Dynamic Diaphragm Test

PAFI-RTP-009

PAFI Rig #9 Diaphragm Test

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	08/05/2025	*12, 16, 18, 20, 21, 23, 25, 26, 27, Appendices*	• *clarifications of terms, added 14 CFR 33.49 to references,* • *added build lot to conformity documents* • *updated posttest shipping information, updated fuel line construction information* • *updated fuel reservoir info* • *corrected text to schematic disconnect re: head rise* • *added handling of fuel filters* • *added data collection rate* • *Added pump adapter text* • *Updated air flow description* • *15.4.1 added fuel swap* • *Clarified fuel selector valve testing* • *Updated Schematics*

PREFACE

PAFI-RTP-009 comprises a detailed test plan for PAFI Diaphragm Testing, also referred to as Rig #9 Diaphragm Test, for a fuel offeror as part OF FAA PAFI TESTING.

This test plan specifies the requirements for conducting comparative Diaphragm-containing Component Exposure tests under the FAA's piston aviation fuels initiative (PAFI). This document is derived from extensive FAA and industry experience and best practices for evaluating the suitability of aviation fuels for use in the piston powered general aviation fleet. This document is used by the FAA to compare and

evaluate new aviation fuels relative to the performance of 100LL aviation gasoline meeting ASTM D910.

In addition to the candidate unleaded fuel, an ASTM D910 fuel formulation is required for the screening tests under this plan.

This document is not intended to provide a method to obtain data to serve as a showing of compliance to regulatory requirements for the certification of aircraft or aircraft engines.

Furthermore, the material in this document does not change or permit deviations from existing regulatory requirements. This material is neither mandatory nor regulatory in nature. Use of this document or any derivative, in an attempt to obtain an FAA authorization of an alternative aviation fuel, should be pre-coordinated and approved by the appropriate FAA office(s) as part of an approved qualification program.

Successful completion of this test plan provides data that may support both FAA Fleet authorization and development of an ASTM production specification for PAFI Fuels.

References made to the Alternative Fuels Program Office or AFPO, refer to the group within the FAA that is responsible for the PAFI program. At the time of this revision, that group is the AIR-650 organization. Please see:

https://www.faa.gov/about/initiatives/avgas/org_info

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Rig Test Plan
PAFI-RTP-009
Dynamic Diaphragm Test

1. SCOPE

This test plan specifies the requirements and procedures for conducting comparative diaphragm operability testing of an unleaded fuel to generate data required for participating in the FAA Piston Aviation Fuels Initiative (PAFI) test program. Diaphragms are tested in-situ, contained in their respective components.

This data is used for the evaluation of an unleaded fuel in the PAFI test program.

Specific objectives of this comparative plan are defined as follows:

1) Procure new components for each of seven types of engine hardware with 8130-3 forms, and if possible new build flow data (see parts list Sections 7.2 and 7.3).

2) Run a set of each of the seven components per manufacturer test parameters for 75% of the mean time between overhaul (MTBO) or OEM in-house durability testing per Section 15.4 in both high aromatic ASTM D910 compliant 100LL and candidate fuels.

3) At the completion of testing, all components are to be returned to the OEM or other designated receiver for site-specific evaluation and review of the diaphragm containing components. Individual components are identified as "successfully completing" or "unsuccessful in completing" full test duration. Units are to be shipped to the respective OEM's, **un**preserved by next-day/ overnight freight. OEM's shall determine respective evaluation requirements.

The rig test plan includes the requirements for confirming baseline rig condition, test set-up, instrumentation, and supporting documentation such as fuel certification documents as prerequisites to the testing identified.

Comparative diaphragm-containing hardware tests between ASTM D910 100LL aviation gasoline (AvGas) and an unleaded test fuel are specified.

Specified aircraft hardware is representative of typical aircraft design philosophies:

- Flow dividers for both Continental and Lycoming engines
- An O-360 A1A carburetor
- Lycoming engine diaphragm pump
- Lycoming engine vane pump (pressure control diaphragm)
- Continental engine Fuel Pump for an IO-550 (pressure control diaphragm)

Each test is performed by providing operational inputs of fuel flow and pressures representative of those experienced during a typical durability test, per 14 CFR 33.49 (b).

Requirements for confirming hardware configuration, component health, test equipment, test instrumentation, and supporting documentation such as component and fuel certification are prerequisites to the testing identified.

1.1. PROVISOS

The following identifies important assumptions, requirements, and provisions associated with the testing prescribed within this test plan. Note that testing performed pursuant to this test plan provides data supporting FAA fleet wide authorization for PAFI unleaded fuels. Except in cases where FAA approval of testing is received a priori, where testing is performed on fuel produced to the final formulation, and when testing is witnessed by an FAA designated representative, the resulting data MAY be designated as supporting fleet wide authorization. Any subsequent change to the fuel formulation outside of specified manufacturing limits negates the use of any collected data, even if appropriately approved and witnessed by the FAA. Testing performed to this test plan must be witnessed by an identified designated representative of the FAA. This may be achieved using a Designated Engineering Representative (DER) or other representative approved by the AFPO Staff prior to executing testing.

NOTE… In the event testing is conducted outside the FAA's William J. Hughes Technical Center, testing performed to this test plan must be witnessed by an identified designated representative of the FAA. This may be achieved through the use of a Designated Engineering Representative (DER) or other representative approved by the FAA AFPO or PAFI Advisory Committee prior to executing testing.

NOTE…Testing performed pursuant to this test plan provides data supporting 1) FAA fleet authorization for each PAFI unleaded fuel, and 2) the development of an ASTM International aviation gasoline production specification for each fuel.

2. OBJECTIVES

The objectives of the PAFI comparative diaphragm tests are defined as follows.

1) Confirm individual components are FAA Conforming prior to testing. FAA 8130-3 forms and/or OEM as-manufactured calibration data are acceptable.
2) Perform rig testing with respect to fuel flows and pressures provided in this test plan, using a high aromatic ASTM D910 compliant aviation gasoline at room temperature.

3) Record all pertinent values including observations of deviations and inability to successfully operate for the entire test duration.

4) Provide rig data and hardware to respective OEM's. OEM's are to evaluate post-test condition to assess operational differences in the performance of the individual parts.

3. BACKGROUND

It is recognized that the diaphragm is a key engine operating component and one of the first items inspected during an investigation when engine failure is suspected. While simple material compatibility can be assessed using industry standard material compatibility tests ("parts in jars"), this may only provide part of the diaphragm's health assessment. Given the potential criticality of diaphragms, it is desirous to understand the functionality of the diaphragm in use under exposure and operating conditions, and to assess condition after exposure.

The intention is to have a test population of six units each, exposed to 100LL and six exposed to the candidate test fuel. Six units exposed to each fuel shifts the analysis away from a statistical population of n=1. While n=3 would be acceptable, three is generally indicated when the precision and repeatability are known, which is not the case here.

The intention is to have the equipment exercised enough to put normal functional stress on the parts, but without running to "failure". This potentially provides the ability to see accelerated attack (if there is any) by the unleaded fuel. The philosophy is 75% of MTBO timeframe should have exercised the component, but not to a point of failure. New units with 8130-3's are assumed to flow in limits, OEM as shipped flow data is desirable. After the testing, the units are to be returned to the respective OEM's where the components are inspected and the post-test measurements determined as defined by the OEM. The OEM may also choose to do post-test teardown in order to find any structural failures of the diaphragms which are not immediately observable during on-bench testing.

4. PAFI RIG SCREENING TEST PLANS

The matrix of rig screening test plans supporting the test protocols identified in TAC-PRJ-008 latest revision is presented as follows. The test plans follow a common format with general procedures, processes, and test instrumentation being common to all. This test plan is highlighted.

