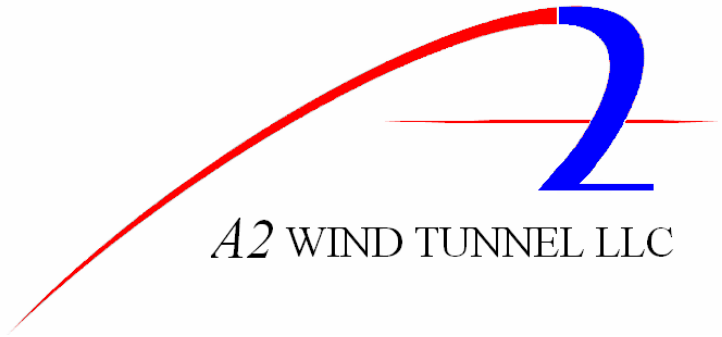
NEW CUSTOMER INFORMATION



This document is intended to give all customers a head start in the process of wind tunnel testing. We want you to have a highly productive test session your first time at A2, rather than spending valuable time learning how to use our wind tunnel. We can answer individual inquiries about specific issues, but our intent is that the document you are now reading will function as our standard "consultation" to our customers. It is a written explanation of

1. A2 operation & policy
2. Planning and preparing for your test
3. Aero basics
4. Instrumentation
5. Reading and analyzing your data
6. Applied aero for your car

But first, a GLOSSARY of a few buzz-words and abbreviations

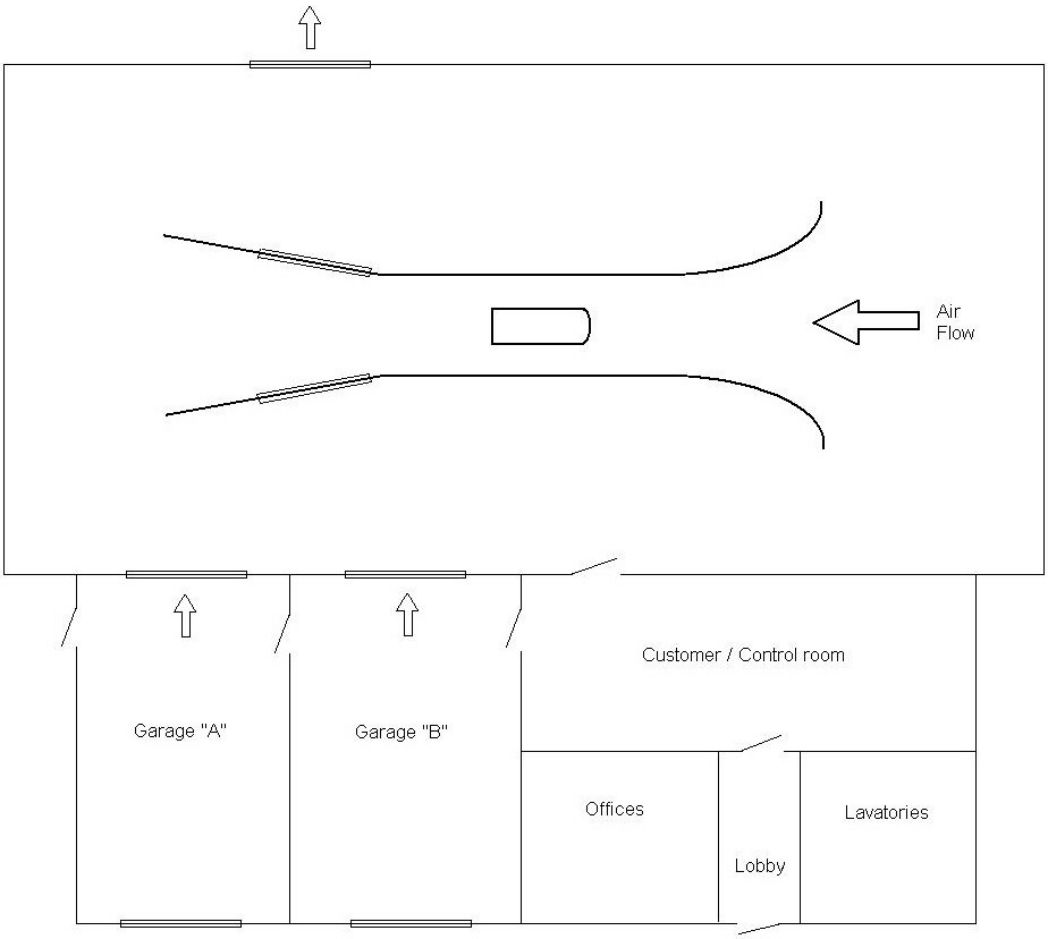
BL	Boundary Layer – The slow moving air near any stationary surface (wind tunnel or test car)
Ht	Height
L/D	Lift to drag ratio – the same, whether calculated in the form of coefficients or forces
LE	Leading Edge - The front of a surface, often the edge exposed to maximum airflow energy
Mod.	Modifications
Rad	Radiator
TE	Trailing Edge – The rear of a surface, the edge at which air must separate from the surface
Tuft	A short (1-2 inch) piece of contrasting yarn or string that is taped to the surface to act as a surface flow tracer – even large numbers of them have virtually no effect on a car's aero (very rare exceptions are possible)
TS	Test Section - The high speed test chamber of a wind tunnel
VG	Vortex generator – Device which generates vortices near a surface and helps energize the BL
VR	Velocity ratio (rad., ducts, scoops) = Speed of air thru area divided by speed of main airflow

