Project 033(A) Alternative Fuels Test Database Library (Year II)

University of Dayton Research Institute, University of Illinois

*This report covers the University of Dayton portion of the project

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- FAA Award Number: 13-C-AJFE-UI-009
- Period of Performance: 7/21/2015 to 8/14/2017
- Task(s):
    1. Development of an alternative fuels test database

University of Dayton Research Institute

- P.I.(s): Steven Zabarnick
- FAA Award Number: 13-C-AJFE-UD-012
- Period of Performance: 7/21/2015 to 8/14/2017
- Task(s):
    2. Development of an alternative fuels test database

Project Funding Level

University of Illinois at Urbana-Champaign
Funding Level: $70K
Cost Share: Software license support from Reaction Design (ANSYS)

University of Dayton Research Institute
Funding Level: $30K
Cost Share: Software license support from Reaction Design (ANSYS)

Investigation Team

- Kyungwook Min (Graduate Student, University of Illinois at Urbana-Champaign): Compilation of fuel test data.
- Anna Oldani (Graduate Student, University of Illinois at Urbana-Champaign): Compilation of fuel test data and development of database.

Project Overview

This study seeks to create a comprehensive, foundational database of current and emerging alternative jet fuels by integrating relevant pre-existing jet fuel data into a common archive which can provide guidelines for design and certification of new jet fuels in our future as well as aid federal work including fuel certification. Thus far, the effort has focused on the integration and analysis of pre-existing jet fuel data from various government agencies and individual research groups with oversight from the Federal Aviation Administration (FAA). We hope that the database will one day serve as 'the comprehensive and centralized knowledgebase' shared by the academic, government, and industrial communities in fuels research and policy, possibly facilitated on a cyber-based infrastructure. With ongoing prolific diversification of new jet fuels, this effort to integrate dispersed information is critical in providing the FAA with an overview of the latest developments and to support many other tangential fields of research in government, industry, and academia impacted by integration of new alternative jet fuels.

Task 1 – Development of an Alternative Fuels Test Database

University of Illinois at Urbana-Champaign

Objective(s)

The main objective of this study is to establish a ***foundational database*** of current and newly emerging alternative jet fuels by integrating all relevant pre-existing jet fuel data into a common archive which can provide guidelines for design and certification of new jet fuels in our future as well as aid and shorten fuel certification relevant work. This proposal outlines the year II efforts under this mandate. The vision is to institute a database that can be utilized for the design and optimization of new propulsion and energy systems including development of next-generation engines, fuel delivery systems, as well as pollution mitigation technologies. Furthermore, it can provide data for screening and certification of newly emerging fuels and thereby impacting legislative measures and national policy. In so doing, the goals of this project are as follows:

- Survey current pre-existing data and analyze information
- Prioritize current data and compile into centralized logical structure
- Analyze the obtained information into chronological order and regroup into relevant groups
- Obtain information on detailed test platforms and test conditions
- Develop a controlled web portal for access to the information
- Develop and implement a database/web portal infrastructure and methodology
- Integrate available alternative fuel test data into the database in organized format
- (Future Work) Integrate FAA ASCENT and NJFCP Data

Research Approach

Development Strategy of a Successful Fuels Test Database (Long Term Plan)