RIG SCREENING TEST PLANS

PAFI-RTP-001, Cold Flow Hardware Test

PAFI-RTP-002, Carburetor Icing Test (Incorporated into Engine Test Plan(s))
PAFI-RTP-003, Dynamic/Operational Hardware Test, (Removed)
PAFI-RTP-004, Long Term Storage Test, Ambient and Elevated
PAFI-RTP-005, Cold Storage Stability Test
PAFI-RTP-006, Hot Surface Ignition Temperature Test, (Removed)
PAFI-RTP-007, Full Scale Engine Emissions Test, (Not Released)
PAFI-RTP-008, Comingling Evaluation with 100LL, (Not Released)
PAFI-RTP-009, Dynamic Diaphragm Test
PAFI-RTP-010, Fuel Sump Valve Test
PAFI-RTP-011, Vented Drum Storage Test

Test plans prepared in support of the FAA PAFI test program for unleaded fuels are subject to the following review and approval protocol.

1) PAFI rig test plans follow a format and content consistent with established practice for FAA compliance projects.
2) Draft test plans are furnished to the FAA AFPO office for review and approval prior to release to the TAC.
3) Upon concurrence from AFPO, the test plan is to be formally furnished to the PAFI TAC for review and concurrence preceded by FAA Contracts review and authorization for release to the TAC.
4) A final test plan is to then be released, incorporating changes resulting from the TAC review.
5) All changes and referrals to this test plan should reference the latest revision level and date.

5. APPLICABLE FAA & ASTM REQUIREMENTS

The following is a listing of the applicable FAA and ASTM documents which contain information relevant to the testing specified by this test plan.

5.1. FAA REGULATIONS

1) FAA Advisory Circular 33.19-1, “Guidance Material for 14 CFR §33.19 Durability for Reciprocating Engine Redesigned Parts”
2) FAA Advisory Circular AC33.4-1, “Instructions for Continued Airworthiness”
3) FAA Order 8110.4C, “Type Certification Process”
4) US Code of Federal Regulations, Title 14 CFR part 33.49 (b)

5.2. SAE STANDARDS

No SAE standards applicable to the testing.

5.3. ASTM GUIDANCE & PRACTICES

No ASTM Guidance or Practices applicable to the testing.

6. APPLICABLE OEM DOCUMENTS

No OEM Documents applicable to the testing.

7. DESCRIPTION OF TEST ARTICLES

All of the following aircraft parts shall be purchased new with all appropriate FAA Form 8130-3 Airworthiness Approval tags and/or manufacturer's as-shipped flow data.

*Note: there are components with long lead-times and delivery schedules of potentially multiple months. Purchase of **new** parts is required for this testing and is typically achieved through the use of aircraft parts distributors. The ability to purchase parts from some industrial facilities requires an industrial account not typically available to individuals. Acquisition of parts through certain aftermarket distributors supplying parts for amateur built aircraft typically do not provide components with an FAA form 8130-3. Components not having an 8130-3, even if a vendor has described the part as new, conforming to a Mil Spec, or conforming to a commercial standard, are not permitted for this test. Overhauled or remanufactured parts are **not** acceptable.*

The following list of recommended parts is comprised of hardware specifically identified (see Sections 7.2 and 7.3). Any deviations from the following component list must be approved by the FAA AIR600 representative prior to testing. Actual sourcing is at the discretion of the testing organization.

7.1. FLOW MONITORING (ALL HARDWARE)

Fuel flow within the rig is measured by the flow meter and monitored by the matching flow display. The aircraft flowmeter described in 7.1.1 or equivalent may be used as the primary flow measuring device, or a separate industrial flow meter may be used.

7.1.1. FLOWMETER

A turbine flowmeter that is representative of a flowmeter used on the aircraft to monitor fuel flow to the engine is recommended, however an equivalent industrial flowmeter is permitted. The purpose of this flowmeter is to monitor the fuel flow and is not a part of the compatibility evaluation.

The Series 200 Turbine Flow Transducers flowmeter used in aircraft has the following performance properties with gasoline:

- *Flow range 0.3 to 30 gph*
- *K factor (pulses/gallon @ 16 gph) -32,000*
- *Pressure drop 0.6 psi @ 15 gph*

  2.4 psi @ 30 gph
- *Working pressure 200 psi*
- *Temperature range -65/100 °C*
- *Bearing life expectancy10,000 hrs*
- *Electrical Specifications 12-15 VDC between + and – wires*

  30 – 50 mA @ 12 VDC

A matching display indicator for the flowmeter chosen is also required.

7.1.2. FLOW DISPLAY

The flow display is matched to the turbine flow meter. A flow display matched to the selected turbine flowmeter is required.

7.2. LYCOMING

The following engine components are representative of typical Lycoming engine components.

Hardware	P/N	Engine	OEM
Fuel Injector [RSA-5AD1]	61M23264 or AvStar AV 2576562-2	IO-360-L2A	
Fuel Manifold Valve (used with RSA-5AD1 Control)	62B26931	IO-360-L2A	
Fuel Pump, Dual diaphragm	62B26931	IO-360-L2A	
Fuel Pump	62E23186	TIO-540-J2B	

Carburetor	MA-4SPA (10-3678-32)	O-320-A2B	
Aircraft Fuel Selector Valve	9910201-1	Cessna 421	

7.3. CONTINENTAL MOTORS LOOP

The following engine components are representative of typical Continental Motors engine components.

Hardware	P/N	Engine
Fuel Pump	649368-60A4	TSIO-550-K
Fuel Manifold Valve	646433-12A2	TSIO-550-K

8. DEFINITIONS & TERMINOLOGY

Definitions, terminology and abbreviations specific to this document and to FAA nomenclature are summarized in the following section.

8.1. CALIBRATION

Calibration is a set of actions that establishes that the instrument which is being calibrated is equal to or reports values equal to a standard. The unknown, the instrument being calibrated, will be checked against a known, the standard, at several different points and adjustments made to the unknown to bring it into alignment with the standard.

8.2. VALIDATION

As opposed to calibration, validation is the act of documenting an instrument actually and consistently gives expected results. This may be done by measuring a specimen with a known value and confirming the instrument reports that value within the repeatability of the instrument. If the expected value does not result, the instrument has failed validation, and some additional action must be taken to repair or adjust (calibrate) the instrument.

8.3. COMPONENT OR TEST ARTICLE

The common industry term for an individual aircraft part is "component" or "test article". Within this document this industry definition is recognized and represents an individual aircraft unit being tested. See also "Specimen".

8.4. SPECIMEN

Within this document the following concept is meant by the term "specimen". Specimens are the individual test articles or components. For example, the five individual fuel pumps with unique S/N's run in the 100LL are the test specimens from the sample "Continental fuel pump, P/N 649368-60A4".

8.5. SAMPLE

Within this document the following concept is meant by the term "sample". A sample is the set of specific components comprised of unique individual units, described as specimens. For example, "Lycoming Fuel Manifold Valve per P/N 63B265, six test articles" is a sample. "Continental Motors Fuel Manifold Valve, P/N 646433-12A2, six test articles" is a second sample.

8.6. SAMPLE SET

A sample set is all of the individual specimens and all of the test fluids which together generate a set of data. For example, the carburetor specimens from the 100LL run and the carburetor specimens from the test fuel run on the test fuel comprise the "Lycoming Carburetor P/N MA-4SPA Sample Set".

9. CONFORMITY

9.1. HARDWARE

Confirmation that the component test article (see Sections 7.2 and 7.3) configurations comply with the respective design data, bill of materials, and associated specifications is a fundamental requirement. Hardware shall be established as prescribed in the following sections on the basis of certificates of compliance, FAA 8130-3 and/or OEM flow data.

Verification of test article conformance with specification shall be established through the reliance on FAA Form 8130-3, Certificates of Conformance (CoC), and/or Certificates of Analysis (CoA) which document that the hardware meets the intent of 14 CFR Part 21.33 Inspections and Tests, which states the following:

> *"(b) Each applicant must make all inspections and tests necessary to determine--*
> *(1) Compliance with the applicable airworthiness, aircraft noise, fuel venting, and exhaust emission requirements;*
> *(2) That materials and products conform to the specifications in the type design;*
> *(3) That parts of the products conform to the drawings in the type design; and*

(4) That the manufacturing processes, construction and assembly conform to those specified in the type design"

The PAFI procedure for documenting the test hardware conforms to specification is NOT a traditional FAA conformity process, but rather is a process that meets the intent "That materials and products conform to the specifications…." through the use of CoC and CoA documentation.

