RFQ 0006-2023 Inline Air Heating System and Expand Operation of FAMU-FSU Polysonic Wind Tunnel

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The Florida A& M University and Florida State University (FAMU-FSU) polysonic wind tunnel (PSWT, Fig. 1) was established with funding from National Science Foundation and the Florida Centre for Advanced Aero-Propulsion (FCAAP), to study experimental aerodynamics and develop advanced flow diagnostics. The PSWT, with a large Mach number range (0.2 to 5), 12-in x 12-in square test-section and advanced diagnostics has created a unique, shared resource to a) advance key fundamental sciences for the development of flight vehicles; b) develop transformational experimental aerodynamics and flow control technologies; c) translate them to large scale test facilities and applications; d) generate a high-fidelity aerodynamic database for the validation of numerical simulations; and e) attract, educate, and help retain a diverse pool of URM engineers and scientists. This facility is serving as an essential research and education tool because it: i) allows the study of fluid/aerodynamics over a range of flow conditions such as Mach number and Reynolds numbers, in practical configurations and subsystems; ii) permits detailed study of fundamental thermal-fluid physics over a range of scales and complexities; iii) facilitates the development of advanced diagnostics; and iv) serves as a shared resource for universities, research organizations, government laboratories, and industry.

Although the facility is designed to operate at a Mach number range of 0.2 to 5, the temperature of the air in the test section goes down significantly due to flow expansion at high supersonic Mach numbers. This limits our blowdown time and affects the Reynolds number during the tests. At Mach 5, we even get liquefaction of oxygen. Installation of a thermal matrix in the air storage tanks and a conventional inline electrical resistive heater is not a solution as the power requirement will be enormous (about 2 Megawatt), so what we need is an inline air heating system, which will be heat charged before the test and drained during the blowdown. In addition, we would like to explore the possibility of expanding the Mach number range of PSWT to Mach 6.

This document provides a description of FAMU-FSU polysonic wind tunnel, proposed upgrades including design, fabrication, installation and commissioning requirements. The document also lists a tentative time schedule and the scope of supply.

The design should include but not be limited to the following unique features and capabilities:

Simple, low-cost operation: The proposed design should yield high-quality data for a modest annual operating budget.
Minimum staffing and overhead costs: The apparatus should allow completion of experiments with very few support personnel, minimizing operational costs. This is critical to the facility’s continued use and long-term sustainability.
Flexible testing capability: The facility is designed to accommodate multiple test configurations and the wide range of operating Mach numbers required for different applications. We must have the option of using or bypassing the inline heating system.

Figure 1 – FAMU-FSU polysonic wind tunnel capable of operation from Mach 0.2 to 5

Description of the Polysonic Wind Tunnel

The PSWT has a 12-in x 12-in cross-section, capable of operating in the Mach number regime of 0.2 to 5 including transonic speeds. The facility produces a unit Reynolds number of 30 million/ft. The facility features two separate test sections: 1) 12-in x 12-in x 24-in test section with solid walls for sub/supersonic Mach number testing, and 2) 12-in x 12-in x 48-in with slotted walls for testing in the transonic speed regime. The facility is connected to a high-pressure storage system of $110m^3$ of dry air at 500psia pressure. We are in process of increasing the air storage capacity by 30%. Typical run times are 30 - 100 seconds depending upon the test conditions.

The wind tunnel contains two 12 inch shut-off valves that isolate the wind tunnel and ejector systems from the high-pressure air supply. The flow through the wind tunnel is controlled by a pressure regulator valve. Flow proceeds through a wide-angle diffuser and baffles into the settling chamber. The settling chamber conditions the flow before the 10:1 contraction and interchangeable nozzles. Downstream of the nozzles is either the solid wall or slotted wall test section, depending on the desired test conditions. After the test section is the model cart, choke system, and movable diffuser. The movable diffuser slides within the fixed diffuser to allow the airline to be opened for model access and tunnel reconfiguration. An ejector system is located in the fixed diffuser, and downstream of this are baffles and the exhaust stack.