- **Phase I:** Integrate Current Pre-Existing Data: Preliminary survey and integration of all pre-existing database and data (including raw data) on jet fuels from universities, national laboratories, government archives, and private industry (i.e., existing database from Sandia, NIST, DoD Labs, ASTM research reports, government technical reports etc. is part of the year I efforts and will be used to initially seed the basic infrastructure of the fuels database proposed in this study). Year II efforts continued to assemble information and annex a prioritized set into the web portal/database. In year II, we focused our efforts on obtaining relevant fuel property specification test data for the certification process.
- **Phase II:** Analysis of Preliminary Data: Conduct comprehensive analysis of the initial data to categorize all relevant physical and chemical characteristics of the fuels and relevant testing conditions. Effort will be made to determine insufficient areas for further investigation. In year II, we have significantly expanded our efforts to the analysis of information into chronological order and in incorporating detailed test platform and test condition data. An effort will be made to re-categorize the data according to different testing groups and performance. A preliminary effort will be made to vet some of the data according to test conditions as required (future efforts will more fully address vetting and analysis of data).
- **Phase III:** Establish Web Portal/Database Infrastructure and Methodology: A basic web portal has been established during the year I efforts. In year II, based on the analysis of pre-existing data, we will work with national laboratories to establish a flexible and accessible database structure and data access protocols both for retrieval of current data and also for integration of new information in the future. This will be integrated into the web portal. We anticipate increased functionality in the web portal to conduct advanced searches and user feedback on each data item (community based vetting system).

- **Phase III-b:** Integration of FAA ASCENT and NJFCP Data: New data generated from both the FAA ASCENT and the NJFCP will be integrated into the database according to the pre-defined infrastructure. This will be coordinated with Area #7 of the NJFCP program.
- **Phase IV:** Integrate with Current and Future Research: Disseminate and integrate new database to relevant research groups in universities, national laboratories, government, and industry. Formulate partnerships for stewardship, preservation, and continued development of the alternative jet fuel database.
- **Phase V:** Continued Development: Continue development of the database after the initial integration and distribution phase into a more widely distributed community based infrastructure (potentially cyber-based). Link and expand the database to encompass pre-existing data from other countries.

Milestone(s)

Milestones from Each Period

Proposed (3 Month): At the 3 month mark, we will have concluded an exhaustive survey to obtain all fuel relevant data from individual PIs and national laboratories. We will work with the advisory committee and other PIs in the NJFCP and ASCENT to ensure that a comprehensive and complete survey of data has been completed. During this time, we will initiate efforts to start the physical construction of a database and work with web designers and relevant personnel for deployment. Data format for the FAA ASCENT and NJFCP research will also be acquired during this time.
Achieved: Basic survey of the fuels test data has been accomplished and a plan is in place for construction of a web based database. We have discussed the format of a metafile to deal with the data. We have a list of data formats that will become available in the database.

Proposed (6 Month): At the 6 month mark, we should have a preliminary version of a standardized platform with integration of data from all federal, academic, and industrial sources. The focus will be on smooth and logical integration of data, and clear organization of information into subgroups.
Achieved: A preliminary outline of a web-based portal is in place and we have started to analyze the data for integration into the database. The NJFCP has also contributed two quarters of data to be integrated in to the database. We have visited AFRL to discuss how to extract data at AFRL for integration into the database.

Proposed (9 Month): At the 9 month mark, we will assess which data categories are insufficient and seek to further populate these areas with continued data searches. The target is to continue building up the resources available in the database to meet the goal of establishing a comprehensive archive. We will also work during this time to ensure the data provided in the database are correctly categorized and properly accessible for users.
Achieved: We have continued with AFRL site visits to gather data including previously approved fuels and fuels currently undergoing the certification process. We have discussed the procedure for inclusion of NJFCP data into the database to ensure that the data provided is in a final, approved format. The data that has been collected thus far has been checked to assure that it is approved for public release and available in a downloadable format. An effort has been made to transfer any tabulated data contained within PDF resources into corresponding .xlsx files to improve the accessibility for users.

Proposed (12 Month): At the 12 month mark, we will assess ways to move forward with the data collection and archiving and begin to outline potential analysis routes. It is also important during this time to assess the capabilities of the web portal and determine if archiving or search procedures require improvement.
Achieved: The data archiving process has been re-formatted to better accommodate the data that has been acquired. We hope to continue to elicit feedback from users of the web portal in the fuels community on improvements they would like to see implemented with regard to data organization and ease of access. We have incorporated new search algorithms that allow for expanded searching capabilities to provide the users with more robust search results. Successful tests of these search capabilities make us confident that users are able to access all relevant data when using both the basic and advanced search functions. We have also begun to identify possible targets for a statistical analysis of the data, focusing on relevant specifications crucial early in the certification process.