Manufacturing or build lot information, certificates of quality, certificates of conformances, or other identifying documentation shall be included in the test results reports.

9.2. TEST FUELS

Each PAFI test fuel shall be shown to conform to the complete specification approved by the AFPO, as documented by a CoA furnished with each fuel batch or bulk volume delivered by the fuel supplier to the test facility. In addition, representative data must be generated by an independent 3rd party laboratory for specific pre- and post-test criteria. Pre-test samples should be fuel collected from the original shipping containers 'as received' by the Test Facility. Analysis must be performed on the fuel samples in accordance with Appendix A. Deviations from the fuel specification shall require approval of AFPO. The full Test Fuel CoA as well as the pre and post-test analysis specified in Appendix A must be included in the test results report.

NOTE: A five-gallon retained sample of the test fuel 'as received' at the test facility must be collected and stored until completion of the PAFI test program. See PAFI-FHP-001.

10. SAFETY PROCEDURES

This document does not purport to address all safety considerations. This document does not replace or supersede individual instrument documentation, Federal, State, and local regulations, site procedures, or general industry practices. Appropriate safety precautions are the responsibility of the Test Facility conducting the test. The Test Facility shall establish and ensure compliance with all applicable safety and health standards. Prior to initiation of test, each test set-up shall be inspected for safe practices. Consideration for personal protective gear (PPE) is the responsibility of the Test Facility.

10.1. STATIC CHARGE

10.1.1. GROUNDING (D4057, SECTION 5.4.1)

Fires and explosions have occurred as a result of hydrocarbon vapors being ignited by static electricity. If electrical charges are not grounded, they are unable to dissipate and become "static." This static electric charge can accumulate and freely migrate to a single point on the sample container by a difference in electrical potential, then jump off as a high-energy spark discharge to a nearby less charged surface. The spark may be hot and prolonged enough to ignite nearby hydrocarbon vapors present above the lower explosive limit (LEL). This potential shall be managed by safely dissipating static charges, and through proper grounding, when handling flammable products.

10.1.2. PERSONAL ATTIRE (D4057, SECTION 5.4.2)

Footwear or clothing, capable of causing sparks, for example, clothing made of synthetic materials, should not be worn during fuel handling activities in which flammable vapors are likely to be present. Sampling should not be carried out during periods of atmospheric electric disturbance or hailstorms. To ground any static charge on the body, the individual performing the handling should touch a grounded structure prior to handling fuel, or use any other such acceptable grounding methods commonly used for personnel grounding.

10.2. VAPOR HAZARDS

All testing must be done in compliance with Federal, State, and local site-specific fire safety protocols as well as applicable NFPA codes and standards.

10.3. PERSONAL PROTECTIVE EQUIPMENT

This document does not replace or supersede any Federal, State, local or site-specific requirements related to personal protective equipment. Proposed test fuels may be substantially different than traditional petroleum-based aviation gasoline. These test fuels should not be assumed to be equivalent in hazards to "gasoline".

NOTE… It should not be assumed that purple nitrile type gloves are sufficient in all cases.

1) *Standard PPE - Technicians and test engineers are advised to familiarize themselves with the safety data sheets (SDS) for all of the fluids under test. Individuals are recommended to use at a minimum safety glasses or goggles, chemical resistant gloves as suited to the fuel chemistry, and lab coats or aprons. Note that fire rated lab coats MAY NOT also be chemical resistant. Note that chemical laboratory coats may be a synthetic material and may create static electric sparks. Closed toed, non-charge isolating footwear is also recommended. The chemical properties of the test fuels may require gloves of differing levels of protection. For example, while nitrile gloves may suffice for 100LL aviation gasoline, nitrile may not be sufficient for protection against*

other chemicals that may be in the test fuels. The test fuels may not yet have undergone hazard and toxicity testing in humans.

2) *Component Run PPE – Technicians and test engineers must use appropriate hearing protection during test runs.*

11. HARDWARE CONFORMANCE TESTING

All hardware are to be confirmed to have an FAA 8130-3 tag and/or OEM manufacturer as shipped flow data, or other approved FAA documentation. Maintain part-to-tag correspondence so these tags/data can be reunited with the individual test articles post testing. Copy all provided tags and flow sheets for inclusion in the final test report. Retain any shipping plugs, caps, etc., and any shipping containers for use in returning the test articles to the respective OEM's.

11.1. PRE-TEST CONFORMANCE TESTING

This paragraph intentionally left blank.

11.2. POST TEST CONFORMANCE TESTING

Following the dynamic exposure testing, each component is to be returned to the corresponding OEM. The test articles are to ***not*** *be preserved in any way, i.e. flushed with preservation oil or fluid. Drain any residual fuel from each component and dispose of the drained fuel as waste. Install all shipping plugs, caps, etc. in the component. Include mated FAA 8130-3 forms and/or flow data sheets with corresponding test articles. Individual components shall be placed in original shipping containers as appropriate. It is recommended that the components being shipped by placing them in open head steel drums for shipment, to preclude the articles being flagged by the transport company as having leaks or chemical odors. The OEM may run the components as received for comparison to pretest conditions, and for comparison in amount of change between the 100LL and the candidate fuel. The OEM will also be responsible for posttest tear down and inspection.*

12. PRE-RIG TEST REQUIREMENTS

This test plan has been developed based on the seven different components identified to represent diaphragm containing components (see Section 7.2 and 7.3) used in piston powered aircraft. This is one means of compliance with this test plan.

A testing organization may elect to use alternative test cell configurations. In the case where alternative means of compliance are selected, additional approval from the FAA AFPO and potentially aviation industry manufacturer representatives will

be required. Additional pre-test requirements are provided to validate the alternative test cell configurations are sufficient. This additional validation:

1) *Demonstrates the configuration can reach and maintain the test temperature with minimal temperature rise from fuel reservoir outlet to reservoir return. Fuel temperatures may rise through a cycle but shall return to the test temperature at the fuel reservoir. Active cooling is permitted.*

2) *Demonstrates the ability to reliably provide fuel to the rig at specified pressures and flows, and to provide fuel flow and pressure measurements at specified locations during the test.*

3) *Demonstrates that all components actuate and operate as required throughout the entire test.*

12.1. TEST STAND INSTALLATION

It is permissible to construct test stands with the hardware from multiple loops (Lycoming and Continental) on a single physical test stand to facilitate testing multiple components simultaneously. The installation of multiple loops must be such that each test loop is fully self-contained including the fuel supply and fuel pumps. As designed, the testing is comprised of two contained loops, the Lycoming loop and a Continental Motors loop. The three individual loops, A, B, and C of the Lycoming loop may be plumbed as a single loop, or as three separate loops at the test facility's discretion.

While no attempt is made to control the component temperatures as the fuel flows from the fuel tank reservoir, through the components, and back to the fuel tank reservoir during the testing, the temperature of the reservoir tank is to be controlled. The temperature of the fuel leaving the reservoir tank and into the test loop must be maintained to the target temperature 22 °C (72 °F) +/- 3 °C (5 °F). Natural fuel heating may occur as the fuel passes through pumps and components, and the increasing fuel temperature is acceptable as the fuel passes through the loop. Active fuel cooling the reservoir is permitted.

12.1.1. TEST RIG CONSTRUCTION

Each of the loop layouts are shown schematically in Appendix B. Rig construction shall comply with the individual schematics with respect to orientation and directional flows. The Lycoming loop is comprised of three individual sub-loops designated as A, B, and C. These may be handled as a single Lycoming loop, or as three individual loops. Schematics provided indicate components relative position. They do not represent actual test design. The contractor will be expected to design

the test fixture and provide input to the FAA where design modifications are required.

