

Presolicitation Conference

RFP CI-01-12637

Aerosol Wind Tunnel System

The Environmental Protection Agency intends to purchase the aerosol wind tunnel system (AWTS) detailed in the following DRAFT specifications. On 12/11/01, at 10:00 A.M. there will be a presolicitation conference held in Research Triangle Park, NC. The purpose of the conference will be to discuss EPA's needs that will be met by the AWTS and to obtain comments and recommendations relative to the specifications. The business aspects of the solicitation will also be discussed. The estimated dollar range for this requirement is \$3 - \$5 million. All comments and recommendations, including those made during the conference must be in writing in order to assure they are given proper consideration. Following the conference, the specifications will be finalized and the solicitation will be posted on the EPA web site. The RFP will be available only through the web site. The current schedule is to issue the solicitation by mid-January.

The meeting will be held in The Annex Cafeteria Conference Room which is located in the Environmental Research Center (ERC) Annex. The address is:

Environmental Research Center Annex
79 T. W. Alexander Drive
Research Triangle Park, NC 27711

From Raleigh, Raleigh-Durham International Airport, and Points East via Interstate 40

Take Interstate 40 West to Exit 279A, "Durham Freeway (NC Highway 147) South". (The sign prior to the exit says "To Alexander Drive".) Take exit, which will put you on the Durham Freeway, and continue until you reach a traffic light at the "T" intersection with Alexander Drive. Turn right onto Alexander Drive. Go through traffic light at intersection with N.C. Highway 54. About 1/2 mile after crossing Highway 54, turn right at "79 T.W. Alexander Drive, Research Commons, US EPA Administration Building and ERC Annex" sign.

Those planning to attend the conference should notify the Contracting Officer, via e-mail at hennessy.mike@epa.gov, no later than 12/7/01.

EPA will consider all comments and recommendations that are received. Any changes resulting from the comments and recommendations will be incorporated into the specifications issued in the RFP.

The attached specifications and drawings will be the basis for discussions at the conference. SPECIFICATION for the
AEROSOL WIND TUNNEL SYSTEM

SECTION 1. OVERVIEW

The Environmental Protection Agency (EPA) plans to acquire a large, state-of-the-art Aerosol Wind Tunnel System (AWTS) for the production, measurement, and evaluation of aerosols, with the larger purpose of determining the exposure, effects, and risks of aerosols in the ambient air on people and the environment. The AWTS is to be a highly specialized wind-tunnel system with very wide ranges of flow speeds, particle sizes, and aerosol loadings, and with controlled air temperature and relative humidity. The system will require automated controls and integrated measurement capabilities for measuring, monitoring, and regulating conditions in the tunnel.

The purpose of this procurement is to acquire the AWTS, which includes its design, construction, installation,

and certification testing in EPA's new Research and Administration Facility in which space for the AWTS has been allocated. The AWTS is envisioned to satisfy a wide range of future EPA-wide research programs. However, the full ranges of all the operational parameters cannot be met simultaneously under any design scenario, so that compromises must be made during the design phase and a high degree of flexibility must be allowed. Hence, we envision multiple and/or interchangeable test sections of different sizes that would allow different options, including large-scale, low-velocity tests and reduced-scale, high-velocity tests – both with particles. Various other interchangeable and/or removable parts or sections may be required, including different fans, flow straightening devices that are necessary at low speeds but unnecessary at high speeds (or which may interfere with aerosol generation), various types of aerosol generators for different sizes, distributions, and loadings of aerosols (including different placements of aerosol generation devices with respect to the test sections), turbulence generators, and filtration devices.

The main features of the AWTS include a closed-return design with two test sections: a larger, low-speed test section primarily for human exposure studies, and a smaller, high-speed test section primarily for testing sampler performance. The offeror shall give due consideration to the two proposed designs of the AWTS (represented in Figures 1 and 2) and any other design of his choosing that will meet or improve on the performance at comparable cost, as well as to two separate open-return tunnels. He shall provide convincing evidence that his choice is superior with regard to (a) meeting the performance specifications set forth herein, in particular, the quality and stability of the flow in the two test sections, (b) producing uniform aerosol concentration distributions in the two test sections, (c) ability to operate independently in the two test sections, and (d) cost. Though we discuss the wind tunnel primarily in terms of the design shown in Figure 1, comparable considerations will be provided for whatever design is proposed by the offeror. Detailed specifications are shown in various tables and in the ensuing discussions. For final acceptance of the AWTS, the contractor must demonstrate through appropriate measurements that the AWTS meets all these specifications.

The term "human exposure" as used throughout this document does not imply that actual human test subjects will be exposed in the AWTS, which would require significant design considerations, cost increases, peer review of protocols, and approvals. Rather, the meaning of "human exposure" here is that the AWTS will be used to generate conditions closely resembling human exposure so that air flow and particle movement around the human form can be studied, understood, and modeled. To keep conditions realistic, the human form used (a manikin) will be heated and clothed to simulate actual human conditions, breathing machines will be used to replicate human respiration rates, frequencies, and volumes, and the manikin may be equipped with some motorized joints to allow study of the effects of human movement on generating aerosols that are then available for exposure.

The complete AWTS will be acquired in two phases as funding is received. The base contract will comprise the design, construction, and installation of the basic wind tunnel, while numerous contract options may be exercised at later dates and in virtually any order to augment its aerosol generation, measurement, and research capabilities. The design of the basic wind tunnel must include due consideration for inclusion of all options. The possible contract options are listed in Table 1. To provide guidance in preparing the offer, Table 1 also shows ratings for each contract option to indicate the level of detail expected in the offer. Level 1 indicates that a comprehensive conceptual design (with sketches) and firm prices are expected in the offer. Level 2 indicates that somewhat less detail is required, that the exercise of this option is expected later in time than that of level 1, and that the acquisition is, in general, commercially available and is expected to require modest efforts to integrate it into the AWTS; hence, little additional design work and fairly firm cost estimates are expected. Level 3 indicates that even less detail is required in the offer, that the exercise of this option is expected to occur later than those of levels 1 and 2, and that considerable design and development work may be required. The contractor should not perform detailed design for his offer or during performance of the base contract; the cost to design the option should be included in the cost estimate for the option itself, though the offeror should provide sufficient discussion in his offer to demonstrate his understanding of the issues. Finally, level 4 indicates that the technology is changing rapidly, that by the time the option is exercised, new technology is likely to be available, and that substantial design and development work may be required. The contractor should not perform detailed design for his offer or during performance of the base contract; the cost to design an

option should be included in the cost estimate for the option itself, though the offeror should provide sufficient discussion in his offer to indicate his understanding of the issues.

Table 1. Contract Options, Level of Detail, Training Required, and Expected Delivery Base or option #

Brief Description	Level of Detail	Level of Training	Time for Delivery
Base Design, construct, and install basic AWTS	1	2	2 years
1 Fluidized bed aerosol generator	2	1	3 mo.
2 Automate Option 1	3	2	3 mo.
3 Condensation monodisperse aerosol generator	2	1	3 mo.
4 Automate Option 3	3	2	3 mo.
5 Dust feeder/powder dispenser	2	1	4 mo.
6 Automate Option 5	3	2	4 mo.
7 Jet mill/opposing jet pulverizer	2	1	6 mo.
8 Automate Option 7	3	2	6 mo.
9 Polystyrene latex production unit	3	2	1 year
10 Sheet or multiple orifice monodisperse aerosol generator	3	2	1 year
11 Automate Option 10	4	2	1 year
12 Spinning top aerosol generator	3	2	6 mo.
13 Automate Option 12	4	2	6 mo.
14 Laser-Doppler Anemometer (LDA)	2	2	4 mo.
15 Same as Option 14 (a second LDA system)	2	2	4 mo.
16 Particle-Image-Velocimeter (PIV) system	2	2	4 mo.
17 Same as Option 16 (a second PIV system)	2	2	4 mo.
18 Upgrade first PIV system to stereo/3D	3	2	4 mo.
19 Upgrade second PIV system to stereo/3D	3	2	4 mo.
20 External traverse for first PIV system	2	2	4 mo.
21 Same as Option 20 (for second PIV system)	2	2	4 mo.
22 Automated air flow calibrator	2	1	3 mo.
23 Phase-Doppler anemometer (upgrade to LDA #1)	3	2	6 mo.
24 PDA upgrade (to smaller particles)	4	2	1 year
25 Micro-orifice uniform deposit impactor	2	1	3 mo.
26 Aerodynamic particle sizer (APS)	2	1	3 mo.
27 Same as Option 26 (a second APS)	2	1	3 mo.
28 Scanning mobility particle sizer (SMPS)	2	1	3 mo.
29 Same as Option 28 (a second SMPS)	2	1	3 mo.
30 Electrical low pressure impactor	2	1	3 mo.
31 Optical particle counter	3	1	2 mo.
32 Scanning fluorometer	3	1	3 mo.
33 Generation system monitor	1	1	4 mo.
34 Same as Option 33	1	1	4 mo.
35 Same as Option 33	1	1	4 mo.
36 Same as Option 33	1	1	4 mo.
37 Same as Option 33	1	1	4 mo.
38 Same as Option 33	1	1	4 mo.
39 High-volume isokinetic sampling system	1	1	6 mo.
40 Traverse system for large test section	1	2	1 year
41 Traverse system for small test section	1	2	8 mo.
42 Adult manikin	2	1	8 mo.

- 43 Child-sized manikin 2 1 8 mo.
- 44 Motorized adult manikin 3 2 3 mo.
- 45 Motorized child-sized manikin 3 2 3 mo.
- 46 Breathing equipment for child-sized manikin 2 1 3 mo.
- 47 Workstation for large test section 2 1 3 mo.
- 48 Workstation for small test section 2 1 3 mo.
- 49 Wireless laptop computer 2 1 3 mo.

Table 1 also provides a column to indicate the level of training that the contractor shall provide to instruct the ultimate users in the safe and proper operation of the AWTS and its components and subsystems. Level 1 suggests that minimal training will be necessary, e.g., the instrument or equipment is provided with normal instruction manuals whose materials can be easily read and understood by the anticipated users and its safe operation requires only normal safe laboratory practices. Level 2 suggests that more extensive training will be necessary, and that the contractor must provide for adequate training of Government personnel and other users of the equipment (up to 8 persons). The offeror shall suggest the types, amounts, levels, and schedules of training required (and include estimated costs for accomplishing such). The location for the training shall be at the Government's choice, but most likely (and for cost-estimating purposes) at Research Triangle Park, NC.

Finally, Table 1 provides a column to indicate the expected time for completion of each option after its exercise by the Government. The offeror shall indicate his schedule for expected completion of each option.

Offer Pricing

Several aerosol generation components and options require the offeror to calculate the number of devices needed to achieve specified output quantities; in these cases, the offer should be priced for whatever number of devices the offeror determines is required to achieve those specified output quantities.

Warranties

All items delivered by the contractor shall be warranted to be free of defects in materials and workmanship and to meet all performance criteria specified herein for a period of one year. Upon the contractor's completion of the base contract and each option, the Government shall perform its own inspection and testing to ensure that all items delivered comply with acceptance criteria given herein. Upon satisfactory findings, the Project Officer shall sign a statement that the item(s) delivered have been accepted by the Government; the date of that signing shall be the commencement date of the warranty period for those item(s). During the warranty period for an item, any defects brought to the attention of the contractor in writing shall be corrected by the contractor at no expense to the Government for parts, materials, or labor.

Organization of Statement of Work

The Base Contract is described in detail in:

- Sections 2, 3, and 4 (wind tunnel and basic equipment)
- Section 10 (Core LAN)
- Sections 11, 12, 13, and 14 (general requirements)

The options are described in detail in Sections 5, 6, 7, 8, 9, and 10.

SECTION 2. BASE CONTRACT: DESIGN AND SPECIFICATIONS

In performance of the base contract, the contractor shall provide the detailed architectural and engineering design of the wind tunnel, which must meet the structural and performance specifications provided in Tables 2, 3, and 4. The design shall utilize good-engineering practice in its aerodynamic and structural design and provide a useful tool that can be operated primarily by one or two technicians. The contractor shall provide quarterly briefings during the performance of the base contract to Government personnel and its representatives at its facilities in Research Triangle Park, NC. Interchanges and feedback will be provided orally and in writing

to assure that the design is on track and meeting the specifications provided herein. Appropriate response to comments and suggestions shall be made by the contractor, including possible modifications to the design of the AWTS.

In addition to designing the basic wind tunnel, the contractor shall make due consideration to the possible inclusion of any or all options so as to produce an integrated, smoothly functioning system at the completion of the contract.

The AWTS must fit within the laboratory space allocated in the EPA Research and Administration Facility. This space, shown in Figure 3, is approximately 74 ft x 101 ft with a suspended (acoustical tile) ceiling at about 20 ft height, has 15 supporting columns (10 of which the AWTS must fit around), and a room in one corner with dimensions of approximately 18 ft x 19 ft. Sufficient space around the tunnel must be left to permit the passage of personnel and equipment: a 5 foot minimum path width is required. Access to the outside is provided by a roll-up door of approximate dimensions 16 ft wide by 16 ft high. Electrical supply (aside from convenience outlets around the laboratory walls and columns) for the high-power components of the AWTS includes two service panels, each with 3-phase, 480 volt, 100 ampere service; additional capacity will be installed as needed, which will require coordination with EPA's Facilities Management staff. The contractor shall give the Government a minimum of eight months advance notice of any additional electrical capacity needed.

