July 25, 2023

Methanol to Jet (MTJ)
- ASTM D02.0J AC724 Task Force

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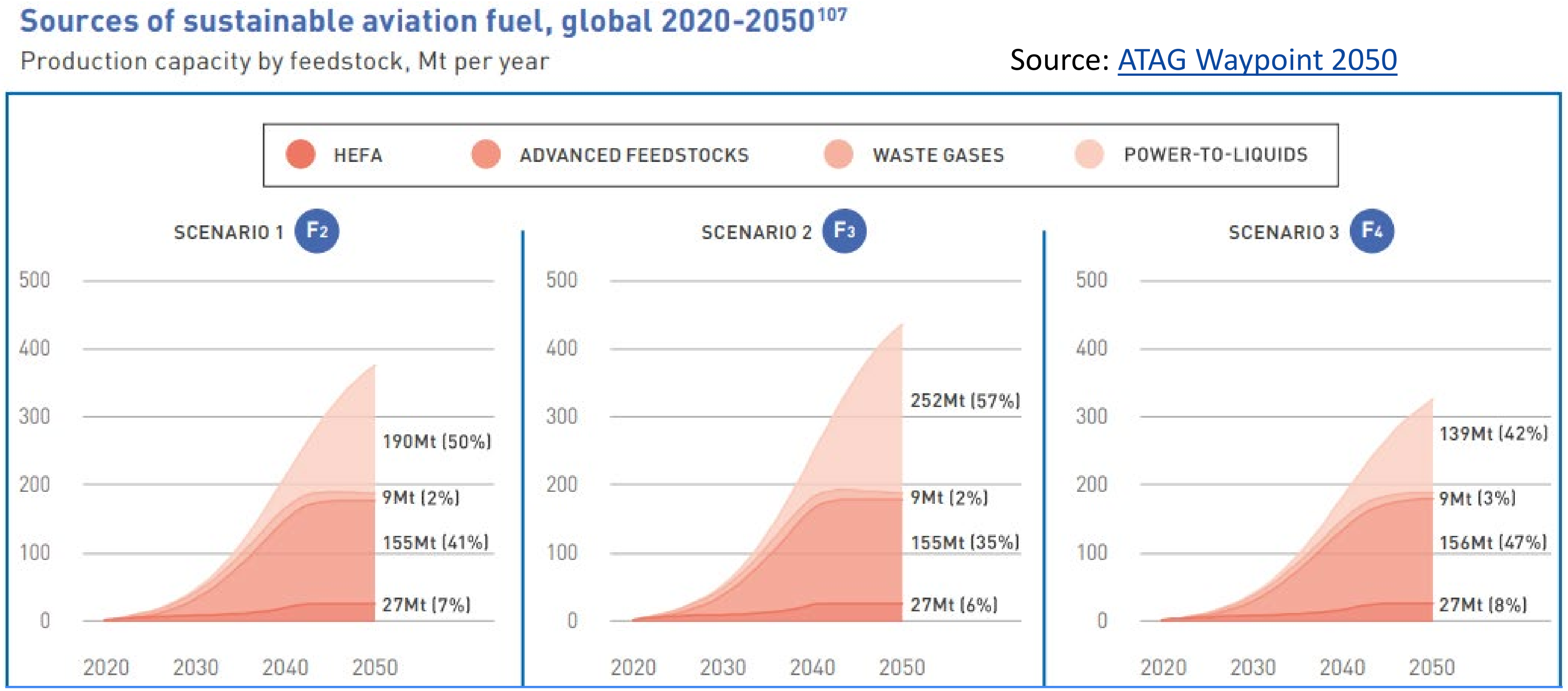
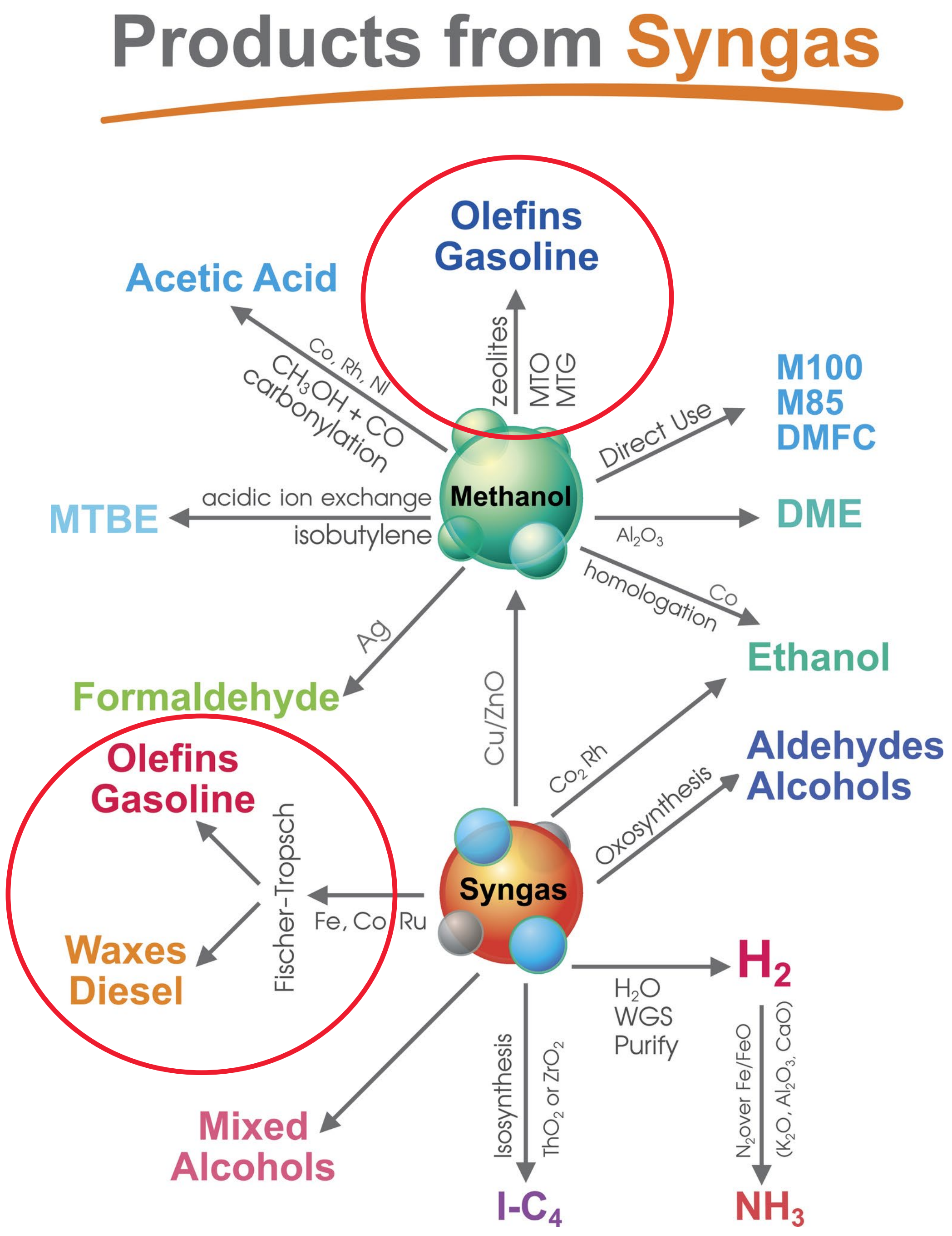
All solutions may be required to meet industry's net-zero goals