12.1.2. COMPONENTS

All components shall be mounted in accordance with generally accepted industry practices. While not specifically required, all components should be mounted in a similar manner and orientation to those typically encountered in use. Mounting positions other than those encountered on the aircraft may introduce operational instabilities unrelated to the fuel under test.

All components shall be installed in compliance with the schematics provided in Appendix B. These schematics mimic the flow path of the represented sub-loops and have the components in the order typically encountered in the aircraft. Caution is recommended with respect to the use of steel fittings into aluminum components.

Prior to the initial testing, the designated FAA representative shall inspect the installation of the components in the test facility for conformance with the requirements and specifications of this test plan. Conformance of facility instrumentation with calibration requirements may also be reviewed by the designated FAA representative.

12.1.3. FUEL LINES

Fuel lines shall be standard aircraft rigid and flexible fuel lines. Rigid lines for primary fuel flow are typically aluminum or stainless steel. Copper is not permitted for this test. Flexible lines shall be of aviation and aerospace quality medium and/or high pressure and should have FAA 8130-3 certification. Lines shall be fitted with appropriate aluminum or stainless steel AN fittings for connection to the hardware components. Components shall be connected together by these fuel lines in compliance with specified installation requirements, or with standard industry practices where no requirements are provided. Note, not all of the ports on a component may be used. These ports may be capped/plugged.

12.1.4. AIR LINES

The use of Teflon™ (PTFE) tubing is recommended for air lines. Route lines from a warm regulator to the RSA ram air pressure sensing port. Dry air or nitrogen gas shall be used. The RSA static air sensing port shall be left open to the environment.

12.1.5. FUEL RESERVOIRS

Individual fuel tank reservoirs shall be used for each loop and for each fuel tested. Loops (A,B,C,D) may run simultaneously and may use the same reservoir. Each set up of a combined A,B,C,D loops shall use its own separate reservoir. The A,B,C,D

loops may have separate reservoirs for the A loop, B loop, C loop, or D loop if desirable or necessary.

In the case where the A,B,C,D loop is combined, each reservoir must be capable of holding sufficient fuel to fill and run a test, typically eight (8) gallons working volume, with a seven (7) gallon minimum. In the case of the B loop, if this loop is run as a standalone, a two-gallon (2) minimum reservoir required provided it can meet the head pressure requirements and must maintain at least one (1) gallon minimum. All fuel reservoirs are to be "gravity fed" from the reservoir and into the respective components in the test loops. The fuel reservoir shall maintain a head rise over the pump inlets of at least +0.5 to +1.0 psi regardless of the fuel flow. Higher gravity feed head pressures are permitted, up to 6 psi.

12.1.6. FUEL PUMP AND MOTOR

The engine fuel pumps are test articles but may be used to provide fuel flow and pressure to the test loops. The engine pumps require an external mechanical or motor drive to actuate the pumps. These mechanical drives must mimic the engine accessory drive case in order to provide the proper pump RPM or pump actuation.

For both the Lycoming and the Continental Motor loops, a separate fixture to actuate the pumps in a manner replicating the engine accessory case drive is required. Any number of drive fixture designs is possible as long as the speed and range of motion of the pumps can be maintained.

12.1.7. FUEL FILTERS

Because the test rig is not equipped with fuel filters, it may be desirous to install 140-micron (150-micron max) finger filters at the outlet of the reservoir. In such cases the filter must be replaced, cause for removal should be documented, the screen should be bagged/bottled for evaluation, and testing resumed. All finger screens should be returned to the OEM's with the components at the end of the testing.

12.2. PRE-TEST RIG VALIDATION

Prior to data collection testing, each test flow rig shall be operated on a D910 compliant aviation gasoline to confirm operation, control, and data collection. This test is used to identify any issues with the set-up prior to actual testing. The validated operation parameters are then to be applied to the remaining individual specimen loops.

12.3. PRE-RIG TEST INSPECTIONS

Ensure all components are new and where available have an appropriate FAA Form 8130-3 Certificates of Conformance and/or OEM manufacturer as shipped flow data, or other appropriate FAA documentation.

A logbook shall be maintained for the test with all starts, stops, test time, total time, all loop pressures, all loop flows, engine power setting being simulated (i.e. idle, 50%, 80%, or full power), system maintenance, and other notes logged as appropriate. Electronic storage of the data is acceptable, however it is recommended that frequent backups of the data files are created, and hard copies of the data are routinely printed.

Anomalies, replacement parts, troubleshooting, and other unplanned events shall be recorded in the log.

12.4. SPECIMEN IDENTIFICATION

Each individual test article shall be identified in a manner to permit matching the specimen back at the end of the test to its original documentation, i.e. 8130-3 forms. The use of component S/N numbers is appropriate. A record should be kept of which identified component was operated in which of the provided fuels.

12.5. LABORATORY NOTEBOOK

Either a bound notebook or digital notebook shall be maintained for any testing. Technicians shall record each individual test article's unique identification, such as S/N, any lot or certification information, and all corresponding pre-exposure data. Each test and test method, as well as any equipment identification shall be recorded. The test results report shall document the manufacturer and model of any analytical equipment used. Information related to the instrument calibration or validation shall be recorded. A record should be kept of which identified component was operated in which of the provided fuels.

This notebook shall also be used to record any start times and dates, test conditions such as temperature, visual observations, and the time and date of test terminations. A logbook shall be maintained for the test with all starts, stops, test time, total time, all loop pressures, all loop flows, engine to pump RPM, system maintenance, and other notes logged as appropriate.

Anomalies, replacement parts, troubleshooting, and other unplanned events shall be recorded in the log. Final test data shall be recorded and positively connected to the appropriate pre-exposure data.

13. TEST FACILITY & EQUIPMENT

13.1. FUEL RESERVOIRS AND FUEL CONDITIONING

13.1.1. FUEL RESERVOIRS

As many fuel reservoirs as test rigs to be operated simultaneously during a test are required. Each rig under test shall have a dedicated fuel reservoir for each of the test fuels (baseline 100LL and any unleaded fuel formulas). The same fuel reservoir may be used with the same fuel in tests that are run serially, however, if tests are to be run in parallel, multiple reservoirs are required, one for each loop under test, even if it is the same fuel. The volume of the reservoir shall be sufficient to flow the rig and maintain the necessary heat sink and head pressures. Alternative reservoir sizes require validation of sufficient temperature control over the entire test protocol and at all fuel flows.

13.1.2. FUEL CONDITIONING

No pre-test conditioning is required.

13.2. ELECTRONICALLY CONTROLLED AND MONITORED COMPONENT CONTROL

Throughout the testing, means of controlling and monitoring individual fuel flows, fuel/air pressure, test cycles, and cycle times on a per pump / per rig basis are required. This control and monitoring shall be maintained throughout the duration of the test run. Continuous data collecting is not required, but a data "snapshot" should be captured no less frequently than every fifteen (15) minutes. A means of monitoring actual test conditions throughout a test is required. An example of a data collection sheet is provided in Appendix C.

A means of shutting down any loop, especially in case of out-of-limits performance of any individual component, shall be provided.

13.3. INSTRUMENT CALIBRATION

Instrumentation used to measure and monitor parameters during the test shall be calibrated with traceability to a national standard, as appropriate. Instrumentation calibration records shall be made available to the FAA representative designated to witness testing prior to start of the test and shall be included in the final test results report.

14. TEST WITNESSING

Test witnessing is required for the collection and reporting of data collected in compliance with this test plan. This data is to be used by the FAA as part of their evaluation for fleet wide authorization. Fuel formulators shall submit a test plan for approval by the FAA before executing testing. Part of the submitted test plan must be a means of test witnessing by an FAA authorized representative.

Testing performed in accordance with an approved test plan shall be witnessed by a representative of FAA AIR600 or their designated representative. The extent of witnessing is at the discretion of the FAA; however, at a minimum the representative shall verify and witness the following segments.

