Project 088 A Method for Rapidly Assessing Jet Fuel Compatibility with Non-Metallic Materials

University of Dayton Research Institute

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- P.I.s: John Graham and Gina Roesch
- FAA Award Number: 13-C-AJFE-UD
- Period of Performance: February 01, 2023, to September 30, 2025
- Tasks:
  1. Material Selection and Acquisition
  2. Detailed Fuel Composition
  3. Volume Swell
  4. Analysis of Absorbed Fuels
  5. Statistical Analysis
  6. Multiple Regression Modelling
  7. Reporting

Project Funding Level

The Federal Aviation Administration (FAA) provided $350,000 for ASCENT Project 088. The funds from the FAA were matched by several cost-sharing partners including Global Bioenergies, The Boeing Company, General Electric (GE) Aviation, National Research Council (NRC) Canada, Lanzatech, Neste, Shell, and IHI Corporation. In the fall of 2023, UDRI submitted a proposal for Phase II funding for Project 088. The FAA provided an additional $350,000 for ASCENT Project 088 Phase II. The same cost share partners were used for Phases I and II. In 2024, a no cost time extension (NCTE) was granted for Phase II testing due to the extended soak time required to execute Phase I testing.

Investigation Team

Dr. John Graham, PhD (P.I.), performs aspects of all parts of Project 088 from ideation, data acquisition, data analysis and reporting, as well as is the primary lead on statistical analysis and modeling of the data.

Dr. Gina Roesch, PhD (Co-P.I.), performs data acquisition and analysis as well as all project briefings.

Barbara Miller (Sealants and Elastomer Group Leader) oversees all technical outputs and controls the financial aspects of ASCENT Project 088.
Mary Galaska (technician) acquires analytical measurements including but not limited to volume swell and gas chromatography–mass spectrometry in support of ASCENT Project 088.
Wesley Waldron (technician) assists in the mechanical testing of the materials used in ASCENT Project 088.
Bradley Swindall (technician) assists in mechanical and physical property testing of the materials used in ASCENT Project 088.

Phase I Testing - Project Overview

The goal of ASCENT Project 088 is to create a prescreening method to assess whether a given synthetic aviation turbine fuel (SATF) is a good candidate for the rigorous fuel certification process established in ASTM D4054 (ASTM International, 2022). As an evaluation method, ASTM D4054 is time-consuming (turnaround times of months to years) and expensive process. In addition, material costs and fuel quantities are substantial barriers to entry for original equipment manufacturers (OEMs) to submit candidate fuels. As a result, ASCENT Project 088 was proposed and designed to develop a low-cost, small-sample-volume method to assess fuel interactions for the list of non-metallic materials proposed for material compatibility testing in ASTM D4054. The advantage of the approach proposed in ASCENT Project 088 is that it is less expensive, has a faster turnaround time (weeks), and requires smaller sample volumes (<250 ml). To keep the requirements to a minimum, the ASCENT Project 088 team chose volume swell as the physical property of interest. In tandem with volume swell experiments, gas chromatography mass spectrometry (GC-MS) will be used to quantify the interaction and exchange between fuels and materials. Using these two techniques as the foundation, statistical models will be generated to predict SATF compatibility with non-metallic materials given the known material response in conventional Jet A. Additionally, the experimental data gathered in ASCENT Project 088 can be used as a method to down select the extensive list suggested in ASTM D4054 (ASTM International, 2022).

ASCENT Project 088 involves two crucial deliverables. The first is the creation of a reference dataset by using a population of Jet A fuels gathered from ten sites across the continental United States (CONUS). This sample of 12 Jet A fuels represents the population of Jet A fuels currently in-service. Using these conventional Jet A fuels, ASCENT Project 088 will study and characterize how the materials on the ASTM D4054 Non-metallic Short List (Annex A3) interact with the current Jet A fuel population thus providing information on how today's non-metallic materials respond when exposed to Jet A fuel. The second deliverable for ASCENT Project 088 is a set of statistical models. The data points gathered for non-metallic materials and the known composition of the Jet A fuels will be used to build statistical models utilizing key class fractions as fitting parameters. Both single and multivariate models will be explored. At the end of ASCENT Project 088, the models generated can be used to compare SATF non-metallic responses in light of the same material's response to conventional Jet A fuels.

References

ASTM International. (2022). ASTM D4054-22L: Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives. https://store.astm.org/d4054-22.html

Task 1 – Material Selection and Acquisition

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Objective

The objective of this task is to select the list of non-metallic materials to evaluate in the survey of Jet A fuels, request quotations, and purchase all necessary materials for the project.

Research Approach

The 12 fuels were selected from a stock of 93 fuels obtained from 10 geographically dispersed locations across the CONUS. One fuel was selected from each of the 10 locations, and the fuels with the highest and lowest percentages of aromatic compounds were also selected for a total of 12 sample Jet A fuels.

Milestones

A survey of Jet A fuels was acquired from various locations across the CONUS so that the population could be considered a statistical representation of fuels being flown at the time of the study. This suite of Jet A fuels includes a variety of compositions (i.e., low aromatic compounds, high aromatic compounds, etc.). Additionally, all materials of interest have been acquired.

Major Accomplishments

Task 1 was completed during the 2024 calendar year.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

None. Task 1 is complete.

Task 2 – Detailed Fuel Composition

University of Dayton Research Institute

Objective

The objective of this task is to provide a detailed chemical analysis of current, in-service Jet A fuels. To achieve this objective, a survey of Jet A fuels was gathered from across the CONUS and characterized using two-dimensional gas chromatography (GCxGC) to determine the fuel composition against which future candidate SATFs can be compared.

Research Approach

The approach to evaluate the selection of the 12 Jet A fuels involved GCxGC, with emphasis placed on a selected set of class fractions known to play a role in the volume swell of non-metallic materials. Table 1 shows the class fractions of interest for ASCENT Project 088. Additionally, GCxGC analysis and simulated distillation curves were provided for each of the 12 fuels.

Table 1. Fuel Composition by GCxGC.

Class	Class Fraction
Aromatics	Alkyl benzenes
	Diaromatics (Naphthalenes, Biphenyls, etc.)
	Cycloaromatics (Indans, Tetralins, etc.)
Paraffins	iso-paraffins
	n-paraffins
	Monocycloparaffins
	Dicycloparaffins
	Tricycloparaffins

Milestone

Task 2 was completed during the 2024 calendar year.

Major Accomplishments

None.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

Task 2 is complete. The GCxGC data will be used for the remainder of the project, to understand material compatibility with the reference fuels and, in the future, with candidate SATFs.

Task 3 – Volume Swell

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Objective

Task 3 is the mission-critical task of ASCENT Project 088 as it provides the experimental data for the selected representative physical property, the volume swell of each material in the ASTM D4054 Non-metallic Short List in each of the 12 Jet A fuels selected in Task 2.

Research Approach

Experimental Approach

Volume swell was chosen as the keystone physical property for ASCENT Project 088 because it captures the overall exchange of components between the material and the fuel. In order to use small material and fuel volumes for the prescreening method, UDRI will utilize a custom technique to measure the volume swell of materials in fuel/fluid called optical dilatometry. Optical dilatometry uses sample sizes on the order of millimeters and fuel volumes of less than 5 mL per test. Task 3 hinges on using optical dilatometry to measure the volume swell of all the materials in the ASTM D4054 Non-metallic Short List in the candidate Jet A fuels selected in Task 2.

Figure 1 shows a schematic of an optical dilatometer on the left and an example system on the right. Up to four small samples are placed in an optical cell with 3–5 mL of test fluid at room temperature (approximately 75°F). The vial is placed on an optical stage that is lit form above with a light-emitting-diode (LED) strip. Below the optical cell is a digital camera and lens setup. The camera photographs the materials every 10 s for the first 3 min and then every 10 min for the remainder of the experiment. The length of the swelling experiments is variable. For ASCENT Project 088, the duration of the soak was chosen to be 160 hours such that an equilibrium or near-equilibrium state was reached for each material.

