Conversion of Peanut Oil into Jet and Diesel Fuels

Panama City, Florida
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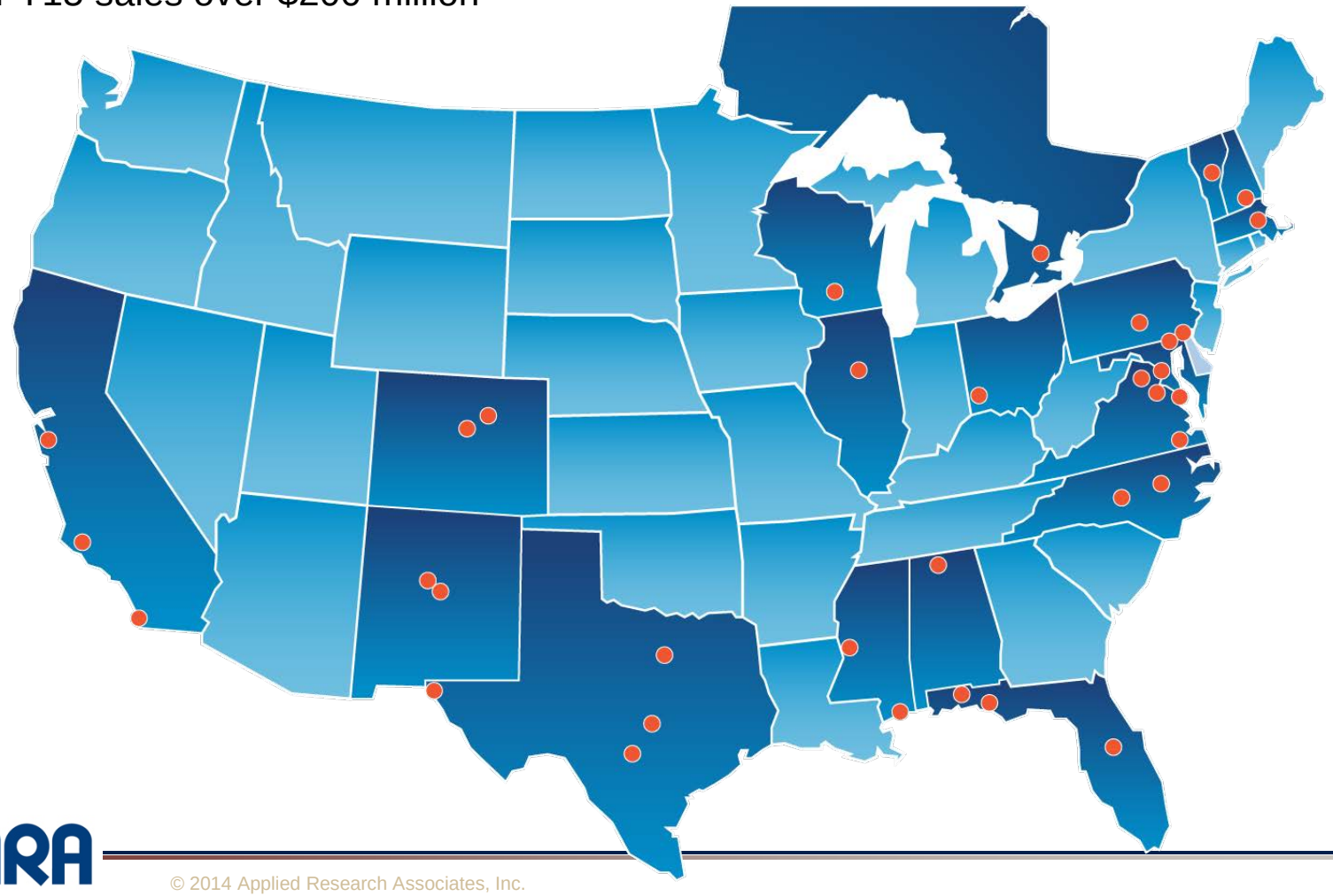
ReadiJet™
ReadiDiesel™

ARA®

About ARA, Inc.

