163E+00  0.1807E+01  0.3302E+00
   4  0.5048E+01  0.2187E+01  0.6958E+00  0.1477E+01  0.3296E+00  0.3925E+01 -0.3878E+01  0.6958E+00  0.1477E+01  0.3296E+00
   5  0.6315E+01  0.2756E+01  0.4839E+00  0.1063E+01  0.3283E+00  0.3922E+01 -0.3879E+01  0.4839E+00  0.1063E+01  0.3283E+00
```

Figure 17b. AGDISP test case #6, first full page of printer output

```
TIME:  0.3019E+01 SEC
  #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  1  0.3012E+01 0.5172E+00 0.3515E+01 0.1267E-01 0.2166E+00 0.6458E-01 -0.3050E+00 0.3515E+01 0.1267E-01 0.2166E+00
  2  0.6030E+01 0.1036E+01 0.3502E+01 0.1258E-01 0.2160E+00 0.6407E-01 -0.3044E+00 0.3502E+01 0.1258E-01 0.2160E+00
  3  0.9046E+01 0.1542E+01 0.3434E+01 0.1281E-01 0.2176E+00 0.6543E-01 -0.3049E+00 0.3434E+01 0.1281E-01 0.2176E+00
  4  0.1204E+02 0.2032E+01 0.3158E+01 0.1332E-01 0.2209E+00 0.6844E-01 -0.3072E+00 0.3158E+01 0.1332E-01 0.2209E+00
  5  0.1503E+02 0.2524E+01 0.2772E+01 0.1373E-01 0.2233E+00 0.7084E-01 -0.3095E+00 0.2772E+01 0.1373E-01 0.2233E+00
  6  0.1803E+02 0.3025E+01 0.2535E+01 0.1403E-01 0.2251E+00 0.7263E-01 -0.3112E+00 0.2535E+01 0.1403E-01 0.2251E+00

TIME:  0.3092E+01 SEC
  #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  1  0.3049E+01 0.4922E+00 0.3516E+01 0.8872E-02 0.1847E+00 0.4298E-01 -0.2851E+00 0.3516E+01 0.8872E-02 0.1847E+00
  2  0.6104E+01 0.9854E+00 0.3503E+01 0.8783E-02 0.1837E+00 0.4251E-01 -0.2845E+00 0.3503E+01 0.8783E-02 0.1837E+00
  3  0.9156E+01 0.1467E+01 0.3436E+01 0.9003E-02 0.1861E+00 0.4384E-01 -0.2851E+00 0.3436E+01 0.9003E-02 0.1861E+00
  4  0.1219E+02 0.1934E+01 0.3160E+01 0.9486E-02 0.1911E+00 0.4667E-01 -0.2874E+00 0.3160E+01 0.9486E-02 0.1911E+00
  5  0.1521E+02 0.2404E+01 0.2774E+01 0.9863E-02 0.1948E+00 0.4892E-01 -0.2894E+00 0.2774E+01 0.9863E-02 0.1948E+00
  6  0.1824E+02 0.2884E+01 0.2537E+01 0.1014E-01 0.1973E+00 0.5059E-01 -0.2909E+00 0.2537E+01 0.1014E-01 0.1973E+00

TIME:  0.3165E+01 SEC
  #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  1  0.3084E+01 0.4579E+00 0.3517E+01 0.5359E-02 0.1342E+00 0.2281E-01 -0.2665E+00 0.3517E+01 0.5359E-02 0.1342E+00
  2  0.6174E+01 0.9160E+00 0.3504E+01 0.5277E-02 0.1327E+00 0.2239E-01 -0.2659E+00 0.3504E+01 0.5277E-02 0.1327E+00
  3  0.9260E+01 0.1364E+01 0.3437E+01 0.5483E-02 0.1369E+00 0.2366E-01 -0.2666E+00 0.3437E+01 0.5483E-02 0.1369E+00
  4  0.1233E+02 0.1803E+01 0.3161E+01 0.5930E-02 0.1449E+00 0.2634E-01 -0.2687E+00 0.3161E+01 0.5930E-02 0.1449E+00