1) *Verify certificates of analysis are available for supporting samples as appropriate and for all test fuels*
2) *Verify instrument calibration/validation as appropriate*
3) *Inspect test set up (jars, specimen arrays, rigs, ovens, etc.*
4) *Verify pre-exposure data, record keeping and specimen control*
5) *Review test plan with test personnel*
6) *Witness test initiation*
7) *Witness fuel exchanges at the FAA's discretion and as appropriate*
8) *Witness test conclusion*
9) *Witness post exposure testing at the FAA's discretion and as appropriate*
10) *Verify testing in accordance with test plan*

15. TEST PROCEDURE

15.1. MATERIALS

1) *High Aromatic ASTM D910 compliant aviation gasoline*
2) *System check fuel - ASTM D910 compliant aviation gasoline without limit may be used to confirm test rig operability on a 100LL loop. This fuel would be drained and the rig filled with the provided high aromatic 100LL aviation gasoline.*

3) Unleaded candidate fuel(s)

15.2. TEST PREPARATION

15.2.1. TRANSFER FUEL

Transfer fuels to appropriate fuel reservoirs. Individual reservoirs are to be used for each fuel type.

15.2.2. FUEL PRESSURE AND FLOWS

Fuel pressures and flows are directly determined by the component pump speeds. The fuel pressures and flows are going to vary accordingly with pump speed. Multiple locations for monitoring fuel pressure are indicated in each of the schematics in Appendix B. Fuel flow is measured using the Floscan flowmeter, or equivalent, and the location of the flowmeter is indicated in each of the schematics in Appendix B. In addition, standard data collection times, fuel flows and pressures are recorded at each speed/flow set point change.

15.2.3. SYSTEM TEMPERATURES

Bulk fuel temperature is to be measured at the fuel reservoir outlet.

15.2.4. PUMP SPEED

For the injection system loops (loops A and D), the fuel pumps are mechanical pumps driven by the engine (motor). For these loops, the motor is replacing the rotational input from the engine. It is necessary to design and install a connection system from the motor into the mechanical pump. The motor is set to provide the required RPM required by the fuel pump for each power setting. This is determined from OEM provided RPM's developed from provided in Appendix D. Pump speeds for Lycoming sub-loop A is one half the engine (motor) RPM. Continental Loop D pump speeds are the same as the engine (motor) RPM.

It is necessary to construct an adapter from the pumps to the test stand motors. Alignment or travel of the engine pump input is critical to the proper life and operation of the pump. Consultation with the FAA, or the FAA representative, may be required to obtain any necessary engineering drawings of the pump drives.

15.2.5. AIR FLOW (CFM)

The Lycoming RSA loop A requires a low pressure-high volume air input to simulate engine intake airflow up to 800 CFM at room temperature. The exact CFM required for each engine RPM setting is provided in

Table 1. Engine airflow is used to actuate the air diaphragms in the fuel servo body.

15.2.6. RSA INJECTION CYCLE SET-UP

For the Lycoming RSA loop A test, set the intake air flow to the specified CFM for the desired engine RPM at each power setting. Set the mixture control to full rich and make no further adjustments. Set the motor RPM to provide the required pump RPM (see 15.2.4).

15.2.7. CONTINENTAL MOTORS INJECTION CYCLE SET-UP

For the Continental Motors test, loop D, no air flow supply is required. Port the air input on the fuel pump to ambient. Set the throttle valve position on the flow divider to full open and the mixture control to full rich. Set the motor RPM to provide the required RPM at the pump for at each power setting from OEM provided RPM's developed from 14 CFR part 33.49 (b) provided in Appendix D. Pump speeds are equal to engine RPM.

15.2.8. 140-MICRON (150 MAX) FINGER SCREENS

The finger screens are used to collect any debris in the fuel loops that may remain from the construction of the loops, and to collect any contamination that may have been inadvertently introduced into the fuel.

15.3. DATA COLLECTION

All data: fuel and air flows, pressures, speeds, and reservoir temperature shall be collected at the beginning and end of a set point as described in Appendix D.

15.3.1. FUEL PRESSURE AND FLOWS

The fuel pressures and flows are set automatically by the system based on the pump RPM's.

Multiple locations for monitoring fuel pressure are indicated in each of the schematics in Appendix B. Fuel flow is measured using the Floscan flowmeter or equivalent and the location of the flowmeter is indicated in each of the schematics in Appendix B.

15.3.2. SYSTEM TEMPERATURES

Bulk fuel temperature is to be measured at the fuel tank (reservoir). The bulk fuel temperature shall be maintained at the test temperature 22 °C (72 °F) +/- 3 °C (5 °F).

15.3.3. AIR FLOW (LOOP A)

The cubic feet per minute (CFM) at ambient temperature is to be recorded upstream of the servo.

15.3.4. ENGINE (MOTOR) RPM

Report the equivalent engine RPM at the motor for each set point.

15.3.5. AIRCRAFT FUEL SELECTOR VALVE

Report any changes in force, rotational, required to move the selector valve. Also note any appearance of leakage.

15.4. TEST PREPARATION

15.4.1. FUEL SWAP

Establish a run schedule to facilitate fuel swaps at the reservoir every minimum 75 hours so as facilitate the run schedule. Fuel swaps shall not be made between set point changes. It is acceptable to delay a fuel swap up to one hour to facilitate this schedule. Record the actual run time accrued on the fuel at each fuel swap. Record any observable anomalies from previous fuel swaps such as dramatic color changes, dramatic (visually observable) viscosity changes, etc. Unless an observable anomaly is observed, removed fuel is treated as waste. Where anomalies are observed, collect the fuel as a retain, contact the FAA POC, and continue running. If observable debris are noted, pause testing and contact the FAA POC for instructions.

15.4.2. LYCOMING RSA (LOOP A)

Establish a run schedule per 14 CFR part 33.49 (b), provided in Appendix D. Repeat the run schedule twelve (12) times for a total of 1800 hours. Runs do not need to be continuous; however, breaks should occur on a set point change. See

Table 1 (Loop A) for motor rpm to % power.

Loop A also includes an aircraft fuel selector valve. Actuate the valve through a full sweep, once per day. Measure rotational force. Monitor for leakage after actuating the selector valve.

Table 1 - CFM Requirements Lycoming Loop A

%RPM	Motor (Engine) RPM	CFM Air Flow	Component (Pump) RPM
100	2600	736	1300

Best Econ	2300	651	1150
91	2366	670	1183
75	1950	552	975
89	2314	655	1157
65	1690	478	845
87	2262	640	1131
60	1560	441	780
84.5	2197	622	1098.5
50	1300	368	650
79.5	2067	585	1033.5

15.4.3. LYCOMING LOOP B

At the beginning of the test and every time there is a Loop A (or Loop C if A is unavailable) power change, actuate the accelerator pump three (3) times.

At the end of every day actuate the accelerator pump three (3) and collect the dispensed fuel volume from the accelerator pump, using a graduated cylinder and record the collected fuel volume. Fuel may be collected as it drains from the carburetor body. At the end of every day, measure the force required to actuate the accelerator pump plunger and record.

15.4.4. LYCOMING LOOP C

Establish a run schedule per 14 CFR part 33.49 (b), provided in Appendix D. Repeat the run schedule twelve (12) times for a total of 1800 hours. Runs do not need to be continuous; however, breaks should occur on a set point change. See Table 2 for motor rpm to % power.

Table 2 - CFM Requirements Lycoming Loop C

%RPM	Motor (Engine) RPM	CFM Air Flow	Component (Pump) RPM
100	2600	736	2600
Best Econ	2300	651	2300
91	2366	670	2366
75	1950	552	1950
89	2314	655	2314
65	1690	478	1690
87	2262	640	2262
60	1560	441	1560
84.5	2197	622	2197
50	1300	368	1300
79.5	2067	585	2067

15.4.5. CONTINENTAL LOOP D

Establish a run schedule per 14 CFR part 33.49 (b), provided in Appendix D. Repeat the run schedule twelve (12) times for a total of 1800 hours. Runs do not need to be continuous; however, breaks should occur on a set point change. See Table 3 for motor rpm to % power.