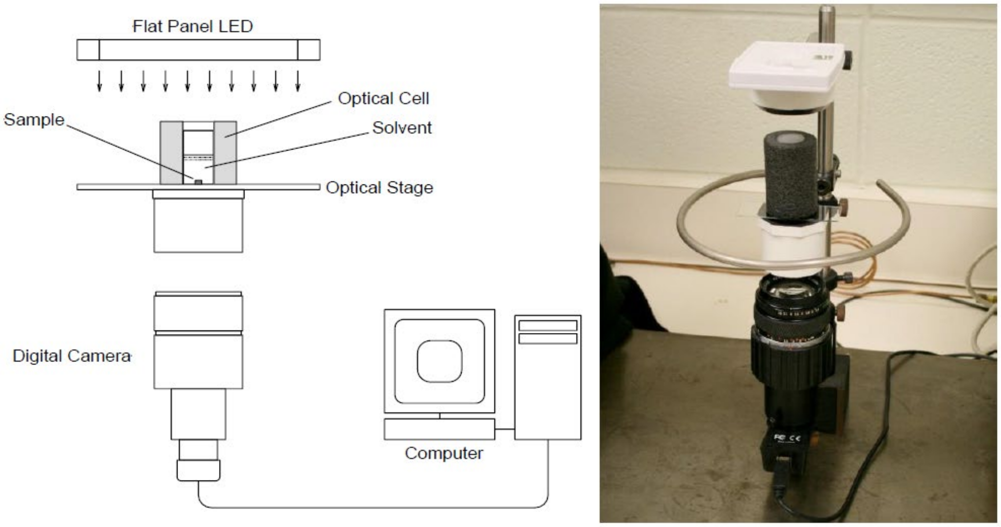

Figure 1. Schematic (left) and photograph (right) of an optical dilatometer.

Data Processing

When the exposure is complete, the images are analyzed via ImageJ, a software program used to extract the cross-sectional area of each of the samples. Assuming isotropic swelling of the material, the two-dimensional (2D) area from the image can be extrapolated to a three-dimensional (3D) volume for each sample over the duration of the experiment. The final volume swell is recorded as an average of the material areas at and around the 160-hour mark.

Figure 2 shows a summary of the results of Task 3. Figure 2 shows the average volume swell of each material in the ASTM D4054 Non-metallic Short List in all 12 Jet A fuels used in ASCENT Project 088. Two major conclusions arise from Figure 2. The first being that the duration of exposure (160 hours) was enough for all materials to reach equilibrium or near-equilibrium states. This is evidenced by the flatlining of the volume swell curves of each material at 160 hours. The second conclusion is that only 6 of the 34 materials tested showed a significant response to fuel exposure. In the context of ASCENT Project 088, significant fuel response is considered any average volume swell that is greater than 3%. Back-calculating from a 3D volume swell to a linear swell, a 3% change in volume corresponds to a 1% change in linear swell. A 1% linear swell was deemed acceptable because it is unlikely for major leaks to occur when there is a less than 1% change in the linear swell of the material. The materials that swelled more than 3% via volume swell are named in Figure 2. Figure 2 serves as one potential method in which the experimental results of ASCENT Project 088 can be used to down select the ASTM D4054 Non-metallic Materials Short List when testing compatibility with candidate SATFs. Specifically, if materials that are responsive and change as a result of fuel exposure to Jet A fuel are within the same statistical range pass compatibility testing, it is likely that materials that do not response to conventional Jet A fuel will also pass compatibility tests.

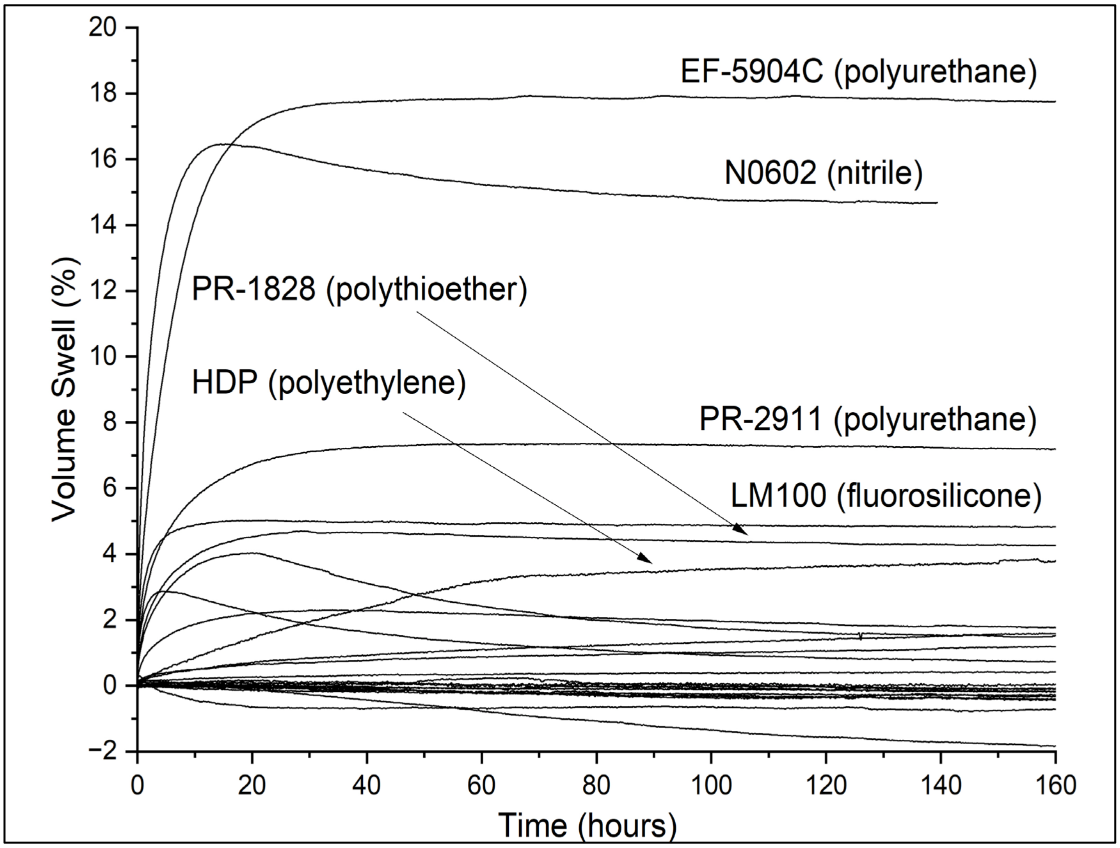

Figure 2. Task 3 summary graph showing the volume swell of all the materials in the ASTM D4054 Non-metallic Short List tested in triplicate in all 12 Jet A fuels selected in Task 2.

Milestones

Task 3 was completed during the previous calendar year.

Major Accomplishments

None.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

None. Task 3 is complete.

Task 4 – Analysis of Absorbed Fuels

University of Dayton Research Institute

Objectives

Task 4 is included to complement the results of Task 3 and gain a fundamental understanding of how the materials and fuels interact with one another throughout the exposure period. Task 3 can be described as the "what," i.e., what happens to a material when it is exposed to fuel and Task 4 is the "why," i.e., why the material does or does not swell. To study what causes the swelling (or lack thereof), gas chromatography mass spectrometry (GC-MS) will be used. GC-MS is a technique that identifies which, if any, of the selected class fractions are absorbed into the material from the fuel and/or what parts of the material are extracted into the fuel. The class fractions of interest are listed in Table 2 and were selected based on previous studies of material interactions with fuels. They were also based on the GCxGC analysis such that several of the class fractions quantified in Task 2 could be utilized here as well. Of note in Table 2, the class fraction labeled "naphthalenes" encompasses all alkyl naphthalene species. Alkyl naphthalenes usually consist of but are not limited to methyl or ethyl groups ($-CH_3$ or $-CH_2CH_3$) across different carbons in the aromatic structure.

