AFRL-AFOSR-VA-TR-2019-0020

Improving Optical Access for the Mach-6 Quiet-Flow Ludwieg Tube

Steven Schneider
PURDUE UNIVERSITY

10/22/2018
Final Report

Air Force Research Laboratory
AF Office Of Scientific Research (AFOSR)/ RTA1
Arlington, Virginia 22203
Air Force Materiel Command

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
19-10-2018	Final Report	30 Sep. 2017-29 Sep. 2018

4. TITLE AND SUBTITLE
Improving Optical Access for the Mach-6 Quiet-Flow Ludwieg Tube

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-17-1-0416

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Steven P. Schneider

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Purdue University
Aerospace Sciences Lab
1375 Aviation Drive
West Lafayette, IN 47907

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Office of Scientific Research

10. SPONSOR/MONITOR'S ACRONYM(S)
AFOSR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This grant funded procurement of (1) a second 7x14-inch rectangular window, similar to the first one, using an existing extra plexiglas window insert, and (2) a second porthole window assembly for the 7x14-inch opening, with a pair of 5-inch conformal plexiglas windows. The two windows were received in March 2018. Initial attempts at testing the windows showed some slight mistakes in the construction that prevented full installation into the BAM6QT. It should be possible to correct the problems in house, using the department machine shop. Once the issues are fixed, the windows will be pressure-tested and then be available for use in the BAM6QT.

15. SUBJECT TERMS
hypersonic wind tunnels, laminar turbulent transition, quiet flow

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Steven P Schneider
U	U	U	unlimited	3	19b. TELEPHONE NUMBER *(Include area code)* 765-494-3343

Reset

INSTRUCTIONS FOR COMPLETING SF 298

1. REPORT DATE. Full publication date, including day, month, if available. Must cite at least the year and be Year 2000 compliant, e.g. 30-06-1998; xx-06-1998; xx-xx-1998.

2. REPORT TYPE. State the type of report, such as final, technical, interim, memorandum, master's thesis, progress, quarterly, research, special, group study, etc.

3. DATES COVERED. Indicate the time during which the work was performed and the report was written, e.g., Jun 1997 - Jun 1998; 1-10 Jun 1996; May - Nov 1998; Nov 1998.

4. TITLE. Enter title and subtitle with volume number and part number, if applicable. On classified documents, enter the title classification in parentheses.

5a. CONTRACT NUMBER. Enter all contract numbers as they appear in the report, e.g. F33615-86-C-5169.

5b. GRANT NUMBER. Enter all grant numbers as they appear in the report, e.g. AFOSR-82-1234.

5c. PROGRAM ELEMENT NUMBER. Enter all program element numbers as they appear in the report, e.g. 61101A.

5d. PROJECT NUMBER. Enter all project numbers as they appear in the report, e.g. 1F665702D1257; ILIR.

5e. TASK NUMBER. Enter all task numbers as they appear in the report, e.g. 05; RF0330201; T4112.

5f. WORK UNIT NUMBER. Enter all work unit numbers as they appear in the report, e.g. 001; AFAPL30480105.

6. AUTHOR(S). Enter name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. The form of entry is the last name, first name, middle initial, and additional qualifiers separated by commas, e.g. Smith, Richard, J, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES). Self-explanatory.

8. PERFORMING ORGANIZATION REPORT NUMBER. Enter all unique alphanumeric report numbers assigned by the performing organization, e.g. BRL-1234; AFWL-TR-85-4017-Vol-21-PT-2.

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES). Enter the name and address of the organization(s) financially responsible for and monitoring the work.

10. SPONSOR/MONITOR'S ACRONYM(S). Enter, if available, e.g. BRL, ARDEC, NADC.

11. SPONSOR/MONITOR'S REPORT NUMBER(S). Enter report number as assigned by the sponsoring/ monitoring agency, if available, e.g. BRL-TR-829; -215.

12. DISTRIBUTION/AVAILABILITY STATEMENT. Use agency-mandated availability statements to indicate the public availability or distribution limitations of the report. If additional limitations/ restrictions or special markings are indicated, follow agency authorization procedures, e.g. RD/FRD, PROPIN, ITAR, etc. Include copyright information.

13. SUPPLEMENTARY NOTES. Enter information not included elsewhere such as: prepared in cooperation with; translation of; report supersedes; old edition number, etc.

