



Project 31(A) Alternative Jet Fuel Test and Evaluation

University of Dayton Research Institute

Project Lead Investigator

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University Participants

University of Dayton Research Institute

- P.I.(s): Steven Zabarnick, Division Head
- FAA Award Number: 13-C-AJFE-UD
- Overall Period of Performance: April 8, 2015 to August 31, 2019
- Period of Performance: April 8, 2015 to March 14, 2016 – Amendment No. 006
 1. Evaluate candidate alternative fuels for their performance via the ASTM D4054 approval process
- Period of Performance: August 13, 2015 to August 31, 2016 – Amendment No. 007
 2. Evaluate candidate alternative fuels for their performance via the ASTM D4054 approval process
- Period of Performance: August 5, 2016 to August 31, 2017 – Amendment No. 012
 3. Management of Evaluation and Testing of Candidate Alternative Fuels
- Period of Performance: July 31, 2017 to August 31, 2019 – Amendment No. 016
 4. Management of Evaluation and Testing of Candidate Alternative Fuels

Project Funding Level

Amendment No. 006 \$309,885
Amendment No. 007 \$99,739
Amendment No. 012 \$693,928
Amendment No. 016 \$999,512

In-kind cost share has been obtained from:

LanzaTech \$55,801 (2015)
LanzaTech \$381,451 (2016)
Neste \$327,000
Boeing \$2,365,338

Investigation Team

Steven Zabarnick, PI, new candidate fuel qualification and certification
Richard Striebich, Researcher, fuel chemical analysis and composition
Linda Shafer, Researcher, fuel chemical analysis and composition
John Graham, Researcher, fuel seal swell and materials compatibility
Zachary West, Researcher, fuel property evaluations



Project Overview

Alternative jet fuels offer potential benefits of reducing global environmental impacts, achieving national energy security, and stabilizing fuel costs for the aviation industry. The Federal Aviation Administration is committed to the advancement of “drop in” alternative fuels and has set the aspirational goal of enabling the use of 1 billion gallons annually by 2018. Successful adoption of alternative fuels requires approval for use of the fuel by the aviation community followed by large scale production of a fuel that is cost competitive and meets safety standards of conventional jet fuel. Alternative jet fuels must undergo rigorous testing in order to become qualified for use and incorporated into ASTM International Specifications.

Cost effective and coordinated performance testing capability (in accordance with ASTM D4054) to support evaluation of promising alternative jet fuels is needed. The objective of this project is to provide capability to conduct the necessary work to support alternative jet fuel evaluation of either a) to-be-determined fuel(s) that will be selected in coordination with the FAA, or b) a fuel test and evaluation project with a specific fuel(s) in mind.

The proposed program should provide the following capabilities:

- Identify alternative jet fuels (which may include blends with conventional jet fuel) to be tested and that have the potential to be economically viable and support FAA’s NextGen environmental goals.
- Perform engine, component, rig, or laboratory tests, or any combination thereof, to evaluate the performance of an alternative jet fuel in accordance with ASTM International standard practice D4054.
- Identify and conduct unique testing beyond that defined in ASTM International standard practice D4054 necessary to support evaluation of alternative jet fuels for inclusion in ASTM International jet fuel specifications.
- Obtain data for baseline and alternative jet fuels to demonstrate any effects of the alternative jet fuel on aircraft performance, maintenance requirements, and reliability.
- Coordinate effort with activities sponsored by Department of Defense and/or other government parties that may be supporting relevant work.
- Report relevant performance data of the alternative fuels tested including a quantification of the effects of the alternative fuel on aircraft and/or engine performance and on air quality emissions relative to conventional jet fuel. Reported data will be shared with both the FAA (NJFCP) and the broader community (e.g. ASTM International) and with ASCENT COE Program 33 “Alternative Fuels Test Database Library.”