1) A2 OPERATION & POLICY

Technical assistance

A2 will provide the best facility, equipment, and test support it can to help the customer meet its aero development needs. Each type of race car must be evaluated for applicability; a WoO car or a T/F dragster, for instance, will not work in our test section due to the aero interference between their wings and the test section ceiling. One other consideration is yaw angle. Because of the aggressive design of the test section, only zero degrees yaw will be tested. Dirt cars run through the corners at very large yaw angles, so applicability of testing at A2 must be determined by the customer. The mechanical mounting of all cars will use tire cradles on the front and tire pads on the rear. Any "lead" of one front tire ahead of the other must be noted before installation to ensure that the car can be mounted square in the tunnel.

All consultation by A2 must be restricted to HOW TO test and WHAT the data mean. Vehicle-specific aero recommendations could lead to technology transfer between race teams. The only vehicle-specific issues discussed will be the most basic, commonly understood topics (addressed in section 6 of this document). Further, only standard data analysis will be suggested. Unique test equipment, methodology, or analysis will be the responsibility of each team. Several independent aero test engineers familiar with AeroDyn have offered their services to potential A2 customers, their services might range from a basic phone consultation all the way to a detailed development plan and attendance at the wind tunnel test. A2 can offer their contact information upon request.



Security

The common areas include the lobby, offices, and bathrooms. The incoming garage and control room are connected by a pedestrian door. Access to the garages by different teams will be controlled by A2 personnel. THE ONLY PEOPLE ALLOWED IN THE CONTROL ROOM ARE A2 AND CURRENT CUSTOMER PESONNEL.

Safety

During a 85 mph test, the airflow in the outer tunnel area is only moving at about 8 mph, however noise and airborne dust may still be a problem. Routine occupancy of the outer flow return area during testing is not recommended. Enter after the fan stop has been initiated and signaled. Even then, you will have time to reach the entry door to the Test Section (TS) while the TS air is slowing down and the suction on the inside of the TS door is being relieved. Entry to the TS will then be possible.

Vehicle Movement

Teams must be responsible for car unloading, movement, specialized prep, helping with installation & removal from the TS, and loading back onto the trailer. A2 personnel are responsible for supervising installation & removal from the TS. Without assistance from the team, the process will take much longer and reduce the team's available test time.

ALL VEHICLE MOVEMENT AND SECURING WITHIN THE BUILDING MUST BE DONE UNDER THE DIRECT SUPERVISION OF AN A2 TECHNICIAN.