Table 3 - CFM Requirements Continental Motors Loop D

%RPM	Motor (Engine) RPM	CFM Air Flow	Component (Pump) RPM
100	2600	832	2600
Best Econ	2300	736	2300
91	2366	757	2366
75	1950	624	1950
89	2314	740	2314
65	1690	541	1690
87	2262	724	2262
60	1560	499	1560
84.5	2197	703	2197
50	1300	416	1300
79.5	2067	661	2067

15.5. DATA COLLECTION

Record and report all pressures, flows, speeds, etc. throughout the test, at the start of the test set, prior to each step change in simulated engine speed, and prior to shut down. Report if excessive torque is required to change the position of the fuel selector valves, or if the valves cannot be cycled.

15.6. POSTTEST

Components are to be returned to identified respective OEM's in as-removed condition.

1. *Drain components, but do not purge*
2. *Plug or cap all ports. Use of original caps is encouraged.*
3. *Reattach / match original FAA 8130-3 or OEM provided data sheets to the individual components.*
4. *Return components to original packaging as appropriate.*

5. *Bag components to contain fluids.*

6. *Place packages into open head, steel drums. Multiple packages being shipped to the same location may be put into the same drum, but packing materials should be used to protect the components.*

7. *Ship the drummed test articles to the respective OEM's.*

15.7. CALCULATIONS

No specialized calculations are required. Data tables showing the measured RPM, GPH, pump speed, test temperatures, etc. shall be prepared (See Appendix C for an example).

16. PASS/FAIL CRITERIA

Neither existing FAA CFR regulations, nor existing fuel specifications, have a specific pass/fail criterion regarding performance. However, it is expected that the test fuel should be no more prone to variations than experienced by an ASTM D910 compliant aviation gasoline.

16.1. ORIGINAL EQUIPMENT MANUFACTURER

16.1.1. CONFORMANCE TESTING

All test articles are to be returned to the respective OEM for any posttest conformance testing. This data is to be collected at the prerogative of the OEM. This data then provides information on any changes from new, differences between 100LL and UL100 exposed components, and any parts out of tolerance (or nearly so), thus providing quantitative data related to documented pass/fail criteria. The consideration of "pass" and "fail" is to be up to the OEM's to ascertain.

16.1.2. DIAPHRAGM DAMAGE

In order to confirm there is no damage to the diaphragms which is not observable in the run and received inspection, the OEMs are to be responsible for any tear down and inspection desired to further confirm no harm greater than the 100LL by the UL100.

It has been suggested that it is possible for the diaphragms to remain functional and in tolerance even with imminent material failure, such as cracking. By performing a tear down inspection, the OEMs are to be able to collect condition data which may be probative. By the OEMs or their designees performing the tear down and inspection, any company sensitive information remains solely in the possession of the OEM.

17. TEST PERSONNEL

The testing source shall identify a single Point of Contact (POC) for conduct of this testing. This POC shall be equivalent to a Test Director who shall have the authority for oversight and supervision of those conducting the test. The identified POC shall have responsibility during the test for decisions regarding execution and integrity of the test. This local POC for the testing shall have the FAA point of contact clearly identified and contact information available.

The local designated POC is not a FAA designated representative and does not have authority to witness testing for the FAA. While the FAA may choose to identify this person as a designated representative, this identification as such is solely at the discretion of the FAA. Any identification of the POC as the designated FAA representative for the purposes of witnessing tests must be made prior to any testing occurring.

18. TEST RESULTS REPORT

The objective of the testing specified is to generate data supporting a fuel formulator's participation in the FAA PAFI testing program with the intent of demonstration that potential changes in fuel flows and pressures across components remain within acceptable limits for the use of the offered fuels. The report documenting the test results pursuant to this Test Plan shall include the fuel certifications, supporting date, time, flow, pressure, and temperature data, notes and observations during the tests, test articles (by part name, part number, and serial number), copies of the FAA 8130-3 forms for the components, and detailed diagrams and/or photographs of the plumbing of the fuel loops. A list of support materials; hoses, lines, support equipment, etc., shall be included. The report shall also include the identification of test equipment used by make and model, and evidence of equipment calibration or validation as appropriate.

