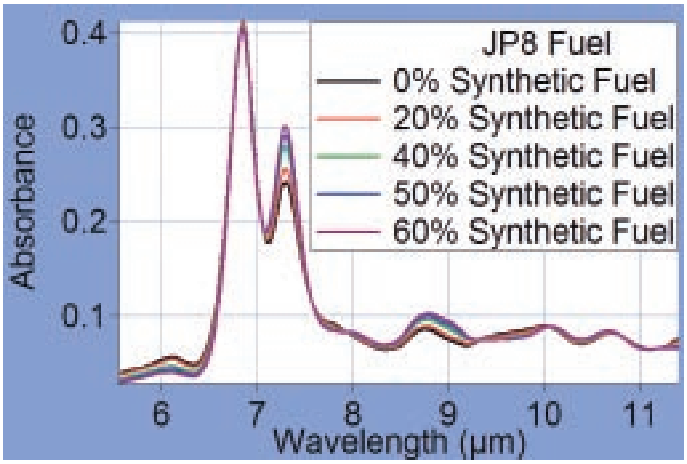
Mid-infrared spectroscopy can help ensure blend quality of synthetic jet fuel

Fuel analysis at the terminal

The US Air Force, one of the largest consumers of fuel in the world, has been testing synthetic jet fuels to replace petroleum fuels –50% of which is supplied by foreign producers.

In addition to the advantage of reducing foreign oil dependence, it is biodegradable, cleaner–burning and has more energy content for its weight. And US tax payers want the best for the $5 billion (€3.67 million) that the Air Force spent on fuel last year.

The fuel being tested is a 50-50 blend of jet fuel made from crude oil and synthetic jet fuel that is currently produced from natural gas or coal and could potentially be made from any biomass. In order to successfully and safely implement synthetic jet fuels into a fuel supply, it is essential to know the blend ratio of synthetic to standard jet fuel.



Synthetic blend ratio comparison

Infrared analysis of jet fuels

Most of the quality concerns up to this point for crude oil replacement fuels have been on energy content of the fuel, system compatibility, and the fuel engineering specifications. Not much emphasis has been put on measuring the blend levels. Currently the blend levels are calculated based on volumes dispensed at blending racks, and no analytical methods are consistently employed to ensure blend accuracy. Although manufacturers of in-line blending systems allege indisputable accuracy, a quick check for the correct blend gives actual data to validate this assumption.

While the synthetic fuel industry speaks of drop in fuels with the claim that there is no significant difference from petroleum based fuels, infrared spectra comparing blend ratios clearly show dissimilarity.

The changes in infrared absorbance are used to determine the blend ratio of the synthetic jet fuel. The same infrared analysis is currently in use by terminal operators to measure ethanol in petrol and biodiesel in diesel. The biodiesel ester has characteristic infrared absorption due to the carbonyl band. As the concentration of biodiesel goes up, the infrared absorbance at that wavelength increases. The infrared absorbance can be directly calibrated to read out in percent biodiesel. Ethanol also has a characteristic absorbance in the mid-infrared range. Like biodiesel, the increase and decrease of infrared absorbance correlates directly to the amount of ethanol present in the sample.

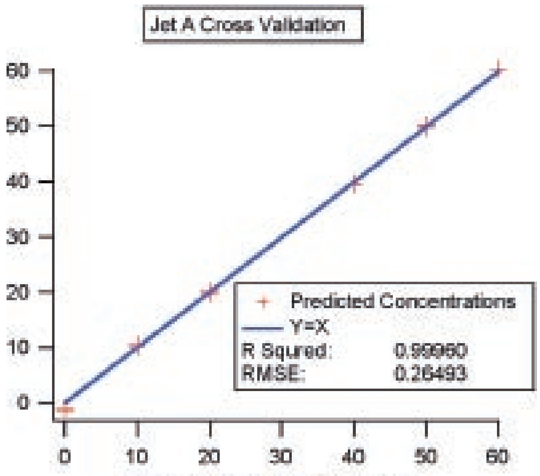
Study results

A recent study was conducted to determine the feasibility of measuring synthetic jet fuel versus conventional jet fuel blend with infrared analysis. Two types of conventional jet fuels were used: Jet A (US civilian turbine fuel) and JP-8 Fuel (US military specified fuel) along with six concentrations of synthetic jet fuel from 0-60%. The synthetic fuels were analysed on an InfraSpec VFA-IR Spectrometer from Wilks Enterprise.