Proposed (15 Month): At the 15 month mark, we will discuss methods by which the data can be analyzed to provide a statistical analysis of existing jet fuel data to-date. During this time, an effort will be made to further define the goal of analyzing fuel data with regard to key specifications of the fuel certification process. Population of the database will continue with additional visits to AFRL to gather relevant fuel testing data.
Achieved: A preliminary outline has been discussed and developed for utilizing the data collected to provide an overview of the fuel certification process with a focus on the specifications and issues relevant to alternative jet fuels. A sampling of fuels representing the various alternative fuel categories has been selected and will be used to furnish the data needed for

the analysis. An AFRL visit provided further fuel test data that has been categorized and is undergoing submission to the database.

Major Accomplishments

The new alternative jet fuels database website homepage is shown in Figure 1 (altjetfuels.web.engr.illinois.edu). The enhanced search features are shown in Figure 2, with the improved search results shown in Figure 3.

Figure 1 Alternative Jet Fuel Test Database site homepage

During year II, several tasks were completed with regard to development of the Alternative Jet Fuels Test Database. The site to house the database, established during year I through the coordinated efforts of members of the University of Illinois, has been further improved and populated with additional relevant jet fuel test data. Improvements to the site were made during year II including the development of basic and advanced search functionalities and enhanced search algorithms to return more robust search results. A screenshot of the homepage of the site is shown in Figure 1, displaying the main features of the site. These features include a general *About* section with information regarding the mission and goals of the database project, funding agencies of the program, a directory of members involved in the work, and links to partner institutions participating in the larger FAA ASCENT database project.

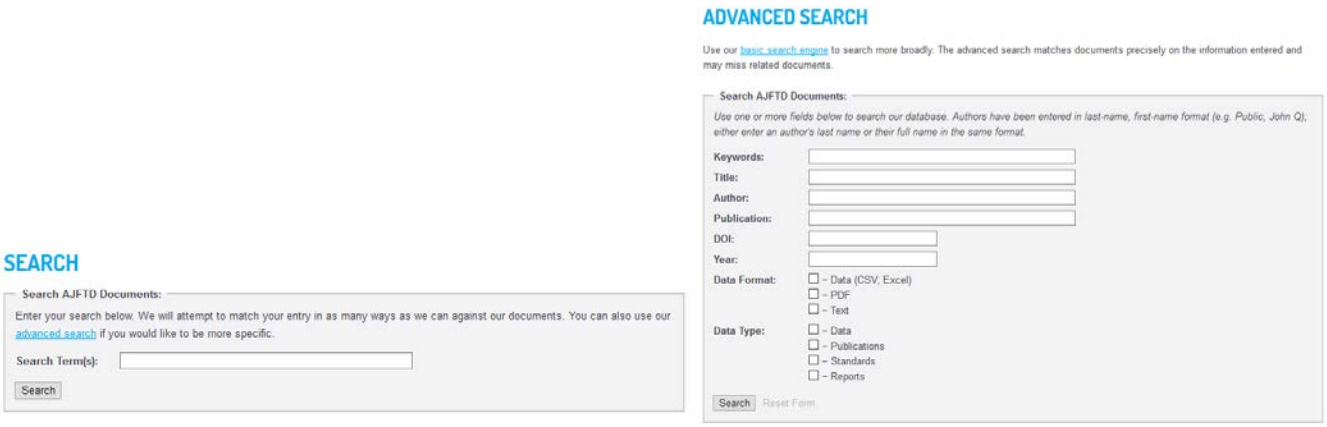

Figure 2 Alternative Jet Fuel Test Database basic (left) and advanced (right) search functions

Users have two methods to access data made available on the site. The first is a search feature where users can select from a basic or advanced search, shown in Figure 2. The advanced search allows users to search by terms of interest including authors, title, DOI, year of publication, data type, and keywords.