The movement of all future test vehicles will be paced by the removal of the current test vehicle (in the TS). Therefore, please show courtesy to the next scheduled customer by ensuring that your test ends promptly, about 10 minutes before the official end-of-test time, allowing enough time to remove your car from the TS. Only after the current test vehicle's removal from the wind tunnel will the incoming garage door be unlocked to allow installation of the incoming test vehicle.

The outgoing team should also leave the control room promptly, since the incoming team cannot have access to the control room until the outgoing team has left.

Prep work, if necessary, can be done in the garage area, but it is STRONGLY recommended that the cars be prepped as thoroughly as possible before arrival at A2. If extra prep time is needed or unusual circumstances arise, please call. The more advanced notice you can give us, the more likely that we will be able to accommodate you. If extra prep is not required at the wind tunnel, the arriving team should plan on entry of its vehicle into the garage about two hours before the start of their test session. Please note that the building does not have the capacity for a "waiting room" for future customers, although the next scheduled customer might be allowed to wait in the garage area with its car(s).

Scheduling, Payment, and Cancellation

Scheduling will be on a first-come, first-served basis. A2 will compile a waiting list, noting customers' specific scheduling needs. Please make sure your authorized contact person is readily available, since some dates may need to be filled quickly. We may be forced to move down the list if confirmation of prospective dates cannot be positively made by those organizations at the top of the list.
First-time, first-visit-only customer rates are:

$345 / hr for the first 2 hours,
$490 / hr thereafter (which is also our regular pricing for all repeat visits).

Reservations require a $500 (full day) or $250 (half day or less) DEPOSIT to lock in the time, with the balance paid at the start of the test. Reservation payment can be with personal check as long as we have time for it to clear. Final payment at the start of the test may be VISA, MasterCard, or certified check (no personal checks for final payment, please).

Installation and removal from the TS are billable time. You should plan for about 20 minutes installation and 10 minutes removal time. If we run into unforeseeable difficulties during installation, we will, at our discretion, stop billing the clock.

The cancellation/rescheduling policy is listed below:

Calendar days before original scheduled test date	FEE as a % of DEPOSIT	
	test CANCELLED	test RESCHEDULED to a later date
14 +	10%	0%
7 - 13	20%	5%
3 - 6	40%	10%
1 - 2	100%	20%

There is no fee for any test rescheduled to a date earlier than the original date.

2) PLANNING AND PREPARING FOR YOUR TEST

The wind tunnel test environment and software are user-friendly, and have standard displays and calculated values in MS Excel format. The customer, however, must have some basic understanding of aero and/or vehicle performance in order to know what the test goals are and what vehicle modifications might be evaluated. A good comparison would be someone who wants to track-test a race car. A competitor shows up at the track with a car, tools, a stopwatch, and no plan other than to "go fast". With no understanding of race cars and/or no plan, he will simply measure lap times, and will make no real progress. Another competitor shows up with no more equipment, but has understanding and a plan. He/she will almost surely make some progress. Being an aero expert or bringing one to the wind tunnel is not necessary, but a clear view of the big picture is necessary. The "big picture" means understanding your car, the rules, and how aero might help you - with handling, straight-line speed, heat exchanger and component cooling, scoop performance, driver ventilation, etc. Some possible strategies are listed below, but…REMEMBER –

AERO IS NOTORIOUS FOR INTERACTIONS BETWEEN SEEMINGLY "INDEPENDENT" MODS.

- The test can be designed to 1) enhance general performance, 2) remedy specific handling/speed (aero/chassis/tire/engine) issues, or 3) "audit" a fleet of cars
- Development can be done on 1) individual, specific cars, or 2) a generic R&D model
- The test can be designed to remedy aero understeer / oversteer by providing 1) a generic front lift vs rear lift graduated scale of mods, or 2) specific "packages" for specific applications.
- The test can be designed to generate a lift vs drag (L/D) scale to consider different combinations for 1) hi speed tracks, and 2) high downforce tracks.
- An R&D test can be designed to LEARN how to make a good aero car & find sensitive areas. This might be done by using parts intended ONLY for the wind tunnel. The parts need not be "legal" as per the rules – only expedient in LEARNING about local flow effects. Examples include spoilers, BL trips, VGs, fairings, and seals – probably in or near critical regions,