  5  0.1538E+02 0.2246E+01 0.2775E+01 0.6275E-02 0.1508E+00 0.2845E-01 -0.2705E+00 0.2775E+01 0.6275E-02 0.1508E+00
  6  0.1845E+02 0.2700E+01 0.2538E+01 0.6525E-02 0.1549E+00 0.3002E-01 -0.2717E+00 0.2538E+01 0.6525E-02 0.1549E+00

TIME:  0.3238E+01 SEC
  #      Y          V          YY         YV         VV         Z          W          ZZ         ZW         WW
  1  0.3115E+01 0.3958E+00 0.3518E+01 0.2168E-02 0.4795E-01 0.4045E-02 -0.2490E+00 0.3518E+01 0.2168E-02 0.4795E-01
  2  0.6237E+01 0.7890E+00 0.3505E+01 0.2092E-02 0.4536E-01 0.3665E-02 -0.2482E+00 0.3505E+01 0.2092E-02 0.4536E-01
  3  0.9354E+01 0.1185E+01 0.3438E+01 0.2279E-02 0.5262E-01 0.4900E-02 -0.2486E+00 0.3438E+01 0.2279E-02 0.5262E-01
  4  0.1245E+02 0.1589E+01 0.3161E+01 0.2682E-02 0.6695E-01 0.7430E-02 -0.2505E+00 0.3161E+01 0.2682E-02 0.6695E-01
  5  0.1554E+02 0.1999E+01 0.2776E+01 0.2994E-02 0.7727E-01 0.9422E-02 -0.2519E+00 0.2776E+01 0.2994E-02 0.7727E-01
  6  0.1864E+02 0.2418E+01 0.2539E+01 0.3217E-02 0.8442E-01 0.1092E-01 -0.2528E+00 0.2539E+01 0.3217E-02 0.8442E-01

INTEGRATION COMPLETE

DEPOSITION DIAMETER RATIOS:
  #      DR        TIME         Y          YY
  1  0.1000E+01 0.3262E+01 0.3121E+01 0.3518E+01
  2  0.1000E+01 0.3262E+01 0.6248E+01 0.3505E+01
  3  0.1000E+01 0.3262E+01 0.9376E+01 0.3438E+01
  4  0.1000E+01 0.3271E+01 0.1250E+02 0.3162E+01
  5  0.1000E+01 0.3280E+01 0.1561E+02 0.2776E+01
  6  0.1000E+01 0.3289E+01 0.1874E+02 0.2539E+01
                  SEC          M          M**2

DEPOSITION FRACTION:  0.1000E+01

NASA AGDISP (MOD 2.0) PROGRAM END
```

Figure 17c. AGDISP test case #6, last full page of printer output

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APPENDICES

The appendices contain variable definitions for the FORTRAN source code for AGDISP, AGPLOT and AGLINE. Explanation of the role of the subroutines may be found in Section 8 of this manual.

The variables summarized in Appendices A, B and C do not, as a rule, include the following:

1. DO loop indices;
2. dummy variables in subroutine statements;
3. temporary variables (holding the results of intermediate calculations); or
4. variables in the scientific subroutines AGBZQ, AGBZT, AGLQD, AGLQS and AGRTF.

Abbreviations have been used whenever possible; thus, deriv = derivative; eqn = equation; relax = relaxation; se = super-equilibrium; wrt = with respect to; etc. Vector variables are identified as such. Duplicated variable names occurring in AGPLOT are not repeated in AGLINE unless their function has changed.