- Founded 1979, Albuquerque, New Mexico
- 1,086 employee owners at locations in the U.S. and Canada
- FY15 sales over $200 million



Business Areas

National Security

ARA delivers innovative solutions to assess, detect, deter, defeat, and respond to threats facing us at home and abroad.

Infrastructure

ARA leads in technologies and services to improve performance and sustainability of infrastructure for transportation, buildings, and energy systems.

Energy & Environment

ARA provides innovative engineering services and products for alternative fuels, and the power and utility services market.

Health Solutions

ARA provides specialized research and technology services, testing and product development in health science and engineering.

Process Background

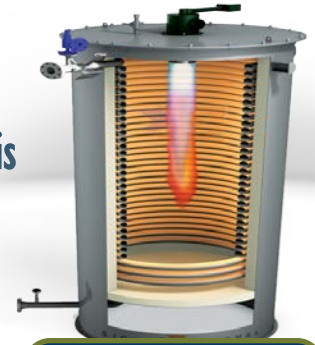
Biofuels ISOCONVERSION Process

Converts fats, oils, and greases from plants, animals, or algae into “drop-in” renewable fuels

ARA

Catalytic Hydrothermolysis

- Supercritical water process
- Produces crude oil that contains the same hydrocarbon types as petroleum crude



2 Minutes
Converts fats oils and greases to crude oil

Hydrotreating

- Saturates olefins
- Removes residual oxygenates

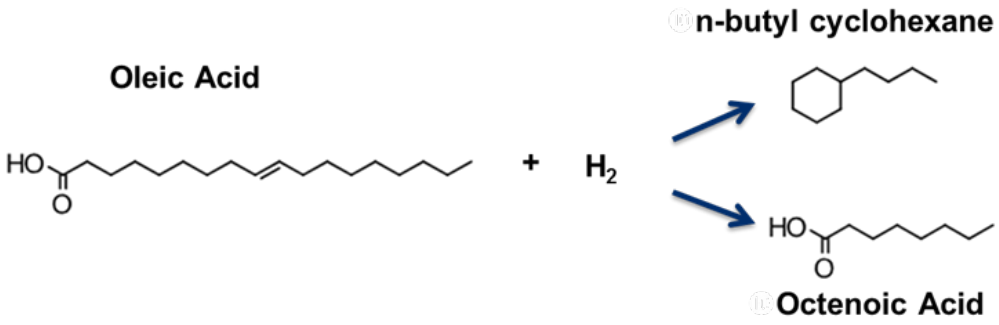
Conventional
Refinery Processes

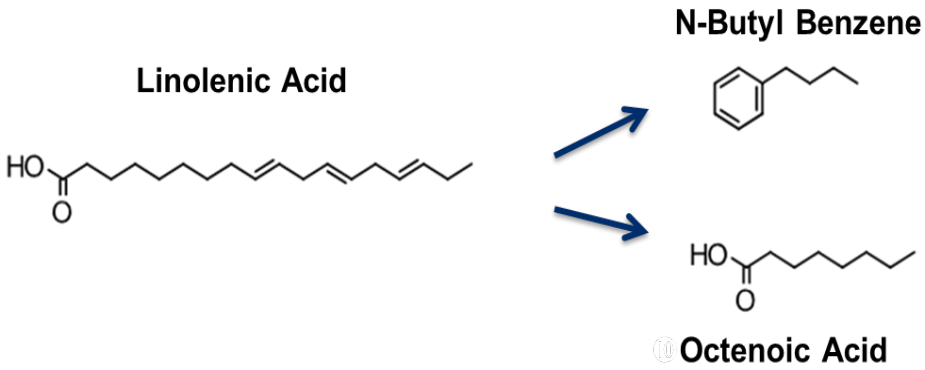
CLG
Chevron Lummus Global

Fractionation

- Produces finished fuels
- Jet and diesel that meet
- Meets petroleum specs without blending
- Renewable chemicals, and naphtha