Preparation

You can get up to six runs per hour (after installation) if you have VERY quick configuration changes (data acquisition and wind-on and time is about four minutes per run). The team must come well prepared, with a plan for quick modifications and an effective test sequence. A logical flow chart of development must be considered – what if results head in a different direction than you anticipated?. Because of the economical nature of A2, teams must come prepared with their own resources – including but not limited to – tape, pop rivets, tie wraps, aluminum, foam core, clay, essential tools, and specialty instrumentation. In summary, if you need it for your test, bring it with you! We do have floor jacks, jack stands, and basic tools. Mods done in the wind tunnel must not generate debris which will become airborne during testing.

Vehicle Height Setting Procedure

It is recommended that vehicle's BODY heights TO GROUND be set up at the team's shop with ½ inch blocks under the rear tires. The vehicle should be set at the desired height of your initial aero run using these ½ inch blocks. The distance to ground can then be measured and marked at 3 or 4 body (or frame) locations to define the absolute vehicle heights. The suggested method is a datum line on the left and right lower body (just behind the front tires) and a third line at the rear bumper centerline. These three points will then conveniently define the plane of the body, rather than chasing 4 points.

Remember, the car's aero ultimately depends upon the BODY and UNDERBODY orientation to the groundplane, NOT the setting of the suspension components per se. This is especially important since the rear tires will be on the ½ inch pads above floor level. The front tire cradles will provide approximately the correct front end height. Remember, the garages do not have surface plates. The test section floor is flat within 1/16".

3) AERO BASICS

Dynamic pressure is also called "ram pressure' or "deadhead pressure". It is the inertial effect of the air being accelerated by the approaching vehicle. Just for your general information, at about 92 mph, dynamic pressure (sometimes called "Q") equals 1% of atmospheric pressure

A reference area, called the FRONTAL AREA must be supplied to calculate dimensionless aero force and moment coefficients. The literal, EXACT area is not necessary. An estimated area is OK. Once established, the frontal area should stay consistent for all future runs and test dates. For a sedan-type vehicle, height times width times 0.85 usually yields a good estimate. For more irregularly shaped open-wheelers, a scaled photograph may work best.

A force coefficient is a dimensionless number which equals [vehicle aero force in one axis] divided by [frontal area x dynamic pressure]. The force coefficients are C Drag, C Lift (including C Lift Front and C Lift Rear), and C Side. Force directions are +CD=back, +CL=up, and +CS=right. The moment coefficients (torques) are C Pitch moment, C Yaw moment, and C Roll moment. Torque directions are +CPM= nose up, +CYM=nose right, and +CRM=right-side tires loaded.

No two wind tunnels provide the exact same numbers – beware of comparing numbers from different wind tunnels.

Aero force and moment coefficients explain WHAT is happening - pressures and tufts might help explain WHY things are happening. Tufts are not always easy to interpret – attached flow is not ALWAYS desired.

Convex areas & edges are usually more sensitive than concave areas. Spoilers are very sensitive at convex areas or trailing edges.

A fully-shaped true ground effect underbody will typically be more sensitive to vehicle attitude changes and the wind tunnel's BL than an unfaired underbody.

85mph TS air speed generally provides good correlation to much higher on-track speeds. Rarely, some critical radii and wing sections might require BL trips or other treatments.

Know the difference between a fairing and a seal. A fairing deflects fast-moving air around a high drag object. A seal prevents flow between two areas with different static pressures. A piece may be incorrectly interpreted as a fairing when it is actually functioning as a seal. That interpretation may affect further development.

Details matter as much as basic shape. For example, an ultra-low CD car was tested in two forms – the original, and one with the details all compromised. The second car had literally DOUBLE the drag of the original concept car.

A car can have aero understeer because 1) too little front down OR 2) too MUCH rear down

4) INSTRUMENTATION

A2 added Instrumentation might include an anemometer rack for the back side of the radiator or large heat exchanger, and 3 inch anemometers for ducts/hoses. Advance notice is required for installation.