APPENDIX A: AGDISP Variable Summary

NAME	SUBR	DESCRIPTION
AGV	AGBZG	vector: absolute value of Betz circulation distribution
APRP	AGDISP	initial frontal area of propeller
AS	AGDISP	airplane planform area
ASV	AGPAC	vector: integrand of average plant area density
AV	AGDISP AGPAC AGPAD	vector: inputted plant area density, function of ZV
	AGWKI AGWKR AGWKS	vector: wake plot file contents at a specified time
B	AGCOR	ratio of particle relax time to turbulent relax time
C	AGCOR	ratio of actual time to turbulent relax time
CD	AGDISP	airplane drag coefficient
	AGPAC	effective plant canopy vortex drag coefficient
CPQ	AGDISP AGPRP	constant for propeller turbulence evaluation
CPR	AGDISP AGPRP	constant for propeller radius evaluation
CTA	AGDISP	cosine of terrain angle
DCUT	AGDEC AGDISP	particle diameter below which AGDISP terminates
DECAY	AGDIF	particle decay constant
DELT	AGBZI AGPAC AGVCH	integration time step
DELTA	AGTUR	spatial distance across which se derivs are computed
DENF	AGDEC AGDISP	particle specific gravity
DG	AGBZG AGBZI	Betz fully rolled up vortex circulation strength
DGMM	AGBZG	error tolerance on computed Betz circulation derivs
DGV	AGBZD AGBZG AGBZI	vector: Betz circulation derivs, functions of YV

NAME	SUBR	DESCRIPTION
DIAM	AGDEC AGDISP	particle diameter
DIST	AGBZG AGDISP	initial vertical distance from ground to Betz vortex sheet initial vertical distance from ground to tip vortex center
DMAX	AGSUP	se maximum local spatial velocity deriv
DMCV	AGDISP AGINT	vector: particle volume ratio at surface impact
DNV	AGBZI AGINT	vector: new time derivs of Betz vortex eqns vector: new time derivs of particle eqns
DOV	AGBZG AGBZI AGINT	vector: old time derivs of Betz vortex eqns vector: old time derivs of particle eqns
DSYM	AGBZG AGBZI AGVEL	vector: unrolled Betz sheet length left-of-centroid
DSYP	AGBZG AGBZI AGVEL	vector: unrolled Betz sheet length right-of-centroid
DT	AGBZI AGDISP AGINT	integration time step
DTAU	AGCOR AGDEC AGDIF AGDISP	particle relax time
DTEMP	AGDISP	evaporation wet bulb temperature difference
DTMN	AGDIF AGINT	minimum particle relax time, function of DIAM
DTV	AGBZG AGBZI	vector: Betz integration time step for each vortex
DU	AGDEC	particle velocity relative to local mean wind velocity
DV	AGBZD AGDIF AGMAT AGSUP	vector: new time derivs of Betz vortex eqns vector: new time derivs of particle eqns vector: se turbulence solution
DVDY	AGSUP AGTUR	deriv of horizontal velocity wrt horizontal distance

NAME	SUBR	DESCRIPTION
DVDZ	AGSUP AGTUR	deriv of horizontal velocity wrt vertical distance
DWDY	AGSUP AGTUR	deriv of vertical velocity wrt horizontal distance
DWDZ	AGSUP AGTUR	deriv of vertical velocity wrt vertical distance
DY	AGBZG AGBZI	Betz fully rolled up vortex radius horizontal increment in Betz vortex location
DZ	AGBZG AGBZI AGDISP	distance above DIST to biplane vertical location vertical increment in Betz vortex location incremental vertical distance
DZBP	AGDISP	incremental vertical distance from DIST to biplane
D1	AGBZD	Betz left-of-centroid spatial circulation deriv
D2	AGBZD	Betz right-of-centroid spatial circulation deriv
EPS	AGDEC AGSUP AGTUR	particle decay constant se incremental turbulence level for root finding se continuity equation error
ETA	AGDISP	airplane propeller efficiency