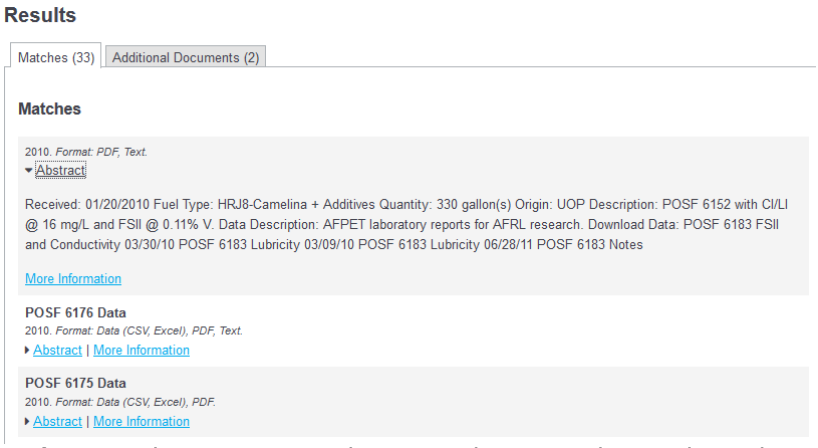

Figure 3 Alternative Jet Fuel Test Database sample search results

The improved search results achieved during year II are shown in Figure 3. Users now see exact metadata matches on the first tab (e.g. if a user searches for "fuel" in the title category, only documents with "fuel" in the title are displayed) with additional documents shown on the second tab (e.g. for the same "fuel" search, documents with "fuel" in additional categories will be displayed).

Data Type	Examples	Sample File Types
Chemical Kinetics Mechanisms	Mechanisms	.TXT, CHEMKIN
Emissions	Emission Test Data	PDF, .XLSX
Testing Results	Shock Tube, Rapid Compression Machine, GC MS	.XLSX, .CSV
Fuel Properties	Lab Analysis Reports	.XLSX, .CSV, PDF
POSF Data	POSF Fuel Specification Testing	PDF, .XLSX
Publications	Production Processes, Reaction Studies, Chemical Kinetics, Economic Analyses, Technical Reports, Fuel Certifications	PDF

Figure 4 Sample data categories

Figure 4 displays a sampling of the current data categorization along with sample file types found under each category. Users are able to download original file formats as well as any tabular data that has been converted into .XLSX files for improved accessibility. The site will also house data from the National Jet Fuel Combustion Program (NJFCP) Areas 1 through 6. Discussions are ongoing as how to best to include data from this multi-group collaborative effort. Once further guidelines have been discussed and approved regarding which data to include, this section of the site will be expanded. The second feature for users to access data is a grouping of data by subject area; users can then follow through a familiar folder sublevel categories to access specific data grouped under various topic areas. This structure is broken down in Figure 5, which shows the various main and sublevel categories of data contained within the database. This structure allows for flexibility as more data is incorporated into the database. It can easily handle adding additional categories as new data is acquired.