14. ABSTRACT. A brief (approximately 200 words) factual summary of the most significant information.

15. SUBJECT TERMS. Key words or phrases identifying major concepts in the report.

16. SECURITY CLASSIFICATION. Enter security classification in accordance with security classification regulations, e.g. U, C, S, etc. If this form contains classified information, stamp classification level on the top and bottom of this page.

17. LIMITATION OF ABSTRACT. This block must be completed to assign a distribution limitation to the abstract. Enter UU (Unclassified Unlimited) or SAR (Same as Report). An entry in this block is necessary if the abstract is to be limited.

Final Report for AFOSR DURIP Grant FA9550-17-1-0416

Improving Optical Access for the Mach-6 Quiet Flow Ludwieg Tube

Steven P. Schneider, Gregory McKiernan and Elizabeth Benitez

Purdue University, School of Aeronautics and Astronautics

tel 765-494-3343, steves@purdue.edu

19 October 2018 Revision 2

Introduction

This is a brief final report for the subject equipment grant. This grant funded procurement of (1) a second 7x14-inch rectangular window, similar to the first one, using an existing extra plexiglas window insert, and (2) a second porthole window assembly for the 7x14-inch opening, with a pair of 5-inch conformal plexiglas windows.

This grant was awarded 30 Sept. 2017 for $59.3K. Since TriModels built the existing 7x14-inch rectangular window, and the existing porthole window assembly, and since TriModels has a good reputation, a sole-source purchase order to TriModels for the new hardware was placed in late October 2017. The old extra 7x14-inch plexiglas window insert was shipped to TriModels, who assembled it into a new casing. Some minor issues with the exact dimensions of the old and new windows were resolved during TriModels design and build process. The new windows are nominally identical to the old ones, so they are interchangeable. The two new window assemblies were delivered the first week of March 2018. They were unloaded from their crates and stored in a labeled drawer. Due to tunnel scheduling and other obligations the spare windows were not immediately fit and pressure tested. Additionally, the student who helped with this project was at JHU-APL on an internship during the summer. Due to this, the initial measurements and fit-testing were not completed until October. A critical need for the windows has not yet arisen but many uses are expected.

7x14-inch Rectangular Window:

A schematic of the window is shown below in order to clarify the discussion's terminology.

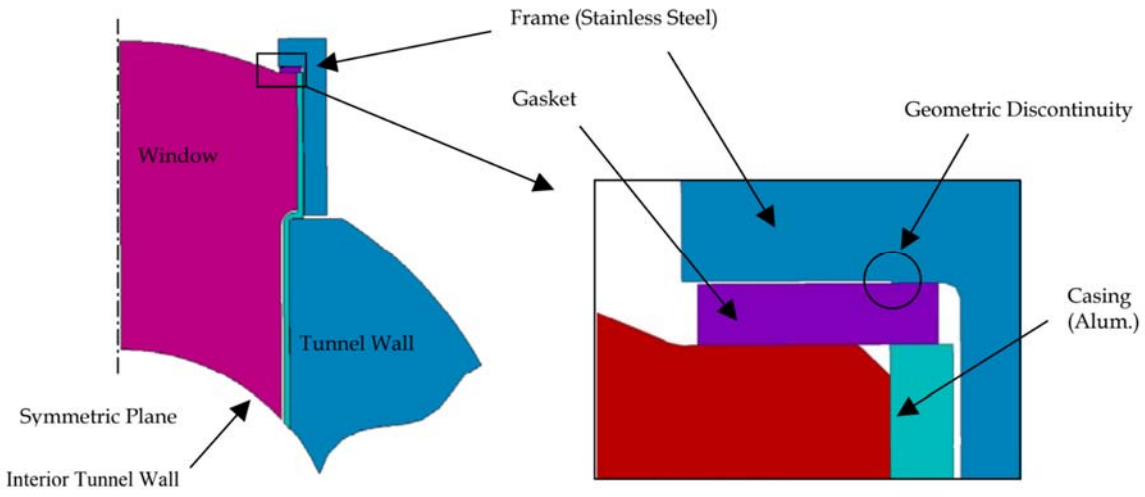

Figure 1 - Cross-section schematic of the 7 x 14 Plexiglas window. Taken from Kwon and Schneider (AIAA 2002-0309)

The larger field-of-view window was the first one to be unpackaged. The window was shipped in two separate pieces. A stainless-steel outer frame is slip-fit over the aluminum casing with a gasket in between the two. The inner casing protects the Plexiglas window and is sealed with a combination of plaster, flowable RTV, and a thicker RTV. However, the inner casing is bulging at the center of the 14-inch side and does not slip fit easily into the frame. The casing is building, probably due to shifting and curing of plaster, as has been observed previously. This issue is being resolved by Robin Snodgrass of Purdue AAE's machine shop. Precise measurements will be made and the outer surface of the aluminum casing will be machined down to the appropriate size prior to pressure-testing.