ETAU	AGDEC AGDISP AGINT	particle evaporation relax time
FACL	AGBZG AGDISP AGPAC AGVEL	vector: plant canopy circulation reduction -Y vortices
FACR	AGBZG AGDISP AGPAC AGVEL	vector: plant canopy circulation reduction +Y vortices
FL	AGPAC AGPAD	vector: plant area density integral -Y vortices
FR	AGPAC AGPAD	vector: plant area density integral +Y vortices
G	AGSVE	Betz unrolled vortex circulation strength
GAMMA	AGDISP	triangular/rectangular vortex circulation strength

NAME	SUBR	DESCRIPTION
GSAV	AGBZG AGBZI AGDISP AGVEL	vector: Betz average sheet circulation per unit length
GV	AGBZG AGBZI AGDISP	vector: inputted Betz circulation, function of YV
G1	AGBZI	Betz left-of-centroid circulation value
G2	AGBZI	Betz right-of-centroid circulation value
G2PI	AGBZG AGBZI AGDISP AGPAC AGVEL	vector: circulation divided by two pi (6.2831853)
HHEL	AGDISP AGINT AGVEL	initial height of helicopter rotor plane above surface
HTPAD	AGDISP AGINT AGPAC AGTUR AGVEL	plant canopy maximum height above surface
ICARD	AGDISP	running count of input cards
ICMX	AGDISP	maximum number of input cards
ICV	AGDISP	vector: input card numbers
IER	AGMAT AGSUP	se error flag
IFL	AGPAC AGPAD	vector: -Y vortex within plant canopy flag
IFR	AGPAC AGPAD	vector: +Y vortex within plant canopy flag
IMAX	AGSUP	se maximum iteration limit
IOUT	AGINT AGSAV	terminal output flag
ISW	AGINT AGSAV	vector: individual particle-to-ground impact flag

NAME	SUBR	DESCRIPTION
ISWC	AGINT AGSAV	summed particle-to-ground impact flag
IY	AGWKI	horizontal vector location within wake array data
IZ	AGWKI	vertical vector location within wake array data
LBP	AGDISP	biplane flag
LCV	AGDISP	vector: admissible input card entries
LENDF	AGDEC AGDISP AGINT	end-of-run flag
LERF	AGBZG	Betz error flag
LEVAP	AGDEC AGDISP AGINT	evaporation flag
LHFPL	AGDISP	half-plane/full-plane flag
LMCRS	AGDISP AGVEL	mean cross wind flag
LMVEL	AGDISP AGINT AGVCH AGVEL	mean velocity flag
LOC	AGDISP	input card counter
LOCA	AGDISP	plant area density input card counter
LOCB	AGDISP	Betz circulation input card counter
LPART	AGDISP	particle flag
LPRP	AGDISP AGINT AGTUR AGVCH AGVEL	propeller flag
LQQSE	AGDISP AGTUR	turbulence flag
LV	AGDISP AGINT	vector: input card flags vector: positive definite variables flag
LZERO	AGDISP	centerline particle flag

NAME	SUBR	DESCRIPTION
L10	AGDISP	card 0010 flag
L20	AGDISP	card 0020 flag
L21	AGDISP	card 0021 flag
L22	AGDISP	card 0022 flag
L25	AGDISP	card 0025 flag
L28	AGDISP	card 0028 flag
L30	AGDISP	card 0030 flag
L50	AGDISP	card 0050 flag
L60	AGDISP	card 0060 flag
L61	AGDISP	card 0061 flag
L65	AGDISP	card 0065 flag
ME	AGBZD AGBZG AGBZI	ending pointer for Betz vortex circulation
MEV	AGBZG AGBZI	vector: ME values for all Betz vortices
MS	AGBZD AGBZG AGBZI	starting pointer for Betz vortex circulation
MSV	AGBZG AGBZI	vector: MS values for all Betz vortices
MT	AGBZD AGBZG AGBZI	total discrete points in Betz vortex circulation
MX	AGBZD AGBZG AGBZI	position of maximum Betz circulation deriv
MXV	AGBZG AGBZI	vector: MX values for all Betz vortices
NBTZ	AGBZG AGBZI	number of Betz vortices
NDAT	AGDISP	card input file unit number

NAME	SUBR	DESCRIPTION
NENDF	AGWKR AGWKS	wake plot file record position counter
NEXTF	AGWKI AGWKS	wake plot file extrapolation flag