Tasks #1 & #2: Evaluate Candidate Alternative Fuels for their Performance via the ASTM D4054 Approval Process and Management of Evaluation and Testing of Candidate Alternative Fuels

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Objective(s)

Cost effective and coordinated performance testing capability (in accordance with ASTM D4054) to support evaluation of promising alternative jet fuels is needed. The objective of this project is to provide capability to conduct the necessary work to support alternative jet fuel evaluation of either a) to-be-determined fuel(s) that will be selected in coordination with the FAA, or b) a fuel test and evaluation project with a specific fuel(s) in mind.

Research Approach

The intent of this program is to provide the capability of performing specification and fit-for-purpose (FFP) evaluations of candidate alternative fuels towards providing a pathway forward through the ASTM D4054 approval process. The UDRI team possesses the capability of performing a large of number of these evaluations, and we are prepared to work with other organizations such as SwRI and engine OEM’s, as needed, for their unique test capabilities. These include additional engine, APU, component, and rig evaluations. The UDRI testing capabilities cover our efforts at the laboratories of the Fuels Branch of AFRL and at our campus laboratory facilities.

The following are examples of the evaluations that UDRI is able to provide:



Tier I

1. Thermal Stability (Quartz Crystal Microbalance)
2. Freeze Point (ASTM D5972)
3. Distillation (ASTM D 86)
4. Hydrocarbon Range (ASTM D6379 & D2425)
5. Heat of Combustion (ASTM D 4809)
6. Density, API Gravity (ASTM D 4052)
7. Flash Point (ASTM D 93)
8. Aromatics (ASTM D 1319)

Tier II

1. Color, Saybolt (ASTM D 156 or D 6045)
2. Total acid number (ASTM D 3242)
3. Aromatics, (ASTM D 1319 & ASTM D 6379)
4. Sulfur (ASTM D 2622)
5. Sulfur mercaptan (ASTM D 3227)
6. Distillation temperature (ASTM D 86)
7. Flash point (ASTM D 56, D 93, or D 3828)
8. Density (ASTM D 1298 or D 4052)
9. Freezing point (ASTM D 2386, D 5972, D 7153, or d 7154)
10. Viscosity, at -20°C, (ASTM D 445)
11. Net heat of combustion (ASTM D 4809)
12. Hydrogen content (ASTM D 3343 or D 3701)
13. Smoke point (ASTM D 1322)
14. Naphthalenes (ASTM D 1840)
15. Calculated cetane index (ASTM D 976 or D4737)
16. Copper strip corrosion (ASTM D 130)
17. Existent gum (ASTM D 381)
18. Particulate matter (ASTM D 2276 or D 5452)
19. Filtration time (MIL-DTL-83133F Appendix B)
20. Water reaction interface rating (ASTM D 1094)
21. Electrical conductivity (ASTM D 2624)
22. Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (ASTM D3241)

Extended Physical and Chemical Characterization

1. Lubricity Evaluation- BOCLE test (ASTM D 5001)
2. Low Temperature Properties – Scanning Brookfield Viscosity
3. Detect, quantify, and/or identify polar species - Analyze as necessary
4. Detect, quantify and/or identify dissolved metals - Analyze as necessary
5. Initial Material Compatibility Evaluation – Perform optical dilatometry and Partition Coefficient Measurements to determine the fuel-effected swell and the fuel solvency in 3 O-ring materials (nitrile, fluorosilicone and fluorocarbon) and up to 2 additional fuel system materials
6. Experimental Thermal Stability Evaluation – Quartz Crystal Microbalance – Measure thermal deposit tendencies and oxidation profile at elevated temperatures
7. Viscosity versus Temperature – (ASTM D 445) determination of the fuels viscosity at 40°C and -40°C to assess the fuel's viscosity's variation with temperature

In addition to the above physical and chemical fuel evaluation capabilities, UDRI also has extensive experience in evaluation of microbial growth in petroleum-derived and alternative fuels. These evaluations include standard lab culturing and colony counting methods, as well as advanced techniques such as quantitative polymerase chain reaction (QPCR) and metagenomic sequencing. These methods allow the quantitative measurement of microbial growth rates in candidate alternative fuels in comparison with petroleum fuels.