Table 2. Overall Structure of Wind Tunnel

Parameter Specification

Wind tunnel type Closed loop, recirculating with rectangular ducting.

Structural type External steel frame with walls, ceiling and floor of wood or other easily machinable material (e.g., 14 ply, cross banded, 3/4" hardwood veneer plywood, bonded and surfaced with phenolic resin). Each section shall be provided with leveling feet. The structure and all surfaces of the AWTS shall be capable of supporting a uniformly distributed live load of at least 60 pounds per ft².

Interior surface Smooth (?1 mm protuberances). Hard (epoxy base) coating or otherwise durable and conductive surface with resistivity ?106 ohms/square. Due consideration shall be given to providing a surface that will hold up to periodic wetting and scrubbing and one that will not peel, chalk, or otherwise emit particles in the long term.

Access doors Sealed and hinged doors with latches, to allow convenient personnel and equipment access to all sections of tunnel for inspection, cleaning, maintenance, and instrument setup. Doors near fan should permit installation and removal of fan blades and drive motor, if placed in fan nacelle. Each test section must contain doors and windows as discussed below. All doors and windows must fit flush with inside walls of tunnel.

Also, all access doors must be easy to operate (hand-operated latches) from inside as well as outside the tunnel and in a reasonable time frame (e.g., less than 10 seconds).

Lights Flush-mounted lights shall provide adequate lighting in all passages in the tunnel for inspection, equipment installation, cleaning, and maintenance.

Fan Vane-axial with variable speed drive and blades with variable pitch while in motion. Sufficient size and performance to achieve target flows in test sections with maximum filter loadings (pressure drops). Cartridge filter II may be removed to obtain maximum flow speeds in each test section. Flexible couplings between fan and remainder of tunnel must isolate mechanical vibrations and prevent transmission to basic structure.

Vibration isolators required to support the fan as well as "inertia block" mounting.

Safety screen Large mesh, strong wire screen just upstream of fan to protect from debris.

Turning vanes In all corners. Removable in third corner (for enhanced mixing of aerosols). Shape & spacing follow good-engineering practice for wind-tunnel design in order to avoid unsteadiness and turbulence.

Diffuser Narrow angle diffuser to enlarge cross section while avoiding local separation. May require splitter plates to obtain adequately small expansion angle for satisfactory performance.

Cartridge filter III Located between end of diffuser and cooling coils. High capacity, cartridge type filters with approx. 95% efficiency. Designed for and operable at variable flow rates without performance degradation.

Capable of 750 fpm face velocity and pressure drops to 2 in. w.g.

Air conditioning system Adequate size and design to remove heat input from fan and motor and with controls

adequate to maintain air temperature in test sections as specified in Table 4 (to avoid problems of natural convection on the sidewalls of the tunnel at low wind speeds). Also must control relative humidity of air in tunnel as specified in Table 4. For design purposes, room temperature may range from 65°F to 80°F and relative humidity from 30% to 70%. Chilled water (2.5" line at 43 to 45°F) is available in laboratory space. Aerosol input and distribution section Located downstream of cooling coils. This section allows various kinds of aerosol distribution systems to be installed a long distance upwind of either test section. Must be easily removable (e.g., open latches & roll out on track or lift vertically using overhead winch).

Grid III Follows aerosol distribution section and provides for creation of large- scale turbulence using grid of bars or Stairmand disk. Must be easily removable (so as not to interfere with aerosol distribution section, this section may need to be removed in the vertical direction, i.e., above the wind tunnel).

Honeycomb I At entrance to large test section to reduce turbulence, remove swirl, and promote uniform axial velocity. Must be easily removable (e.g., open latches & roll out on track). Cell length-to-diameter ratio ≥ 6 .

Grid I Following honeycomb I to generate turbulence of prescribed scale and intensity - see Table 4. Must be easily removable (e.g., open latches & roll out on track) and allow for insertion of other grids or mixing devices.

Test sections Large, low-speed and small, high-speed test sections - see Tables 3 & 4. Floor heights of large test section must be at least 26" above laboratory floor (suggesting that floor height of small test section would be 57.5").

Cartridge filter I Located at end of large test section. Must be easily removable (e.g., open latches & roll out on track). High capacity, cartridge type filters with approx. 95% efficiency. Operable at variable flow rates without performance degradation. Capable of 750 fpm face velocity & pressure drops to 2 in. w.g.

Contraction Located between test sections. Aerodynamically designed for smooth transition from low- to high-speed flow, to reduce spatial irregularities in the velocity distribution and to reduce turbulence in the air stream. Contraction ratio: 4.4 to 1.

Honeycomb II At entrance to small test section to reduce turbulence, remove swirl, and promote uniform axial velocity. Must be easily removable (e.g., open latches & roll out on track). Cell length-to-diameter ratio ≥ 6 .

Grid II Following honeycomb II to generate turbulence of prescribed scale and intensity - see Table 4. Must be easily removable (e.g., open latches & roll out on track) and allow for insertion of other grids or mixing devices.

Air speed monitor Sonic anemometer placed appropriately at downstream end of small test section to give continuous (1 sample/sec) indication of air speed and direction (three dimensional). Accuracy in speed of ± 0.03 m/s; in wind direction of 0.5° ; in absolute temp. of $\pm 2^\circ\text{C}$. Resolution in speed of 0.01 m/s; in wind direction of 0.1° ; in temp. of 0.01°C . Path length ≥ 15 cm.

Breather Breather slot provided just upwind of fan to equalize pressure at that point with room pressure and allow intake of air in event of sampling as well as exhaust in event of aerosol aspirations. Size and orientation should follow standard practice. Must be equipped with approx. 95% efficient filters while sustaining pressure differential ≥ 0.1 " w.g.

Sound attenuation Inlet and exhaust acoustic silencers up- and downstream of the fan should be provided as necessary to minimize noise levels within the test sections of the tunnel (≥ 70 dBA). The exterior of the fan section, from inlet silencer to outlet silencer must be completely housed by a sound deadening enclosure so as to limit noise levels anywhere within the laboratory to 60 dBA or less at wind speeds in the sampler test section of 24 km/hr or less, and to 65 dBA or less at all higher wind speeds.

Cartridge filter II Located after first corner. Must be easily removable (e.g., open latches & roll out on track). High capacity, cartridge type filters with approx. 95% efficiency. Operable at variable flow rates without performance degradation. Capable of 750 fpm face velocity & pressure drops to 2 in. w.g. Used only when utilizing small test section at speeds below 3.8 m/s (750 fpm).

Seals and floor drains Joints in the floors, sidewalls and ceilings as well as mating surfaces on all access doors and removable sections of the entire AWTS must be sealed against air leaks. As the interior of the tunnel is to be subjected to periodic "hosing down" with water and/or surfactant to remove aerosol deposits, the interior surfaces must be sealed and resistant to periodic wettings. Floor drains shall be provided in several locations to aid in the disposal of this wash water. The floor drains shall be fitted with sealed and flush covers when the tunnel is in normal use. No floor drains are provided in the laboratory space, thus the contractor shall provide sump pumps or other adequate means of drainage of wastewater.

Table 3. Test Sections

Human Exposure (Large Test Section) Sampler (Small Test Section)
3.66 m wide x 3.05 m high x 9.14 m long
(12 ft x 10 ft x 30 ft) 1.75 m wide x 1.45 m high x 6.1 m long
(5.75 ft x 4.75 ft x 20 ft)
Human body area: 1.8 m x 0.6 m = 1.08 m² Sampler area: 0.76 m x 0.5 m = 0.38 m²
Blockage: 9.7% (<10% required) Blockage: 15% (?15% required)

Table 4. Wind Speeds, Turbulence, and Air Conditioning

Human Exposure Test Section Sampler Test Section
Speed: 0.1 to 2.22 m/s (0.22 to 5.0 mph, or
0.36 to 8 km/hr) with accuracy of $\pm 7\%$ at low end and 3% at high end.
Spatial uniformity of speed: Coefficient of
variation of <10% over central 80% of cross sectional area
Turbulence: $\approx 0.5\%$ at all speeds Speed: 0.56 to 13.3 m/s (1.24 to 29.8 mph,
or 2 to 48 km/hr) with accuracy of $\pm 5\%$ at low end and 2% at high end.
Spatial uniformity of speed: Coefficient of
variation of <10% over central 80% of cross sectional area
Turbulence: $\approx 0.5\%$ at all speeds
Drift: very low frequency fluctuations (e.g., < 1 Hz) in flow speed with amplitude greater than 1% are
unacceptable and must be corrected. Drift: very low frequency fluctuations (e.g., < 1 Hz) in flow speed with
amplitude greater than 1% are unacceptable and must be corrected.
Swirl: straighteners as necessary to remove
detectable swirl in flow at any section Swirl: straighteners as necessary to remove
detectable swirl in flow at any section
Low frequency pulsations: Cause(s) of surges or pulsations (e.g. in freq. band of 1 to 60 Hz) with rms
amplitude larger than 0.5% of the mean velocity indicated during testing must be located and removed. Low
frequency pulsations: Cause(s) of surges or pulsations (e.g. in freq. band of 1 to 60 Hz) with rms amplitude
larger than 0.5% of the mean velocity indicated during testing must be located and removed.
Turbulence generation capability
Intensity: 1 to 8%
Spatial uniformity: Coefficient of variation
<10% over central 80% of cross sectional area
Integral scale: ~ 0.5 m Turbulence generation capability
Intensity: 1 to 8%
Spatial uniformity: Coefficient of variation
<10% over central 80% of cross sectional area
Integral scale: ~ 0.5 m
Air temperature: Operator specified at a set point from 20°C to 25°C and maintained within $\pm 1^\circ\text{C}$ of the set
point under continuous operation at speeds up to 2.22 m/s. Air temperature: Operator specified at a set point
from 20°C to 25°C and maintained within $\pm 2^\circ\text{C}$ of the set point under continuous operation at speeds up to 13.3
m/s.
Relative humidity: system must achieve any target setpoint from 20 to 75% within 0.5 hour and maintain it
within $\pm 3\%$ thereafter. Relative humidity: system must achieve any target setpoint from 20 to 75% within 0.5
hour and maintain it within $\pm 3\%$ thereafter.
Volume flow rate: 1.11 to 24.8 m³/s
(2,360 to 52,490 cfm) Volume flow rate: 1.42 to 33.8 m³/s
(2,990 to 71,690 cfm)

Test Carts

The test section shall be designed to accept "test carts" in any of three locations in each of the two test sections. These test carts shall permit the rapid installation and removal of test setups in the test sections of the wind tunnel; installation and removal shall be possible from either side of either test section. The test carts might be described as tables on wheels, where a sampler or manikin might be installed on the table top, and with its accessories mounted, for example, on a shelf beneath the table top. The test sections shall contain side doors of appropriate size and height (see Table 5 and following discussion) so that carts with test apparatus installed may be wheeled into place, with the "table tops" forming the test-section floor, and the side doors closing to form a smooth and sealed test section. These "side doors" are separate and apart from the normal "access doors" described in Table 2, and should contain glass for visualization and flow measurement purposes (e.g., particle image velocimetry). The carts shall be mobile (i.e., swivel, locking casters), of the proper height to align with the test-section floors, and contain folding leaves to easily and rapidly install within the test sections. Seals shall be provided around all joints where the cart mates with the test section and the installed cart shall be free of leaks. As a part of the basic wind tunnel, five test carts shall be provided for each test section. The crosswind dimension of the carts for the small test section shall be the full width of the test section itself. The crosswind width of the carts for the large test section shall be 1.5 m.

Table 5. Test Carts

Human Exposure Test Section Sampler Test Section

Crosswind width: 1.5 m Crosswind width: full test-section width

Along-wind dimension: 1.5 m Along-wind dimension: 1.0 m

Test-section doors: 1.5 m wide x 2.0 m high Test-section doors: 1.0 m wide x 1.2 m high

Test Section Windows and Door

Both sidewalls and the ceilings of both test sections shall contain glass windows suitable for transmission of the light sheets generated by the pulsed or continuous lasers during PIV measurements (see Section 6). Figure 4 shows sketches of the desired window configurations and sizes for the sidewalls of the two test sections. Three openable windows are provided on each side of each test section, with locations corresponding to the locations of the test carts. Two fixed windows are interspersed between the three openable windows on each side of each test section as shown in Figure 4. The ceilings of the respective test sections shall be fitted with fixed windows with the same streamwise dimension and material type as those on the sidewalls. The crosswind width of the ceiling windows of the human-exposure test section shall be 2.0 m; those of the sampler test section shall be 1.2 m.

The glass in the windows shall be capable of withstanding pressures generated inside the tunnel, resistant to breakage from tunnel vibrations and ordinary door operations, and in all other ways safe for personnel working nearby. The optical properties of the glass shall be suitable for use with the PIV system described in Section 6; the windows shall be capable of withstanding thermal stresses resulting from the high-powered pulsed lasers and flat enough to maintain sufficiently coherent light sheets. Further, due consideration shall be given to the transmittance of the glass and to anti-reflection treatment in order to avoid back reflections, which might lead to loss of transmission and eye safety considerations for the users. In his proposal, the offeror shall specify in detail the optical properties necessary for such measurements as well as the proposed optical properties of the glass to be provided. (Possible vendors: PPG, Schott, F.J. Gray)

Each glass window shall be outfitted with a retractable shield (e.g., a roll-up blind) on the outside of the tunnel for the purpose of blocking the transmission of laser light. The material of the shields shall be suitable for reception of all laser light, including the high-powered pulsed lasers (Section 6) without degradation.