– END OF TEXT –

APPENDIX A
TEST FUEL COA REQUIREMENTS

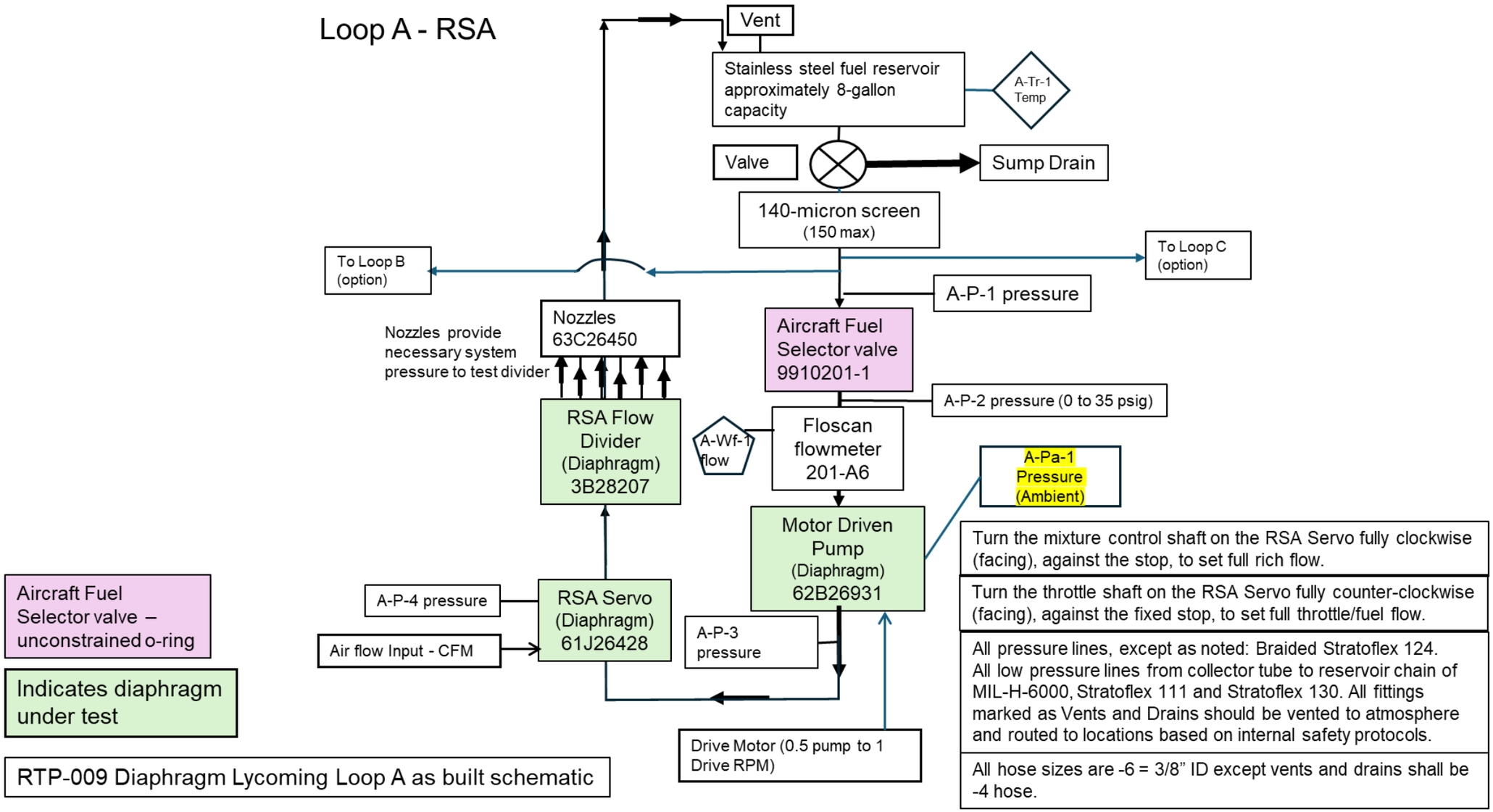
TEST FUEL COA REQUIREMENTS
PRE AND POST TEST FUEL ANALYSIS PARAMETERS

PROPERTY	TEST METHOD
Distillation	D86
Viscosity	D445
Density	D4052

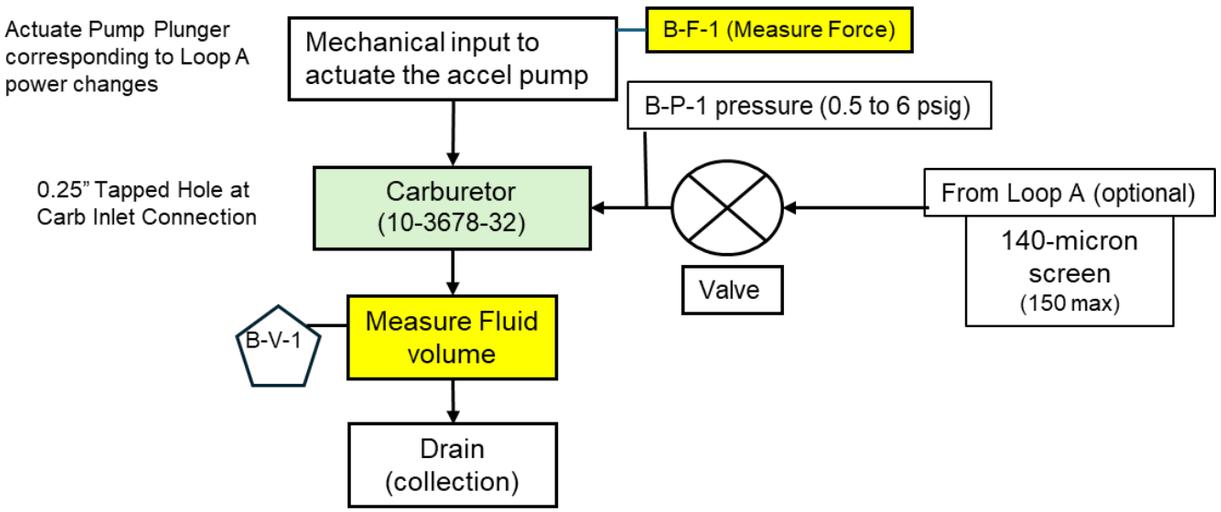
APPENDIX B
INDIVIDUAL SCHEMATICS

1) Lycoming Loop

Loop A – RSA


Loop A - RSA
Vent
Stainless steel fuel reservoir approximately 8-gallon capacity
A-Tr-1 Temp
Valve
Sump Drain
140-micron screen (150 max)
To Loop B (option)
To Loop C (option)
A-P-1 pressure
Nozzles 63C26450
Nozzles provide necessary system pressure to test divider
Aircraft Fuel Selector valve 9910201-1
A-P-2 pressure (0 to 35 psig)
RSA Flow Divider (Diaphragm) 3B28207
A-Wf-1 flow
Floscan flowmeter 201-A6
A-Pa-1 Pressure (Ambient)
Motor Driven Pump (Diaphragm) 62B26931
A-P-4 pressure
RSA Servo (Diaphragm) 61J26428
Air flow Input - CFM
A-P-3 pressure
Drive Motor (0.5 pump to 1 Drive RPM)
Aircraft Fuel Selector valve – unconstrained o-ring
Indicates diaphragm under test
RTP-009 Diaphragm Lycoming Loop A as built schematic
Turn the mixture control shaft on the RSA Servo fully clockwise (facing), against the stop, to set full rich flow.
Turn the throttle shaft on the RSA Servo fully counter-clockwise (facing), against the fixed stop, to set full throttle/fuel flow.
All pressure lines, except as noted: Braided Stratoflex 124. All low pressure lines from collector tube to reservoir chain of MIL-H-6000, Stratoflex 111 and Stratoflex 130. All fittings marked as Vents and Drains should be vented to atmosphere and routed to locations based on internal safety protocols.
All hose sizes are -6 = 3/8” ID except vents and drains shall be -4 hose.

Loop B - Carburetor



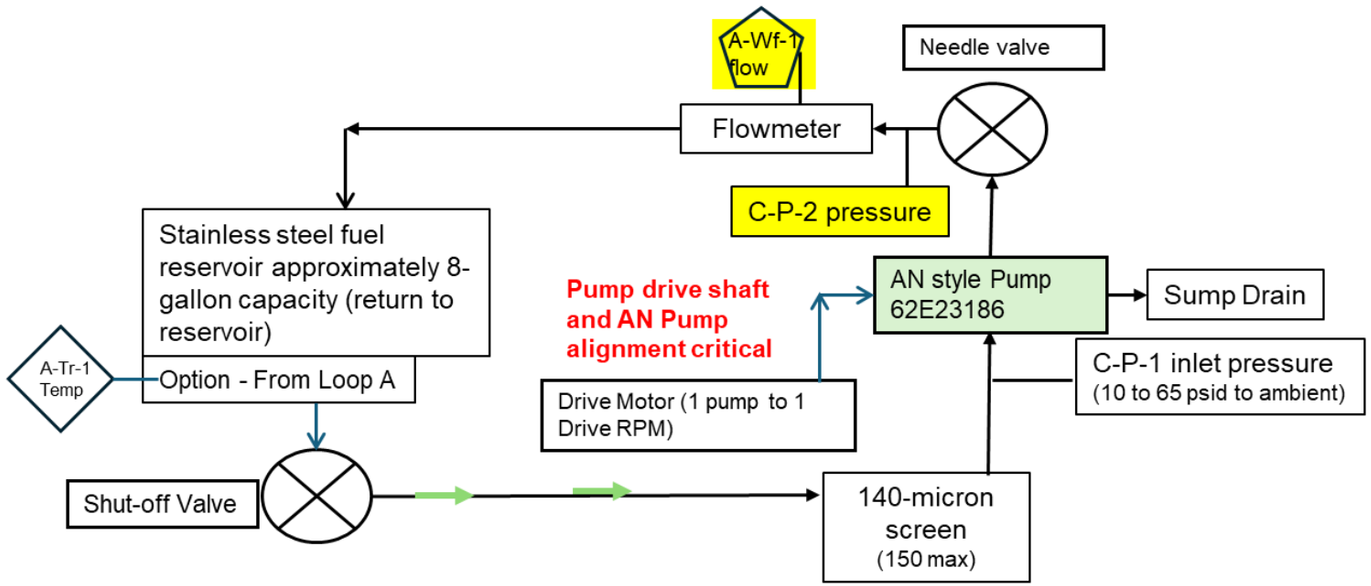
All pressure lines, except as noted: Braided Stratoflex 124. All low pressure lines from collector tube to reservoir chain of MIL-H-6000, Stratoflex 111 and Stratoflex 130. All fittings marked as Vents and Drains should be vented to atmosphere and routed to locations based on internal safety protocols.

All hose sizes are -6 = 3/8" ID except vents and drains shall be -4 hose.