UDRI also has extensive experience in evaluation of elastomer degradation upon exposure to candidate alternative fuels. Various methods are used to evaluate seal swell and o-ring fixture leakage, including: optical dilatometry, measurement of sealing pressure, fuel partitioning into elastomer, and a pressurized temperature controlled o-ring test device.

UDRI is also able to perform fuel-material compatibility testing using the D4054 procedures for fuel soak testing, post-exposure non-metallic and metal materials tests, and surface and microstructural evaluation. Testing of both 68 “short-list” materials and the complete 255 materials list can be performed.

Milestone(s)

The schedule for this project is dependent upon receipt of alternative fuel candidates for testing. As candidate fuels are received a schedule of testing will be coordinated with the FAA and collaborators. Our existing relationships with these organizations will help expedite this process.

Major Accomplishments

The Phase I Research Report for the LanzaTech/PNNL Ethanol-to-Jet (LT/PNNL ATJ) Synthetic Paraffinic Kerosene Fuels and Blends has been completed and submitted to the OEM’s for approval. The Boeing/Neste HFP-HEFA research report has been completed and is in the process of Phase I review by the OEM’s. We are awaiting arrival of the Shell IH2 and IHI Bb Oil fuels for Phase 1 evaluations.

Publications

“Evaluation of LanzaTech/PNNL Ethanol-to-Jet (LT/PNNL ATJ) Synthetic Paraffinic Kerosene Fuels and Blends Phase 1 Research Report,” 2016.

“Evaluation of High Freeze Point HEFA as Blending Component for Aviation Jet Fuels,” ASTM Research Report Version 1.1, 2017.

Outreach Efforts

Presentations were given at the April and Sept 2017 ASCENT meeting and meetings were held with European D4054 Clearinghouse initiators at the Rome IASH meeting in September. Meetings were held in Dayton with IHI, a Japanese company interested in entering their algae fuel in the D4054 process. We also continue to speak with Shell on their soon to be submitted IH2 fuel.

Awards

None

Student Involvement

None

Plans for Next Period

We plan to attend the ASTM December meeting in Houston and hold an OEM meeting with fuel producers in a separate session prior to the main ASTM meeting as in the past. We expect to receive the first shipment of the Shell IH2 fuel and begin the process of testing the fuel for Tier 1 and 2 evaluations. We expect to receive the first shipment of the IHI Bb oil algae fuel near the end of 2018.

Tasks #3 & #4: Management of Evaluation and Testing of Candidate Alternative Fuels

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Objective(s)

The objective of this work is to manage the evaluation and testing of candidate alternative jet fuels conducted in accordance with ASTM International standard practice D4054 (see Figure 1).