An access door shall be provided at the downstream end of each test section to allow convenient personnel access. All openable windows must be easy to operate (hand-operated latches) and in a reasonable time frame

(e.g., less than 30 seconds). Further, the access doors must be openable from inside as well as outside the tunnel and in a shorter time frame (e.g., less than 10 seconds).

Surveillance camera systems

As a part of the basic wind tunnel, the contractor shall supply three video surveillance camera systems for monitoring chosen areas around and inside the wind tunnel. Each camera shall have remotely controlled pan, tilt, and zoom and shall send a standard NTSC color signal to its corresponding video monitor in the control room (see Figure 3). Each of the three color video monitors shall have a 19" (diagonal) or larger screen. A video server shall be installed in the LAN's workstation in the control room and shall have the capability of taking three video inputs and sending one over the LAN upon request to a remote node. The remote node shall have the capability of selecting one of the three channels and fully controlling the corresponding camera. The three camera systems shall be supplied with sufficient cable to allow the cameras to be mounted anywhere in the wind tunnel room. Initial mounting locations for the cameras shall be: 1) inside the tunnel near the top outside corner at the downstream end of the human exposure test section with view looking upstream, 2) inside the tunnel near the top outside corner at the downstream end of the sampler test section with view looking upstream, and 3) outside the tunnel looking at the middle test-cart position of the human exposure test section. Cameras installed inside the wind tunnel shall be mounted so as to minimize disturbance to the air flow; these cameras and any associated mounting hardware shall be readily removable so as to eliminate any disturbance to the air flow if desired. All cameras shall be sufficiently protected from dust so as to maintain operation with only routine cleaning of the lens or any optical window in front of the lens. If the front element of a camera lens is directly exposed to wind tunnel flow, it shall be protected with an inexpensive, replaceable, clear-glass filter.

Purging system

As a part of the basic wind tunnel, a purging system shall be provided to cleanse the tunnel air of solvents, aerosols, or other impurities. This system would presumably work in conjunction with a low-speed recirculating flow in the tunnel, draw in fresh room air (through the breather), and exhaust impure air through ducting into the room air exhaust system (thence outside the building). It must be capable of reducing impurities in the tunnel air to less than 2% of the initial value in a time period not to exceed one hour. The system shall be provided with a cutoff valve or door to prevent leakage to or from the wind tunnel when the fan is not operating. The valve/door and fan shall be controllable through the LAN system (Section 10).

Electrical outlets

As part of the basic wind tunnel, the contractor shall provide convenience outlets of adequate number, location, and power for operation of all the various pieces of equipment and instrumentation included with the complete AWTS. At a minimum the contractor shall provide:

- four 120 volt, 20 amp circuits along each test section with four receptacles every five feet.
- two 120 volt, 20 amp circuits along the remainder of the tunnel (i.e., other than along the test sections) with four receptacles every fifteen feet.
- two 208 volt, 15 amp circuits along each test section with four receptacles every five feet.
- two 120 volt, 20 amp circuits and two 208 volt, 15 amp circuits at each of the aerosol generation/injection sites along the tunnel.

All electrical installations shall meet all applicable electrical codes.

Laser Safety

At all times the contractor shall give due consideration to the safety aspects of using Class IV lasers, as described more fully in Section 12.

Appearance

All parts of the wind tunnel shall be finished and present a pleasing appearance in accordance with standard construction practices, e.g., raw metal and wood must be properly primed and painted, rough surfaces and sharp edges must be avoided, wiring must be run in straight-lengths of conduit with right-angle corners, ducting must be run in a professional manner and properly attached, and appendages must be out of sight or provided with

appropriate covers.

Internal cleanliness

The contractor shall use construction methods, materials, equipment, and filtration products so as to minimize inadvertent loading of the air streams in the test sections with aerosols, both while the AWTS is new and in the longer term (e.g., choose surfaces that will not degrade with time or scrubbing, avoid leakage around filter modules, use a totally-enclosed motor, etc.). The AWTS will be tested for contamination levels as provided in Section 3.

SECTION 3. BASE CONTRACT: CONSTRUCTION AND INSTALLATION

The contractor shall construct and install the basic wind tunnel with automated controls in EPA's new Research and Administration Facility at Research Triangle Park, North Carolina, following acceptance of the contractor's design by the Government. The basic wind tunnel shall include that part of the LAN (i.e., the "Core LAN") necessary for controlling the fan using appropriate feedbacks from velocity and/or pressure sensors, as well as full temperature and humidity control. This Core LAN shall allow tunnel operations from the control room (see Figure 3). The components and architecture of this Core LAN shall conform to the specifications described in Section 10. Further, the basic wind tunnel shall contain all safety sensors and interlocks as described in Section 11.

During installation of the AWTS, the contractor shall be responsible for maintaining a clean and safe site: construction materials shall be stacked neatly, safely, and in orderly fashion, excess materials and debris shall be disposed of promptly and properly, and the construction area shall be maintained broom-clean on a daily basis.

The contractor shall deliver a written set of Standard Operating Procedures for operation of the wind tunnel, including fan operation, filter changing, leak testing and repair, cleaning of the interior surfaces of the wind tunnel, routine maintenance, and any other facet of basic operations that may help preserve the life and performance of the AWTS.

Once the AWTS is installed and substantially complete, the contractor shall demonstrate that the system is sealed to air leaks by performing the following pressure test: with the breather vent sealed, the pressure inside the AWTS shall be increased to a pressure of 4 inches of water above ambient; then, without further supply of air, measurements shall demonstrate that the pressure inside the tunnel changes by no more than 0.4 inches of water (10%) over a time period of 15 minutes.

Following successful completion of the tunnel's pressure tests, the AWTS will be evaluated for internally generated contamination. For these tests, the tunnel will be continuously operated for six consecutive hours at a mean velocity of 48 km/hr as measured in the sampler test section. A PM10 sampler will be installed in the sampler test section and operated continuously during the six-hour test. At the completion of the test, the sampler's collection filter will be removed and the filter's mass gain quantified gravimetrically. Based on the mass gain and the volume of air sampled during the test, the PM10 mass concentration in the tunnel will be determined. The acceptable PM10 concentration measured during these tests shall not exceed 3 µg/m³ based on conditioning of the filters before and after sampling at 22°C and 35 percent relative humidity. Following the gravimetric analysis, the filter will be analyzed fluorometrically for the equivalent fluorescein content of the collected aerosol. The fluorescein loading measured during these tests shall not exceed 0.1 ng/m³ (10-10 g/m³). If the test results show exceedences of these aerosol loadings, the contractor shall locate and eliminate the sources of the contamination, whereupon the Government will repeat the testing sequence. All test setups, sampler operation, and gravimetric and fluorometric analyses of filters shall be the responsibility of the Government; if the Government fails to complete the tests within two weeks of being notified by the contractor that the AWTS is available for these tests, it shall be deemed that the test has been passed. Furthermore, the

contractor shall warrant the tunnel to be free of internally generated contamination for a period of one year following acceptance by the Government. The Government may repeat the above series of tests at any time within this one-year period provided that the tunnel's interior surfaces have been properly cleaned immediately prior to the tests; if these tests show exceedences of the gravimetric or fluorometric limits above, the contractor shall locate and eliminate the sources of the contamination at no cost to the Government. The phrase "properly cleaned" shall mean that the tunnel has been cleaned according to the Standard Operating Procedure for such cleaning as delivered with the AWTS by the contractor.

For acceptance, the contractor shall demonstrate through appropriate measurements that the installed system meets all the design and performance specifications prescribed herein and in the design documents delivered under the base contract. The contractor shall submit a written report of these acceptance tests giving full details of how the tests were conducted and the results.

SECTION 4. BASE CONTRACT: ADDITIONAL COMPONENTS REQUIRED

4.1 Vibrating Orifice Aerosol Generator System

A monodisperse aerosol generator system operating on the principle of controlled breakup of a liquid jet (Rayleigh breakup) and producing dried, charge-neutralized aerosol at the following rates as a function of particle size shall be supplied:

Particle diameter, μm	2	5	10	20	50
particles/second	3,500,000	1,000,000	400,000	120,000	50,000

The above production rates are approximately five times those of a standard commercially available vibrating orifice aerosol generator when operated at the optimum frequency for producing the most monodisperse particles and lowest satellite particle production and using solution concentrations of between 1 percent and 0.1 percent. Jet orifices supplied shall include 5, 10, 20, 50, and 100 μm nominal diameter in quantities of 15, 10, 10, 5, and 5 sets, respectively (one "set" is whatever number of orifices or orifice plates are required to fully operate the vibrating orifice system at one nominal jet diameter). The liquid feed system shall operate without user intervention for eight hours or more; it shall have a total delivery rate including the range of 0.1 to 20 $\text{cm}^3/\text{minute}$ and a delivery rate stability of better than 2% per hour. The system shall permit the simultaneous generation of up to five sizes of particles from up to five different liquid solutions. All system components shall be compatible with aqueous and alcohol based solutions. The system shall produce aerosols having a monodispersity (measured as the geometric standard deviation) of 1.1 or less over the entire range of sizes produced. The system's frequency generator(s) shall have a stability of better than 50 parts per million per day and be settable to within 0.5% of a given frequency. The system shall perform as required in 40 CFR part 53 for PM10 (Subpart D) and PM2.5 (Subpart F) sampler testing. Briefly, these requirements stipulate monodisperse liquid aerosols from 3-25 μm and solid particles at 25 μm for PM10 testing, and solid particles from 1.5-4 μm and liquid aerosol at 3 μm for PM2.5 testing.

4.2 Aerosol distribution systems

The contractor shall deliver two or more aerosol distribution systems for conducting the output of various aerosol generators into the tunnel so that the particles are well-distributed across the width and height of the tunnel as the aerosol enters each test section. Aerosol generators are expected to be positioned outside of the tunnel and the aerosol distributed into the tunnel via a system of tubes or pipes having multiple outlets. Multiple distribution systems and injection points will be required for the wide range of particle sizes, concentrations, wind speeds, and turbulence intensities for which the wind tunnel is designed. At a minimum, one system will be needed immediately downstream of the cooling coils for aerosols below 10 μm diameter, and one system will be needed immediately upstream of the test sections for aerosols above 10 μm diameter. It is critical that these distribution systems be designed for minimal particle losses. Losses in the distribution system for 25 μm particles shall not exceed 50% from the entrance of the system to its outlets; for 10 μm

particles such losses shall not exceed 20%; for 1 μ m particles such losses shall not exceed 10%. The outlets must have remotely and individually controlled shutoff valves.

4.3 Static charge elimination system

The contractor shall deliver one or more static charge elimination system(s) that will reduce the aerosol charge distribution as nearly as possible to that of a Boltzmann charge distribution at least by the time the aerosol enters the mainstream flow of the wind tunnel, since many aerosol generation mechanisms produce aerosols having a high static electrical charge that renders them difficult to use without bias or loss. This reduction can be achieved by employing ion generators, such as radioactive sources or electronic means, placed at appropriate locations and in sufficient quantity and strength. If any radioactive sources are used, they must employ isotopes having a half-life of five years or longer.

Acceptance Criteria for Sections 4.1, 4.2, and 4.3

Acceptance testing shall consist of demonstration by the contractor that: (1) the aerosol distribution and static charge elimination systems adhere to the stated requirements; and (2) the Homogeneity Testing Requirements given below have been successfully met; and (3) the aerosol generation system meets all other and more restrictive requirements of 40 CFR part 53 regarding PM10 and PM2.5 sampler testing with the inclusion of the additional requirements at a wind speed of 48 km/hr. The contractor shall submit a written report of these acceptance tests giving full details of how the tests were conducted and the results.

Homogeneity Testing Requirements

The contractor shall test aerosol homogeneity in the test sections by the following protocol:

Two test areas are defined as follows:

Human exposure test section: a rectangle 2.5 m wide and 2.0 m high normal to air flow, centered vertically, laterally, and streamwise in the human exposure test section.

Sampler test section: a rectangle 1.25 m wide and 1.0 m high normal to air flow, centered vertically, laterally, and streamwise in the sampler test section.

For the human exposure test section, test aerosols shall be monodisperse fluorescein aerosols of 1.5, 4, and 10 μ m diameter, each size being tested at wind speeds of 0.1 and 1 m/s, resulting in six combinations of particle size and wind speed.

For the sampler test section, test aerosols shall be monodisperse fluorescein aerosols of 1.5, 10, and 25 μ m diameter, each size being tested at wind speeds of 0.56, 3, and 13.3 m/s, resulting in nine combinations of particle size and wind speed.

All test aerosols shall be generated using the vibrating orifice method and shall be collected using five filtration samplers equipped with isokinetic inlets and operated simultaneously. Analysis shall be by fluorometry.

The mean for each rectangle shall be defined as the average of five measurements: one at each of the four corners and one at the center of the rectangle. Homogeneity is achieved when none of the five measurements differs from their mean by more than 10%.

4.4 Theatrical smoke/fog generators

Three commercially available generators shall be supplied for use in flow visualization and in flow measurements (Laser-Doppler Anemometry and Particle Image Velocimetry). Each unit shall:

- produce a highly visible, neutrally buoyant, and non-fouling smoke,

- have an output of at least 2000 ft³/minute and a warm up time of 15 minutes or less, and
- be remotely controllable.

One of the generators shall produce smoke particles with a size range of 0.5 to 0.7 μ m using pharmaceutical grade mineral oil. Another one shall have a much broader output size range of 0.25 to 60 μ m using polyethylene glycol. At least one generator shall be capable of being powered using compressed gases of nitrogen or carbon dioxide. Possible vendors: Martin, MDG, Rosco, Corona, or Lightwave.