Source: ATAG Waypoint 2050



- Agricultural waste, forestry residue and MSW may be needed to provide the volumes of SAF required to meet 2050 ambitions
- Power to Liquids (eFuels) provide another possible solution for the industry
- Methanol provides an alternative technical pathway for accessing both advanced feedstocks and eFuel solutions



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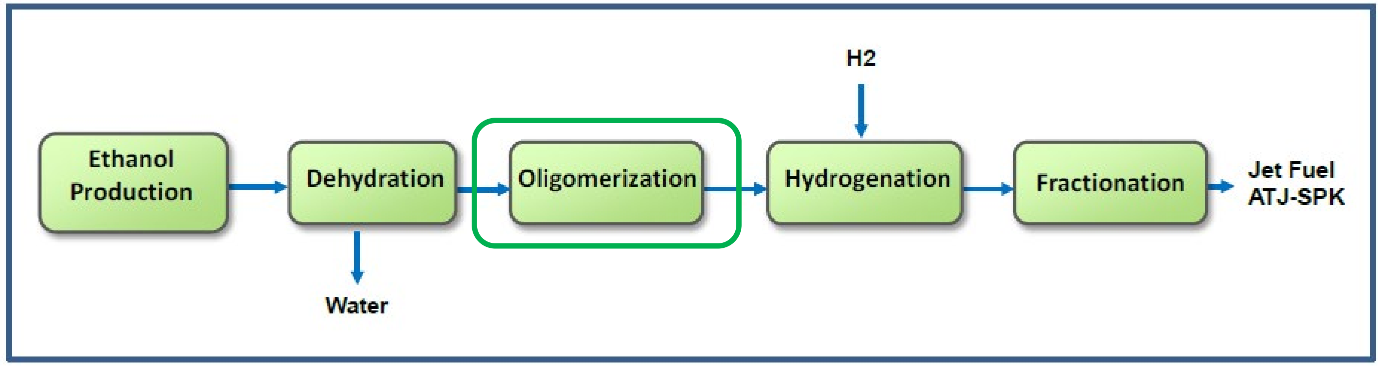
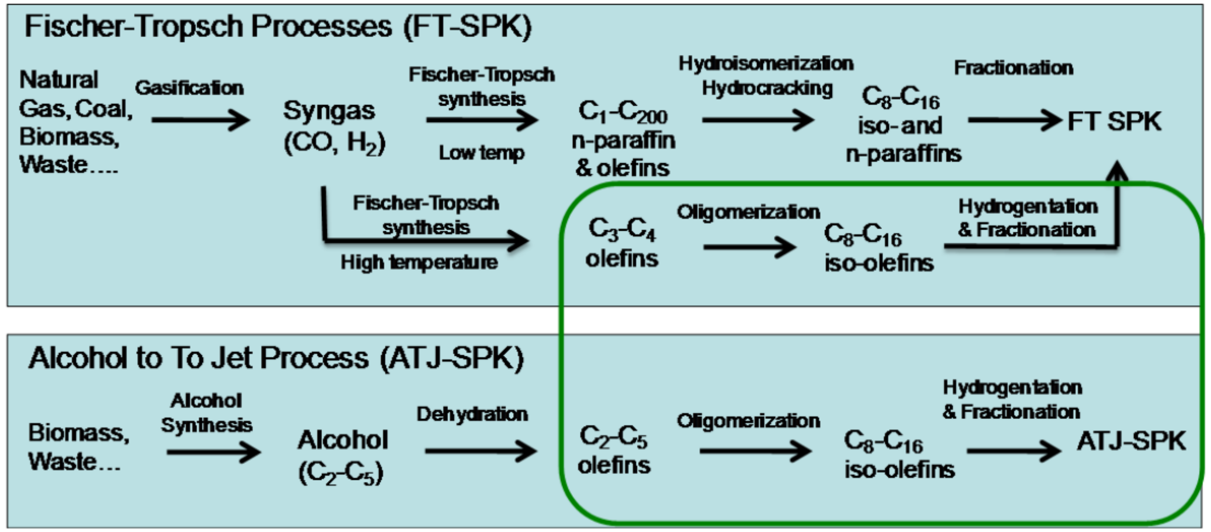
ATJ and Methanol to Jet (MTJ) Process Comparison

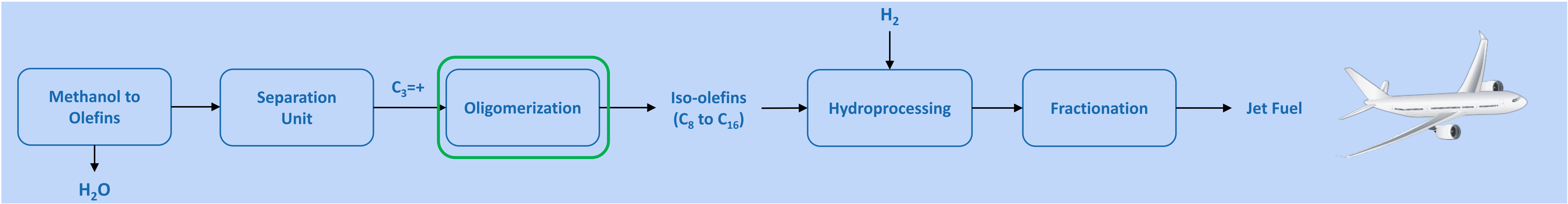
- Alcohol to Jet (ATJ) – from ASTM D7566 RRs for Annex A5

LT-PNL Process





- MTJ combines the Methanol to Olefin (MTO) and Olefin to Jet (OTJ) processes
  - Intermediate iso-olefins similar to prior ATJ efforts, including latest ATJ/SKA ballot



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MTJ Task Force Objectives

- TF Objective: Steward the ASTM D4054 evaluation and qualification of kerosene derived from methanol blended at up to 50 vol% with conventional jet fuel or components

  - Define the feedstock
    - Methanol

  - Define the process
    - Methanol Dehydration → Oligomerization → Hydrogenation → Fractionation