Table 2. Class fractions investigated via GC-MS.

Class	Class Fraction
Aromatics	Alkyl benzenes
	Diaromatics (Naphthalenes, Biphenyls, etc.)
	Cycloaromatics (Indans, Tetralins, etc.)
Paraffins	iso-paraffins
	n-paraffins
	Monocycloparaffins
	Dicycloparaffins
	Tricycloparaffins

Research Approach

Experimental Approach

GC-MS is performed with an Agilent® 7890A gas chromatograph equipped with an Agilent 5975C VL Mass Selective Detector (MSD). The sample preparation for the material is as follows:

1. Remove aged samples from fuel, and pat dry three times with laboratory wipes to remove any fuel residing on the outside of the material (i.e., not absorbed by the material).
2. Place one piece of test material in a 1.5-ml GC vial with 1 ml methylene chloride (MeCl).
3. Repeat steps 1 and 2 with a second aged test material from the sample vial.
4. Place the samples sitting in solvent (MeCl) on the autosampler and run under UDRI's standard method/temperature ramp.
5. After GC-MS analysis is complete, decant the residual solvent and dry the test material and vial in an oven for 30 min using a predetermined heating cycle.
6. Remove and weigh the dried test material. Record the final weight of the sample for quantitative analysis.

Steps 1–4 should be repeated for the sample Jet A fuels (1 µL of fuel in 1 ml of MeCl) to quantitatively compare the material's ability to extract from the fuel (and vice versa).

Data Analysis

Data analysis for Task 4 consists of integrating the area under the curve of each peak present in the overall chromatogram (total ion chromatogram [TIC]) and the extracted ion chromatograms (EICs) for the representative class fractions.

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Integration is performed using Agilent ChemStation® Analysis software and Agilent MassHunter,® both via manual integration methods. The area under each curve for TICs and EICs are exported to another software program in which partition coefficients (K_{pf}) are calculated. The K_{pf}, the ratio of a class fraction in the polymer relative to its concentration in the neat fuel, is the metric used to summarize the interaction between the non-metallic material and the surveyed Jet A fuels. Figure 3 provides a visual representation of the two-way exchange that occurs between the material extracting from the fuel and the fuel extracting from the material. The bottom panel of Figure 3 shows the test fuel (sample Jet A), and the top panel shows the absorbed fuel in a sample O-ring (AMS-P-5315). The ratio of the two spectra shows that the material only absorbed a fraction of the fuel components because it has a lower overall signal response.

As shown on the left side of Figure 3, K_{pf} values can fall into three regions. A $K_{pf} < 1$ indicates that the material is resistant to the class fraction of interest. A $K_{pf} > 1$ indicates that the material absorbs or extracts a substantial portion of the class fraction of interest. Finally, a $K_{pf} = \sim 1$ indicates relatively equal exchange in material and fuel. The K_{pf} values calculated for the materials can be used to predict the swelling behavior of fuels with similar class fractions in the future.

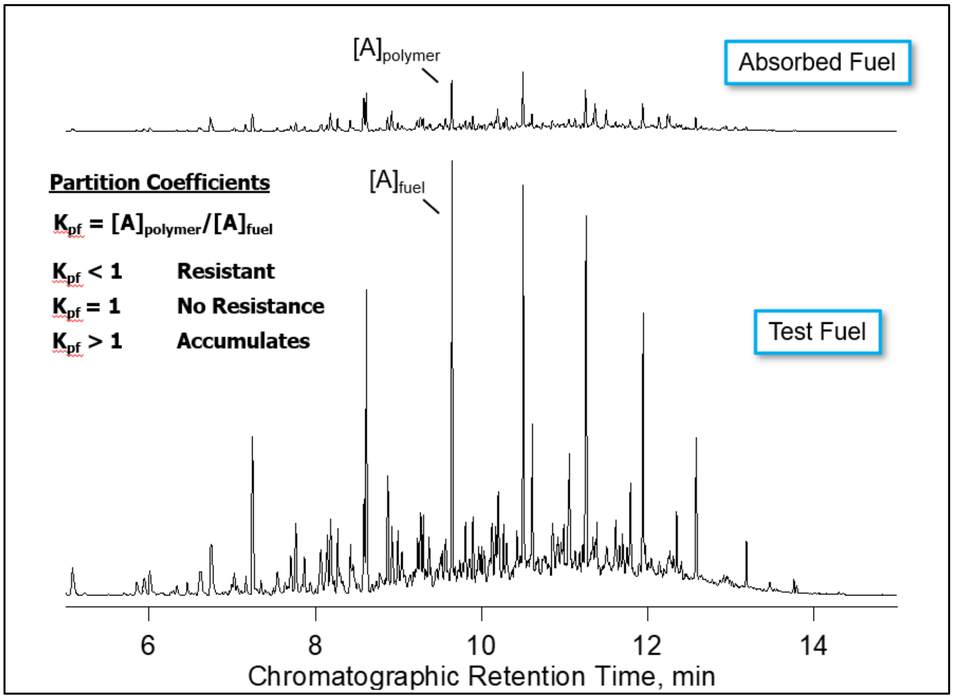

Figure 3. Absorbed fuel analysis via GC-MS. This technique is used to compare a neat polymer (AMS-P-5315), the reference fuel (Jet A) and the exchange between the fuel and material during the volume swell experiment.

Table 3 and Table 4 contrast experimental K_{pf} values associated with O-rings and Films found in the ASTM D4054 Non-metallic Short List. These two examples show a stark contrast in experimental partition coefficients and, by extension, starkly different responses to fuel exposure. In Table 3, AMS-P-5315 (Table 3, Column 1) has K_{pf} values that are all greater than 0.10 with some values even nearing 1.0. On the other hand, Kapton (Table 4, Column 3) showed so little response to fuel exposure that it could not be quantified via GC-MS, which is approximately a 10 ppm technique. This result is confirmed by the low volume swell experimentally determined in Task 3 (0.02% volume swell). A more quantitative example compares AMS-P-5315 and polyethylene (Table 4, Column 2). Even the most readily absorbed class fraction (the naphthalenes), had experimental K_{pf} value of 0.21 indicating that approximately less than 1/5 of the class fraction was absorbed into the material. The large K_{pf} values in AMS-P-5315 (large values relative to high-density polyethylene (HDP) and many other non-metallic species in the ASTM D4054 Non-metallic Short List) indicate that AMS-P-5315 responds to all class

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fractions in a significant amount relative to other materials. Comparing materials, both within a material class and externally between material classes, demonstrates the power of Task 4's quantitative approach to material-fuel interactions. The quantitative approach enhances the understanding of what class fractions play a role in volume swell, lifetime, hardness and other physical and mechanical properties of materials.

Table 3. Experimental K_{pf} values for all O-rings across sample Jet A fuels.

Class Fraction	AMS-P-5315 N0602	AMS25988 LM100	AMS7276 V0747	AMS83485 VM125
Overall	0.17	0.04	0.01	0.02
n,i-Paraffins	0.12	0.04	0.01	0.01
Cycloparaffins	0.15	0.04	0.01	0.01
Alkyl Benzenes (C10 Bz)	0.37	0.09	0.03	0.07
Naphthalene	0.94	0.16	0.07	0.17
Naphthalenes (C11 & 12)	0.60	0.09	0.03	0.09

Table 4. Experimental K_{pf} values for all films across sample Jet A fuels. High-density polyethylene (HDP) is below the detection limit (bdl).