4.5 Liquid nebulizer(s)

The contractor shall deliver one or more units that nebulize solutions of various salts, oils, or polystyrene latex (PSL) microspheres, followed by dessication, to produce 0.1-5 μ m mass median diameter (after drying) salt or oil aerosols at mass concentrations of 10-1000 μ g/m³ in the test sections or 0.5-10 μ m diameter PSL aerosols. The terms “dessication” and “drying” refer to the virtually complete evaporation of any solvent in which the solutes are dispersed prior to nebulization. The number of units required must be determined by the contractor after taking into consideration the following factors: unit output, aerosol losses in the distribution system, and dilution in wind tunnel flows ranging from 1.1 to 34 m³/s. While compressed gas operation is acceptable for nebulizing salt solutions and smaller PSL, the use of ultrasonic nozzles is required for PSL sizes above 5 μ m. Possible vendors: BGI, TSI, Sono-Tek, DeVilbiss, or NUCON.

Acceptance criteria for Sections 4.4 and 4.5

Acceptance testing of each aerosol generator shall consist of demonstration by the contractor that its specifications listed have been met or exceeded. The contractor shall submit a written report of these acceptance tests giving full details of how the tests were conducted and the results.

4.6 Automated operation

The contractor shall provide hardware and software to fully automate control through the LAN of all aerosol generators delivered under sections 4.1, 4.4, and 4.5, including manual and automatic control and monitoring of each generator’s operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Acceptance criteria for Section 4.6

Acceptance testing of the automation of the aerosol generators shall consist of demonstration by the contractor that the specifications listed have been met or exceeded for each automated aerosol generator.

4.7 Air compressor system

The contractor shall provide an air compressor/reservoir system capable of supplying a continuous stream of compressed, oil-free, particle-free, dry air for use by the aerosol generation equipment. The air shall be delivered at a pressure of 100 psi and the rate shall be the larger of: (1) 20 actual cubic feet per minute (ACFM), or (2) the maximum needs of any of the aerosol generators proposed under any of the options. The term "particle-free" shall mean equivalent to HEPA filter performance standards. The term "dry" shall mean having a pressure dew point not exceeding 40°F. The building’s compressed air supply shall be used to charge the reservoir during most periods. An auxiliary, electrically driven air compressor shall operate automatically whenever the building air supply is off or insufficient and shall fully meet the flow rate and pressure requirements on a continuous-duty basis. This auxiliary compressor shall be located inside the tunnel room, possibly in the sound enclosure for the main wind tunnel fan, and, wherever located, shall not cause noise anywhere in the laboratory exceeding 60 dBA when operating.

4.8 Point ventilation systems

At each location where generated aerosol will be injected into the wind tunnel, the contractor shall provide a point ventilation system to collect particles and vapors produced during setup of the aerosol generator(s). Each system will likely consist of a hood or shroud, a duct to the exhaust point, and a fan to move the air. Each ventilation system shall have sufficient flow to remove all generator output from the vicinity of the operators and shall transport and vent this flow directly into the room’s HVAC exhaust flow.

4.9 Hot-Wire Anemometry

A hot-wire anemometry (HWA) system is required to measure two components of velocity, including turbulent fluctuations, shear stresses, and spectra of the turbulence in cases where the use of the LDA system is impractical, where seeding of the flow is not possible, where measurements must be made in locations otherwise inaccessible, or where safety issues prohibit use of the LDA. The HWA system is a well-established technique in the fluid mechanics field; it measures velocities through the cooling effect on a heated sensor, typically a fine heated wire or a plated quartz fiber coated with a thin resistive film. The primary system in use today is the so-called constant temperature anemometer, where a feedback loop in the electronics keeps the sensor temperature constant under all flow conditions. For multi-dimensional measurements, the fine wires or films are placed at angles to the flow, and the desired orthogonal velocity components are derived by adding and subtracting the signals from the two sensors. The typical two-dimensional measurement system thus consists of two basic anemometers or "bridge circuits", an array of probes, probe supports, and a probe calibrator, analog-to-digital (A/D) converter, software, and computer.

4.9.1 Hot-wire anemometry system

The contractor shall provide a complete HWA (constant-temperature) system that measures two components of velocity simultaneously, including capabilities for measuring velocity fluctuations, shear stresses, and spectra of the turbulence, and be easily upgradable to a three-component system. The system shall comprise as a minimum:

- A high-quality (i.e., state-of-the-art, low noise, low drift) constant-temperature anemometer with integrated signal-conditioning electronics (with analog zero suppression and gain control) and with frequency response of at least 100 kHz,
- A basic set of one- and two-dimensional probes and supports (see below),
- A/D converter with minimum of 12-bit resolution and capable of true simultaneous sampling up to three sensor inputs with frequency response to at least 100 kHz,
- Comprehensive, user-friendly, Windows-based software that permits full control of setup, calibration, automatic temperature corrections, and convenient acquisition and analysis of one-, two-, or three-sensor probe data as well as traverse control, and
- Personal computer that provides sufficient power and capabilities to control the hardware and run all the software for HWA measurements with ease. The computer should be state-of-the-art at the time of its acquisition. Currently, the minimum acceptable system would be a dual-processor Pentium 4 with 1.0 GHz processor speed, 1024 MB RAM, >40 GB hard drive, 250 MB Zip drive, R/W CD-ROM drive, 19" monitor, with HWA software integration and testing, and an 8 page per minute black & white laser printer (Bluetooth enabled, if available).

The basic set of probes and supports to be delivered with Option 30 shall include:

- 2 - single film end-flow probes
- 2 - single-sensor right-angle adapters
- 2 - regular single-sensor probe supports (18" length)
- 2 - "X"-film end-flow probes (mean flow in line with probe axis)
- 2 - dual-sensor right-angle adapter (for use with above "X"-sensor end-flow probes)
- 2 - "X"-film cross-flow probes (mean flow perpendicular to probe axis)
- 2 - regular dual-sensor probe supports (18" length)
- 2 - regular locking protective shields (for above 18" probe supports)
- a means of attachment of the probes to the traverse system, allowing orientation of the probe support axis in x-, y- or z- directions.

The anemometer system shall be a fully self-contained and integrated hardware and software system that permits complete computer control of all setup and measurement operations for the HWA. All cabinetry and necessary interface cables shall be included. The personal computer shall be interfaced and integrated with

other sensors and controls of the AWTS as specified in Section 10. It shall be capable of automated data acquisition, including collection of data at a set of predefined measurement locations.

4.9.2 HWA Probe array

The contractor shall provide the following array of probes to be completely adaptable and interchangeable with the set provided above:

- 2 - single wire end-flow probes
- 2 - single wire cross-flow probes (supports bent so that sensor upstream of probe)
- 2 - single film cross-flow probes (supports bent so that sensor upstream of probe)
- 2 - "X"-wire end-flow probes (mean flow in line with probe axis)
- 2 - "X"-wire cross-flow probes (mean flow perpendicular to probe axis)
- 4 - "X"-wire cross-flow probes (sensors upstream, two measuring u- and v-components, two measuring u- and w-components)
- 4 - "X"-film cross-flow probes (sensors upstream, two measuring u- and v-components, two measuring u- and w-components)
- 2 - short single-sensor probe supports (for small spaces - about 2" length)
- 2 - short dual-sensor probe supports (for small spaces - about 2" length)

4.10 Generation system monitor

The contractor shall provide a compact light scattering-based device to monitor the generation of aerosols in the diameter range including 0.2 to 10 μm and a concentration range including 1 to 10⁴ $\mu\text{g}/\text{m}^3$ to ensure that the generation system is working and stable. The device shall sound an alarm audible to the operators if specified upper or lower concentration limits are exceeded, shall operate independently of the LAN and all size distribution instruments, and shall have outputs that are recorded by the LAN. A mounting rake shall be provided to hold up to seven of the monitors in position in the wind tunnel. Possible vendor: TSI.

Acceptance criteria for Sections 4.7, 4.8, 4.9.1, 4.9.2, and 4.10

Acceptance testing of each Section shall consist of demonstration by the contractor that its specifications listed have been met or exceeded.

4.11 Isokinetic Sampling System

Isokinetic sampling systems are used to measure the concentrations of aerosols in the test sections of the AWTS: (1) a multiport (rake) sampler to determine the homogeneity of the aerosol distributions, and (2) a high volume, single nozzle sampler to measure the total aerosol concentration once homogeneity of the distributions has been confirmed. The multiport sampler consists of a set of nozzles that may be distributed across some area of interest in the test section; samples of aerosol-laden air are drawn isokinetically from the tunnel and the aerosols are deposited on standard-sized (47 mm) glass-fiber filters for specified time periods for later analysis and determination of concentrations. Generally, the sampling stream-tube is of small diameter and the sampling time is large, perhaps as long as several hours. By contrast, the high volume sampler consists of a single, large-area nozzle, and the aerosols are again collected on glass-fiber filters for specified time periods. Because of the much larger stream-tube for this system, the sampling time is generally much shorter than that for the multiport sampler. The multiport sampling system is to be used in both the human-exposure and sampler test sections and, hence, some parts of the systems are common and other parts are distinct. The high volume sampler is expected to be used in the sampler test section only. The multiport sampling system is to be delivered under the Base Contract, while the high volume sampler is an option (Option 39).

4.11.1 Multiport isokinetic sampling system

The contractor shall provide a multiport isokinetic sampler system suitable for use in both the human exposure and sampler test sections. This system shall draw aerosol-laden air from the tunnel through sets of 5 to 7

sampling nozzles that may be mounted on racks to allow variable positioning of the nozzles within the two test sections of the AWTS. The aerosols are then collected on glass-fiber filters inside filter holders at the downstream end of each nozzle. Sets of flow controllers mounted in a control box shall permit accurate setting and monitoring of the flow rates through the nozzle/filter assemblies. Sets of dry-gas meters shall permit totalizing of the flow through each of the nozzles. A suitable vacuum source shall draw the samples from the tunnel through the system.

The multiport samplers in the sampler test section are to be used primarily to meet the requirements of the Code of Federal Regulations (40 CFR 53 Subpart D), which requires isokinetic sampling at wind speeds of 2, 8, and 24 km/hr. In addition to satisfying the requirements of the CFR, an additional set of nozzles shall be provided for isokinetic sampling at a wind speed of 48 km/hr in the sampler test section. To permit testing of aerosol homogeneity in the human exposure test section at the smallest anticipated flow speed, a further set of nozzles shall be provided for isokinetic sampling at a wind speed of 0.36 km/hr (0.1 m/s). Table 6 summarizes the sets of nozzles required. Possible nozzle diameters and flow rates are provided in the table, but other combinations of nozzle sizes and flow rates could achieve isokinetic flow conditions and may be accepted for good reason, provided that flow rates are kept above 4 liters per minute. A suggested nozzle design is provided in Figure 5. The nozzles shall be made of 316 stainless steel and machined to interchange with commercially available 47-mm filter holders (Gelman model 2220); each set shall comprise 10 nozzles of each size (7 to be mounted at any given time and 3 spares).

Table 6. Nozzle sets for Multiport Isokinetic Sampler System

Wind speed	Nozzle diameter (cm)	Flow rate (lpm)	Test section
0.36 km/hr (0.1 m/s)	2.94	4.09	H/E
2 km/hr (0.55 m/s)	2.94	22.7	H/E or Sampler
8 km/hr (2.22 m/s)	1.86	36.0	H/E or Sampler
24 km/hr	1.22	46.7	Sampler
48 km/hr	0.863	46.7	Sampler

The control box shall be equipped with mass flow controllers to control and measure the flow through each of the sampling lines with accuracies of $\pm 2\%$ based on the actual flow rate. The control box shall also include a timer (with start, stop, and reset capabilities) and sets of 7 dry-gas meters, pressure gages, and temperature sensors for totalizing the flow through each line; this system shall provide accuracies of $\pm 2\%$ based on the actual flow rate in each line. Because of the wide range of flow rates (Table 6) and required accuracies, it is anticipated that two or more flow meters may be required (with appropriate valves and switches) in each line.

The contractor shall provide a test cart and rack for each test section that is instrumented with a set of 7 nozzle/filter holder assemblies, tubing, connectors, etc., as necessary for sampling concentrations anywhere within two areas as follows:

- Human exposure test section: a rectangle 2.5 m wide and 2.0 m high normal to the air flow and centered vertically and laterally in the test section.
- Sampler test section: a rectangle 1.25 m wide and 1.0 m high normal to the air flow and centered vertically and laterally in the test section.

For design purposes, the offeror may assume that three nozzles would be placed along the top edge, three along the bottom edge, and one at the center of the rectangle. The design of this rack containing the nozzle/filter holder assemblies, accompanying tubing, etc., shall include due consideration for the aerodynamics of the flow and minimize flow disturbances.

Connectors permitting rapid attachment and detachment shall be provided for hooking together the various vacuum tubes at primary junctions in the system, e.g., at the AWTS, at the control box, and at other places as

appropriate (dependent upon the design of the system). Each vacuum line to a nozzle shall contain a shut-off valve so that smaller sets of nozzles may be operated independently (i.e., so that unused lines will not disrupt operation of the system). For independent calibration and testing purposes, all pressure gages and flow meters shall be provided with convenient means of disconnection from the system and reconnection to other devices.