  - Define the product
    - Paraffinic OR paraffinic with aromatics @ up to 50 vol% blended with conventional jet fuel
    - Is there a way in a single Annex to reflect two different product compositions?
    - **Suggestion: Wait until the initial product composition is understood as part of the D4054 analysis**

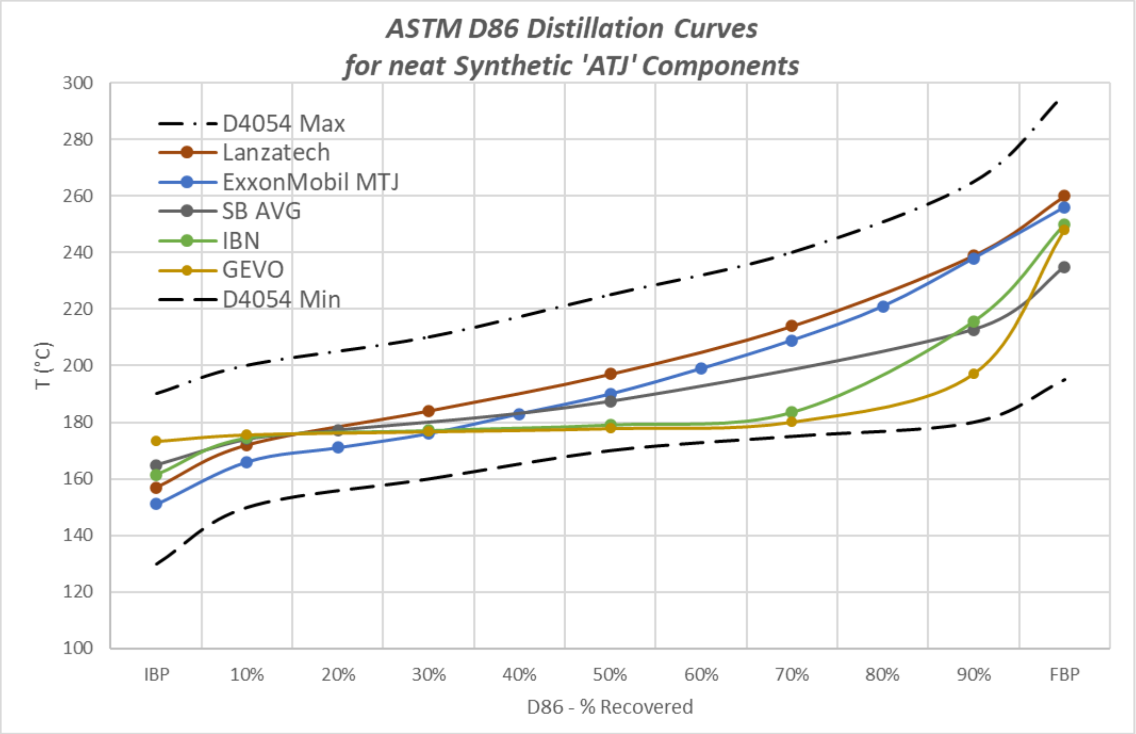
- Goal: Review data with the aviation industry and determine whether there is sufficient evidence to support balloting of a new ASTM D7566 Annex

Task Force AC724 History

- Methanol to Jet (MTJ) Task Force approved at ASTM D02.J06 meeting in Orlando (Dec 2022)
  - TF kick-off meeting held Feb 23, 2023
- First sample submitted to ASTM D4054 Clearinghouse in Feb 2023, with additional samples provided over the past two months
  - ExxonMobil produced three batches (~200 gallons)
  - UOP produced 10 gallons
  - Topsoe produced 40 gallons
- Additional producers are expected to submit samples in 2023/2024
- Nearly all Tier 1/2 data has been received on the first sample
  - Expect to have sufficient data by YE2023 to review with OEMs

Preliminary Tier 1 MTJ Data (ExxonMobil Sample #1)

- Tier 1 properties all on-spec for 50:50 blend
- Tier 1 properties all on-spec for 100% MTJ product, using D7566 Annex A5 ATJ comparison (e.g. density)
  - Density of 1st MTJ sample is 758 kg/m³ @ 15°C
  - Low temperature performance of MTJ sample is excellent
  - NHOC of MTJ sample is 44.2 MJ/kg