Characteristic CH Conversion Reactions

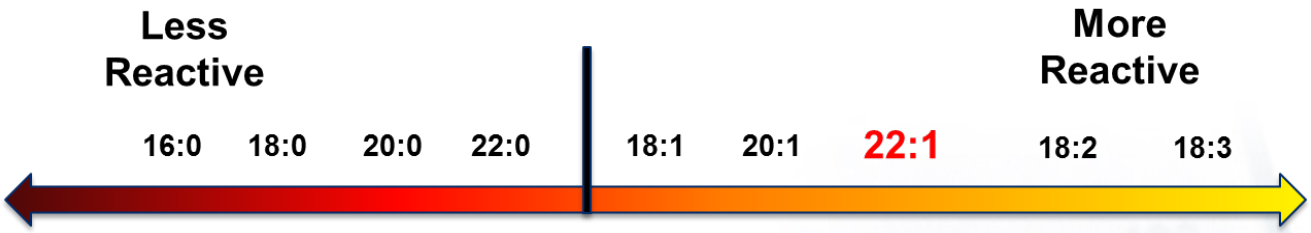




- Cycloparaffins and Aromatics are formed
- Entire homologous series of isomers are formed
- Ring structures are conserved during hydrotreating
- Hydrogen is conserved by formation of ring structures

Conversion of Peanut Oil

- Unsaturated FFAs are more reactive
  - High yield of cycloparaffins & aromatics
  - High density and energy content
  - Excellent low-temperature properties

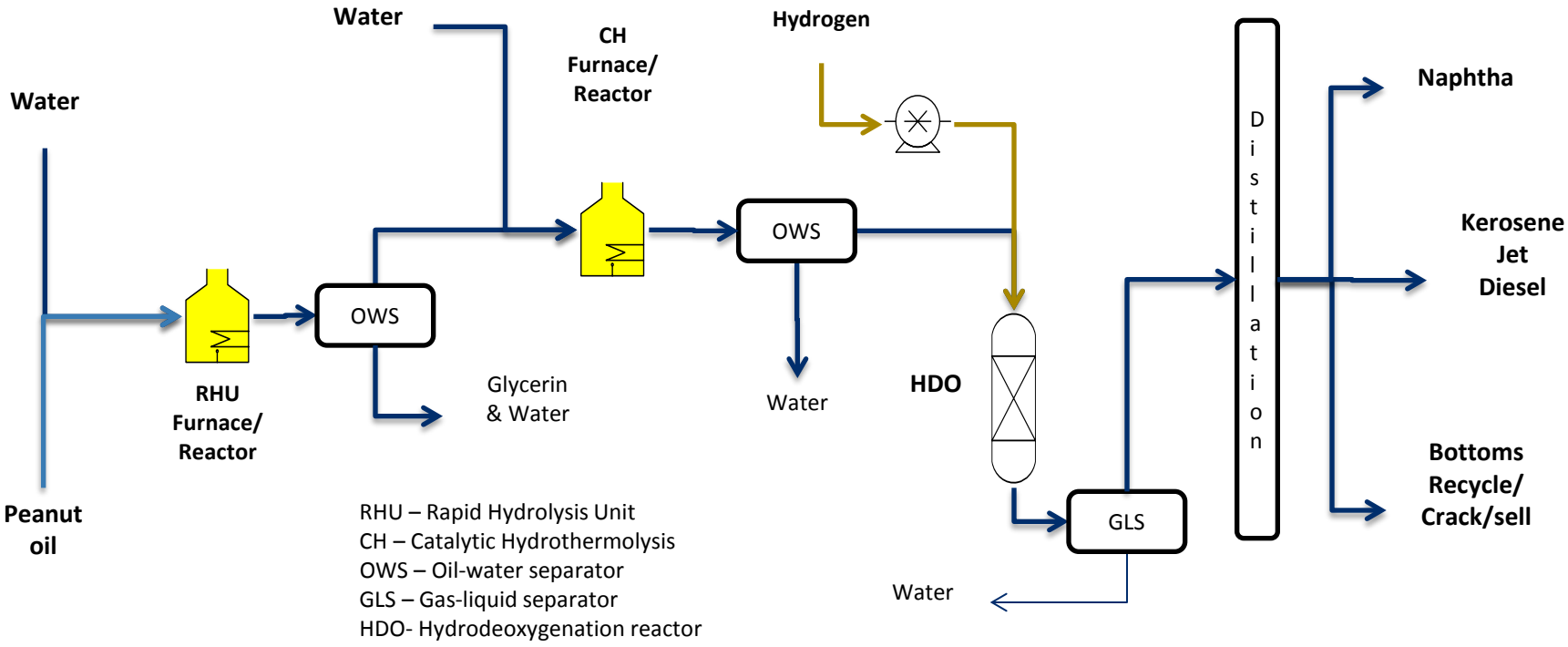


Composition of Oil Received

Lipid	Concentration
Free Fatty Acid	0.6 %
Monoglyceride	0.1%
Diglycerides	7.7%
Triglycerides	91.7%