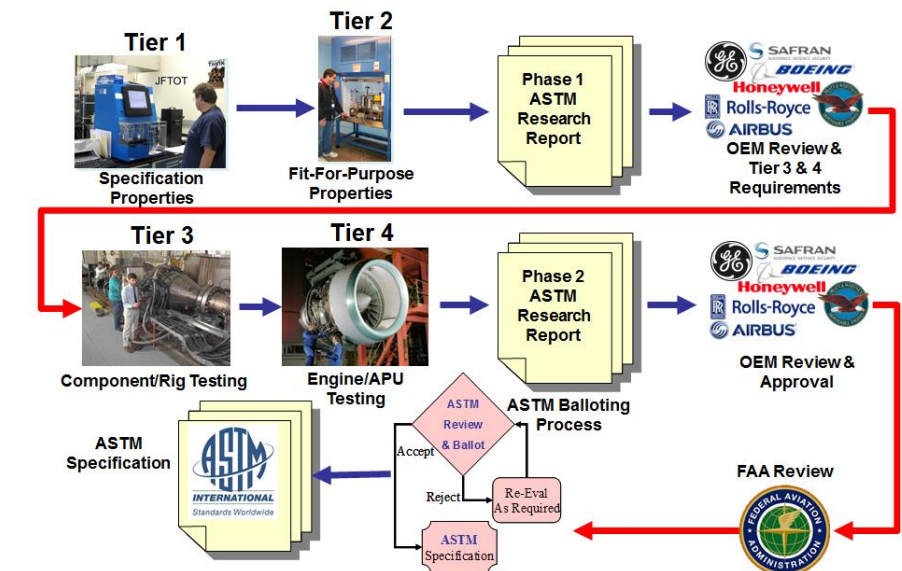


Figure 1. ASTM D4054 Qualification Process

Research Approach

UDRI will subcontract with other research organizations and/or test laboratories or OEMs to carry out the following tasks in support of evaluation and ASTM specification development for AJFs. The purpose of the project is to manage and coordinate the D4054 evaluation process shown in Figure 2 to facilitate transition of alternative fuels to commercial use.

Subtask 1: General Support

- Develop and make available a D4054 process guide that describes logistics procedures for handling of test fuels, documentation requirements, test report issuance and delivery, and contact information. This is intended to provide clear instructions to candidate fuel producers for entering into the ASTM D4054 process.

Subtask 2: Phase 1 Support

- Coordinate the handling of the Phase 1 candidate test fuel samples for Tier 1 and 2 testing.
- Review process description provided by the fuel producer for acceptability for incorporation into the Phase 1 research report.
- Review test data from Tier 1 and 2 testing for acceptability for incorporation into the Phase 1 research report.
- Issue and deliver a Phase 1 research report to the OEMs.
- In conjunction with the fuel producer, review and respond to comments to Phase 1 Research Report submitted by the OEMs.
- Conduct additional Tier 1 or 2 testing in response to OEM comments as required.
- Review and consolidate OEM requirements for D4054 Tier 3 & 4 testing submitted by the OEMs.
- Deliver consolidated D4054 Tier 3 & 4 testing requirements to the fuel producer.

Subtask 3: Phase 2 Support

- Coordinate the funding and scheduling of D4054 Tier 3 & 4 testing with OEMs and other test facilities.
- Coordinate the handling of the Phase 2 candidate test fuel samples for Tier 3 and 4 testing.
- Review test data from Tier 3 and 4 testing for acceptability for incorporation into the Phase 2 research report.
- Issue and deliver the Phase 2 research report to the OEMs.
- In conjunction with the fuel producer, review and respond to comments to the Phase 2 Research Report submitted by the OEMs.
- Conduct additional Tier 3 or 4 testing in response to OEM comments as required.
- Issue and deliver Phase 2 research report addendums reporting the additional Tier 3 or 4 test results as required.

Subtask 4: OEM Review Meetings

- Schedule periodic OEM Review Meetings to review the status of testing and research report review.
- Identify suitable meeting venues and support equipment.
- Develop agendas and coordinate with attendees for participating in the meeting.
- Record meeting minutes, including agreements, commitments, and other action items.



- Issue and distribute the meeting minutes to all attendees.