Indicates diaphragm under test

RTP-009 Diaphragm Lycoming Loop B as built schematic

Loop C – AN Style Pump



Indicates diaphragm under test

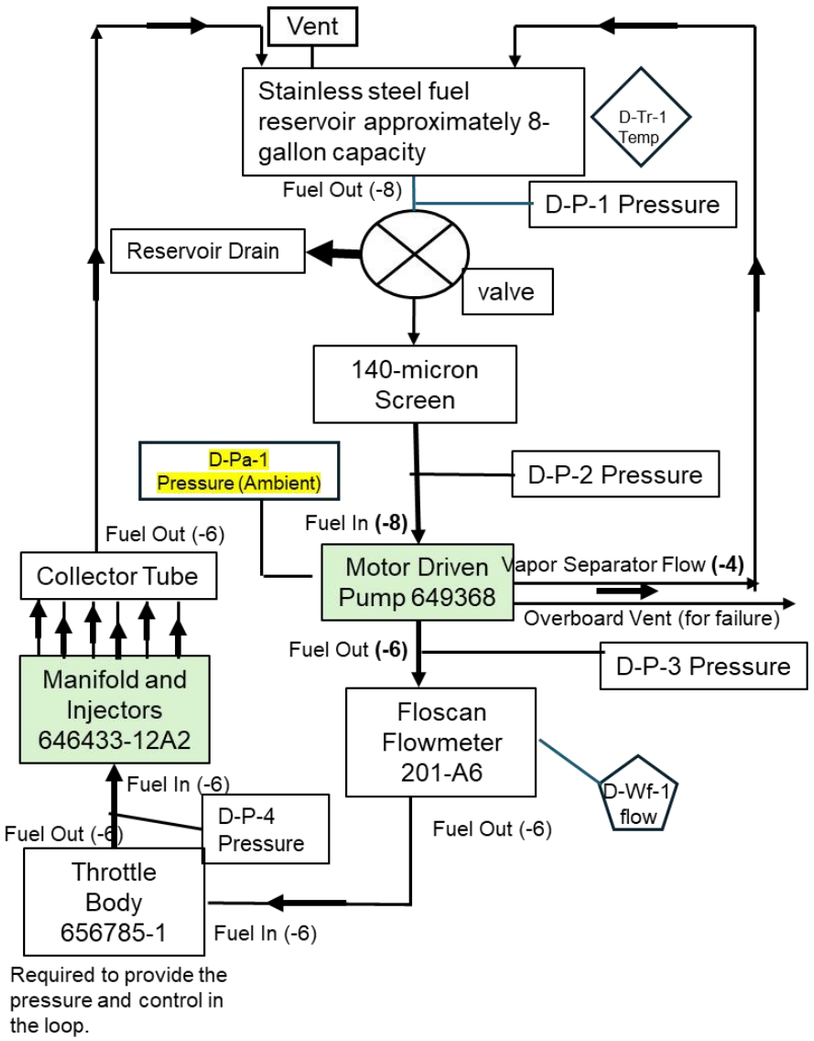
All pressure lines, except as noted: Braided Stratoflex 124. All low pressure lines from collector tube to reservoir chain of MIL-H-6000, Stratoflex 111 and Stratoflex 130. All fittings marked as Vents and Drains should be vented to atmosphere and routed to locations based on internal safety protocols.

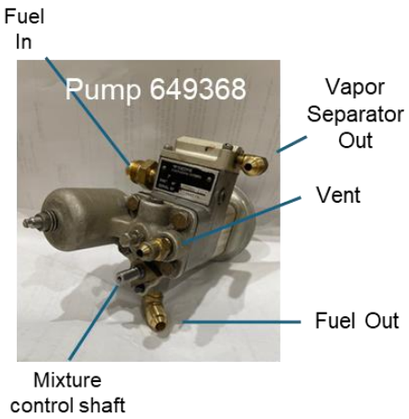
All hose sizes are -6 = 3/8" ID except vents and drains shall be -4 hose.

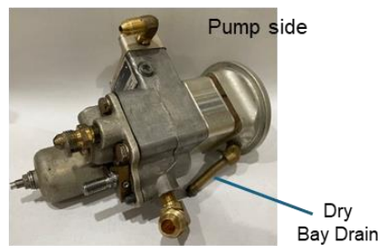
RTP-009 Diaphragm Loop C as built schematic

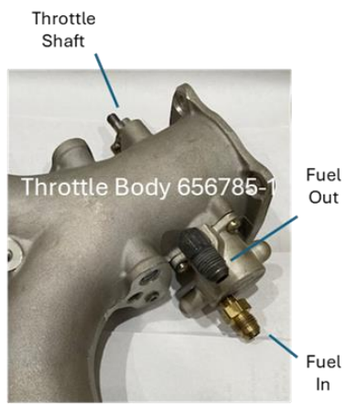
2) CONTINENTAL MOTORS Loop D

Continental Motors - Loop D









Turn the mixture control shaft on the motor driven pump fully counter-clockwise (facing), against the stop, to set full rich flow.
Turn the throttle shaft on the Throttle Body fully clockwise (facing), against the fixed stop, to set full throttle/fuel flow.
All hose sizes are indicated on the schematic. -4 = ¼" ID; -6 = 3/8" ID; -8 = ½" ID minimum. Vents and drains shall be -4 hose. Dash numbers noted on drawing.
All pressure lines, except as noted: Braided Stratoflex 124. All low pressure lines from collector tube to reservoir chain of MIL-H-6000, Stratoflex 111 and Stratoflex 130. All fittings marked as Vents and Drains should be vented to atmosphere and routed to locations based on internal safety protocols.

Indicates diaphragm under test

RTP-009 Diaphragm Continental Motors TSIO-550 Loop D schematic

APPENDIX C
EXAMPLE DATA COLLECTION SHEETS

					Lycoming Engine Loop A									
	Date	Time	Cycle No.	Step No.	Pump Speed (RPM)	Flow (GPH)	Fuel Temp (°C)	Pressure (PSI)				Air Intake (CFM)	Fuel Type	Notes
						A-Wf-1	A-Tr-1	A-P-1	A-P-2	A-P-3	A-P-4			
	8/1/2025	8:40 AM	1	1	544	5.0-5.8	24.3	0.35	1	3	3		100LL	
		8:45	1	2	2699	21.9 - 23.0	24.3	0.36						Adjusted Reservoir height
		8:50	1	3	2699	21.2 - 22.0	24.3	0.35						
		8:55	1	4	2148	29.2	24.3	0.37						
							24.4							
							24.3							

Note: This is only an example. Actual data sheets shall conform to the test rig design, pertinent data, and local use

APPENDIX D
14 CFR PART 33.49(b) TEST PROTOCOL

14 CFR part 33.49 (b)

(b) Unsupercharged engines and engines incorporating a gear-driven single-speed supercharger. For engines not incorporating a supercharger and for engines incorporating a gear-driven single-speed supercharger the applicant must conduct the following runs:

(1) A **30-hour run** consisting of alternate periods of 5 minutes at rated *takeoff power* with takeoff speed, and 5 minutes at *maximum best economy* cruising power or maximum recommended cruising power.

(2) A **20-hour run** consisting of alternate periods of 1½ hours at rated maximum continuous power with *maximum continuous speed*, and ½ hour at 75 percent rated maximum continuous power and *91 percent* maximum continuous speed.

(3) A **20-hour run** consisting of alternate periods of 1½ hours at rated maximum continuous power with *maximum continuous speed*, and ½ hour at 70 percent rated maximum continuous power and *89 percent* maximum continuous speed.

(4) A **20-hour run** consisting of alternate periods of 1½ hours at rated maximum continuous power with *maximum continuous speed*, and ½ hour at 65 percent rated maximum continuous power and *87 percent* maximum continuous speed.

(5) A **20-hour run** consisting of alternate periods of 1½ hours at rated maximum continuous power with *maximum continuous speed*, and ½ hour at 60 percent rated maximum continuous power and *84.5 percent* maximum continuous speed.

(6) A **20-hour run** consisting of alternate periods of 1½ hours at rated maximum continuous power with *maximum continuous speed*, and ½ hour at 50 percent rated maximum continuous power and *79.5 percent* maximum continuous speed.

(7) A **20-hour run** consisting of alternate periods of 2½ hours at rated maximum continuous power with *maximum continuous speed*, and 2½ hours at maximum best economy cruising power or at maximum recommended cruising power.

– END OF APPENDICES –