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Tier 1- Fuel Specification Properties							
			Identification	Exxon Mobil MTJ 23-002515-12 POSF 14465	POSF 14482 Blend	POSF 10325 Jet A	
			vol.% MTJ	100%	50%	0%	
	Property	Limit	D1655/D7566				ASTM Test
COMPOSITION							
	Acidity, total mg KOH/g	Max	0.10 BD/0.015 NT	0.001	0.003	0.000	D3242
	Aromatics, vol %	Max	26.5	0.0	8.5	16.4	D6379
	Sulfur, mercaptan, mass %	Max	0.003	<0.0003	<0.0003	0.001	D3227
	Sulfur, total mass %	Max	0.30 BD/0.0015 NT			0.0402	D5453
	Sulfur, total mass %	Max	0.30 BD/0.0015 NT	<0.0003	0.0198		D2622
VOLATILITY							
	Distillation temperature, °C:						D86
	10 % recovered, temperature (T10)	Max	205	166	170	177	
	50 % recovered, temperature (T50)		report	190	198	205	
	90 % recovered, temperature (T90)		report	238	241	244	
	Final boiling point, temperature	Max	300	256	264	271	
	Distillation Residue, %	Max	1.5	1.5	1.3	1.4	
	Distillation Loss, %	Max	1.5	0.5	0.2	0.5	
	Flash point, °C	Min	38	46	45	48	D93
	Density at 15°C, kg/m3	Min	775 to 840 BD/ 730 to 772 NT	758	781	803	D4052
FLUIDITY							
	Freezing point, °C	Max	-40	<-80	-58	-51	D5972
	Viscosity @-20°C, mm 2/s	Max	8.0	3.9	4.1	4.5	D7042
COMBUSTION							
	Net Heat of Combustion, MJ/kg	Min	42.8	44.2	43.7	43.1	D4809
	Smoke point, mm OR	Min	25	49	32	26	D1322
CORROSION							
	Copper strip, 2 h at 100°C	Max	No. 1	1a	1a	1a	D130
THERMAL STABILITY							
	JFTOT, Temperature, °C		260BD, 325NT	325	260	260	D3241
	Filter pressure drop, mm Hg	Max	25	1	0	0	
	Tube Rating:						
	nm avg over area of 2.5 mm	Max	85	16	13	9	
CONTAMINANTS							
	Existent gum, mg/100 mL	Max	7	<1	<1	<1	D381
	Microseparometer, Rating						D3948
	W/O electrical conductivity additive	Min	85	100	93	92	D3948

Preliminary Tier 2 MTJ Data (ExxonMobil Sample #1)

- Tier 2 properties on-spec for 50:50 blend
  - Not all Tier 2 results shown
- Available Tier 2 properties meet all typicals for 100% MTJ product, using D7566 Annex A5 ATJ comparison
  - Hydrogen content is excellent
  - Distillation slope meets/exceeds the petroleum component
  - Viscosity @ -40C better than petroleum component
  - Derived cetane comparable to petroleum component
- Initial halogen result higher than expected, but retest at 2nd lab gave on-spec result
  - There are no halogens in the feed or process
- Only remaining Tier 2 test to complete is Autoignition

Tier 1- Fuel Specification Properties							
			Identification	Exxon Mobil MTJ 23-002515-12 POSF 14465	POSF 14482 Blend	POSF 10325 Jet A	
			vol.% MTJ	100%	50%	0%	
	Property	Limit	D1655/D7566				ASTM Test
CHEMISTRY							
	Aromatics vol% on blend	Min	8.4		8.5		D6379
	Hydrogen Content	Min	13.4	15.3	14.7	14.2	D5291
	Nitrogen, mg/kg	Max	2	<1	1	4	D4629
	Distillation Slope						
	T50-T10, °C	Min	15	24	27	28	
	T90-T10, °C	Min	40	71	70	68	
	Lubricity, mm	Max	0.85	0.81	0.72	0.61	D5001
	Conductivity, mm			3	6	0	D2624
	Viscosity -40C mm2/s	Max	12	7.8	8.3	9.2	D7042
	Water Content, mg/kg	Max	75	7	14	24	D6304
	IQT Derived Cetane	Min	40	47	50	49	D6890
	IQT Ignition Delay (milliseconds)			4.38	4.13	4.16	D6890
	Total Halogens, mg/kg	Max	1	3.6 (<1)			D7359
	FAME, ppm	Max	50	<5	<5	<5	IP585
	Carbon and Hydrogen Content, Mass %	Min	99.5	100.0 (84.7/15.3)	100.0 (85.3/14.7)	99.8 (85.9/13.9)	D5291

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Preliminary Tier 2 MTJ Data (ExxonMobil Sample #1)

- Additional Tier 2 Fit for Purpose data meets typical expectations
- Some materials compatibility has been completed and shows limited impact on o-ring swell for 50:50 blends, and as-expected performance from a paraffinic SBC such as MTJ