A vacuum pump shall be provided with adequate capacity to draw the necessary isokinetic flow rates through the system of 7 nozzles; it shall be provided with acoustic silencers and/or placed inside the sound enclosure surrounding the fan so as to avoid noise levels anywhere within the laboratory in excess of 60 dBA. Valves for vacuum shut-off and vacuum-release (vent) shall be provided in the supply line between the pump and the control box.

Acceptance Criteria for Section 4.11.1

Acceptance testing shall consist of demonstration by the contractor that (1) the overall design of the system, including nozzle/filter holder assemblies, rake systems, control box, etc., meets the stated requirements, (2) the flow meters and temperature and pressure sensors meet the stated requirements, (3) the vacuum pump is of adequate capacity to handle the highest flow requirements of the multipoint sampler system and meets the low-noise requirement. The contractor shall further demonstrate that the sampling systems are leak-free by performing the following test on each system (i.e., with each test-cart connected to the control box): the system shall be set up as in a normal test using the 2 km/hr set of nozzles, except that the inlets of the nozzles shall be plugged with rubber stoppers. A vacuum of 45" H₂O shall be imposed on the system, then the vacuum shut-off valve shall be closed, and the vacuum monitored for a 5-minute period. If the leak rate is such that the vacuum changes by less than 1" H₂O, the system will be accepted; otherwise, the system will not be accepted. The contractor shall submit a written report of these acceptance tests giving full details of how the tests were conducted and the results.

SECTION 5. AEROSOL GENERATION OPTIONS (Options 1-13)

Option 1: Fluidized bed aerosol generator(s)

The contractor shall deliver one or more units that use the fluidized bed principle to generate 1-40 μ m diameter solid particles at a stable rate to produce mass concentrations of 1-100 μ g/m³ in the test sections. Each unit shall have a classifying device at its output to remove agglomerates that have not been dispersed properly. The number of units required must be determined by the contractor after taking into consideration the following factors: unit output, aerosol losses in the distribution system, and dilution in wind tunnel flows ranging from 1.1 to 34 m³/s.

Option 2: Automated operation for Option 1

The contractor shall provide hardware and software to fully automate control through the LAN of aerosol generators delivered under Option 1. This option will provide manual and automatic control and monitoring of each generator's operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Option 3: Condensation monodisperse aerosol generator(s)

The contractor shall deliver one or more units that use the principle of condensation of organic materials onto salt nuclei to generate particles of 0.1-8 μ m diameter and having a geometric standard deviation of less than 1.3. Mass concentrations in the test sections must be 100-4000 μ g/m³ for 5 μ m diameter particles. The number of units required must be determined by the contractor after taking into consideration the following factors: unit output, aerosol losses in the distribution system, and dilution in wind tunnel flows ranging from 1.1 to 34 m³/s. The unit(s) must be capable of continuous operation for a period of at least 12 hours.

Option 4: Automated operation for Option 3

The contractor shall provide hardware and software to fully automate control through the LAN of aerosol generators delivered under Option 3. This option will provide manual and automatic control and monitoring of each generator's operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Option 5: Dust feeder/powder disperser(s)

The contractor shall deliver one or more units that disperse dry deagglomerated particles from the bulk dust of various materials, such as natural road dust, pulverized minerals, or pollen. Although dust diameter is determined by the product selected, the deagglomeration system must reduce the bulk dust to its fundamental particles. The unit shall have a classifying device at its output to remove agglomerates that have not been dispersed properly. Concentration output capacity as delivered in the wind tunnel must include the range of 0.1-70 cm³ of the bulk dust per hour.

Option 6: Automated operation for Option 5

The contractor shall provide hardware and software to fully automate control through the LAN of aerosol generators delivered under Option 5. This option will provide manual and automatic control and monitoring of each generator's operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Option 7: Jet mill/opposing jet pulverizer(s)

The contractor shall deliver one or more units capable of reducing bulk powders having 10-500 μ m diameter particles to 1-10 μ m diameter aerosols using opposing air jet or collision technologies and having a production rate of 0.1-100 g/hr.

Option 8: Automated operation for Option 7

The contractor shall provide hardware and software to fully automate control through the LAN of aerosol generators delivered under Option 7. This option will provide manual and automatic control and monitoring of each generator's operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Option 9: Polystyrene latex (PSL) microsphere production system

The contractor shall construct and deliver a system for manufacturing small batches (2-4 liters) of monodisperse PSL microspheres of 0.5 to 3 μ m diameter as a hydrosol following the methods of NASA report TM-89163 and J. Poly. Sci.: Poly. Chem. Ed., 14:2089-2107 (1976). The process involves putting several ingredients into a reaction vessel, purging of oxygen, heating, adding a catalyst, and allowing it to react with stirring for 24 hours. After production, the size and uniformity of the microspheres must be verified by light or electron microscopy. This method is capable of producing particles of a chosen mean diameter in the range of 0.5 to 3 μ m and having extremely uniform size (a coefficient of variation of less than 2%) at low cost. The PSL would be used primarily as seeding particles for Laser Doppler Velocimetry.

Option 10: Sheet or multiple-orifice jet monodisperse aerosol generator

The contractor shall deliver one sheet or multiple-orifice aerosol generator operating on the principle of Rayleigh jet breakup, having at least 25 times the aerosol output of a TSI model 3450 Vibrating Orifice Aerosol Generator, and having a monodispersity (as the geometric standard deviation) of better than 1.1.

Option 11: Automated operation for Option 10

The contractor shall provide hardware and software to fully automate control through the LAN of the aerosol generator delivered under Option 10. This option will provide manual and automatic control and monitoring of each generator's operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Option 12: Spinning top aerosol generator

The contractor shall deliver one spinning top monodisperse aerosol generator, as described in Aerosol Science and Technology, 9:105-113 (1988).

Option 13: Automated operation for Option 12

The contractor shall provide hardware and software to fully automate control through the LAN of the aerosol

generator delivered under Option 12. This option will provide manual and automatic control and monitoring of each generator's operating parameters, timing, and other functions needed for reliably generating stable, well-characterized aerosols.

Acceptance criteria for Options 1, 3, 5, 7, 9, 10, and 12

Acceptance testing of each option shall consist of demonstration by the contractor that the specifications listed have been met or exceeded. The contractor shall submit a written report of these acceptance tests giving full details of how the tests were conducted and the results.

Acceptance criteria for Options 2, 4, 6, 8, 11, and 13

Acceptance testing of each automation option shall consist of demonstration by the contractor that the specifications listed have been met or exceeded for each automation option.

SECTION 6. FLOW MEASUREMENT CAPABILITY (Options 14-22)

Laser-Doppler Anemometer (LDA) Systems

A laser-Doppler anemometer (LDA) is required to measure two components of velocity simultaneously, including turbulent fluctuations, shear stresses, and spectra of the turbulence. A basic LDA system consists of a continuous wave laser, transmitting optics which include a beam splitter, Bragg cell (frequency shifter) and a focusing lens, receiving optics which include a focusing lens and a photo detector, a signal conditioner and processor to extract the velocity information, and computer with software to resolve the data and provide feedback to the user. The most convenient, economical, and effective system for our purposes includes a self-contained fiber-optic probe with focusing and receiving optics built into one compact unit. We anticipate that the LDA system will be used primarily in the large test section, with the probe mounted on an internal traverse system (Option 40, Section 8). In general, LDA systems may be upgraded to Phase-Doppler Anemometers (PDAs) to allow measurement of particle sizes by adding more receiving optics and higher capacity signal-processing equipment.

Option 14: Laser-Doppler anemometer (LDA) system #1

The contractor shall provide a complete, commercially available LDA system that measures two components of velocity simultaneously, including capabilities for measuring velocity fluctuations, shear stresses, and spectra of the turbulence. The system supplied shall be traverse-ready and easily ungradable to measure either: (1) three components of velocity simultaneously (LDA), or (2) two components of velocity simultaneously with particles sizes at high resolution (i.e., upgradable to a high-resolution PDA system – see Section 7). The system shall comprise, as a minimum:

- 5-watt argon-ion laser that can be used in multi-line mode for two- or three-component measurements,
- laser power meter,
- transmitting optics that include a multicolor beam separator to provide color separation of the laser light for two-component measurements and a Bragg cell to shift the frequency of the light (to permit resolution of positive and negative flow direction),
- two-component fiber-optic probe with diameter not exceeding 85 mm and front optics to provide focal lengths of approximately 250, 350 and 700 mm, supplied with a connecting fiber-optic cable of at least 15 m length,
- beam expander with lens on the fiber-optic probe to provide a focal length of approximately 1 m with high resolution and small measurement volume,
- removable 45° mirror on fiber-optic probe to permit measurements either parallel or at right angles to the probe axis (i.e., with the focal point in-line with or perpendicular to the probe axis),
- receiving optics to collect scattered light by wavelength, convert light energy to electrical signals, and provide frequency mixing capabilities for flow reversal measurements,

- signal processing and analysis system that removes noise from the signals, rejects bursts from particles larger than $3 \mu\text{m}$, and extracts velocity information in the range of 0.01 to 20 m/s with resolution on all ranges of at least 9 bits, and
- computer and software system that allows real-time operation and measurements with the LDA as well as integration with the traversing systems.

The computer and software system shall support experimental setup, data acquisition, processing, analysis, storage, and display and exportation of collected data. Raw and intermediate data shall be accessible to the users, and all file formats, including binary files, must be well documented. It shall provide complete control of signal processors, receiving optics and traverse system, and implement two-component data analysis, including flow statistics, power spectrum, and graphical displays. Capabilities of the graphical display shall include profile plots of mean or rms velocities, vector plots, real-time histograms, spectra, and time series of the velocity signals. The software shall be capable of handling and displaying data with or without transit-time weighting.

The data acquisition system must be capable of logging at least two 12-bit channels of external analog data and at least one digital event tag or count into the same time-stamped stream used for the raw LDA data. It must be able to transmit a user-determined command string to at least one serial (RS-232-C) port on a predetermined schedule or in response to the acquisition of a predetermined number of data points or a digital event tag input. It must additionally support a network card (10/100 Base-T) and allow remote control and file access using a non-proprietary standard (i.e., tcp/ip web browser technology or ftp) and components that are supported under Microsoft Windows. The contractor shall provide documentation of all internal data structures and file formats. Post-acquisition software must run on at least one other networked host. For further details see the AWTS LAN specifications in Section 10.

The LDA system shall be a complete, fully functioning system that includes all hardware and software necessary for set up, installation and operation to measure two components of velocity in the large test section of the AWTS. All cabinetry and necessary interface cables shall be included. Its computer shall be interfaced and integrated with other sensors and controls of the AWTS as specified in Section 10. It shall be capable of automated data acquisition, including collection of data at a set of predefined measurement locations without operator intervention.

All fiber-optic probes must be sealed and furnished with replaceable protective windows, as they are to be mounted inside the AWTS and thus subjected to airborne dusts, sprays, etc. Exposed parts of the optics must be easily cleanable and with little risk to the performance of the system.

The total mass of the fiber-optic probes and suspended portions of cables shall not exceed 10 kg. This system shall be delivered with an appropriate means of attachment to both traverse systems (i.e., to provide maximum stability with minimum flow interference) so that (u,v) and (u,w) components of velocity may be measured by simply rotating the probe by 90° .

Option 15: Laser-Doppler anemometer (LDA) system #2

The contractor shall provide a second LDA system identical to the one delivered under Option 14.

Acceptance Criteria for Options 14-15

Acceptance testing shall consist of demonstration by the contractor that the specifications listed have been met or exceeded.

Particle-Image Velocimetry (PIV) Systems

Particle-image velocimetry (PIV) systems are required to measure whole fields of velocity and to understand large-scale turbulent structures. The process involves seeding the flow with particles that trace the motion of the fluid. In current state-of-the-art systems, a narrow slice of the flow field is illuminated using a short duration light sheet produced by a pulsed laser, thus illuminating the particles, which are detected and recorded by a camera placed at right angles to the light sheet. The light sheet is pulsed twice at a controlled time interval,

and images are "frozen" by a synchronized camera, thus showing initial and final positions of the seed particles. The two camera frames are divided into small areas called interrogation regions. Each interrogation region is then processed to determine the displacement, hence the speed and direction of the flow (particles), in each interrogation region using correlation techniques. This process is repeated for each interrogation region to obtain the velocity vector map for the entire field. In principle, a fast camera with a continuous laser could be used to achieve the same objective. Stereo PIV systems using two cameras allow measurement of three-dimensional particle displacements in the flow field.

Components of the PIV system may include pulsed lasers, optics to create and position the light sheets, high resolution, high frame-rate CCD or gated SIT cameras, high-speed camera interface, master control unit to synchronize the lasers, camera and camera interface, and fast, powerful processing systems (including hardware and software). A further option (Option 20) includes an external traverse system that permits two axes of motion of the beam delivery system, i.e., positioning of the laser light sheet.