Class Fraction	Nylon Dupont Zytel 101	Polyethylene HDP	Kapton UPILEX
Overall	bdl	0.10	bdl
n,i-Paraffins	bdl	0.09	bdl
Cycloparaffins	bdl	0.14	bdl
Alkyl Benzenes (C10 Bz)	bdl	0.20	bdl
Naphthalene	bdl	0.31	bdl
Naphthalenes (C11 & 12)	bdl	0.21	bdl

Milestones

During the 2025 calendar year, all GC-MS analysis was completed and vetted by Dr. Graham and Dr. Roesch.

Major Accomplishments

Task 4 was completed.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

None. Task 4 is complete.

Task 5 – Statistical Analysis

University of Dayton Research Institute

Objective

The primary objective of this task is to explore if there is a correlation between the volume swell of a given material and the aromatic content of the fuels to which it was exposed. To achieve this objective, the volume swell data will be fit with a linear model against the aromatic content of the fuels, thus providing a line of fit in which experimental data points of candidate SATFs can be plotted and referenced against. This fit, along with the associated confidence and prediction intervals, will be the primary point of comparison used to evaluate the viability of future SATF candidates.

Research Approach

In Task 5, linear statistical models were created correlating the swell of each material to the aromatic content of the 12 Jet A fuels used in this study. Figure 4 is a sample single-variable model (AMS-P-5315). Each single variable model was generated using Statistical Analysis System (SAS®) software. As shown in Figure 4 for AMS-P-5315, both the visual/graphical representation and the numerical model (equation of fit) are provided. The equation of fit for each material produces three key variables: (1) the slope of the line, (2) the intercept, and (3) the coefficient of determination. The slope of the line of fit describes if the average volume swell is a function of the aromatic content of the fuel. The intercept of the linear model represents the estimated volume swell for a Jet A fuel with 0% aromatics in the fuel. This is a useful data point given that many candidate SATFs could have little to no aromatic content. Lastly, the coefficient of determination, the R^2 value, describes the strength of correlation between the measured aromatic content of the fuel and the volume swell. All these parameters contribute to the overall understanding of the aromatic content of the fuel's effect on a given material in the ASTM D4054 Non-metallic Short List.

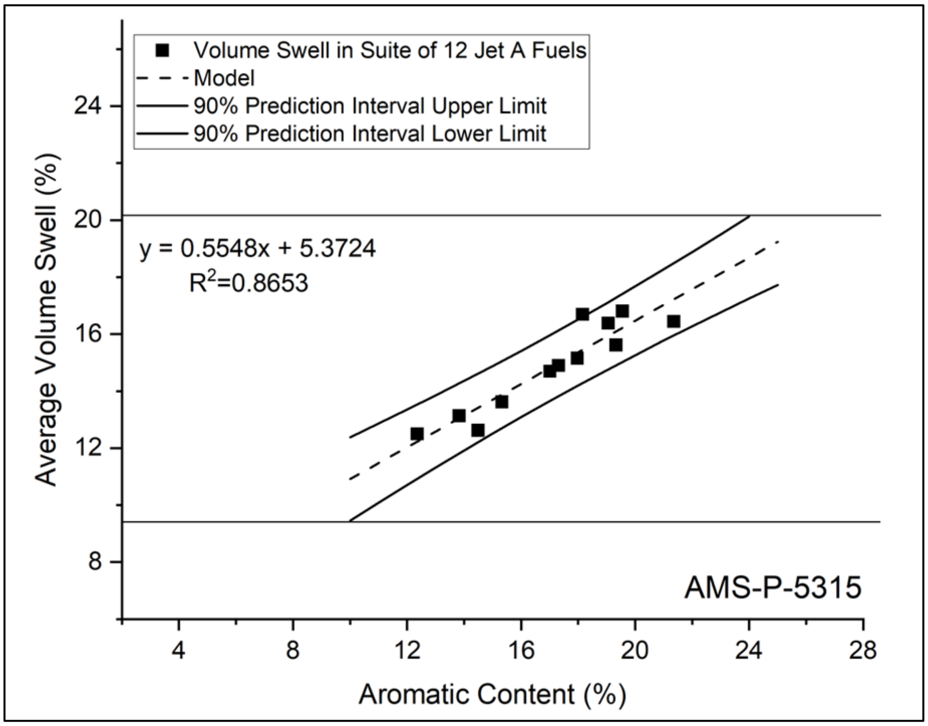

Figure 4. Single variable linear model describing the volume swell of AMS-P-5315 as a function of the aromatic content of Jet A fuels.

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In addition to the key outcomes described above, SAS also generates a 90% prediction interval for the data. The 90% prediction interval is distinct from a traditional confidence interval in that it describes individual fuels within a larger population and is not based solely on the mean value of the 12 sample fuels used in this study. Producing and graphing prediction intervals is a key aspect of Project 88 because it contextualizes each material response with 90% of ***all*** in-service Jet A fuels being flown at the time of the study. Essentially, the prediction intervals for each material describe the response of the material to 90% of all Jet A fuels used today and thus depicts the field as it stands in 2024/2025.

Figure 5 shows an example of how to use one of the single variable models generated in Task 5 of ASCENT Project 088. Specifically, Figure 5 shows the volume swell observed for the material as a function of the aromatic content in a candidate SATF (blue) and a 50:50 blend of the candidate SATF and Jet A (red) superimposed on the Task 5 model. As is seen, the neat SATF (blue) falls outside of the prediction interval generated for the material in Jet A. A data point falling outside of the statistical range of the material in Jet A fuel does not imply that the candidate SATF is not compatible with the material. It simply means that the material will see a condition which it has not seen in service before. It also does not indicate that the candidate SATF will fail full-scale material compatibility testing. It is simply an indication that the material responds differently. Often, further investigation is necessary to determine if this is an issue or simply a difference. Ultimately, this information helps inform OEMs as to how their products interact with materials relative to that material's response in conventional Jet A fuel. The second observation – and somewhat of a comfort to a potential OEM - is that the 50:50 blend falls within the predicted range of Jet A-material compatibility. P088 investigators suggest that 50:50 blends be run alongside the neat SATF so that fuels more akin to ASTM D7566 (ASTM International, 2022) regulations are also tested. This approach simply gives OEMs an additional data point helping them to make data-informed decisions.

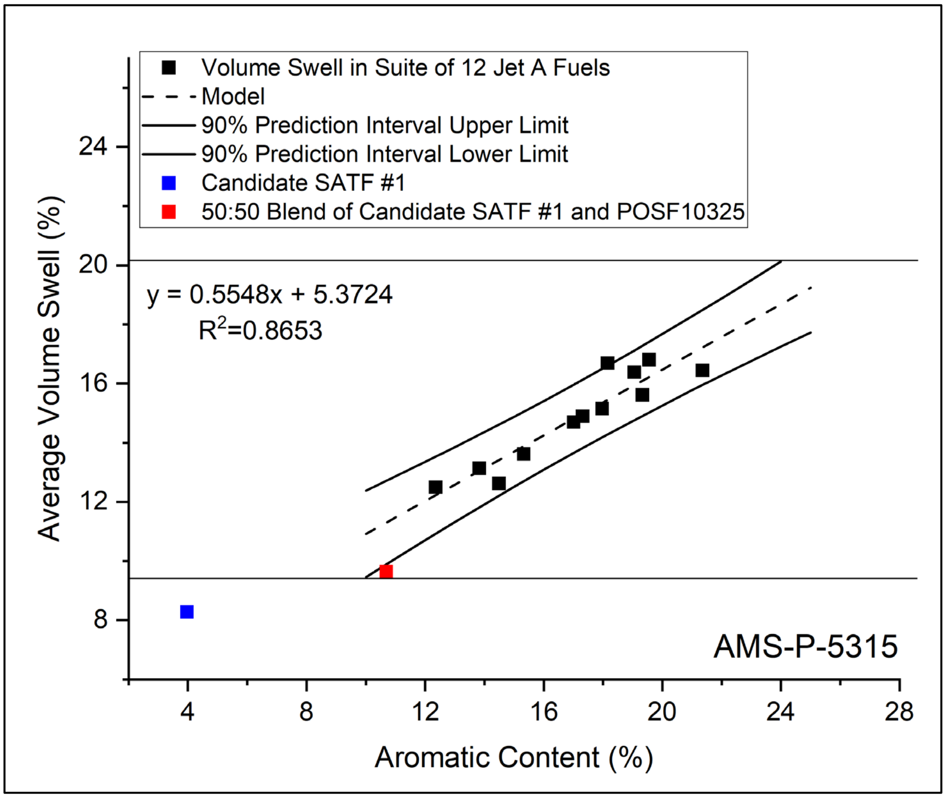

Figure 5. Single variable linear model demonstrating how a candidate SATF (blue) and a 50:50 blend of the candidate SATF and Jet A fuel (red) fall with respect to AMS-P-5315 in 90% of all in-service Jet A fuels.