Fatty Acid	Mass %
16:0	11.1
18:0	2.8
18:1	51.8
18:2	27.0
20:0	1.3
20:1	1.4
22:0	3.0
22:1	0.2
24:0	1.4
unidentified	0.0

Flow Diagram for CH & HCU Pilot Systems



Hydrothermal Cleanup (HCU) Results

Patent Pending

- **Achieves Rapid Hydrolysis**
  - **Production of free fatty acids and glycerin**
  - **An effective alternative to chemical degumming/metals reduction**

Parameter	Feed	Product
Specific Gravity (60°F)	0.9166	0.8854
Total Acid Number, mg KOH/g	4.8	173.6
Free Fatty Acids, wt%	0.1	93.0
Monoglycerides, wt%	0	4.4
Diglycerides, wt%	3.4	2.5
Triglycerides, wt%	96.5	0.1
Calcium, ppm	25.6	4.0
Magnesium, ppm	28.0	0.9
Phosphorus, ppm	146.7	2.4
Sodium, ppm	0.0	7.1
Potassium, ppm	67.5	2.8

Analysis of HCU Aqueous Phase

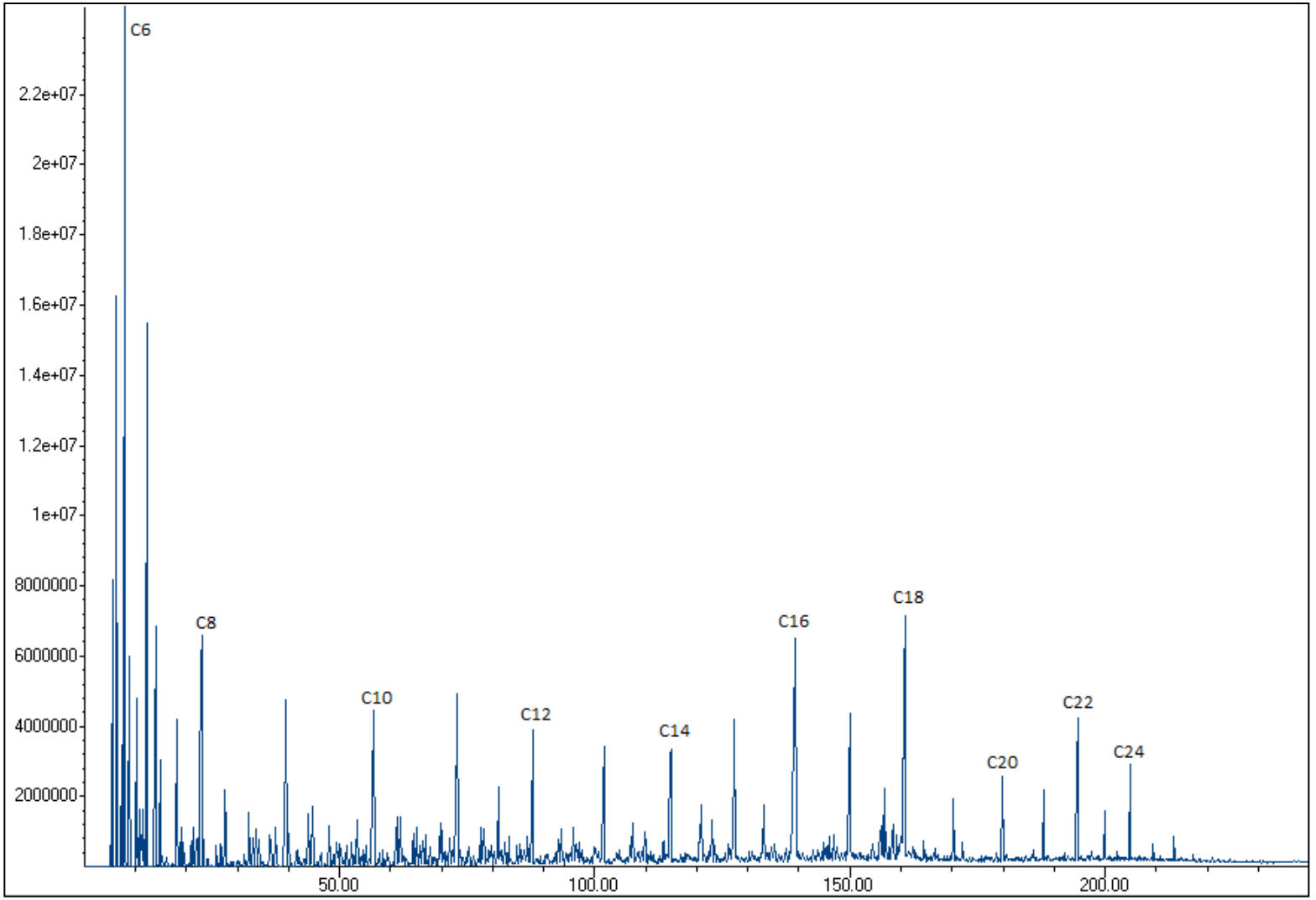
- 70% of Glycerin partioned to the aqueous phase
- High-purity glycerin and water can be recovered by distillation