Option 16: Particle-Image Velocimetry (PIV) System #1

The contractor shall provide a PIV system for making measurements in the human exposure test section. It shall consist of the following components and/or meet the following specifications:

- Means of illuminating the flow field of interest. If pulsed lasers are proposed, the system shall include dual Nd-YAG lasers (flashlamp-pumped) with integrated beam combination optics in a compact package. Their output shall produce at least 200 mJ of energy per pulse on the 532 nm wavelength and be capable of "powering down" or operating with reduced energy output for alignment purposes. The integrated beam optics shall allow the pulses from the two lasers to precisely overlap. The pulse frequency (repetition rate for the pair of pulses) shall meet or exceed 15 Hz. An accessory kit shall be included to implement alignment of the system. The cable connecting the laser head and power supply shall be at least 15 feet in length. If continuous illumination is proposed, the offeror shall specify an alternative design.
- If pulsed lasers are proposed, a synchronizer to trigger the laser pulses and camera and other external devices with the correct sequence and timing for PIV imaging and image-capturing is required. This synchronizer must be fully integrated with other system components to allow fully automated operations. If continuous illumination is proposed, the contractor shall specify an alternative.
- Beam delivery arm and light-sheet generation optics. This system comprises an articulated mechanism and optics for safely delivering the laser sheet to any position and with any orientation within the field of interest. It converts the above laser beam into a flat, diverging light sheet in order to illuminate a suitable area of the flow field and deliver it to the experimental region of interest, i.e., to facilitate its movement from one plane to another. The light-sheet optics shall provide for a measurement region of at least 30 cm x 30 cm and allow its placement at any position within a 1.8 m radius of either manikin in any of the test-cart locations of the human-exposure test section. The articulated arm shall permit positioning of the light sheet with any orientation virtually anywhere within a sphere of radius 1.8 m.
- Video camera. If pulsed lasers are proposed, the video camera shall be of the CCD type, have a resolution of at least 1K x 1K pixels, a frame rate of at least 30 frames per second, and provide for digital video output of at least 8 bits. It must be capable of capturing sequential PIV images in conjunction with two laser pulses with separations as small as 0.3 ?sec. It shall be equipped with lenses suitable for the anticipated PIV measurements and with connecting cables. If continuous illumination is proposed, the offeror shall specify an alternative design.
- High-speed camera interface. This is a high-speed digital frame grabber with a minimum of 8-bit resolution and capable of transferring images to a host computer RAM at the full camera frame rate (i.e., 30 Mbytes/sec); it shall have a maximum data transfer rate of at least 90 Mbytes/sec.
- Image processing software. This software package shall provide control, setup, and operation of the

synchronizer to fully automate PIV measurements; it shall provide for high-resolution image capture, analysis and validation, and display of the two-dimensional vector field and its detailed properties. It should provide processing speeds for velocity vector analysis in both autocorrelation and cross-correlation modes so as to display a complete PIV vector field on-line and with high measurement accuracy. The software must interact directly with all video cameras, lasers, synchronizers, frame grabbers and any other PIV hardware. It shall allow the user to interactively configure the processing scheme, interrogation grid size, signal-to-noise ratio, image enhancement, and correlation algorithms, to obtain the best possible results from the PIV system. It shall permit the velocity vectors, along with the input particle image, to be displayed, saved, or printed. Graphical displays should permit profiling of points, lines, areas of interest, and whole flow fields, all as vector or contour plots.

- Personal computer. This computer shall provide sufficient power and capabilities to control the hardware and run all the software for PIV measurements with ease. The computer should be state-of-the-art at the time of its acquisition. At the present, the minimum acceptable system would be a dual-processor Pentium 4 with 1.0 GHz processor speed, 1024 MB RAM, 40 GB hard drive, 250 MB Zip drive, CD-RW drive, 19" monitor, with PIV software integration and testing.

Option 17: Particle-Image Velocimetry (PIV) System #2

The contractor shall provide a second PIV system identical to the one delivered under Option 16.

Option 18: Upgrade of PIV system #1 to stereo/3D

The contractor shall provide an upgrade to the PIV system delivered under Option 16 that will allow stereoscopic imaging and on-line display of the three-dimensional velocity vector field. The additional components required (i.e., in addition to those specified in Option 16) include:

- An additional video camera. As specified above, if pulsed lasers are proposed for illumination, the video camera shall be of the CCD type, have a resolution of at least 1K x 1K pixels, a frame rate of at least 30 frames per second, and provide for digital video output of at least 8 bits. It must be capable of capturing sequential PIV images in conjunction with two laser pulses with separations as small as 0.3 μ sec. It shall be equipped with a 60 mm, f/2.8, F-mount lens, and with connecting cables. If continuous illumination is proposed, the contractor shall specify an alternative.
- An additional high-speed camera interface. As specified above, this high-speed digital frame grabber shall be capable of at least 8-bit resolution and of transferring images to a host computer RAM at the full camera frame rate (i.e., 30 Mbytes/sec); it shall have a maximum data transfer rate of 90 Mbytes/sec.
- Stereoscopic PIV assembly. This assembly consists of the hardware required to effect the use of two cameras for stereo PIV measurements; these might include a base, brackets, rotary camera mounts, Scheimflug mounts, alignment and calibration kits.
- High-resolution stereoscopic software. This software package shall provide all of the features specified above, and permit the incorporation of the additional hardware and handling of the data from the two cameras to provide accurate particle displacements and on-line display of the all three components of the velocity field, with very high spatial resolution and high measurement accuracy, even for very large flow fields. On-line calibration shall eliminate the need to measure camera angles.

Option 19: Upgrade of PIV system #2 to stereo/3D

The contractor shall upgrade the PIV system delivered under Option 17 so that it is identical to the one delivered under Option 18.

Option 20: External traverse system for PIV system #1

The contractor shall provide an external traverse system for PIV system #1 (delivered under Option 16) that

permits precise and repeatable positioning of the light sheet at the desired measurement area within the human exposure test section as well as brackets to position the camera(s) to view the measurement areas. So that both xy- and xz-planes may be illuminated, this traverse system shall be easily moveable from the sidewall to the top of the large test section of the AWTS. (x is the longitudinal or streamwise direction, y is the lateral or cross-wind direction, and z is the vertical direction.) Correspondingly, the camera brackets shall be moveable from the top to the sidewall of the AWTS. Further, to permit measurements at different longitudinal positions in the tunnel, the traverse gear and camera brackets must be moveable from one measurement station to another, i.e., located so as to permit measurements at any of the test cart locations. When located on the sidewall, the traverse shall permit positioning in the x- and z-directions; when located on the top of the tunnel, it shall permit positioning in the x- and y-directions. In the x-direction, the range of movement should include the full width of the door (1.5 m). In the y- and z-directions, the range of movement should be 1.5 m and be capable of incremental (manual) adjustment to obtain coverage over the entire (cross-wind or vertical) dimension of the respective window. Features of the traverse system shall include:

- Rigid and stable mechanical structure capable of carrying the laser beam delivery arm and light-sheet-generation optics.
- High-resolution positioning (at least 0.1 mm) and accuracy better than ± 0.3 mm over full distance of travel for each axis.
- Speeds of motion are not critical, although an upper limit of 30 cm/s should likely be imposed as a safety factor. The system should be capable of accelerating and decelerating at such rates so as to avoid damage to sensitive laser beam delivery arm and light-sheet generation optics. As a lower limit of speed, the carriage should be capable of moving the entire length of its travel in a maximum of thirty seconds.
- Personal computer controlled with programmable motions on all axes, allowing integration with PIV measurement software. The system must be capable of interfacing with other sensors and controls of the AWTS as specified in Section 10. It shall be capable of automated data acquisition, including collection of data at a set of predefined measurement locations.

Option 21: External traverse system for PIV system #2

The contractor shall provide an external traverse system for PIV system #2 (delivered under Option 17) so that it is identical to the one delivered under Option 20.

Option 22: Automated air flow calibrator for Hot Wire Anemometer System

The contractor shall provide an airflow calibrator for use with the Hot Wire Anemometer System and having the following capabilities:

- Calibration range of 0.05 to 20 m/s, with built-in transducer to indicate velocity
- Flat velocity profile over full calibration range
- Velocity accuracy of 0.5%
- Turbulence intensity of less than 0.5%
- Ambient (room) temperature air stream
- Mounting system that can handle any type HWA probe and support delivered under the Base Contract, providing flexible and accurate positioning for yaw and pitch calibrations
- Permit automatic probe calibration through operator-prescribed velocity range and automatic integration of calibration data into the software calibration routine

Acceptance Criteria for Options 16, 17, 18, 19, 20, 21, and 22

Acceptance testing shall consist of demonstration by the contractor that the specifications listed have been met or exceeded.

SECTION 7. PARTICLE MEASUREMENT CAPABILITY (Options 23-39)

Option 23: Phase-Doppler Anemometer (PDA)

The contractor shall provide a phase-Doppler anemometer (PDA) system that is fully compatible with the LDA system previously provided under Option 14. The PDA system shall comprise a receiver probe with appropriate signal processing hardware and software to allow size measurements of transparent spheres (water, oil or polystyrene latex) with physical diameters greater than 5 μm . This performance shall be verified by the contractor using VOAG-generated droplets of Bis Ethyl Sebacate (BES) or other low-vapor-pressure oil. The optics must work at standoff distances corresponding to the transmitter standoff distances (focal lengths). All other requirements with regard to data acquisition, control, and communications remain the same as for the base LDA system.

For effective PDA measurements of transparent spheres in the size range specified, optics must be mounted in the forward hemisphere of the scattering volume. Thus, the traverse system must either accommodate both sets of optics or two separate carriages that track with very high precision so that correct alignment is maintained (see Section 8 for further details on the traverse systems). The contractor shall provide a means of attaching the transmitting and receiving optics to the traverse system in the human-exposure test section and measurements in the vicinity of the manikin (permitting reception in the forward hemisphere). This mounting system shall be designed to provide precision alignment and maximum stability while minimizing interferences with the flow to be measured. The total payload, including transmitting and receiving optics, suspended cables, and connecting arm, shall not exceed 30 kg.

Option 24: Upgrade of PDA system to smaller particles

The contractor shall extend the operational sizing range of the PDA system delivered under Option 23 down to 0.5 μm with the following accuracy: the indicated mean must be within 5% of the true mean and the indicated geometric standard deviation (gsd) must be within 10% of the true (gsd). The standoff distance requirements will be relaxed, if necessary, to 250 mm on the receiving side to accomplish this task. Multiple additional receiver (and possibly transmitting) probes and processor channels may be necessary. The contractor shall demonstrate compliance using monodisperse aerosols produced by a condensation generator in the size range between 0.5 and 5 μm following the procedures described by Göbel, Wriedt, and Bauckhage. A means of attaching the additional and/or modified optics to the traverse system in the human-exposure test section to permit measurements in the vicinity of the manikin (including immediately upwind) shall be provided. This mounting system shall be designed to provide precision alignment and maximum stability while minimizing interferences with the flow to be measured. The total additional payload for this option should be minimized and be compatible with the capabilities of the traverse system.

Acceptance Criteria for Options 23 and 24

Acceptance testing shall consist of demonstration by the contractor that the specifications listed have been met or exceeded.

Option 25: Micro-Orifice Uniform Deposit Impactor

The contractor shall deliver one Micro-Orifice Uniform Deposit Impactor suitable for collecting particles by inertial impaction in ten stages over an aerodynamic size range of 0.056 to 18 μm . Possible vendor: MSP Corp.

Option 26: Aerodynamic Particle Sizer

The contractor shall deliver a particle sizing device that measures the aerodynamic particle size of an aerosol by the principle of time-of-flight in an accelerating flow field and having at least 25 channels over the size range of 0.5 to 20 μm . Possible vendor: TSI.

Option 27: Second Aerodynamic Particle Sizer

The contractor shall deliver a second particle sizing device identical to the one delivered under Option 26.

Option 28: Scanning Mobility Particle Sizer

The contractor shall deliver a particle sizing device that measures the electrical mobility size distribution of aerosols over the diameter range of 0.01 to 1.0 μm with a resolution of at least 30 channels per decade at concentrations up to $10^7/\text{cm}^3$ and within one minute. Butanol vapors normally contained in the exhaust gas of the device shall be trapped by adsorbents, or collected, transported, and vented into the room's HVAC exhaust flow. Possible vendor: TSI.

Option 29: Second Scanning Mobility Particle Sizer

The contractor shall deliver a second particle sizing device identical to the one delivered under Option 28.

Option 30: Electrical Low Pressure Impactor

The contractor shall deliver one particle sizing device that measures the aerodynamic size distribution of an aerosol in real-time using the principle of inertial impaction with electronic detection over the size range of 0.03 to 10 μm .

Possible vendor: TSI.

Option 31: Optical Particle Counter

The contractor shall deliver one particle sizing device that measures diameter and concentration of an aerosol by the principle of light scattering. The device shall categorize the aerosol into at least 15 channels over the size range of 0.1 to 10 μm and shall accommodate concentrations of up to 10^4 particles/ cm^3 . Possible vendors: Particle Measuring Systems, Climeq, or Pacific Scientific Instruments.

Option 32: Scanning Fluorometer

The contractor shall deliver one synchronously scanning spectrofluorometer suitable for measuring the concentration of fluorescent dyes, including uranine, Rhodamine WT, Tinopal CBS-X, and Uvitex, which are used as tagging agents for aerosols. The instrument shall detect these dyes with a sensitivity of 1 ng (10^{-9} g) or better. Possible vendors: Photon Technology Intl. or SLM/Aminco/Horiba-SPEX.

Options 33-38: Additional generation system monitor(s)

Upon the exercise of each of these Options, the contractor shall supply one additional generation system monitor identical to the one delivered under the Base Contract.

Acceptance Criteria for Options 25-38

Acceptance testing shall consist of demonstration by the contractor that the specifications listed have been met or exceeded.