NF	AGWKR	wake plot file record read counter
NGAM	AGBZG AGDISP	number of discrete inputted Betz circulation data points
NMAX	AGWKS	maximum admissible grid positions in wake plot file
NOUT	AGBZG AGDISP AGMAT AGPAD AGSAV AGSUP AGWKS	terminal output unit number
NPAD	AGDISP AGPAC AGPAD	number of discrete inputted plant area density data points
NPLT	AGDISP AGSAV	plot output file unit number
NPRT	AGBZG AGBZI AGDISP AGPAC AGSAV AGWKI AGWKR	printer output file unit number
NSAV	AGDISP AGINT	frequency of writes to plot output file
NV	AGWKS	vector: number of admissible variables in wake plot file
NVAR	AGDIF AGDISP AGINT AGSAV	total number of particles

NAME	SUBR	DESCRIPTION
NVOR	AGBZG AGBZI AGDISP AGPAC AGTUR AGVCH AGVEL	total number of vortices
NWPF	AGWKR AGWKS	wake plot file unit number
NWPV	AGWKR AGWKS	total number of wake plot file variables
NY	AGWKI AGWKR AGWKS	total number of horizontal points in wake plot file
NZ	AGWKI AGWKR AGWKS	total number of vertical points in wake plot file
PGBP	AGDISP AGBZG AGBZI	biplane circulation factor
PSBP	AGDISP AGBZG AGBZI	biplane semispan factor
QQ	AGDIF AGTUR	local background turbulence level
QQMX	AGDISP AGTUR	constant background turbulence level
QQPRP	AGDISP AGPRP AGTUR	propeller turbulence level
R	AGTUR AGVEL	radius
REYNO	AGDEC	Reynolds number based on relative velocity
RHEL	AGDISP AGVEL	helicopter blade radius
RLIM	AGBZG AGDISP AGVEL	limiting cutoff radius for triangular wing loading

NAME	SUBR	DESCRIPTION
RPRP	AGDISP AGPRP AGTUR AGVEL	radius of propeller flow field effect, function of X
S	AGDISP AGSVE AGVEL	airplane semispan length of unrolled Betz vortex sheet
SL	AGDIF AGTUR	turbulent macroscale length
SLMX	AGDISP AGTUR	maximum turbulent macroscale length
SRV	AGBZG AGBZI AGDISP AGPAC	vector: vortex core radius
STA	AGDISP	sine of terrain angle
T	AGCOR AGDEC AGDIF AGINT AGSAV AGWKR	integration time
TA	AGDISP	terrain slope angle
TDOT	AGDISP	propeller shaft rpm
TFE	AGWKR	wake plot file time just beyond desired time
TFS	AGWKR	wake plot file time just before desired time
TIME	AGBZI AGDISP	integration time
TMAX	AGDEC AGDISP AGINT	maximum integration time
TMCV	AGDISP AGINT	vector: time of particle-surface impact
TR	AGWKR AGWKS	wake plot file interpolation time
U	AGDISP	cross wind reference velocity

NAME	SUBR	DESCRIPTION
UO	AGDISP AGINT	aircraft flight speed
USK	AGDISP AGVEL	constant for cross wind evaluation
UU	AGSUP AGTUR	local background axial turbulence component
UV	AGCOR AGDIF	particle velocity/background velocity correlation
UX	AGCOR AGDIF	particle position/background velocity correlation
UY	AGMAT AGSUP	deriv of axial velocity wrt horizontal distance
UZ	AGMAT AGSUP	deriv of axial velocity wrt vertical distance
V	AGDIF AGDISP AGSVE AGVEL	horizontal velocity
VPRP	AGDISP AGPRP AGVEL	propeller tip velocity
VV	AGDIF AGSUP AGTUR	local background horizontal turbulence component
VY	AGMAT AGSUP	deriv of horizontal velocity wrt horizontal distance
VZ	AGMAT AGSUP	deriv of horizontal velocity wrt vertical distance
W	AGDIF AGDISP AGSVE AGVEL	vertical velocity
WHEL	AGDISP AGINT AGVEL	helicopter downwash velocity at blade plane
WT	AGDISP	helicopter weight

NAME	SUBR	DESCRIPTION
WTAU	AGCOR AGDIF	turbulent relax time
WW	AGDIF AGSUP AGTUR	local background vertical turbulence component