Test Parameter	Result
Total Acid Number, mg KOH/g	0.8
Specific Gravity	1.0314
Refractive Index	1.3489
Glycerin by RI, wt%	13.5%
Glycerin by GC, wt%	12.9%

CH Crude Oil Production and Properties

CH Production Test		Peanut Oil
Specific Gravity of Feed Oil	g/cc	0.8854
Specific Gravity of CH crude product	g/cc	0.8528
Approximate Actual Residence Time	sec	8-12
Conversion to <C16 FFAs	wt%	76
Off-Gas Production Rate	scfb	379
Off-gas yield	wt%	12
Organic acids in Aqueous Phase	wt%	3
CH Crude Product Yield	wt%	85
CH crude Product Acid Number	mg KOH/g	153

Gas Chromatogram of Whole Hydrotreated Product



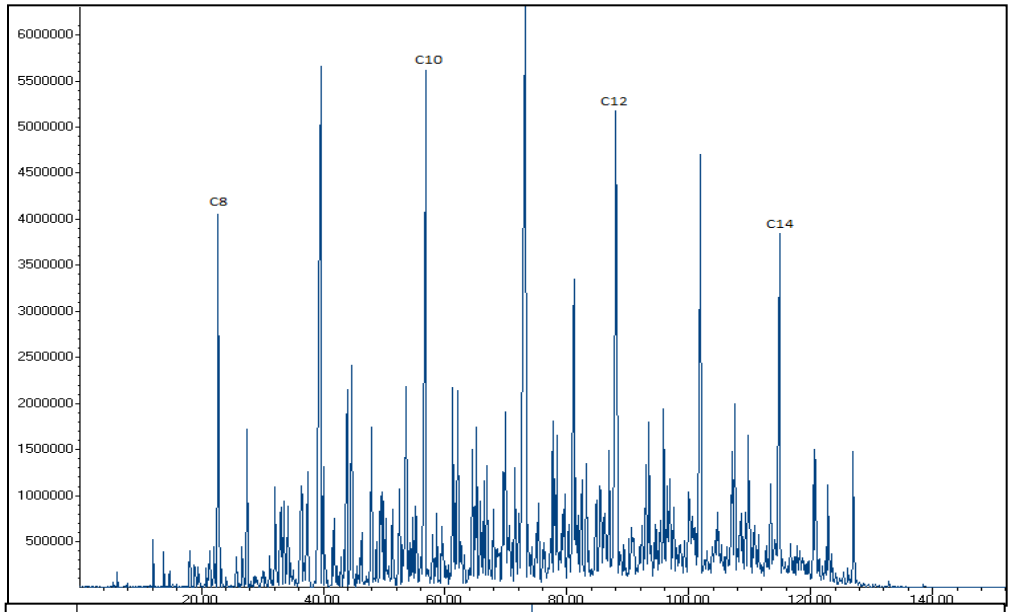
Distillation Results

Temperature Range	Volume % Yield	Mass % Yield
20 - 74°C	10.4	9.2
74 - 135°C	19.6	18.2
135 - 140°C	1.2	1.1
140 - 145°C	1.4	1.3
145 - 166°C	5.5	5.5
166 - 249°C	21.5	22.3
249 - 260°C	2.4	2.6