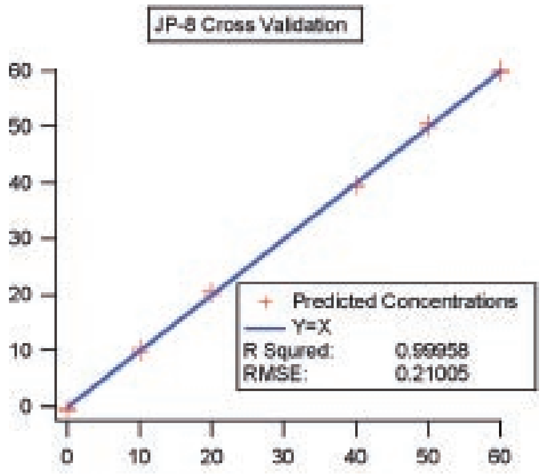
The InfraSpec Spectrometer incorporates a patented design consisting of an Attenuated Total

The Infraspec VFA-12 Spectrometer used for the jet fuel study

Cross validation results:



Synthetic jet fuel concentration



Synthetic jet fuel concentration

Reflection (ATR) sample plate with an electronically modulated source on one end and a linear variable filter (LVF) coupled with a linear variable array on the other. The result is a compact spectrometer with no moving parts and no optical path exposed to air, which makes it extremely portable, rugged and able to be operated in a field environment such as a fuel terminal.

Once the data was generated for the different blend concentrations, the calibrations were then analysed in two ways. First, a calibration was compared against itself, using leave-one-out cross validation, which involves removing all samples of a given concentration level, then generating a calibration without these samples, and finally, predicting the concentration of the removed samples. This is done in succession with each concentration of conventional/synthetic blend fuel. The leave-one-out cross validation method shows how robust the calibration is since it forces a calibration to predict samples not seen in the calibration set.

Alternative fuels offer countries without significant crude oil reserves the opportunity to produce their own fuel as well as reduce emissions

Cross validation results for Jet A and JP-8 calibrations

The second stage of calibration analysis involved predicting the conventional/synthetic blend percentage of one fuel type with the calibration of the other. For example, the Jet A calibration was used to predict the JP-8 samples and vice versa. This cross-fuel analysis further quantifies the flexibility of the analysis since the calibration must compensate for different fuel types. Since the Jet A and JP-8 fuels used in the study were significantly different in the mid-infrared region used, this analysis provides a good example as to how the analyser may perform with varying fuel types and additives.

The Standard Error of Prediction (SEP) was used to gauge how well the calibrations performed. The SEP can be used in the same manner as a standard deviation, to give an approximation of the overall instrument accuracy. By using 2*SEP, it is assumed that approximately 95% of samples will fall within the given range provided by the 2*SEP predictor, so this is used as an approximation of the accuracy of the instrument in measuring synthetic blends in conventional jet fuels.

The cross-validation and cross-fuel results all have a predicted accuracy of around 1% or less, showing that a calibration with Jet A fuel would work for a synthetic blend ratio on JP-8 fuel. These preliminary results indicate that this infrared spectrometer is capable of analysing synthetic jet fuel in conventional jet fuel with reasonable accuracy.

While the price for a barrel of oil has dropped significantly since last year, the desire for a viable drop-in alternative fuel for both military and commercial aviation still prevails as long as it can meet the rigorous performance requirements.

Alternative fuels offer countries without significant crude oil reserves the opportunity to produce their own fuel as well as reduce emissions. Whether the blend analysis is for synthetic jet fuels, biodiesel or ethanol, infrared analysis offers a simple and portable method for on-site testing necessary for the safe implementation of alternative fuels into the existing fuel supply.

For more information:

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Statistic	Jet A cross-validation	JP-8 cross-validation	JP-8 predicted with Jet A	Jet A predicted A with JP-8
Standard Error of Prediction (SEP)	0.515	0.458	0.302	0.409
SEP *2 (+/- accuracy)	1.030	0.916	0.604	0.818

Table 1: SEP and SEP*2 for various calibration analyses