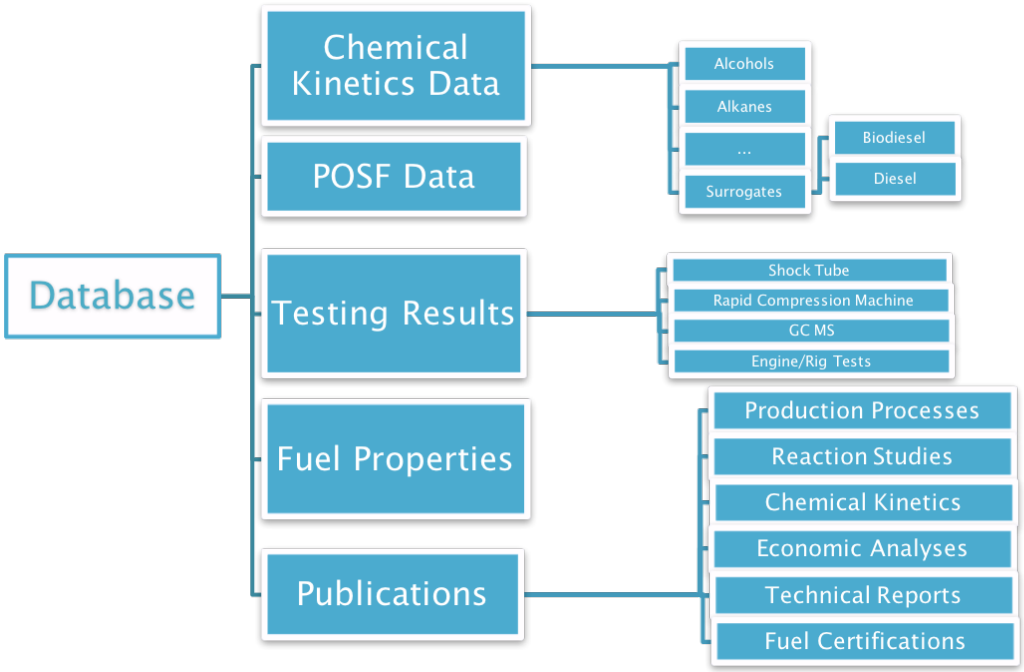

Figure 5 Database structure breakdown

To access any data (in the *Search*, *Database*, and *NJFCP* menu headings), users will first be required to request access, and once the request for access has been approved by site administrators, the user can then register a username and password to login on the site and search through the database. Registered users will also be able to submit data directly to the site. These submissions will be received by the site administrators and posted once the proper classification has been assigned to the data. The site will display general information available to the public only in the *About* and *News* headings. The *News* section highlights recent activity related to the various projects underway in the program and general activity in the alternative jet fuels field. Finally, users will be able to leave comments under the *Contact* section, which will direct all submissions to site administrators. The general sections of the site have been and testing of the search features for sample data submissions has been completed. Data received from AFRL has been populated on the database and data from the NJFCP program areas is currently ongoing discussions for future inclusion once finalized. Data will continue to be uploaded and updated on the site as it is received, with registered users able to submit comments on all available data.

The University of Dayton's contributions to the project primarily involve the identification, collection, and critical review of alternative fuel data and reports. Through UD's on-site work with AFRL, we have access to a wide variety of alternative and petroleum-based fuels data. We have a large amount of expertise in conventional and alternative fuel composition to property relationships which gives us the ability to provide critical evaluation of candidate for inclusion in the database.

Thus we continue to provide access to alternative and conventional fuel data and reports and the expertise to advise on the value of including the numerous identified data into the FAA database.

Publications
None

Outreach Efforts
None

Awards
Anna Oldani (Graduate Student): Society of Women in Engineering (SWE) Award for Research Excellence

Student Involvement
Two graduate students (listed above) have participated in this project on a rotational basis to address various aspects of the project. Their main tasks have been to survey the data, interact with the data source and come up with a strategy to integrate the data into the database. They have also been working to develop the web-based portal for the actual implementation of the web interface.

Plans for Next Period: Start of Analysis
Year III for the database project will be an exciting period which transitions from the database construction and seeding of initial data to analysis and prioritization of the data. Several key efforts are planned and are currently underway. They are:

- Continued refinement of the database (search algorithms, database structure)
- Analysis of data I: determine key correlations between fuel properties and performance properties (i.e., DCN, viscosity, chemical group content, etc.)
- Analysis of data II: analysis of data to support the ASTM General Annex effort of fuel certification which includes a careful study of all relevant data used in the General Annex work to date and determine gaps or improvements as well as additional correlation work to link fuel properties to the overall evaluation
- Inclusion of NJFCP data: put up vetted and organized NJFCP data on the database.