Up to 16 supplemental pressures can be monitored during the test, but the pressure taps and tubing must be installed in advance by the customer. The tubing must be routed and secured, and have enough tubing to extend 3 ft below the right front tire. Any elastomeric tubing between 1/16 inch ID and 1/8 inch ID can be used. As the number of pressure tubes increases, the OD of each tube must be minimized to implement routing.

Team-added Instrumentation is acceptable. It can be anything that is self-contained, handled entirely by the team, and does not interfere with the aero or wind tunnel operation.

5) READING AND ANALYZING YOUR DATA

The data system is composed of two computers: one data acquisition computer for the A2 technician, measuring and recording force, pressure, and anemometer channels, and one customer computer. All data will be calculated and recorded in Microsoft Excel. ALL real-time data will be available to the customer during the test. Aero information about your vehicle will be displayed in many ways. The flow of information will be ONE-WAY from the data acquisition computer to the customer computer. The customer has control of the customer computer and can include any unique spreadsheets or graphs set up by the customer during the test. A default format is supplied at the beginning of each test.

At the conclusion of the test, all data will be transferred onto a CD-R for the customer. All data will be included, beginning with raw transducer voltages, transforming into forces at the balance and the vehicle, and finally resulting in aero coefficients and unique customer calculations.

6) APPLIED AERO FOR YOUR CAR

Suspension locks may be desired. PVC tubing can replace springs or aluminum collars/clamps can be installed on shock absorber shafts. Attitude mods can include any combination of heave and pitch.

For an R&D shape, minimize body volume in areas where development will be done. That will allow the build up of the surface (with panels or filler materials)

Clay extrusions can be applied/taped to simulate spoilers or gurneys

Foam plastic extrusions (such as a child's swimming "noodle") can be cut length-wise into half- rounds and taped to the car to "soften" hard edges (for valance edges and/or filling in sharp edges)

The L.E. of applied pieces should fit well (don't depend on tape to hold down poor-fitting edges)
Perhaps 1 or 2 pop rivets on large LE (otherwise use good tape).

Average underbody/underhood area pressures (low velocity regions only!) can be "integrated by using ¼" ID soft AL tubing with .040 holes (max 18 holes) by routing within the region of interest.

We suggest testing proven, track tested cars before testing "new" cars (you will want a frame of reference between the track and the wind tunnel).

Know your rule book –and inspectors and the inspection process – what will be interpreted and enforced strictly vs liberally?

Remember to bring specialized tools (inclinometer, kleeko's, shrinkers/stretchers, . . .). Install tufts ahead of time if you want to use them during the test.

The following lists for sedans and open wheelers are a few brief thought-provokers.

SEDAN aero variables

Grille, shaker screens, radiator orientation
Scoop, cowl, front inlet
Valance edge
Front & rear wheel openings (front wheel openings are usually more sensitive). Variables include:

- Total fender width (both front & back of each wheel opening)
- Plan view angle ahead of each fender opening

Roof L.E. & T.E. treatment
A-pillars, B-pillars, C-pillars
Rocker lower edge/skirt
Q-panel TE
Spoiler angle (+ Gurney?)
Rear bumper lower edge

Open-wheelers

Wings
    Primary element – shape, angle
    2nd element – angle, fore/aft offset, gap
    Gurneys
    End plates
Front wing (interaction with rear wing?)
Underbody VGs
Underbody outer edges & treatments ahead of rear tires
Windshield height/lip
Cooling inlet, outlet location and deflectors
Inlet scoop (interaction with rear wing?)
Slopes of curves (most effective L/D)
Mirrors

DRAG racing / BONNEVILLE

Scoop
Drogue parachute deployment
Wheelie bars?
Only enough front down needed to maintain control?
Enough rear to maximize traction
Bonneville note – basic shape may be less important than peripheral details (see *3 AERO BASICS*)

COMMON MODS for all vehicle types

Pitch, heave, roll
VGs
Inlets
- radiator
- oil cooler
- intercooler
- engine inlet
- brake ducts
- axle cooler
- driver vent
- component/electronics cooling

NACA duct performance (monitored with VR flow, tufts, aero forces). Modified by:
- Placement
- angularity (planview angle rel to local streamlines)
- edge fences
- attached ductwork