The facility is designed to operate at various Reynolds numbers at a fixed Mach number with the help of varying stagnation pressure and an ejector system. The facility has been calibrated over the entire operational regime and exhibits excellent flow quality. The rms pressure fluctuations at supersonic speed are less than 0.2%, turbulence intensity less than 0.2%, and flow angularity over the entire measurement section is less than 0.2°, respectively. The test model can be mounted in the centerline pitch system capable of the angle of attack range -10° to +12° and roll angle variation between 0 - 360°, or any sidewall of the tunnel. All four sidewalls of the tunnel have optical windows for flow visualization and diagnostic studies. The wind tunnel has required instrumentation and flow diagnostic capabilities. The facility is equipped to carry out shadowgraph, surface oil flow visualizations, steady and unsteady pressures, aerodynamic forces and moments, and flow diagnostic measurements.

The major components of the PSWT are described below:

High-pressure air supply system: The FSU-FCAAP polysonic wind tunnel requires multiple upstream components to enable the amount and quality of air required for testing on-demand. Three 250hp compressors are maintained on-site to provide the necessary compressed air. During operations, two compressors are used simultaneously, while the third compressor is idle. The three-compressor configuration allows redundancy in case of a compressor failure as well as keeping the wear rates down by being able to switch between compressor pairs.

Figure 2 – High-pressure air supply system including compressors (left), dryers (middle), and storage tanks (right)

Downstream of the compressors are wet tanks that feed into two heatless desiccant dryers. Only one dryer is operational at a time, therefore again allowing redundancy for continuing operations. After drying, the air is stored in six 5000 gallon storage tanks at 500 psi that is piped such that the majority of the tanks can be individually isolated from the system and so that the incoming and exiting air can be maximally evenly distributed. On a blowdown event, the air is allowed to exit the storage tank system through two converging 12-in diameter pipes leading to the PSWT pipe system.

Pressure Regulator Valve: The pressure regulator valve (PRV) is responsible for controlling stagnation pressure in the settling chamber. The valve is a Fisher V260 equipped with an Aerodome attenuator for noise reduction. The valve is hydraulically actuated and commanded with feedforward and feedback control to achieve tunnel start in under five seconds and stagnation pressure control better than 0.25%. The feed-forward control makes use of a precise in-situ valve characterization. The PRV is shown upstream of the wide-angle diffuser and settling chamber in Figure 3.

Settling Chamber: The settling chamber is situated between the wide-angle diffuser and contraction. The upstream portion of the chamber contains acoustic baffles for noise reduction. The downstream portion contains five screens and a honeycomb flow straightener to reduce turbulence, flow angularity, and nonuniformity to a minimum. Pitot pressure and total temperature are measured downstream of the last screen before the contraction, and there are extra flanges at this location to allow access to additional equipment such as a seeder for PIV techniques. The downstream end of the settling chamber includes the round-to-rectangular contraction, as well as the primary axial support legs of the airline.

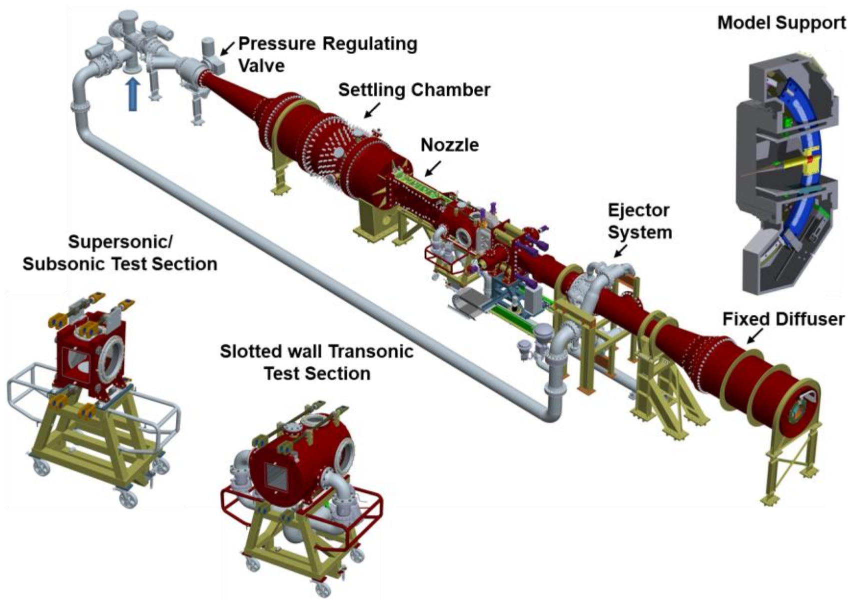

Figure 3 – Polysonic wind tunnel and its major subsystems (components)

