Technical Notes
028

Exceeding Expectations

Linear vs. Non-Linear…that is the question

When blending, it is important to understand whether the specification you are blending for is linear or non-linear in nature. Not all properties of fuel are capable of being blended in a linear fashion.

Linear Blending

When someone refers to a test or product blending linearly, they are basically saying 1 + 1 = 2.

For example: you are asked to deliver a gasoline cargo meeting a 30 ppm max sulfur specification. Currently in inventory you have two tanks. Tank A has a sulfur result of 72ppm and Tank B contains 12ppm. Assuming you have an unlimited volume in the tanks. What percentage of each tank would be needed to meet the 30ppm spec?

In this case we could use a linear blend model in excel to make the calculation easy. The correct answer would be 30% of Tank A and 70% of Tank B. To check the answer you must calculate each part of the blend and add them together. Behind the scenes the math looks like the below.

Result * percentage = result as percent of the blend
Tank A (72ppm) * 30% = 21.6ppm
Tank B (12ppm) * 70% = 8.4ppm
21.6ppm + 8.4ppm = 30ppm

	Unit	Component 1	Component 2	Blend
Name		Tank A	Tank B	
Volume	bbls	30.00	70.00	100.0
Percentage	%	30.00	70.00	100.00
Sulfur		72.0	12.0	30.00

Non-linear Blending

When someone refers to a test or product blending as non-linear, they are basically saying something like 1 + 9 = 4.

These properties are the most difficult to blend. Two of the largest offenders in the testing world are Distillation and Flash.

Let's discuss Flash blending…

To paint a better picture, we must first understand the methodology of flash point testing. The flash point is the lowest temperature which oil first gives off sufficient flammable vapor to ignite and form a combustible mixture with air when ignited by an external flame.

First, an aliquot of sample is poured into a brass cup and placed in the heating section of the unit. Second, a lid containing an igniter, thermometer, and stirring mechanism is affixed to the brass cup. The sample is heated while stirring per the method and checked every couple degrees. Flash point is found when the igniter dips into the cup and ignites the light ends trapped inside. (Reference photo)

Flash is basically a derivative of the light ends contained in the sample. If the product contains more light ends the flash will be closer to ambient (i.e. gas/diesel). If the product contains less light ends (i.e. fuel oil) the flash will be much higher.

EXAMPLE: You are asked to deliver a Diesel cargo meeting a 140°F min flash specification.

Currently in inventory you have product in two tanks. Tank A has a flash result of 100°F and Tank B is flashing at 180°F. Assuming you have an unlimited volume in the tanks. What percentage of each tank would be needed to meet the 140°F spec?

If we could use a linear blend model in excel to make the calculation. It would be relatively easy, 50% Tank A and 50% Tank B for 140°F (see below). This is not the case. In a 50/50 blend you would find the flash would still be closer to 100-120°F. Tank A would continue to heavily influence the blend due to the higher light end content. The 50/50 blend is only diluting the 100°F light ends by 50%.

In order to find the appropriate volume to meet spec, a different approach needs to be taken. You must start with Tank B at a larger percentage. (i.e. 90 %) and start adding small amounts of Tank A in until a suitable result is found. The spread between results will also influence the nonlinear blending. The larger the gap the less likely linear blending is possible. The opposite applies when the test results are very close together.

	Unit	Component 1	Component 2	Blend
Name		Tank A	Tank B	
Volume	bbls	50.00	50.00	100.0
Percentage	%	50.00	50.00	100.00
Flash	°F	100.0	180.0	140.0

In summation, there are hundreds of different streams / tests out there and not every situation is the same.

In the pages that follow, a quick guide is presented for reference only regarding linear vs. non-linear blending. If you have any questions about blending, please contact your AmSpec local lab manager or brett.downs@amspecllc.com for more details.

Gasoline Blending
Reference Guide

Method	Test	Linear or Nonlinear
ASTM D4052	API Gravity @ 60F	Linear
ASTM D5191-EPA-07	DVPE, psi @ 100°F	Nonlinear
ASTM D2699	Research Number	Nonlinear
ASTM D2700	Motor Number	Nonlinear
Calculated	Octane (R +M)/2	Nonlinear
ASTM D86	Distillation	Nonlinear
ASTM D4814	Temperature @ V/L = 20	Nonlinear
ASTM D4814	Driveability Index	Nonlinear
ASTM D2622-05	Sulfur	Linear
ASTM D3227	Mercaptan Sulfur	Linear
Olefactory	Odor	Nonlinear
Visual	Color	Nonlinear
Visual	Appearance	Nonlinear
ASTM D4952	Doctor Test	Linear
ASTM D3606-07	Benzene	Linear
GCMS-DCPD	Dicyclopentadiene	Linear
ASTM D381	Gum, Solvent Washed	Nonlinear
ASTM D525	Oxidation Stability @ 212°F	Nonlinear
ASTM D130	Copper Corrosion 3 hrs @ 122ºF/50ºC	Nonlinear
ASTM D4814	Silver Corrosion 3 hrs @ 122ºF/50ºC	Nonlinear
ASTM D1319-03e1	Olefins	Linear
ASTM D5769-04	Aromatics	Linear
ASTM D3237	Lead Content	Linear
ASTM D3231	Phosphorous	Linear
ASTM D5599-00(2005)	Oxygenates	Linear
TM 01-72-01	NACE	Nonlinear
ASTM D4176	Haze Rating @ 77°F	Nonlinear

Diesel Blending
Reference Guide

Method	Test	
ASTM D4052	API Gravity @ 60F	Linear
ASTM D93 A	Flash Point, PMCC	Nonlinear
ASTM D86	Distillation	Nonlinear
ASTM D1500	ASTM Color	Linear
Visual	Color	Nonlinear
ASTM D445	Viscosity @ 40ºC	Nonlinear
ASTM D97	Pour Point	Nonlinear
ASTM D2500	Cloud Point	Nonlinear
ASTM D130	Copper Strip Corrosion	Nonlinear
ASTM D5453	Sulfur	Linear
ASTM D976	Cetane Index	Nonlinear
ASTM D482	Ash Content	Linear
ASTM D524	Carbon Residue-Ramsbottom 10%	Linear
ASTM D2709	Sediment & Water	Linear
DUPONT	Thermal Stability Pad Rating	Nonlinear
DUPONT	Thermal Stability % Reflectance	Nonlinear
ASTM D4176	Haze Rating @ 25°C	Nonlinear
TM0172	Nace Corrosion	Nonlinear

Bunker Blending
Reference Guide

Method	Test	
ASTM D4052	API Gravity @ 60°F	Linear
ASTM D445	Kinematic Viscosity, cSt @ 50ºC	Nonlinear
ASTM D93 B	Flash Point, PMCC	Nonlinear
ASTM D97	Pour Point	Nonlinear
ASTM D4530	Carbon Residue-Micro	Linear
ASTM D482	Ash Content	Linear
ASTM D95	Water by Distillation	Linear
ASTM D4294	Sulfur, Total by X-Ray Fluoresc.	Linear
ASTM D4870B	Total Sediment - Accelerated	Nonlinear
ASTM D664	Acid Number	Linear
ASTM D974	Strong Acid Number	Linear
ASTM D5705	H2S, Drager Tube	Nonlinear
IP-501	Metals	Linear