260 - 343°C	25.2	26.7
343 - 371°C	3.7	4.1
371+°C	solid	5.9
Column Hold Up	-	3.2
Naphtha (20 - 135°C)	30.0	27.4
Jet A-1 (135 – 260°C)	32.0	32.8
JP-5 (166 - 249°C)	27.0	27.8
Diesel (140 - 371°C)	59.7	62.5
F-76 Diesel (166 - 343°C)	49.1	51.6

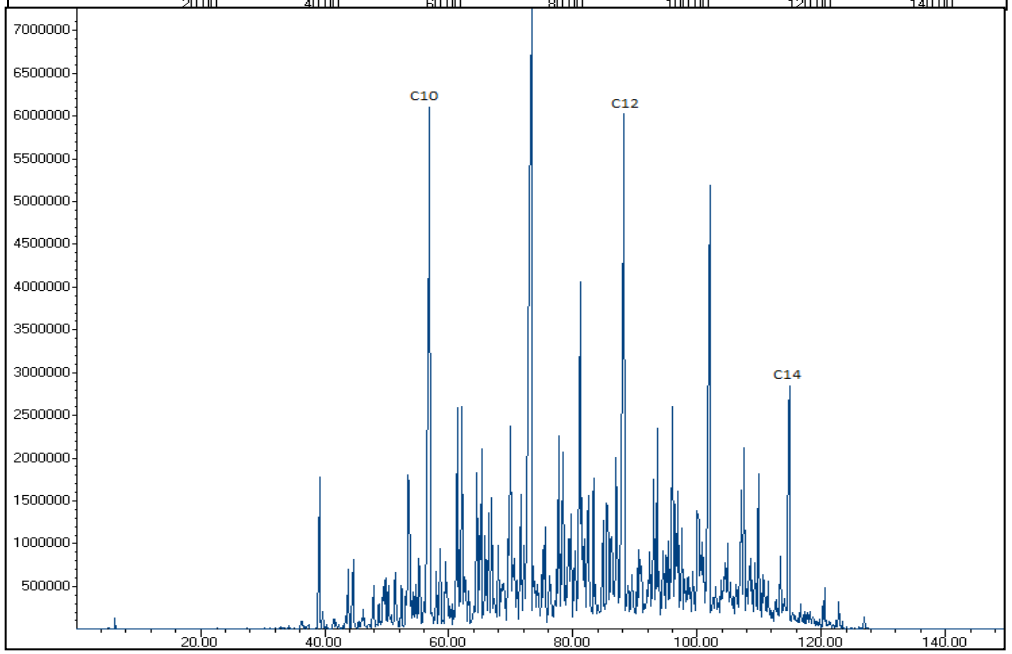
Jet Fuel Properties

	Jet A-1 (135 - 260°C)		JP-5 (166 - 249°C)	
	Measured	Spec	Measured	Spec
Specific Gravity, g/cc	0.798	0.775-0.840	0.807	0.788 – 0.845
Cetane Index	42.7		42.2	>42**
Total Acid Number, mg KOH/g	0.008	≤ 0.015*	0.008	≤ 0.015
Flash Point (°C)	42	≥ 38	61	≥ 60.0
Freeze Point (°C)	-51	≤ -47	-47	≤ -46
Aromatic content, vol% est.	12-18	8.4-26.5*	12-18	8.4-25**
Distillation, ASTM D86 (°C)				
IBP: 0.5wt%	152		187	
10%	164	≤ 205	190	≤ 205
50%	194		201	
90%	230		225	
FBP: 99.5%	247	≤ 300	239	≤ 300
Distillation Slope				
T50-T10	30	>15*	11	>10**
T90-T10	66	>40*	35	>28**