Lastly, the results of Task 5 can be used to generate informative graphics for OEMs based on specific fuel components. Today, many material compatibility questions revolve around the concentration of aromatics in synthetic fuels because aromatics are known to contribute to the volume swell. To address this question, Figure 6 (below) shows one way of visualizing the experimental data produced by Task 5 to address the previous question. Because the coefficient of determination defines the ‘goodness’ of the linear model, the materials that have high swelling character and high coefficients of determination would be of main interest for a fuel producer that is concerned about their low or no aromatic fuel being compatible with a non-metallic material that would normally only see Jet A fuels. The top right quadrant of Figure 6 shows materials who exhibited significant volume swell (greater than 3% swell) ***and*** volume swell that positively correlated to the aromatic content of Jet A fuels (R^2 value greater than 0.5). OEMs now have the option to make data-based decisions on what materials to test if aromatic content is the most important variable. The results of Figure 6 suggest a matrix that potentially decreases from 36 materials to 4. Not only is this a data-backed decision, but it saves time and costs for OEMs with specific questions related to fuel composition and material compatibility.

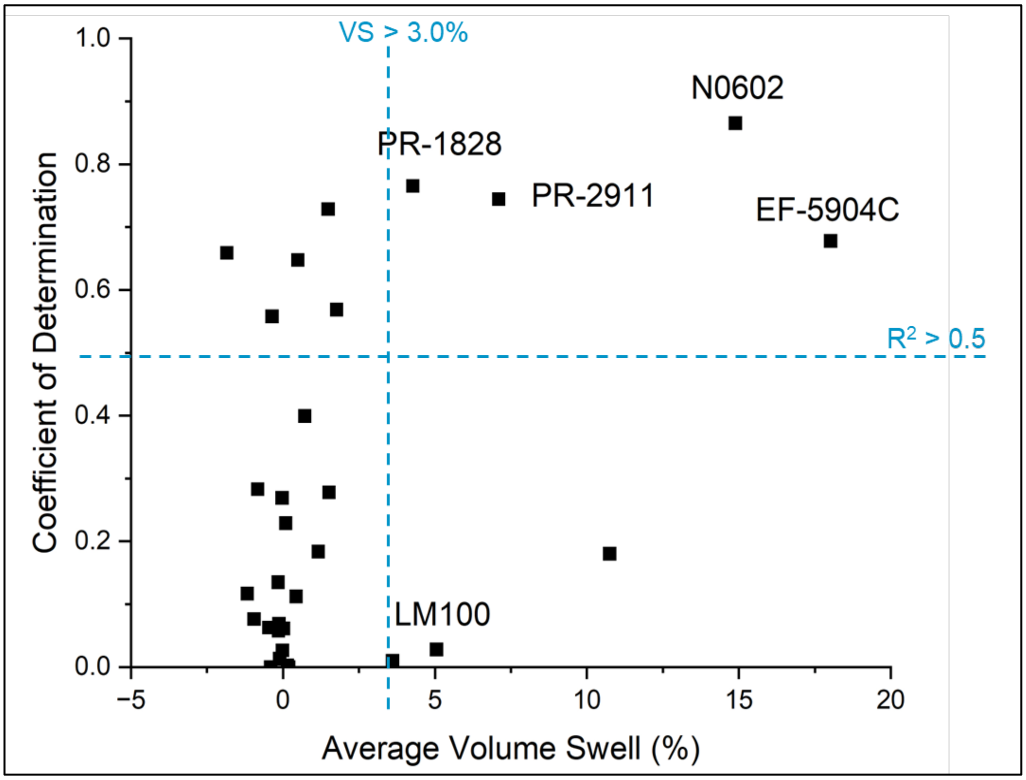

Figure 6. Average volume swell as a function of the coefficient of determination for the single variable model for all materials on the ASTM D4054 Non-metallic Short List.

Milestones

Task 5 was completed during the 2025 calendar year.

Major Accomplishments

The statistical models created in Task 5 will achieve one of the primary goals of implementing ASCENT Project 088 as a prescreening method. First, Task 5 summarizes the results of Task 3, volume swell, and graphs them as a function of the aromatic content of the 12 Jet A fuels used in this study. These models and the resulting data analysis approaches will help OEMs determine how their fuel compares to the current, in-service, safe-to-fly fuels currently in the fleet.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

None. Task 5 is complete.

Reference

ASTM International. (2022). ASTM D 7566-21: Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. https://doi.org/10.1520/D7566-21

Task 6 – Multiple Regression Modeling

University of Dayton Research Institute

Objective

The objective of Task 6 is to expand on the single-variable correlations generated in Task 5. In Task 6, multi-variate models will be created to understand in more depth the influence of the fuel composition on volume swell (as opposed to just the impact of the aromatic content). Task 6 will utilize the experimental volume swell results (Task 3) as well as the partition coefficients generated in Task 4. These models aim to provide a more holistic picture of material and fuel interactions.

Research Approach

Task 6 will combine the results of Task 2 and Task 3 to create a more robust predictive model. The model will relate the measured fuel composition (Task 2) and the measured volume swell (Task 3) via a multiple regression linear model. The model will be fit to Equation 1:

$$Volume\ \text{Swell} = \sum_{i=1}^{n} ki[Ai] \qquad \text{(Eq. 1)}$$

where *ki* is the regression coefficient for a given component or class fraction, *i* is the class fraction, and *[Ai]* is the concentration of the component or class fraction *i.* The regression coefficient is calculated using Equation 2:

$$\text{Regression coefficient} = \frac{\text{Percentage volume swell of material in fuel}}{\text{Percentage concentration of class fraction in fuel}} \qquad \text{(Eq. 2)}$$

for all class fractions, *n,* which will be used in the model. In ASCENT Project 088, the class fractions of interest are normal and iso-paraffins, cycloparaffins, alkyl benzenes, diaromatic compounds, and cycloaromatic compounds (Table 2). In addition to fitting the class fractions from the HTA, the model will include a term to account for the average molecular weight because molecular weight of the fuel impacts the volume swell. This aspect will be an essential component enabling extension of the model to the candidate SATFs in the future that are also likely to have different chemical compositions than traditional Jet A fuels.

Table 5 shows the coefficients generated for the full Task 6 model for a sample material (AMS-P-5315). Upon initial glance, the coefficients make little physical sense. Upon verification of the source code, it was determined that indeed the multi-variate model was a good *predictive tool* and that the coefficients provided the correct fuel compositions when the model was run in reverse. However, Dr. Graham wanted a tool that was more *interpretable* for OEMs and researchers. Therefore, an intermediate model was created in Task 6. The intermediate model decreased the number of independent variables and therefore gave the model more degrees of freedom. By removing the mean molecular weight and making the n,i-paraffins an implicit parameter, the model became far less constrained, and the outputs were far more reasonable. Table 6 shows the coefficients generated for the intermediate model for the same sample material (AMS-P-5315).