Option 39: High-volume isokinetic sampling system

The contractor shall provide a high-volume isokinetic sampler system suitable for use in the sampler test section. This system shall draw aerosol-laden air from the tunnel through a high-volume isokinetic sampling nozzle that shall be mounted on one of the test carts within the sampler test section of the AWTS. The aerosols are collected on a glass-fiber filter in a standard 8" x 10" filter cartridge at the downstream end of each nozzle. A converging funnel and tubing downstream of the filter directs the air stream to a flow controller, which permits accurate setting and monitoring of the flow rates through each nozzle/filter assembly. A positive-displacement meter shall permit totalizing of the flow through the system. A vacuum pump shall be provided to effect the sampling flow.

The high-volume sampler is to be used primarily to sample the tunnel air stream while evaluating various sampler-inlet designs to meet the requirements of the Code of Federal Regulations (40 CFR 53 Subpart D). Hence, nozzles to accommodate isokinetic sampling at wind speeds of 2, 8, and 24 km/hr are required. In addition, a further nozzle size shall be provided for isokinetic sampling at a wind speed of 48 km/hr. Table 7 summarizes the various nozzles required. Possible nozzle sizes and flow rates are provided in the table, but other combinations of sizes and flow rates could achieve isokinetic flow conditions and may be accepted for good reason, provided that flow rates are kept above 1,000 liters per minute. A suggested nozzle design is

provided in Figure 6. The nozzles shall be fabricated of 316 stainless steel and machined to interchange with standard 8" x 10" filter holders. Two of each size of nozzle shall be supplied.

Table 7. Nozzles for high-volume isokinetic sampler system

Wind speed (km/hr)	Nozzle dimensions (cm)	Flow rate (lpm)
2	15.2 x 22.2	1130
8	9.21 x 9.21	1130
24	5.4 x 5.4	1167
48	3.82 x 3.82	1167

The flow controller shall control and measure the flow through the nozzles with an accuracy of $\pm 2\%$ based on the actual flow rate. A timer (with start, stop, and reset capabilities) shall also be provided as well as a positive-displacement meter with pressure gage and temperature sensor for totalizing the flow through each line; this system shall provide an accuracy of $\pm 2\%$ based on the actual flow rate through the nozzle.

The contractor shall provide a test cart instrumented with this high-volume sampler system for the sampler test section; the nozzle shall be adjustable in height above the wind-tunnel floor (from 20 to 100 cm). The design of this nozzle/filter holder assembly, accompanying piping, etc., shall include due consideration for the aerodynamics of the flow and minimize flow disturbances.

A vacuum pump shall be provided with adequate capacity to draw the necessary isokinetic flow rates through the system; it shall be provided with acoustic silencer and/or placed inside the sound enclosure surrounding the fan so as to avoid noise levels anywhere within the laboratory in excess of 60 dBA. Valves for vacuum shut-off and vacuum-release (vent) shall be provided in the supply line between the pump and the control box.

Acceptance Criteria for Option 39

Acceptance testing shall consist of demonstration by the contractor that (1) the overall design of the system, including nozzle/filter holder assemblies, piping, etc., meets the stated requirements, (2) the flow meters and temperature and pressure sensors meet the stated requirements, (3) the vacuum pump is of adequate capacity to handle the highest flow requirements of the sampler system and meets the low-noise requirement. The contractor shall further demonstrate that the sampling system is leak-free by performing the following test: the system shall be set up as in a normal test using the 2 km/hr nozzle, except that the inlet of the nozzle shall be plugged. A vacuum of 45" H₂O shall be imposed on the system, then the vacuum shut-off valve shall be closed, and the vacuum monitored for a 5-minute period. If the leak rate is such that the vacuum changes by less than 1" H₂O, the system will be accepted; otherwise, the system will not be accepted.

SECTION 8. INTERNAL TRAVERSE SYSTEMS (Options 40-41)

Two independent internal traverse systems (or instrument carriages) are options, one for each test section. These traverse systems shall provide accurate, stable, and full three-dimensional positioning of measuring instruments in each test section, with remote control and readout of position. The control system shall be programmable to the extent that the carriages can step through sequences of positions, allowing measurements to be taken at each position. The positioning accuracy shall be ± 0.3 mm, with a resolution of 0.1 mm. The traverse system shall be capable of handling all the various payloads with the specified accuracy.

Each traverse system is envisioned as comprising three basic parts: (a) rails near the top of the sidewalls of the test sections which would support (and upon which would ride) (b) a cross-beam or bridge, which would, in turn, support (and upon which would ride) (c) a vertical member to support measuring instruments. Alternative designs will receive consideration. Various properties of the traverse systems are described below:

- Mechanical design features include a cross beam that extends across the entire width of each test section, is supported at the ends only, can move along the entire streamwise distance (x) of each (respective) test section. This cross beam is to be supported on rails located along the sidewalls approximately 1/3 of the distance from the ceiling to the floor of the respective test section.

- Vertical traverse member rides on the cross beam to provide crosswind positioning of the probe (y-direction) over the full width of the test section. The vertical traverse member itself permits uninterrupted movement of measuring probe in the vertical (z) direction over 2/3 of the height of the respective test section, with the ability to incrementally adjust the height of the member manually to obtain coverage over the entire height of the test section.
- Rigid and stable mechanical structure capable of carrying precision-measurement payloads with blockage of the cross-sectional area by the entire traverse system (including cables, trays, motors, and any and all other protuberances associated with the carriage) of less than 5%. As much as possible, all cables should be concealed from view and/or avoid obstruction of the flow and due consideration should be given to the aerodynamic performance of the traverse system as a whole (minimizing interferences with the flow being measured, avoiding flow-induced vibrations, etc.).
- High-resolution positioning (at least 0.1 mm) and accuracy better than ± 0.3 mm with all payloads over the full distance of travel for each axis. The payloads include the full weights of the probes, attachment contrivances, suspended portions of cables, etc., for the LDA, HWA, or the PDA.
- Speeds of motion are not critical, although an upper limit of 30 cm/s should likely be imposed as a safety factor. The system should be capable of accelerating and decelerating at such rates so as to avoid damage to sensitive measurement instruments such as hot-wire and pulsed-wire anemometers, laser-Doppler anemometers, and phase-Doppler anemometers. As a lower limit of speed, the carriage should be capable of moving the entire length of its travel in a maximum of thirty seconds.
- Computer controlled with programmable motions on all axes, allowing integration with flow- and particle-measurement software.
- High natural frequency to avoid flow-induced vibrations or resonance at all wind speeds.
- All parts of traverse system must be immune to malfunction due to aerosol deposition or routine cleaning. This might be accomplished by sealing the critical drive mechanisms, pressurizing the internal drive cavities, designs that are unaffected by aerosol loading, or other means.

Option 40: Traverse system for large test section

The contractor shall provide, deliver, and install a traverse system as described above for the human-exposure test section. He shall fully integrate the traverse system with flow- and particle-measurement systems via the LAN in the manner described in Section 10. He shall demonstrate the accuracy of the positioning system with payloads of zero and maximum through appropriate (independent) measurements and show that it meets the accuracy requirements specified above. He shall demonstrate its integration with the other software systems by successfully performing appropriate sets of interactive measurements.

Option 41: Traverse system for small test section

The contractor shall provide, deliver and install a traverse system as described above for the sampler test section. He shall fully integrate the traverse system with the flow- and particle-measurement systems via the LAN in the manner described in Section 10. He shall demonstrate the accuracy of the positioning system with payloads of zero and maximum through appropriate (independent) measurements and show that it meets the accuracy requirements specified above. He shall demonstrate its integration with the other software systems by successfully performing appropriate sets of interactive measurements.

Acceptance Criteria for Options 40 and 41

Acceptance testing shall consist of demonstration by the contractor that the specifications listed have been met or exceeded.

SECTION 9. MANIKINS (Options 42-46)

Manikins are needed for use in human exposure research. There are two options for acquiring basic manikins and two options for acquiring motorized manikins. The specifications for each option are described below. Possible vendors: Measurement Technology Northwest, Physical Sciences Inc., Finnish Institute of Occupational Health, or The Character Shop.

A fifth option in this section is for equipment used to simulate breathing for the child-sized manikin. Possible vendor: Michigan Instruments.

Option 42: Adult-sized manikin with body heat

Body articulation

- An adult-sized manikin of approximate height 5' 9" and articulated (not motorized) body parts including, but not limited to, joints at the neck, shoulders, elbows, wrists, hips, knees, and ankles.
- Although the manikin must have flexible motion in its joints, it must also have the capability to lock rigidly at each joint independently (resisting motion in wind speeds up to 2.2 m/s) once it has been positioned in any desired manner.
- The manikin shall contain a means of attachment to a base or stand. It is not intended to be free-standing.

Heating

- Total heating capacity up to 500 watts.
- Independent temperature control in at least 10 different zones, constituting the major body parts (upper and lower legs, upper and lower arms, torso, and head). Temperature control to $\pm 0.5^{\circ}\text{C}$ in each zone.
- Monitoring equipment shall quantify heat rates and temperatures in the zones.

Access to head cavity

- Physiologically correct mouth and nose cavities with attachment points to connect breathing tubes. These tubes shall be plumbed through the back of the body (through either the back of the head, neck, or torso) and will be connected to an existing ventilator/lung system.

Upon the exercise of Option 42, the contractor shall deliver one adult-sized manikin meeting the specifications given above. Acceptance criteria include verification of the above-listed features by inspection. The contractor shall demonstrate temperature control through appropriate measurements with surface-mounted thermocouples in each heating zone and document the findings in a written report to the Government.

Option 43: Child-sized manikin with body heat

The child-sized manikin shall have an approximate height of 2' 6" and the same articulation, heating, and access specifications as for adult manikin above, except that the required total heating capacity is 100 watts.

Upon the exercise of Option 43, the contractor shall deliver one child-sized manikin meeting the specifications provided above. Acceptance criteria include verification of the above-listed features by inspection. The contractor shall demonstrate temperature control through appropriate measurements with surface-mounted thermocouples in each heating zone and document the findings in a written report to the Government.

Option 44: Motorized adult-sized manikin

The contractor shall deliver an adult-sized manikin having motorized joints (including, but not limited to, joints of the hip, knee, ankle, shoulder, elbow, and wrist) and provide software to control the position, acceleration, and speed of each motorized joint so as to enable realistic low-to-moderate speed motion of its arms and legs. The software shall be capable of coordinating simultaneous multiple-joint movements into realistic human movements. The contractor shall deliver software routines that reproduce the motion of operating a vacuum cleaner and the motion of marching in place (although the manikin will still be supported so that balance is not an issue). It is acceptable that the hip and shoulder joints be simple one-axis joints (i.e., capable of movement in one plane only) and that the forearms and lower legs not have motorized rotation capability. The shoulder, elbow, hip, knee, and ankle joints shall each allow motion in planes that are perpendicular to a line passing through the shoulder joints. All motion shall be controllable via the LAN. So that the manikin's dimensions

and resulting aerodynamic effects are not altered, all motors and control structures shall be internal to the manikin's "skin". The manikin shall meet the heating and access to head cavity requirements listed in Option 42. Acceptance criteria consist of verification of the above-listed features by inspection and demonstration.

Option 45: Motorized child-sized manikin

The contractor shall deliver a motorized child-sized manikin so as to meet the same motorization and software requirements as Option 44, except that the delivered software routines shall reproduce the motion of crawling (the manikin will still be supported so that balance is not an issue). The manikin shall meet the head access requirements listed in Option 42 and the heating capacity required in Option 43. Acceptance criteria consist of verification of the above-listed features by inspection and demonstration.

Option 46: Breathing equipment for child-sized manikin

Ventilation equipment shall be provided to connect to the child-sized manikin to obtain realistic breathing patterns. Tidal volume shall range from 0.1 to 2.5 liters, with breathing rates from 20 to 40 breaths per minute, and I:E ratios (the ratio of the time of the inspiratory and the expiratory parts of the breathing cycle) from 1 to 5.

Upon the exercise of Option 46, the contractor shall deliver and install the equipment necessary to provide realistic breathing patterns for the child-sized manikin as described above. Acceptance testing shall consist of demonstration by the contractor that the specifications listed have been met or exceeded.

SECTION 10. LOCAL AREA NETWORK (LAN) FOR PROCESS CONTROL, DATA COMMUNICATIONS, AND DATA ACQUISITION (Base Contract and Options 47-49)

10.1 Overview

The Government's intent is to obtain a powerful and flexible process control and data acquisition/management system for the AWTS, yet one that is relatively easy to operate and upgrade for persons without extensive computer training. This Section mainly contains specifications and clarifications as to the performance and components of the LAN that are to be delivered under those options that are exercised; however, it also has several options to acquire additional computers for the LAN. Conceptual system diagrams are shown in Figures 7 and 8.

- All sensors, systems, and controls shall be fully accessible via a 10/100 Base-T Dual Speed Hub. This hub shall allow both 10 and 100 Base-T nodes to operate at their maximum data rate.
- Human access to the data shall be accomplished via browser-based or graphical software technology. Exceptions may be allowed if they can be shown to be suitable for the overall objective of the AWTS LAN.
- All controls, measurements, and data sets shall be accessible at any node within the laboratory's LAN.
- Equipment that does not have compatible input and output (I/O) hardware and/or software must be supplied with a server or similar device that will provide the required connectivity. For example, an array of pressure sensors or thermocouples would require a host containing both a data acquisition subsystem and the necessary LAN hardware. A further example would be equipment using older or non-standard data communication interfaces such as RS-232-C, RS-485, IEEE-488, DMX-512, etc. Such devices require a host containing both the necessary hardware and driver software and the required LAN hardware.
- Some systems in the AWTS will require tightly coupled, real-time or near-real-time levels of throughput and performance (e.g., hot-wire anemometry, LDA, PIV, PDA). These must be integrated into the LAN using appropriate interfaces. However, the controls, outputs, and sensor data must be LAN accessible.