Jet A



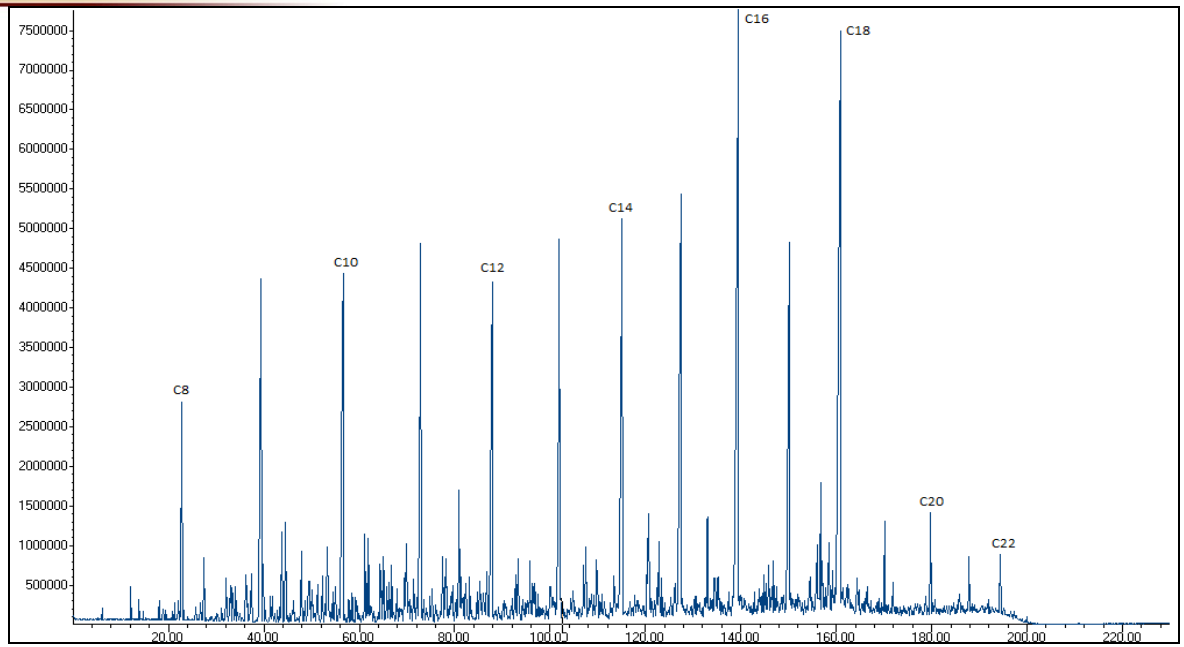
JP-5



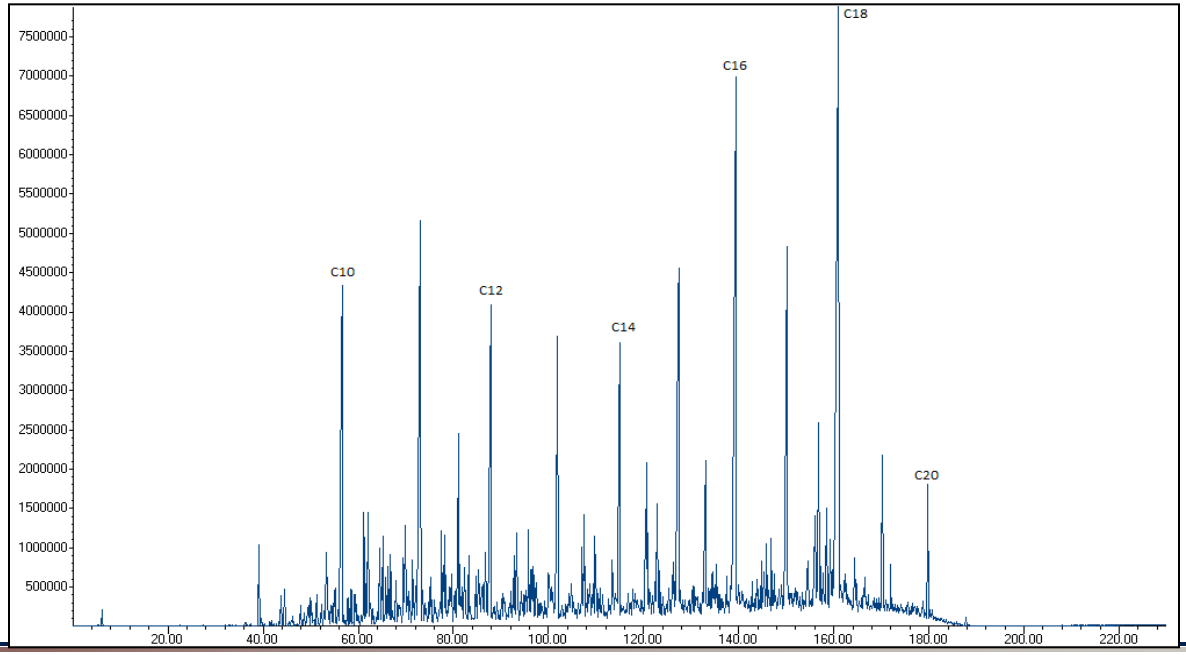
Diesel Fuel Properties

	No. 2 Diesel (140 - 371°C)		F-76 Diesel (166 - 343°C)	
	Measured	Spec	Measured	Spec
Specific Gravity, g/cc	0.813		0.817	≤0.876
Cetane Index	55.9	≥ 40	56.5	42-60*
Total Acid Number mg KOH/g	0.010		0.008	≤ 0.15*
Flash Point (°C)	54	≥ 52	74	≥ 60.0
Cloud Point (°C)	-10		-9	≤ -1
Pour Point (°C)	-9		-9	≤ -6
Viscosity, cSt (@40°C)	2.03	1.9 – 4.1	2.2	1.7 – 4.3
Distillation, ASTM D86 (°C)				
IBP: 0.5wt%	165		190	
10%	183		203	191-290
50%	249		257	
90%	313	282 - 338	300	285-357*
FBP: 99.5%	337		314	295-385*
Distillation Slope				
T50-T10			54	≥ 15*
T90-T10			97	≥ 35*

Diesel #2



F76 Diesel



Summary of Peanut Oil Testing

- Peanut oil is an excellent feed stock for conversion to transportation fuels via the ARA-CLG BIC Process
  - Drop-in, unblended jet and diesel fuels can be produced
  - Fuels meet existing petroleum specifications
  - Jet fuel will meet Navy and commercial specifications for renewable fuels
- Production of valuable byproducts improves economics
  - Glycerin (propylene glycol precursor)
  - Normal (straight-chain) paraffins
    - For making detergents (linear alkyl benzene)
  - Renewable acetic acid
- Sensitivity regarding food vs fuel issue
  - Must define available sources as non-edible
- Commercial production of fuels requires sustainable, consistent supply
  - Need to be integrated with other renewable oil sources

Production of Certification Fuels for DLA-Navy

100% Drop-in, Unblended

	JP-5 (CHCJ-5) 60°C Flash Jet	F-76 (CHCD-76) 60°C Flash Diesel	Gallons Total
U. S. Navy (DLA)	72,000	79,000	151,000
Other*	9,000		9,000
Total	81,000	79,000	160,000

- CH crude oil produced in St Joseph, Missouri
  - 100 barrel-per-day pilot demonstration facility
- Hydrotreating and distillation of jet and diesel fuels
  - Performed by Centauri – Pasadena, TX
- ASTM certification of commercial jet fuel is on-going
- Commercial diesel - registration

100 bbl/day CH Conversion System – St Joe, MO

Centauri Refinery – Pasadena, Texas

Commercialization Activities

- Several licensees of the technology
- Pursuing multiple commercialization efforts up to 5000 bbl/day
- One commercial system is in preliminary engineering
    - Scheduled to begin construction this year

Next Generation Aviation Fuel

ReadiJet™