Interchangeable Nozzles The polysonic wind tunnel has six sets of nozzle blocks that allow configuration for subsonic/transonic, Mach 1.6, 2, 3, 4, and 5 operations. In the future, additional sets of nozzle blocks may be added to enable other supersonic Mach numbers. Nozzle blocks are mounted between flat-wall side plates using pins and high-tension bolts. Two sets of sidewalls are available, enabling one nozzle set to be re-configured while the other is in use. Interchanging nozzles takes about 30 minutes, and re-building a nozzle set from one Mach configuration to another is done in about two hours. The nozzle components were fabricated out of high-strength carbon steel and treated with a surface hardening and corrosion resistance process known as "Nitreg Oxy-Nitro-Carburization" (ONC).

Solid Wall Test Section: The 12-in by 12-in by 24-in Sub/Supersonic test section is designed for maximum optical access. The sidewall windows are large, with a clear diameter of 14-in, which allows a viewer to sight across the test section floor or ceiling. With this diameter a seven-inch length of the floor or ceiling edge is visible. Due to the size of the side windows, the top window in the ceiling will be smaller. Two sets of windows, as well as a solid blank, are available for each side and the top of the test section. One set of windows are made from optical quality glass suitable for Schlieren photography. The test section is aligned with the nozzle upstream and the model cart downstream by pins. The ONC surface finish gives a flat black finish with low reflectance that will be better than a shiny surface (such as stainless steel) for optical flow diagnostic techniques.

Transonic Test Section: The transonic test section is typically used for Mach numbers between 0.6 and 1.2. The test section airline is 12-in wide by 12-in tall by 48-in long, with slotted sidewalls, floor, and ceiling. The slotted wall test section sits within a plenum that contains an acoustically treated interior surface to eliminate the acoustic resonance common to transonic wind tunnels. The external pressure shell has three windows for viewing the model which is interchangeable with the windows for the sub/supersonic test section. The transonic test section is designed to be readily interchanged with the sub/supersonic test section. Alignment and sealing of the transonic test section are accomplished using pins and hydraulic actuators in the same way as for the solid wall test section. When in use, the transonic test section attaches to a blow-off pipe using a quick disconnecting flange. Two six-inch valves control plenum suction to control Mach number. An ejector in the blow-off pipe is used to produce adequate suction for test cases with low plenum static pressure. The slats are bolted to four portal frames forming an assembly that is supported on rollers and rails within the test section plenum. The second set of side walls is available that includes large, rectangular windows made from optical quality glass suitable for Schlieren photography. These windows overlap the floor and ceiling for a clear view across the floor or ceiling. The slats and portal frame components are made of high-strength steel that is finished with ONC treatment.

Model Cart: The model cart is directly downstream of the test section and houses the sting model mounting mechanism. Pitch is set by the sector so that the pitch center is at the centroid of the solid-wall test section. Model roll attitude is set by the rolling mechanism housed in the middle of the pitch sector. The rear sting mount and pitch sector is designed to withstand up to 400 lb vertical and 200 lb lateral loads at the pitch center. The airline shape of the model cart is adjustable by setting the position of flaps on the top and bottom walls. This feature allows the model cart to mate to the solid wall test section as well as the slotted-wall transonic test section. When connected to the slotted wall test section, the inlet height of the model cart airline is increased to encourage some entrainment flow from the transonic plenum. The spaces in the model cart above and below the airline are available to house instrumentation. There are multiple pressure ports and cable gland pressure shell pass-through points, as well as a patch panel for additional electrical connections. There is access through the pitch sector to both spaces to communicate with the test article. The model cart is mounted to the choke and movable diffuser sections as a cantilever. The three components move together along rails along the tunnel axis direction to break the airline and allow test sections and nozzle block sets to be interchanged. This also allows easy access to the test article.