WY	AGMAT AGSUP	deriv of vertical velocity wrt horizontal distance
WZ	AGMAT AGSUP	deriv of vertical velocity wrt vertical distance
X	AGPRP AGSVE AGWKI	axial distance measured from particle release point
XMU	AGDISP	helicopter forward advance ratio
XNV	AGBZI AGINT	vector: new time values of Betz vortex eqns vector: new time values of particle eqns
XO	AGINT AGVEL	axial distance measured from particle release point
XOV	AGBZG AGBZI AGDISP AGINT	vector: old time values of Betz vortex eqns vector: old time values of particle eqns
XPR	AGDISP AGPRP	propeller axial virtual origin
XV	AGBZD AGDIF AGSAV	vector: new time values of Betz vortex eqns vector: new time values of particle eqns
X1	AGBZI	Betz integral for left-of-centroid
X2	AGBZI	Betz integral for right-of-centroid
Y	AGSVE AGTUR AGVEL AGWKI	horizontal distance
YBAL	AGBZG AGBZI AGDISP AGTUR AGVCH AGVEL	vector: horizontal location of 2nd quadrant vortices

NAME	SUBR	DESCRIPTION
YBAR	AGBZG AGBZI AGDISP AGTUR AGVCH AGVEL	vector: horizontal location of 1st quadrant vortices
YE	AGBZI	right-of-centroid maximum location of Betz rollup
YHEL	AGDISP AGVCH AGVEL	horizontal location of helicopter centerline
YNV	AGBZI	new horizontal location of Betz vortex centerline
YOV	AGBZG AGBZI	vector: old horizontal location of Betz vortex centerlines
YPRP	AGDISP AGTUR AGVCH AGVEL	horizontal location of propeller centerline
YS	AGBZI	left-of-centroid minimum location of Betz rollup
YV	AGBZD AGBZG AGBZI AGDISP	vector: inputted discrete wing stations for Betz GV
	AGWKI AGWKS	vector: horizontal spatial locations in wake plot file
Y1	AGBZD AGBZI	left-of-centroid location of Betz rollup point
Y2	AGBZD AGBZI	right-of-centroid location of Betz rollup point
Z	AGDISP AGSVE AGTUR AGVEL AGWKI	vertical distance
ZBAL	AGBZG AGBZI AGDISP AGPAC AGTUR AGVCH AGVEL	vector: vertical location of 2nd quadrant vortices

NAME	SUBR	DESCRIPTION
ZBAR	AGBZG AGBZI AGDISP AGPAC AGTUR AGVCH AGVEL	vector: vertical location of 1st quadrant vortices
ZHEL	AGDISP AGINT AGVCH AGVEL	vertical location of helicopter centerline
ZNV	AGBZI	new vertical location of Betz vortex centerline
ZO	AGDISP AGVEL	surface roughness height
ZOPAD	AGDISP AGVEL	plant canopy effective surface roughness height
ZOV	AGBZG AGBZI	vector: old vertical location of Betz vortex centerlines
ZPRP	AGDISP AGTUR AGVCH AGVEL	vertical location of propeller centerline
ZV	AGDISP AGPAC AGPAD	vector: inputted vertical locations of plant density AV
	AGWKI AGWKS	vector: vertical spatial locations in wake plot file

APPENDIX B: AGPLOT Variable Summary

NAME	SUBR	DESCRIPTION
ANSWR	AGPLOT AGPLT	interactive user response
AV	AGPLT AGSPD	vector: particle solution from plot output file
CT	AGSPD	particle direction cosine
DELT	AGPLOT AGPLT	tag time increment
DIST	AGPLOT AGSPD	initial vertical distance from surface to aircraft wing
DMCV	AGPLOT	vector: particle volume ratio at surface impact
DV	AGGRD AGPLOT	vector: particle volume ratio at surface impact vector: horizontal spread and location at surface impact
DZBP	AGPLOT	incremental vertical distance from DIST to biplane
GDLT	AGGRD	ground deposition plot scale interval
GMAX	AGGRD	ground deposition plot scale maximum
GMIN	AGGRD	ground deposition plot scale minimum
GV	AGGRD	vector: ground deposition