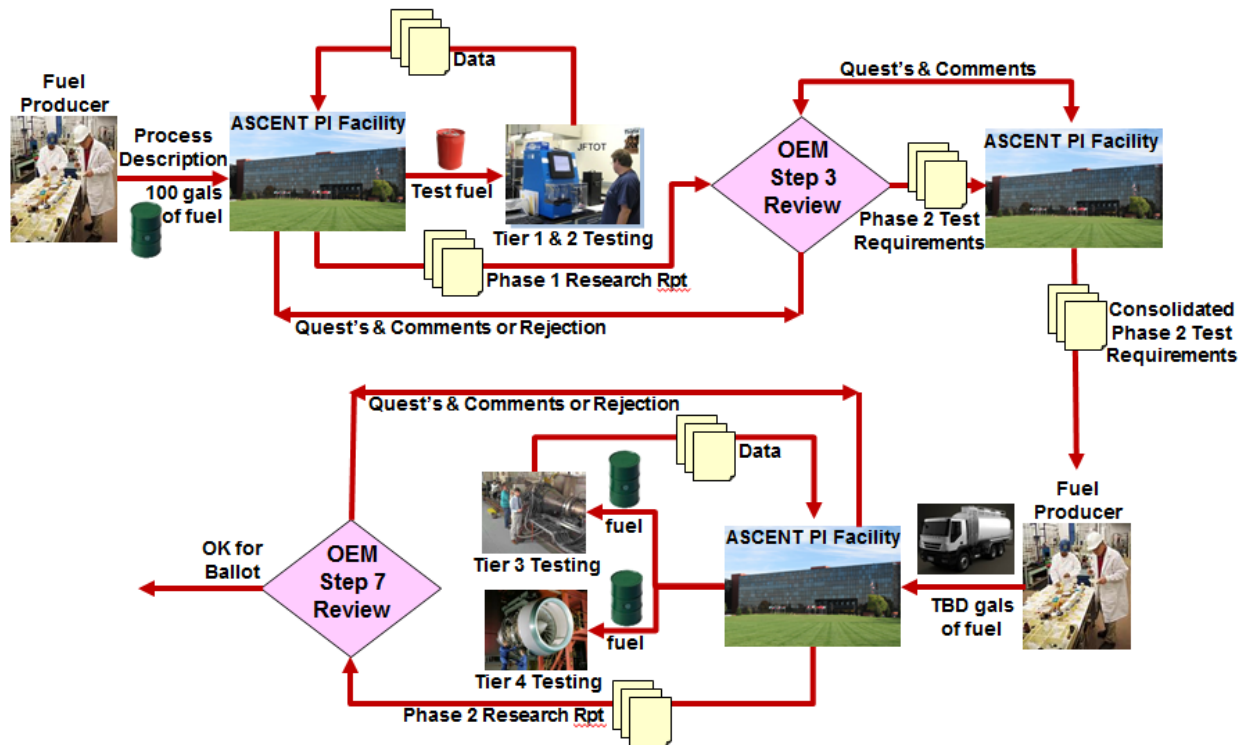


Figure 2. D4054 Evaluation Process

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A number of major activities occurred during the period. We attended the ASTM OEM meeting (Dec 2016 in Orlando) with engine and airframe OEMs to review progress on ASTM research report reviews. We gave a presentation on the chemical analysis of heteroatomic polars for development of a generic annex for alternative fuel certification. We presented the results of the on-going project at the April 2017 ASCENT meeting in Alexandria. We also attended the AFC meeting in London and discussed alternative fuel qualification and certification with the FAA and OEMs. Discussions with alternative fuel candidate producers also occurred at each of these meetings.

In addition, we presented a poster on the project at the Sept 2017 ASCENT meeting in Alexandria VA. We also attended the IASH meeting in Rome Italy and met with a European group that wishes to start a European version of the D4054 Clearinghouse. We advised this group on how the Clearinghouse is structured and will continue to work with them to



identify entities in the EU that can perform the necessary evaluations for D4054 certification. We also met with representatives from IHI, a Japanese company that wishes to certify their algae feedstock product via a modification to the HEFA annex of D7566. In addition, a Gantt chart showing the status of new fuels in the D4054 process was generated and sent to the fuel producers and OEM's. This Gantt chart is being continuously updated and provided to the FAA, fuel producers, and the OEM's. We have finally finished getting all six of the original engine and airframe OEM's on subcontract for the research report review process. We have also begun the process of funding AirBus for an initial amount for research report reviews.

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