Table 5. Full model volume swell coefficients for AMS-P-5315 at 75°F in Jet A fuels.

Model Coefficients (%/%)					**Average M.W.**	**Intercept**	**R^2**
Aromatics			Paraffins				
Alkyl-	Cyclo-	Di-	n, i-	Cyclo-	%/(g/mol)	%v/v	Value
-1.891	-2.045	-1.605	-2.530	-2.452	-0.159	279.951	0.950

Table 6. Full model volume swell coefficients for AMS-P-5315 at 75°F in Jet A fuels.

Model Coefficients, %/%				**Intercept**	**R^2**
Aromatics			Paraffins		
Alkyl-	**Cyclo-**	**Di-**	**Cyclo-**	**%v/v**	**Value**
0.698	0.386	0.250	0.081	1.974	0.919

Milestones

During the previous reporting period, Task 6 full and intermediate models were completed for all 36 materials.

Major Accomplishments

Task 6 expands ASCENT Project 088's prescreening toolkit for SATF and Jet A fuel compatibility with non-metallic materials beyond the singular contributions of the aromatics to volume swell. The model built in Task 6 will incorporate the effects of selected class fractions on volume swell both in terms of concentration and molecular structure. In the long term, the model in Task 6 will help OEMs understand the impact of individual class fraction on individual non-metallic materials. On a fuel-design level, the model will provide OEMs with numbers indicating which class fractions play the greatest role in a material's swell, thus informing the design of future SATFs.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

None. Task 6 is complete.

Task 7 – Reporting

University of Dayton Research Institute

Objective

The objective of this task is to document and report the results of ASCENT Project 088 in both quarterly and annual reports. Additionally, at the end of ASCENT Project 088, the results will be compiled into a final report and shared with the FAA.

Research Approach

None.

Milestones

During the previous reporting period, the first half of the Phase I report was completed. Tasks 1-3 were fully vetted and reported on. Additionally, all figures and graphics were made for Tasks 4-6.

Major Accomplishments

Dr. Gina Roesch provided status updates for ASCENT Project 088 at the Spring SATF Meeting in Knoxville, Tennessee, and the Fall ASCENT Meeting in Alexandria, Virginia.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

The remaining part of Task 7 involves completion of the Phase I report. The report is projected to be completed by mid-February of 2026. The final report will then be reviewed by the FAA and UDRI will make edits as requested.

Phase II Testing - Project Overview

The goal of Phase II of ASCENT Project 088 is to narrow the list of materials studied and expand the set of fuels used to begin to describe how specific materials respond to synthetic aviation turbine fuels (SATFs). In Phase I, O-ring seals continually came up as high-swelling or high-responding materials (see Figure 2). Furthermore, the field continues to document O-ring seals as the most common locations for leaks in modern aircraft systems. This is especially true when testing new, synthetic fuels as a result of the different chemistry between synthetic fuels and conventional jet fuels. Therefore, Phase II will narrow the material investigation from all 36 materials in the Annex A3 list to 4 O-ring seal materials. The four seal materials will be tested in not only Jet A as the reference fuel, but a SATF and a 50:50 blend of the Jet A:SATF. This test matrix will improve upon the dataset generated in Phase I which depicted the state of material and jet fuel compatibility as it is today by beginning to characterize and understand what the state of material compatibility could be if SATFs are used interchangeably with conventional jet fuels.

Because there is interest in SATF compatibility with respect to Jet A fuel, Phase II will begin with an evaluation of the volume swell of the candidate seal materials in the SATF and 50:50 blend to compare and contrast the material response to the experimental results of Phase I. The bulk of Phase II testing, however, will focus on determining the engineering performance properties of seals in conventional versus synthetic jet fuels. Two key metrics will be measured: (1) the compression set and (2) sealing pressure. Compression set is a well-known performance metric for seal lifetimes and sealing pressure characterizes the conditions under which leaks will or will not occur. These metrics will be measured in a variety of scenarios including neat fuels and switch-loading between Jet A fuel and SATFs/SATFs blends. By experimentally determining the seal performance in SATFs, Phase II will provide OEMs with critical information on how or if material performance is affected when SATFs are substituted for traditional jet fuels.

Phase II brings two major advantages to the previous body of work executed in Phase I. First, it includes the study of the SATFs and, critically, switch-loading scenarios between SATFs and conventional Jet A fuel. This is of great interest to the community because of the differences in swelling character of common materials in conventional and synthetic jet fuels due to the difference in fuel composition. Second, Phase II expands from studying analytical properties of interest – the volume swell – to measuring actual engineering metrics for seal performance. With a narrow focus on seals and the inclusion of SATFs of interest, Phase II aims to generate information to inform airframe and fuel OEMs on the critical aspects of fuel switching as it relates to material compatibility.

Task 1 – Material Selection & Acquisition

University of Dayton Research Institute

Objective

The objective of this task is to determine the appropriate materials and fuels to execute the test plan and provide the best possible data to the FAA.

Research Approach

The research approach for Task 1 involved evaluating Phase I data to elucidate which materials were of most interest to study in Phase II testing. Additionally, UDRI talked with FAA project managers (PMs) and other OEMs to gather information on which SATFs and associated synthetic blending components to investigate based on industrial and gubernatorial relevance.

Milestones

Task 1 was 75% completed during the 2025 calendar year.

Major Accomplishments

All materials for ASCENT Project 088 Phase II were acquired, and the fuels of interest were decided upon. Four O-rings spanning three material chemistries were chosen (nitrile rubber, fluorosilicone, fluorocarbon and low temperature fluorocarbon). A standard Jet A fuel and a Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA-SPK) were chosen as the candidate fuels for testing. It was also decided that a 50:50 blend of Jet A:HEFA-SPK should be used to model a true candidate SATF given the blending rules dictated in ASTM D7566. Finally, both the neat Jet A fuel and neat HEFA-SPK were characterized via GCxGC for detailed information on bulk hydrocarbon type analysis.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

During the next reporting period, the remaining amounts of the HEFA-SPK will be acquired for testing.

Task 2 – Volume Swell & Switch-loading

University of Dayton Research Institute

Objective

The objective of this task is to measure the fuel-material interaction via volume swell in both static (single-fuel) and switch-loading conditions. To measure the volume swell, optical dilatometry will be used. All four seal materials will be exposed to four different fuel scenarios: (1) neat Jet A fuel, (2) neat HEFA, (3) a 50:50 blend of Jet A:HEFA-SPK and, finally, (4) the switch-loading scenario. All static soaks will be two weeks long. Switch loading will occur been Jet A fuel and neat HEFA for all four materials at a switching cadence of every two weeks for a minimum of 26 weeks.

Research Approach

For detailed information on optical dilatometry and static fuel soaks, please refer to Task 3 in the Phase I report. Here, the technique of optical dilatometry as applied to switch-loading will be discussed.