ICARD	AGPLOT	running count of AGDISP input cards
ICV	AGPLOT	vector: particle-surface impact flag
IE	AGPLT	number of scale tick marks
IV	AGGRD	vector: particle-surface impact flag
IX	AGCHK	number of scale divisions
IXD	AGDRW AGPLT	horizontal screen interval size equivalent
IXE	AGDRW AGPLT	horizontal screen maximum size equivalent
IXN	AGDRW	vector: horizontal screen coordinate equivalent
IXS	AGDRW AGPLT	horizontal screen minimum size equivalent
IXT	AGPLT	horizontal screen scale divisions

NAME	SUBR	DESCRIPTION
IXV	AGPLT	vector: terminal horizontal screen limits
IXZ	AGPLT	horizontal screen zero axis coordinate equivalent
IX1	AGPLT	horizontal screen pointer for mean particle index
IX2	AGPLT	horizontal screen pointer for right-of-particle index
IX3	AGPLT	horizontal screen pointer for left-of-particle index
IYD	AGDRW AGPLT	vertical screen interval size equivalent
IYE	AGDRW AGPLT	vertical screen maximum size equivalent
IYN	AGDRW	vector: vertical screen coordinate equivalent
IYS	AGPLT	vertical screen minimum size equivalent
IYT	AGPLT	vertical screen scale divisions
IYV	AGPLT	vector: terminal vertical screen limits
IYZ	AGPLT	vertical screen zero axis coordinate equivalent
IY1	AGPLT	vertical screen pointer for mean particle index
IY2	AGPLT	vertical screen pointer for right-of-particle index
IY3	AGPLT	vertical screen pointer for left-of-particle index
LBOX	AGPLT	tag time pointer
LENDF	AGPLT	end-of-plot flag
LFOLD	AGGRD AGPLOT AGPLT	symmetry plot flag
LHF	AGGRD	half-plane/full-plane flag
LHFPL	AGPLOT	half-plane/full-plane flag
LMPLT	AGPLOT AGPLT	mean particle trajectory plot flag
LSC	AGPLT	equal plot scales flag
LSPLT	AGPLOT AGPLT	standard deviation trajectory plot flag

NAME	SUBR	DESCRIPTION
LTERM	AGGRD AGMDL AGPLOT AGPLT	terminal type flag
LTPLT	AGPLOT AGPLT	tag plot flag
LZERO	AGPLOT	centerline particle flag
LZR	AGGRD	centerline particle flag
NINU	AGGRD AGPLOT AGPLT	terminal input unit number
NOUT	AGCHK AGGRD AGMDL AGPLOT AGPLT	terminal output unit number
NPLT	AGPLOT AGPLT	plot input file unit number
NPTS	AGDRW AGGRD	total number of plotted particles
NTOT	AGGRD	ground deposition discretization
NVAR	AGGRD AGPLOT AGPLT	total number of particles
PSBP	AGPLOT	biplane semispan factor
RSPD	AGSPD	average standard deviation
S	AGPLOT	aircraft semispan
SRTPI	AGGRD	constant for ground deposition normalization
SSS	AGDRW AGGRD AGPLT	symmetry parameter
ST	AGSPD	particle direction sine
SY	AGGRD	horizontal particle turbulent spread
TA	AGPLOT AGPLT	terrain slope angle

NAME	SUBR	DESCRIPTION
TIME	AGPLOT AGPLT	simulation time
TMAX	AGPLOT	maximum simulation time
TV	AGPLT	vector: simulation time
XD	AGDRW AGPLT	horizontal screen interval value
XDC	AGPLT	horizontal screen interval value for equal axes
XDD	AGPLT	horizontal screen interval value
XDLT	AGCHK	plot scale interval
XMAX	AGCHK	plot scale maximum
XMIN	AGCHK	plot scale minimum
XS	AGDRW AGPLT	horizontal screen starting value
XSS	AGPLT	horizontal screen starting value
XTT	AGPLT	horizontal screen total value
XV	AGDRW AGGRD	vector: horizontal screen coordinate vector: horizontal spread and location at surface impact
Y	AGGRD	horizontal distance
YD	AGDRW AGPLT	vertical screen interval value
YDC	AGPLT	vertical screen interval value for equal axes
YDD	AGGRD AGPLT	vertical screen interval value