Main Ejectors: The main ejectors are located in the fixed diffuser upstream of the exhaust baffle. The main ejector system is used to lower the static pressure in the test section during high Mach number runs, which allows for a lower blowing pressure threshold to achieve the tunnel start. This is the primary method for reducing starting loads at Mach numbers of three or higher in the PSWT. The main ejectors are supplied by the same air storage system as the wind tunnel.

Proposed Design and Supply

The successful vendor has to provide a detailed design of the inline heating system capable of operation up to Mach 6 and a preliminary design of components needed to expand the operation of PSWT to Mach 6. Discrete Work Packages as shown in Table 1. The Final Design shall be based on the results of the concept design study and delivered in the form of build packages. The work packages should contain drawings, calculations and specifications of each component and subsystem. Since the upgrades are jointly handled by the FAMU-FSU team and awarded vendor, the specific responsibilities are listed in Table 1.

Table 1: Work Packages & Responsibilities

WP Item	Description	Responsibility
1.0	Mechanical Design of inline heating system	1. Awarded vendor must provide mechanical design of various components 2. Awarded vendor must provide foundation loads (if any) for the design of the floor in and out of wind tunnel room. FAMU-FSU will be responsible for the civil works related to foundation
2.0	Preliminary assessment of existing PSWT subsystems and design modifications required for Mach 6 operation.	Vendor to perform preliminary assessment of existing PSWT subsystems if those are suitable for Mach 6 operation such as pressure loads, expansion/contraction due to temperature changes. Vendor to suggest modifications required and approximate cost to operate at Mach 6.
3.0	Overall Assemblies	Awarded vendor has to provide drawings
4.0	Air Delivery System	FAMU-FSU will be overall responsible for air delivery system.
5.0	Procurement of various components of inline heating system	FAMU-FSU will procure various components as suggested by Vendor in the bill of materials. Vendor to suggest OEM suppliers or their distributors in the US.
6.0	Piping and control valves, cables and connectors	Vendor to specify piping, control valves, cables and connectors in bill of materials. FAMU-FSU will procure these components.
7.0	Control System Upgrade	Vendor to upgrade the PSWT control system to integrate inline heating system
8.0	Data Acquisition System Upgrade	FAMU-FSU will make necessary upgrades in consultation with the vendor
9.0	Installation & Commissioning	Vendor will be responsible for installing & commissioning inline heating system.
10.0	Project Management	Project management will be jointly carried out by FAMU-FSU and Vendor team.

Evaluation of the Proposals

Vendors are requested to submit their best offer. The proposals will be evaluated by a committee of FCAAP researchers. The evaluation committee will decide based on the following in order of importance: adherence to technical specifications, past experience, and cost. Available budget for this project will also be a deciding factor.

If we are able to reach a contract with the lowest bidder, negotiations with other short listed firms will not take place. If FCAAP elects to negotiate concurrently, with two or more proposers, then following the negotiation period, companies with whom negotiations have progressed satisfactorily will be asked to submit a Best and Final Offer. After evaluation of the Best and Final Offer(s) then it will be followed by contract award.

The Evaluation Committee will evaluate and provide a consensus opinion of all initial responses. The responses most closely aligned with the preferred requirements will be asked to participate in negotiations. After all negotiations are complete, the Evaluation Committee will make an award to the respondent whose response best meets the needs of FCAAP.

As the best interests of the FCAAP indicate, after initial written responses have been evaluated, the following negotiation process will be utilized:

The committee will short list based on the following in order of importance:

- Adherence to Technical Specifications
- Past Experience
- Cost

Price Structure
Vendors are requested to provide a written price proposal, with the following price break down:

1. Detail design and drawings of inline heating system
2. Preliminary design of PSWT upgrade for Mach 6 operation
3. Installation & commissioning cost including control system upgrade