To perform switch-loading experiments via optical dilatometry, no change in hardware is necessary (see Figure 1). In lieu of multiple specimens being tested at one time, one singular 1 mm thick O-ring cross section is placed in the center of the glass vial with 3-5 mL of fuel 1. The first exposure proceeds as a normal optical dilatometry experiment with images acquired every 10 seconds during the first exposure period and every 10 mins during the second exposure period. It is of great importance to note that there was procedural change in the timings for optical dilatometry experiments between Phase I and Phase II. In Phase II, the first exposure period is 30 mins as opposed to the previous 3 mins used in Phase I. Overall volume swell is still taken as an average at the end of testing, so there is no concern about the comparability of datasets. At the end of the 2-week exposure period, a new test vial is prepared with fuel 2. Once the new test vial is setup, the sample is removed from fuel 1 and dabbed dry at least three times with a KimWipe™ to remove excess fuel on the outside of the sample. The sample is then placed in the new vial with fuel 2 and the experiment exposure proceeds as normal. This procedure can be done as many times as desired. With respect to data processing, there are only two differences. First, each fuel exposure uses the extrapolated time-zero area from the very first exposure to fuel 1 as the reference area. Second, for all the last and first data points between switches, the volume swell values are adjusted (normally averaged) so that the progression between datasets is smooth. A sample showing the volume swell of a material switching between JP-8 fuel and an iso-paraffinic kerosene (IPK) is in Figure 7 below.

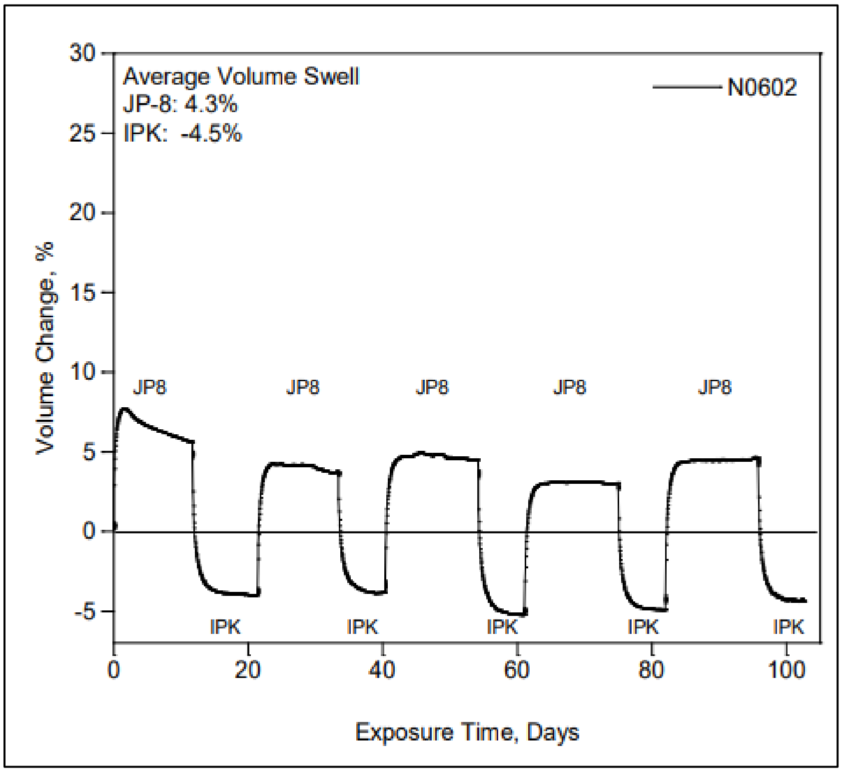

Figure 7. Switch-loading volume swell profile for AMS-P-5315 material switching between JP-8 fuel and an iso-paraffinic kerosene (IPK).

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Milestones

During the previous reporting period, all static, two-week fuel soaks were completed for all four materials. Additionally, long-term switch-loading soaks for each material in duplicate were started and will have completed 18 weeks of exposure by January 01, 2026.

Major Accomplishments

One of the major accomplishments achieved throughout the previous reporting period was experimental determination of the volume swell of each of the four materials in each neat fuel and the 50:50 blend. This information will be used to complement the data taken in Phase I of ASCENT Project 088.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

The plans for the next reporting period are to complete the long-term switch loading soaks and perform appropriate data analysis for both static and switch-loading volume swell experiments.

Task 3 – Compression and Switch-loading

University of Dayton Research Institute

Objective

The objective of this task is to measure the compression set of O-rings in model face seals under switch-loading conditions. Compression set was chosen as the measurement of interest because it is a good indicator of the proverbial age of an O-ring. In Phase II, UDRI-designed model face seal fixtures will be used to better simulate in-service conditions (i.e., in a gland as opposed to free-floating). Ultimately, the compression set data will be used in conjunction with the Task 2 volume swell data to better strengthen the link between volume swell measurements and seal performance.

Research Approach

Compression set, by definition, is a measure of an elastomeric material's ability or inability to return to its original dimensions after being exposed to various conditions (Parker O-ring Handbook, 2001). In Task 3, the compression set of all four O-ring materials in each fuel will be measured using UDRI's model face seal glands. The face seal glands, shown in Figure 8, are often referred to as compression set fixtures. UDRI's compression set fixtures were custom designed to mimic a 25% compressed gland for standard 2-214 O-rings. The small, modifiable-in-height stack can be easily placed in fuels or fluids. Fluid access is achieved via a channel and opening in the middle which can be best seen in the two stacks on the far right of Figure 8. The fixtures can also be placed at temperature, adding yet another opportunity to more closely imitate in-service conditions for these materials.

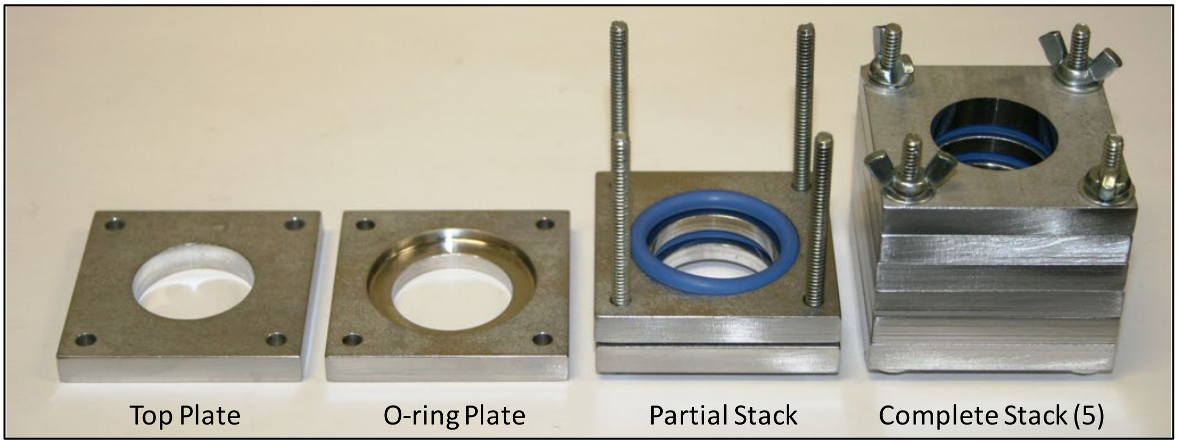

Figure 8. UDRI compression set fixtures used to age O-ring materials under nominal 25% compression. The stacks can be placed in fuel and at elevated temperatures to accelerate the aging of O-ring materials.

To conduct compression set measurements, the O-rings are removed from the fixtures, and the thickness is measured at three points around the O-ring. Once the measurements have been made, the O-rings are reinstalled in the fixtures, the compression is applied by tightening the wingnuts, and the stack is returned to the previous exposure conditions. Once completed, the compression set measurements will be combined with the volume swell measurements (Task 2) to investigate the correlation between volume swell and seal performance.

Milestones

During the previous year, compression set measurements were started for all four O-ring materials in Jet A fuel at 160°F. As of January 01, 2026, the O-rings will have been in compression set testing for approximately 16 weeks. Compression set measurements are being made and recorded on a two-week basis.

Major Accomplishments

Data sheets, policies and procedures were put in place in UDRI's Sealants and Elastomers Lab for full-scale compression set testing at elevated temperatures.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

During the next reporting period, full-scale compression set testing at elevated temperature will be conducted in the other soak scenarios. Also, the UDRI researchers will examine Tasks 2 and 3 datasets to determine the correlation between volume swell and seal performance.

