Cold and Altitude Testing
B29i-AXS Development
Rev 2.0

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CONTENTS

I. BACKGROUND

This work is a continuation of the work summarized in the report titled “Cold and Hot Start Testing”. With that temperature chamber testing as a starting point, the calibrations were tested on a small fleet of engines in cold operating conditions.

This report discusses the method and results of a series of tests to characterize engine cold performance and validate laboratory tested cold start settings.

The subject was a B29i-AXS, an air-cooled, 2-stroke, single-cylinder reciprocating engine with a displacement of 28.5 cubic centimeters (cc) intended primarily for unmanned aircraft applications. Starting is accomplished by spinning the engine’s spinner cone with an electric starter motor that is coupled to a conical rubber grip which is pressed against the spinner. The engine uses an electronic fuel injection (EFI) system and runs on unleaded gasoline at a 50:1 oil premix ratio. The engine is designed for a direct-drive propeller in pusher or tractor configuration. It also drives a generator to provide up to 250 W continuous power (500 W intermittent) to the user’s aircraft electrical busses.

As part of the B29i-AXS system development, optimizing cold engine starting response and running was necessary. These are the results of the testing.

This testing was the culmination of a two year development cycle that included calibration on a motoring dynamometer, batch builds of engines, cold start development, a 300 hour endurance test (2 modified FAR 33, 150 hour profiles), customer flight operations, and development of a fleet calibration file.

II. SUCCESS CRITERIA

In addition to confirming that start times were close to the temperature chamber starting times, the engines were required to run in an overcooled state at unreasonably low indicated cylinder head temperature (CHT). The engines must continue to run at the coldest possible CHT as a minimum criteria. In addition, these tests would be conducted at altitude. Thus the test would confirm that the ECU's air/fuel control settings would adjust properly with the temperature change as well as the altitude change.

III. TEST CONDITIONS

Location	Mt. Hood Timberline Lodge, Oregon (45.33078, -121.70809)
Temperature	28.4 °F (-2 °C)
Elevation	5,878 ft (1792m) MSL
Barometric Pressure	26.05 in. Hg (88.2 kPa)
Relative Humidity	81%
Date and Time	11Nov2015, 18:00 – 21:30 PST
Engines Serial Nos.	006, 008, 009, 010

Figure 1 – Conditions at test site

IV. Test Method

A. Four B29i-AXS (Corvid-29) fuel-injected 2-stroke engines were tested inside a mobile test facility (Figure 2 and Figure 3) to validate starting and operation under cold (-2 °C), rarefied (88 kPa) atmospheric conditions.

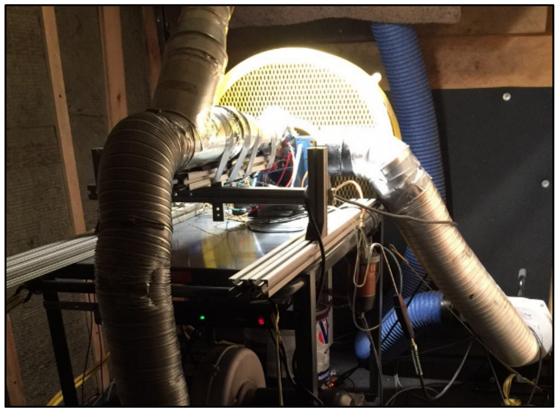

Figure 2: Portable test cell interior

Figure 3 - Portable test cell exterior and conditions on test day

B. All engines were subjected to our standard ground based checkout profile. The checkout profile included abrupt throttle transients across a range of throttle positions from idle to wide open throttle (WOT). These transient profiles were established years ago as a worst-case stress test of the engines' ability to handle unusually abrupt changes in operating conditions. The checkout test was not relaxed in any way during the cold and high altitude test conditions.

C. After all four engines complete the transient engine performance checkout profile, the final engine continued to run through a 2-hour notional flight profile. For this extended run, air-to-fuel mixture would be monitored along with steady state and transient performance.

V. Results

A. All four engines tested well during the transient performance checkout profile, with excellent response to RPM and throttle commands. Low operating cylinder head temperatures (as low as 25 °C continuous) had little effect on overall operation.

B. Following the transient testing of all four engines for starting and warmup performance, SN 010 was run for an additional two hours in a notional cruise/climb/descent flight profile. Figure 4 below shows an RPM trace in blue with corresponding throttle adjustments in black and engine temperature in red. The engine responded as commanded throughout the flight profile.

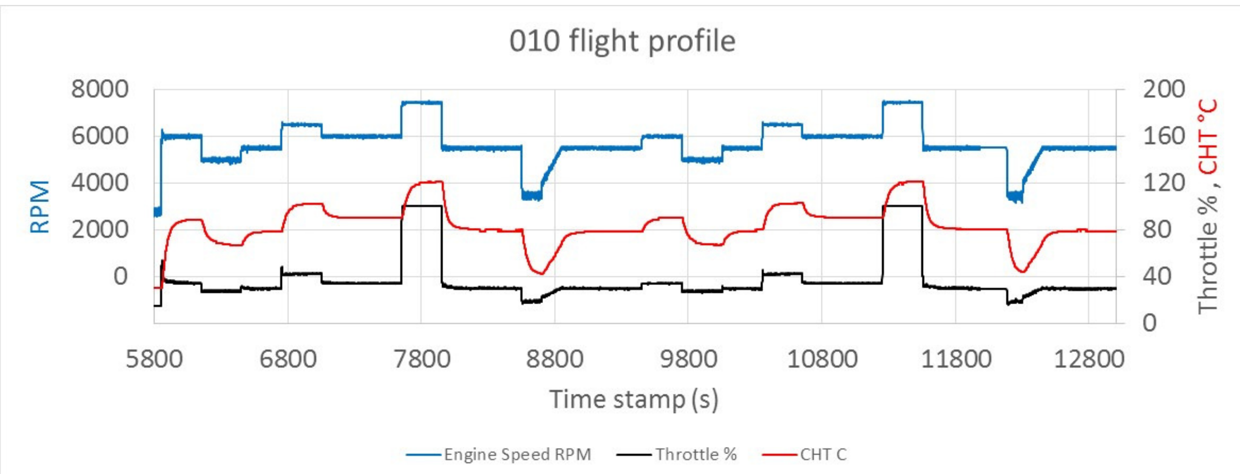

Figure 4: Engine 010 flight profile data

C. Measurement of exhaust gases during the transient and flight profile testing showed that engine mixture was properly controlled over the entire range of test conditions, based on reference data from hundreds of laboratory testing in cool to hot operating conditions. It is notable that no changes were made to the engine base calibrations when moving from sea level to the altitude test. Only slight refinements were made to the CHT based part of the ECU enrichment functions. None of the post-start enrichment values were changed in the ECU calibration settings during this test and validation cycle.

VI. DISCUSSION

A. The validation exercise was a success. The test conditions exceed a typical UAS operators acceptable flight minimums. Furthermore, the fuel control strategy used is a robust model-based system that can be expected to continue controlling effectively for much more severe conditions than tested here.