- The system must include a method of setting the time bases of attached components to a common clock, so that system-wide data integrity may be maintained. Timebase synchronicity must be maintained to one millisecond referenced to the control room computer's clock over the course of twelve hours. It is believed that this level of synchronicity is possible using LAN technology, however, the use of a separate synchronization bus is not excluded.

- Any device added to the LAN under any option shall have appropriate hardware and software installed for proper operation on the LAN.

- All operating parameters and measurement techniques must be designed to allow quality assurance (QA) of data produced (including traceability of standards).

- The AWTS LAN is to be viewed as a stand-alone isolated network. Security is not an issue and should not be considered in this planning. The AWTS LAN may be connected to EPA's office LAN in the future.

We anticipate that commercially available software such as LabVIEW (National Instr.) or a comparable product will be used to provide basic control and data acquisition functions for the LAN. The contractor shall provide software components in the installed system having the following functionality:

- Scheduling the operating sequence of system components.
- Monitoring safe operation of the fan and the tunnel's temperature and humidity.
- Selecting which sensors and instruments are to be logged.
- Maintaining the system's time-base synchronization.
- Providing an interface to powerful graphical and analytical software.
- Allow the introduction of user-written components, macros, etc., for data acquisition and analysis.
- Organize and archive the acquired data for permanent storage and later retrieval and use.

Source code (including documentation) of programs developed for the AWTS shall be supplied when the device or software is delivered. This includes any patches and microprocessor codes required to integrate third party instruments (such as aerosol analyzers) into the AWTS LAN. A list of all software tools required for future maintenance and modifications shall be provided. A detailed description of all file formats and headers used to store raw and intermediate data produced by the AWTS instruments shall also be delivered.

All commercial software supplied with the AWTS LAN, including operating systems, network software, office suites, control and data acquisition packages, data analysis programs, libraries, and compilers and other system software, shall be among the leading software of its type, so as to maximize the future availability of experienced programmers, technical support, and continued development.

10.2 Core LAN

Under the Base Contract it is required that certain key components of the LAN be supplied. These items, both hardware and software, are referred to as the "Core LAN". The Core LAN shall include, at a minimum, the following components and functionality:

- The fan's controller(s) and associated sensors. The fan is expected to run in a controlled velocity mode using a sonic anemometer to constantly monitor the mean air speed in the sampler test section and various pressure sensors at some points in the tunnel circuit. The control system will:

- ? Accept the operational set point
- ? Set the appropriate fan pitch
- ? Servo the fan speed to achieve the desired wind speed
- ? Limit or shut off the fan if certain pressure safety limits are exceeded

- The tunnel's internal temperature and humidity are to be maintained to close tolerances. This requires that an array of hygrometers and thermometers must be monitored and the system's air conditioner and humidifier controlled. If a separate process controller is used for these tasks, the LAN shall monitor conditions and alert

the operator if a control problem exists.

- One well-equipped workstation-class Windows computer to be located in the control room. Currently, such a computer would include a Pentium 4 processor operating at 2.0 GHz, 400 MHz system bus, 1024 MB of RDRAM memory, either ATA/100 or ULTRA 160/M hard drive controller, two hard drives each of >40 GB capacity, CD- RW drive, 250 MB Zip drive, network interface card, at least two empty expansion bays, at least 3 empty PCI slots, 21" monitor, mouse, keyboard, Windows NT 4.0 operating system, uninterruptible power supply, a 15 page per minute black & white laser printer (Bluetooth enabled, if available), and a color laser printer (Bluetooth enabled, if available).
- A software system for process control and data acquisition/management, including the specific modules that may be added by the contractor to control the tunnel's fan, temperature, and relative humidity.
- A 10/100 Base-T Dual Speed Hub with all connections made using Category 5 cable (shielded if necessary to achieve maximum speed and reliability). The hub shall have eight ports more than the maximum needed if all contract options are exercised. The contractor shall install cable trays to elevate and protect all LAN cable runs around the wind tunnel and to the control room.
- A server for the video monitoring equipment. This server will be located in the control room along with appropriate analog video processors and live displays for the surveillance camera feeds. All camera and camera platform control must be accessible via the LAN as well as by a dedicated control panel in the control room.

10.3 Additions to the LAN

As options are exercised, additional nodes may be added to the LAN by connection to the hub. Many of the contract options will deliver devices that have dedicated computers as an integral part of their design. The contractor shall connect these computers to the LAN so that all control and data acquisition can be done by the LAN. Other devices delivered under the various options may require only connection to an existing server already on the LAN. In every case, however, additional software shall be provided by the contractor so that the addition is fully functional via the LAN.

Some specific items that may be added include:

- Two well-equipped workstation-class Windows computers to be located at the test sections (see Options 47 and 48).
- One wireless networked laptop computer to be used at various locations in and around the wind tunnel (see Option 49).
- Aerosol generation apparatus: If the associated automation option is exercised, all operating parameters and set points of an aerosol generation option shall be monitored as often as necessary to maintain proper generation, with data logged for subsequent analysis and quality assurance.
- Flow measurement instruments: All anemometer probes and any internal or external traverses shall operate autonomously once set up and as a tightly integrated unit.
- Aerosol measurement instrumentation: Output from the aerosol measurement systems will be monitored by the LAN at the normal intervals for each device, with data logged for subsequent analysis and quality assurance.
- Manikins: Temperature and input power to the various zones shall be logged. If motorization options are exercised, the joints shall be individually controllable via the LAN.

Option 47: A workstation for the large test section

The contractor shall provide one well-equipped workstation-class Windows computer to be located at the large test section. Currently, such a computer would include a Pentium 4 processor operating at 2.0 GHz, 400 MHz system bus, 1024 MB of RDRAM memory, either ATA/100 or ULTRA 160/M hard drive controller, two hard drives each of >40 GB capacity, CD-RW drive, 250 MB Zip drive, network interface card, at least two empty expansion bays, at least 3 empty PCI slots, 21" monitor, mouse, keyboard, Windows NT 4.0 operating system, uninterruptible power supply, and a professional quality and speed color ink-jet printer (Bluetooth enabled, if available). This computer shall be built to industrial standards and housed in a suitable instrument rack. This computer shall include an attached work surface.

Option 48: A workstation for the small test section

The contractor shall provide one well-equipped workstation-class Windows computer to be located at the small test section. Currently, such a computer would include a Pentium 4 processor operating at 2.0 GHz, 400 MHz system bus, 1024 MB of RDRAM memory, either ATA/100 or ULTRA 160/M hard drive controller, two hard drives each of >40 GB capacity, CD-RW drive, 250 MB Zip drive, network interface card, at least two empty expansion bays, at least 3 empty PCI slots, 21" monitor, mouse, keyboard, Windows NT 4.0 operating system, uninterruptible power supply, and an 8 page per minute (or greater) black & white laser printer (Bluetooth enabled, if available). This computer shall be built to industrial standards and housed in a suitable instrument rack. This computer shall include an attached work surface.

Option 49: A wireless laptop computer

The contractor shall provide one well-equipped wireless networked laptop computer, including the associated wireless base station that is physically connected to the LAN. Currently, such a computer would include a Pentium III processor operating at 1.266 GHz, 15" TFT display, 1024 MB memory, hard drive of >40 GB capacity, CD-RW drive, wireless network interface card, lithium-ion battery (with one spare), Windows operating system, and a portable ink-jet printer (Bluetooth enabled, if available).

SECTION 11. BASIC SAFETY REQUIREMENTS

All system components, assemblies, and subcomponents shall comply with all applicable safety and health regulations. A safety interlock must be provided to prevent operation of the fan if the fan access door is open. A safety interlock is required on Cartridge Filter II to prevent the fan's operation at higher speeds when this filter is in place, i.e., speeds that would result in pressure drops exceeding the maximum allowable. Safety interlocks on the other filters should prevent or limit fan operation when their pressure drops exceed their respective allowable limits.

Because the tunnel's inside surfaces may become coated with oily or watery liquids and with aerosols, they may become quite slippery and falls may be likely. Because of this, sharp edges, particularly on the interior of the tunnel, must be avoided.

Access doors in the tunnel must permit opening from the inside to avoid personnel being locked inside.

Honeycombs shall be protected by coarse wire-mesh screens on both sides. In addition, a coarse wire-mesh screen shall be located just upstream of the fan to prevent loose debris from entering the fan.

SECTION 12. LASER SAFETY REQUIREMENTS

12.1 General laser safety requirements

Use of both continuous wave and pulsed lasers is anticipated in both test sections, so that laser-safety protections are essential. All lasers, laser products, and laser systems installed under this contract shall comply fully with the most current version of the following standards:

- ANSI Z136.1, "Standard for the Safe Use of Lasers"

- NFPA 115, "Laser Fire Protection"
- 21 CFR 1040.10 & 1040.11, "Federal Laser Products, Performance Standards"

In the case of any conflict among the above standards on any point, the contractor shall follow the more or most stringent of them on that point.

The Government will inspect the safety aspects of each laser installation to ensure compliance with these standards. The contractor shall make appropriate modifications, adjustments, or response to the resulting comments and suggestions. After written acceptance of a laser installation's safety system, a one-year warranty period shall commence to ensure the durability of the laser safety system. During this one-year period, any faults that cause the system to fail to comply with these standards shall be corrected by the contractor at no expense to the Government.

The contractor shall provide enclosures to contain any direct or stray light from the laser operations (LDA, PIV, or PDA measurements - see Sections 6 and 7). Numerous windows are necessary in the sidewalls and ceilings of both test sections to provide visual access to the tunnel, e.g., for aligning instruments, for siting measurement positions, for introducing the light sheets for PIV measurements, and for photography. A 5-watt argon-ion continuous wave laser is anticipated for LDA and PDA measurements, and a dual Nd-YAG pulsed laser producing at least 200 mJ of energy per pulse (or, possibly, a continuous laser) is anticipated for PIV measurements. A commercial product such as Kentek Corp.'s "Ever-Guard" may be suitable for such enclosures.

The nominal hazard zone will consist of the areas adjacent to the test sections. The region will be bounded on one side by the back window of the test section (backed by a laser safety curtain) and on three sides by a laser safety curtain (which will form a rectangle with the front wall of the test section). The lengths of the regions are defined by the lengths of the test sections (one 9 m, the other 6 m). The horizontal width coming away from the test section shall be 3 m. The heights of the regions must exceed the heights of the tops of each test section's side windows by approximately two feet and the height of the roll-up door, if the nominal hazard zone is located in close proximity to the door. (The reason for the curtain to exceed this height is to prevent the curtain support structure from interfering with access through the door.) These curtains shall be retractable to clear the floor area for moving equipment through this space and to permit free access when lasers are not being used. Additional curtains about two feet high located on top of the tunnel at the ends of both test sections will stop laser light that might escape down the length of the tunnel during times when the laser is located on top of the tunnel. Due consideration shall be given to avoiding the possibility of laser light reflecting from the ceiling of the laboratory or other high structures such as room lights, ducts, wiring, or conduit that might be located near the ceiling.

All section numbers mentioned in this paragraph refer to ANSI Z136.1-1993, "American National Standard for Safe Use of Lasers." The curtains shall contain the hazard zone such that the area outside the curtained area will not be a laser hazard area. The curtain shall be equipped with defeatable entryway safety controls as discussed in Section 5.3.10.2. These safety controls shall include two panic buttons, one inside and one outside the enclosure. These panic buttons shall permit deactivation of the laser when pressed. The nominal hazard zone shall have laser warning signs sufficient for a Class IV laser area and warning lights that are activated when the laser is operating (following the guidelines of Section 5.7). The curtain shall have several small (1 ft² is sufficient) viewing portals made from a material with properties capable of maintaining the laser radiation (from either laser) below the maximum permissible exposure (as defined in section 8) outside of the curtained area. These viewing portals shall not interfere with the curtains' ability to retract.

12.2 Laser Safety Training

The contractor shall provide on-site training for laboratory personnel on the use of the laser safety systems for laboratory personnel after the systems have been installed. In addition, the contractor shall develop and provide laser safety training materials (videotapes and printed material) for future training of personnel.

SECTION 13. QUALITY CONTROL AND QUALITY ASSURANCE

All operating parameters, programming, measurement approaches, and devices shall be designed to allow effective and efficient quality control (QC) and quality assurance (QA) of data produced (including traceability of standards).

SECTION 14. GENERAL PROVISIONS

Aerosol Generators

All aerosol generators delivered under the Base Contract and any elected Options shall be safe for the operators and listed with either UL, CSA, or CE. They must operate on 120 or 208 volt, 60 Hz AC power and run for a minimum of eight hours without attention. Any generator producing static charged aerosols that exceed the capabilities of the static charge elimination system delivered under the Base Contract shall include augmentation of that static elimination system so that the resulting aerosol charge distribution is reduced as nearly as possible to that of a Boltzmann charge distribution at least by the time the aerosol enters the mainstream flow of the wind tunnel.

Aerosol Sizing Devices

All aerosol sizing devices delivered under the Base Contract and any elected Options shall be safe for the operators and listed with either UL, CSA, or CE. They must operate on 120 or 208 volt, 60 Hz AC power. Every instrument shall be delivered as a complete unit including any vacuum pumps, controlling or display computers, detectors, and other devices necessary to operate the instrument as intended by its manufacturer. All operating controls and timing functions of the real-time instruments shall be controlled by the LAN. All data outputs shall be acquired, stored, and displayed on command by the LAN.