YDLT	AGPLOT	horizontal axis plot scale interval
YE	AGGRD	ending horizontal distance along surface
YM	AGPLOT	particle horizontal mean position from plot file
YMAX	AGPLOT	horizontal axis plot scale maximum
YMIN	AGPLOT	horizontal axis plot scale minimum
YMMN	AGPLOT	minimum horizontal value for mean particle trajectories

NAME	SUBR	DESCRIPTION
YMMX	AGPLOT	maximum horizontal value for mean particle trajectories
YP	AGPLOT	particle horizontal standard deviation from plot file
YS	AGDRW	vertical screen starting value
	AGGRD	starting horizontal distance along surface
	AGPLT	vertical screen starting value
YSMN	AGPLOT	minimum horizontal value for particle spread trajectories
YSMX	AGPLOT	maximum horizontal value for particle spread trajectories
YSS	AGGRD	vertical screen starting value
	AGPLT	
YTT	AGGRD	vertical screen total value
	AGPLT	
YV	AGDRW	vector: vertical screen coordinate
	AGGRD	vector: horizontal distance
	AGPLT	
ZDLT	AGPLOT	vertical axis plot scale interval
ZM	AGPLOT	particle vertical mean position from plot file
ZMAX	AGPLOT	vertical axis plot scale maximum
ZMIN	AGPLOT	vertical axis plot scale minimum
ZMMN	AGPLOT	minimum vertical value for mean particle trajectories
ZMMX	AGPLOT	maximum vertical value for mean particle trajectories
ZP	AGPLOT	particle vertical standard deviation from plot file
ZSMN	AGPLOT	minimum vertical value for particle spread trajectories
ZSMX	AGPLOT	maximum vertical value for particle spread trajectories
ZV	AGPLT	vector: vertical distance

APPENDIX C: AGLINE Variable Summary

NAME	SUBR	DESCRIPTION
CBAR	AGLINE	equivalent Gaussian magnitude
CV	AGELP	vector: isopleth position value
DFOM	AGLINE	desired figure-of-merit
DIAM	AGEQD	particle diameter
ETAU	AGEQD	evaporation time constant
FOM	AGLINE	equivalent Gaussian figure-of-merit
IGRDV	AGLINE	vector: ground interaction pointer
IZERO	AGLINE	number of zero spread points
NPTS	AGLINE	desired sequence number
SYB	AGLINE	equivalent Gaussian horizontal standard deviation
SYV	AGLINE	vector: horizontal standard deviation
SZB	AGLINE	equivalent Gaussian vertical standard deviation
SZV	AGLINE	vector: vertical standard deviation
XC	AGEQD	sum of concentration
XFn	AGEQD	figure-of-merit integrals (n=1,2,3,4)
XY	AGEQD	sum of horizontal position
XYS	AGEQD	sum of horizontal variance
XZ	AGEQD	sum of vertical position
XZS	AGEQD	sum of vertical variance
YB	AGLINE	equivalent Gaussian horizontal position
YV	AGLINE	vector: horizontal particle position
ZB	AGLINE	equivalent Gaussian vertical position

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16. Abstract

This is a user manual for the computer code 'AGDISP' (AGricultural DISPersal) which has been developed to predict the deposition of material released from fixed and rotary wing aircraft in a single-pass, computationally efficient manner. The formulation of the code is novel in that the mean particle trajectory and the variance about the mean resulting from turbulent fluid fluctuations are simultaneously predicted. The code presently includes the capability of assessing the influence of neutral atmospheric conditions, inviscid wake vortices, particle evaporation, plant canopy and terrain on the deposition pattern.

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