Upon further inspection, the larger Plexiglas window also has a couple of regions where the sealant was not fully adhered. This can be seen in Figure 1. The RTV will be replaced.

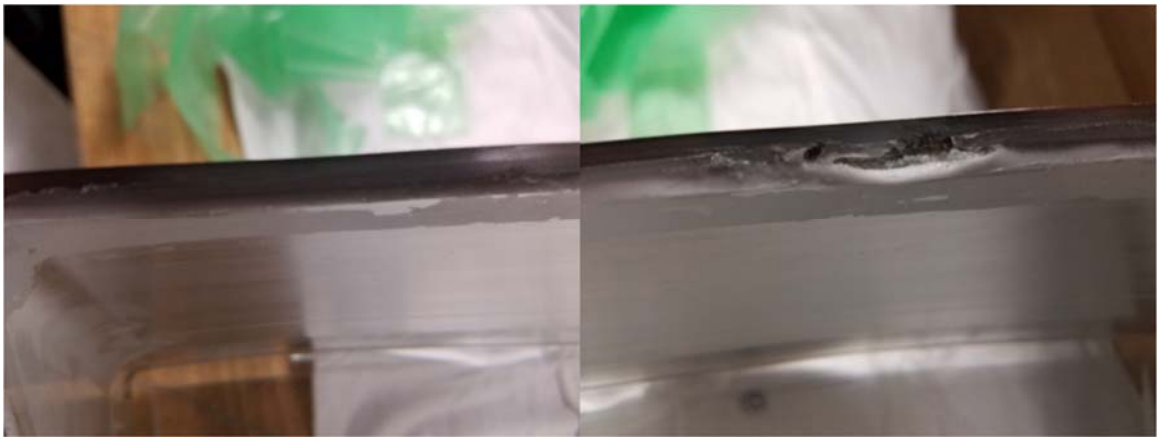

Figure 2 - Left: Correctly sealed RTV. Right: Incorrectly Sealed RTV.

Porthole Window:

The porthole window was shipped in a single assembly. Initial measurements of the window showed that some surfaces were oversized. The surface that slip fits into the BAM6QT nozzle opening measured approximately 0.005 inches larger than our current porthole window. As a result, the window would not easily slide into place. No further attempts will be made to install the window until our machine shop can make precise measurements and confirm or repair the oversize dimensions.

Window Status:

Two windows were received from Trimodels Inc. in March, 2018. Initial attempts at testing the windows showed some slight mistakes in the construction that prevented full installation into the BAM6QT. It should be possible to correct the problems in house, using the department machine shop. Once the issues are fixed, the windows will be pressure-tested and then be available for use in the BAM6QT.

Near-Term Use for Windows: FLDI Measurements

These new windows will be very useful in many different ways for a variety of projects. The 5-inch plexiglas inserts can be replaced with an infrared-clear insert for IR camera imaging; two such IR inserts are now feasible to enable view from two IR cameras. If any one window fails, there is a replacement already available.

The first use of these windows is expected to be for Focused Laser Differential Interferometry measurements. Focused laser differential interferometry (FLDI) is an optical measurement technique that utilizes common-path interferometry to measure density fluctuations in a flow. It is sensitive enough to pick up density changes due to sound and can provide high-frequency measurements that can be off the surface of a model. The FLDI is unique in that no seeding or other interference in the flow is required. Additionally, the focusing of the laser beams helps to lessen the influence of the tunnel wall boundary layer in the overall measurement, providing better spatial resolution than its non-focusing counterpart.

The rectangular windows will be essential for the FLDI. Part of the requirements of the interferometer is to have optical access across the span of the tunnel, which these windows provide. The large rectangular window in particular will be useful for obtaining FLDI measurements. Its greater size provides more options for the placement of the laser beams with respect to the model, allowing measurements to be taken in areas that would otherwise be unavailable to us. The newly available porthole window pair can be installed in the tunnel while the newly available pair of rectangular windows can be used to test the FLDI apparatus outside the tunnel. The pairs of windows can then be swapped out.