Task 4 – Real-time Measurement of Sealing Force & Pressure During Switch-loading

University of Dayton Research Institute

Objective

The objective of this task is to bridge the gap between analytical measurements and engineering performance metrics. Specifically, Task 4 will involve measuring how and if the sealing pressure of an O-ring changes when the fuel is switched from a conventional Jet A fuel to the candidate SATF. The final step in Task 4 will be to determine the minimum sealing pressure required to prevent fuel leaks in the model face seals.

Research Approach

The research approach for Task 4 involves obtaining two critical experimental variables that will be used to calculate the sealing pressure of the material. First, the sealing force of the O-ring must be measured as function of time in dry, wet and changing fuel environments. This measurement is made using a modified Elastocon® compressive stress relaxometer (CSR). In short, a CSR measures the sealing force required to maintain the applied compression from a load cell (the value of which is set by the operator). In order to understand the change as a result of fuel exposure, the CSR was equipped with fuel lines as shown in Figure 9. The leftmost image in Figure 9 shows the bottom gland and fuel inlets. The glands used to hold the O-rings are the same dimensions as the glands used to hold O-rings in the UDRI compression set fixtures (Figure 8). The right side of Figure 9 shows the bottom gland in the CSR configured to run sealing force tests (load cell not shown). Second, the area over which the force is applied must be measured. To make this measurement, Dr. John Graham designed an optical cell that consists of the same bottom gland used on the CSR and compression set fixtures, but instead of a flat platen on top, the gland is topped with a thick glass window providing optical access. Critically, the compression applied by the glass window can be varied by placing metal shims of various thicknesses between the gland and the window. Thus, the area of the contact band of an O-ring can be measured at various compressions and fuel exposures. A camera and lens setup are placed directly above the glass window to acquire real-time information on how the area of the contact band changes. ImageJ is used to measure the area of the contact band with distances in the image calibrated based on known distances in the gland/fixture.

Figure 9. O-ring flow cell equipped with fuel lines (left) and the flow cell installed in the compressive stress relaxometer (CSR) (right).

The modified CSR and the optical flow cells are equipped to measure O-ring the sealing force whether in their dry, as-received forms or O-rings after they have been conditioned using elevated temperature, fuel/fluid exposure, etc. The sealing force from the CSR and the area of the contact band as a function of applied compression will be used to determine the sealing pressure of O-rings in each scenario (Equation 3). The most informative scenario is expected to be the change in sealing pressure under switch-loading conditions. These results can be correlated to the change in volume swell (Task 2) and compression set (Task 3). Once or if leaking conditions are calculated, the model face seals with optical access can be

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pressurized up to 60 psi to determine if a leak will occur. This measurement will add yet another engineering metric by which we can understand the impact of fuel switching on various in-service conditions as we move towards implementing SATF in the field.

$$Sealing\ Pressure = \frac{Sealing\ force\ required\ to\ maintain\ O{-}ring\ compression}{Area\ of\ the\ contact\ band\ of\ the\ O{-}ring} \qquad \text{(Eq. 3)}$$

Lastly, UDRI has a suite of flexible fuel couplings that were – at one time – actual flight hardware. Figure 10 shows the fuel couplings which house up to four candidate O-rings. The fuel couplings can be filled with fuel and, similar to the compression set fixtures, can undergo accelerated aging at temperature. Given the information gathered in Tasks 2, 3 and 4, these fuel couplings can be aged to a given compression set and then tested for fuel leaks. The use of flight hardware will provide the most realistic results to the FAA and OEMs on the lifetime of seals under switch-loading conditions.

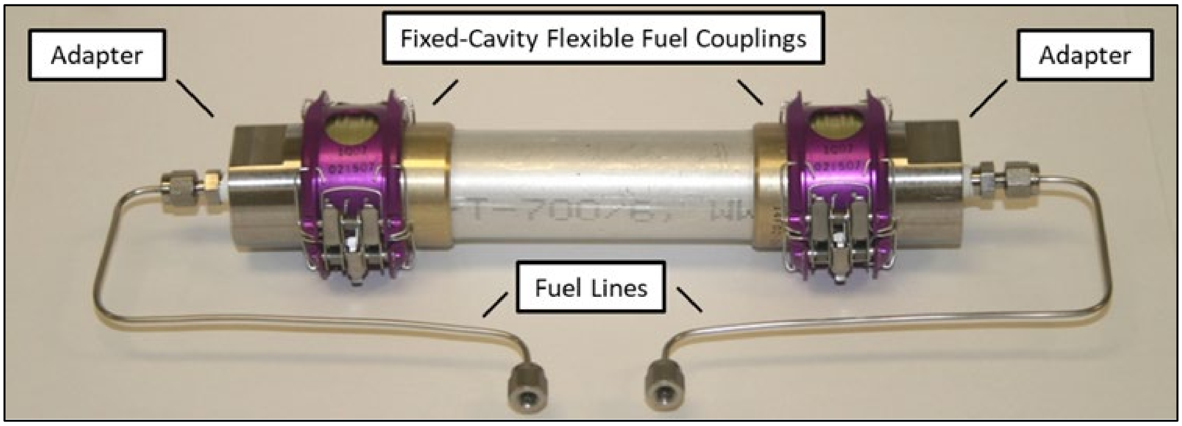

Figure 10. Flexible fuel couplings equipped to be a closed, fuel-filled system for accelerated O-ring agings.

Milestones

UDRI experimentally measured and reported on the sealing pressure of all four materials in their dry, as-received state using the optical cells and the Elastocon® CSR.

Major Accomplishments

During the 2025 calendar year, the CSR was set up for sealing force measurements and four optical cells for imaging contact bands were created. This setup equips UDRI to execute one full material investigation at a time and will increase the efficiency of the overall data collection process.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

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Plans for Next Period

During the next reporting period, UDRI will finish the plumbing of the modified CSR and optical cells so that fuel can be pumped through the instruments. Then, all O-ring materials will be characterized upon initial fuel wetting with Jet A fuel. After understanding the change in the sealing pressure as a result of exposure to Jet A, the investigation of changes in the sealing pressure under switch loading conditions will begin.

Task 5 – OEM Engagement

University of Dayton Research Institute

Objective

The objective of this task is to ensure that the materials and experiments are relevant to the real-world use of SATFs for OEMs, maintainers and the FAA.

Research Approach

The research approach to ensuring that Phase II is relevant for OEMs, maintainers and the FAA is establishing clear and regular communication. Communication can be in the form of updated results and meeting presentations, or less formal discussions based on observations in the field. Ultimately, ASCENT Project 088 hopes to obtain information not only on the experimental approach and results, but real-world examples of O-rings that have leaked when fuel was switched from Jet A to a SATF or SATF blends.

Milestones

This year, many SATF companies (Global Energies, Montana Renewables, etc.) were reached out to for fuel samples. In the end, the ASCENT SATF Repository was used to obtain a preliminary 1L of HEFA-SPK for testing.

Major Accomplishments

None.

Publications

None.

Outreach Efforts

The Fall Meeting was used as an opportunity to connect and build relationships between UDRI with ASCENT Industry partners, specifically fuel OEMs.

Awards

None.

Student Involvement

None.

Plans for Next Period

During the next reporting period, UDRI will make further efforts to contact and connect with both fuel and materials OEMs. UDRI will continue to leverage FAA PMs and FAA ASCENT meetings to get quality facetime with supporting partners who are already invested in the ASCENT program.

Task 6 – Reporting

University of Dayton Research Institute

Objective

The objective of this task is to properly document and analyze all the results of ASCENT Project 088 Phase II.

Research Approach
None.

Milestones
None.

Major Accomplishments
None.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period
During the next period, reporting will begin for Phase II by means of collecting, organizing and processing all the data collected in Tasks 1-5.