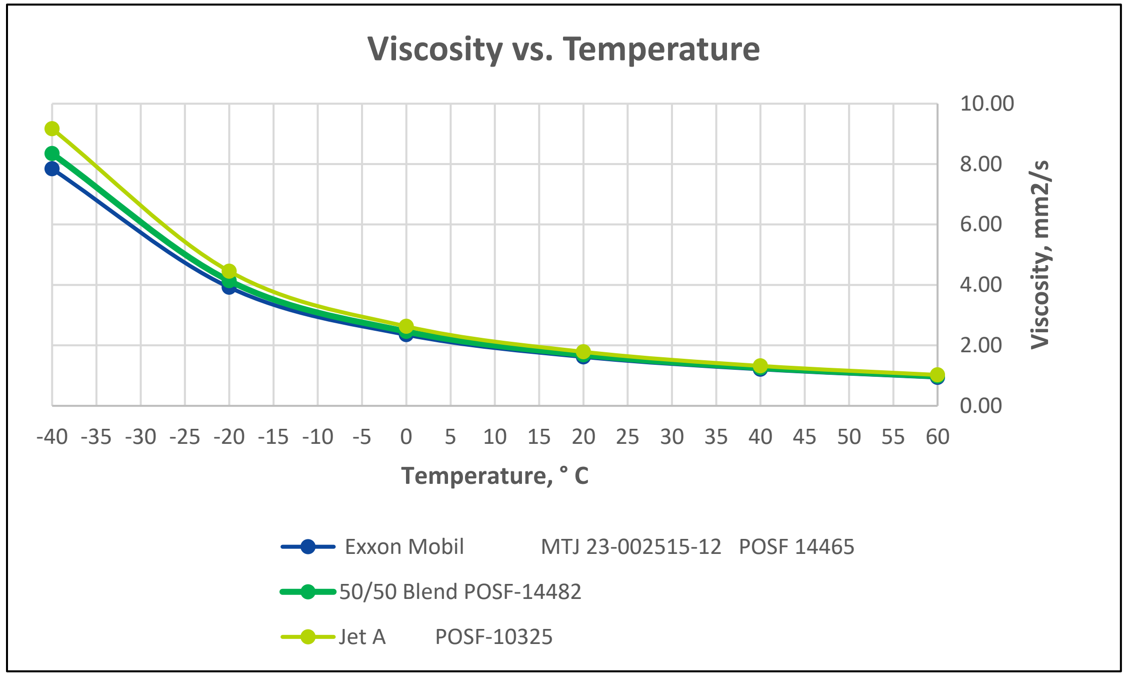
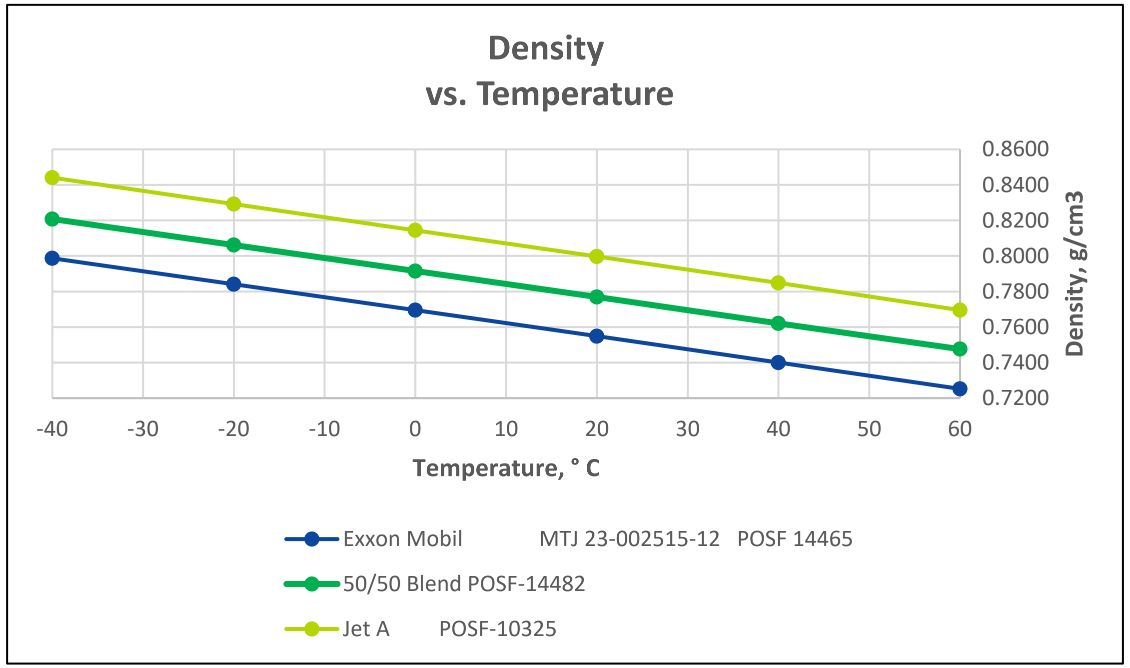


Table 2
Summary of Volume Swell of Selected O-rings
Aged in the Test Fuels and the Average Values for JP-8

Specification	Material	Material ID	JP-8 90% Prediction Interval			POSF 14465	Blend 14482	Jet A 10325
			LL %v/v	Mean %v/v	UL %v/v	%v/v	%v/v	%v/v
AMS5315	Nitrile Rubber	N0602e*	16.4	21.4	26.5	8.6	14.4	20.0
		N0602	3.4	6.9	10.5	0.5	5.0	6.9
AMS25988	Fluorosilicone	L1120	5.0	6.0	6.9	5.7	6.0	6.0
AMS7276	Fluorocarbon	V0747	0.2	0.4	0.7	-0.2	0.0	0.2

*Plasticizer pre-extracted



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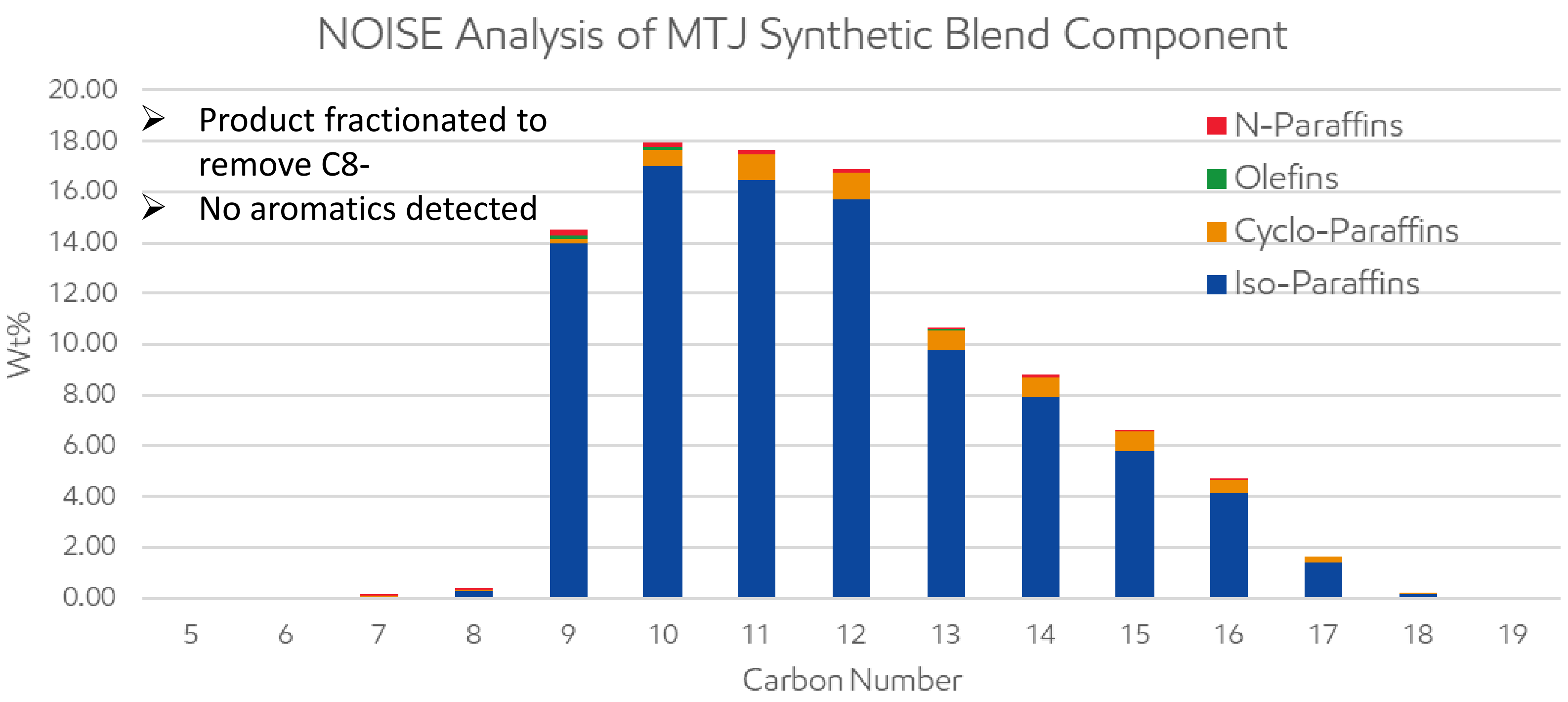
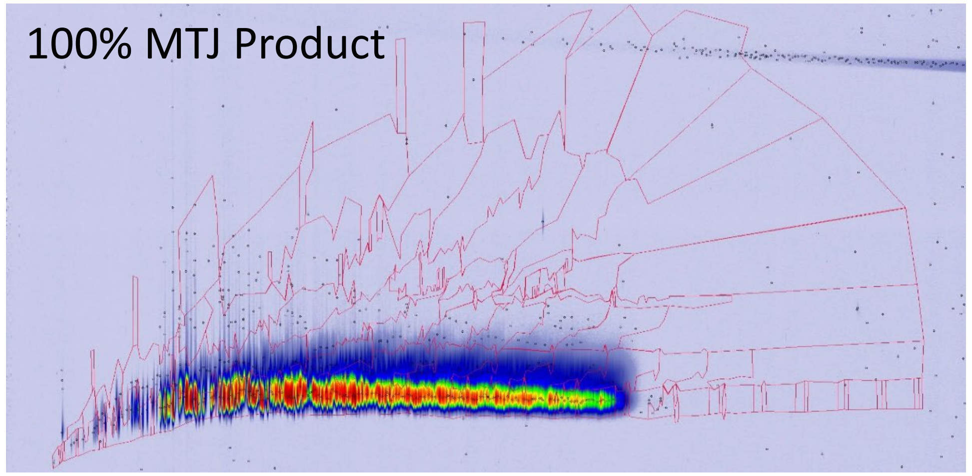
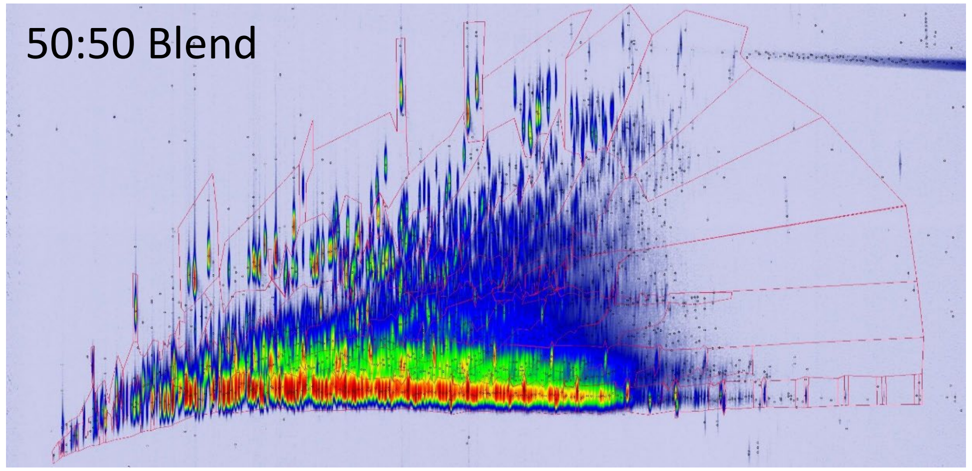
ExxonMobil Sample #1 MTJ product is paraffinic



Volume % MTJ	100	50	0
	Exxon Mobil MTJ 23-002515-12 POSF 14465	50/50 Blend POSF-14482	Jet A POSF-10325
D2425 (mass %)			
Paraffins (normal + iso)	98	71	51
Monocycloparaffins*	2	15	23
Dicycloparaffins (condensed)	<1	4	7
Tricycloparaffins (condensed)	<1	1	2
Alkylbenzenes	<0.1	6.4	13.0
Indans and Tetralins	<0.1	1.6	2.9
Indenes and C_nH_{2n-10}	<0.1	0.1	0.2
Naphthalene	<0.1	0.1	0.3
Naphthalenes	<0.1	1.0	1.8
Acenaphthenes	<0.2	<0.2	<0.2
Acenaphthylenes	<0.2	<0.2	<0.2
Tricyclic Aromatics	<0.2	<0.2	<0.2
Total	100	100	100
*& noncondensed polycycloparaffins			





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Thank you

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