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Analysis of Aviation Turbine Fuel Containing Synthesized Hydrocarbons

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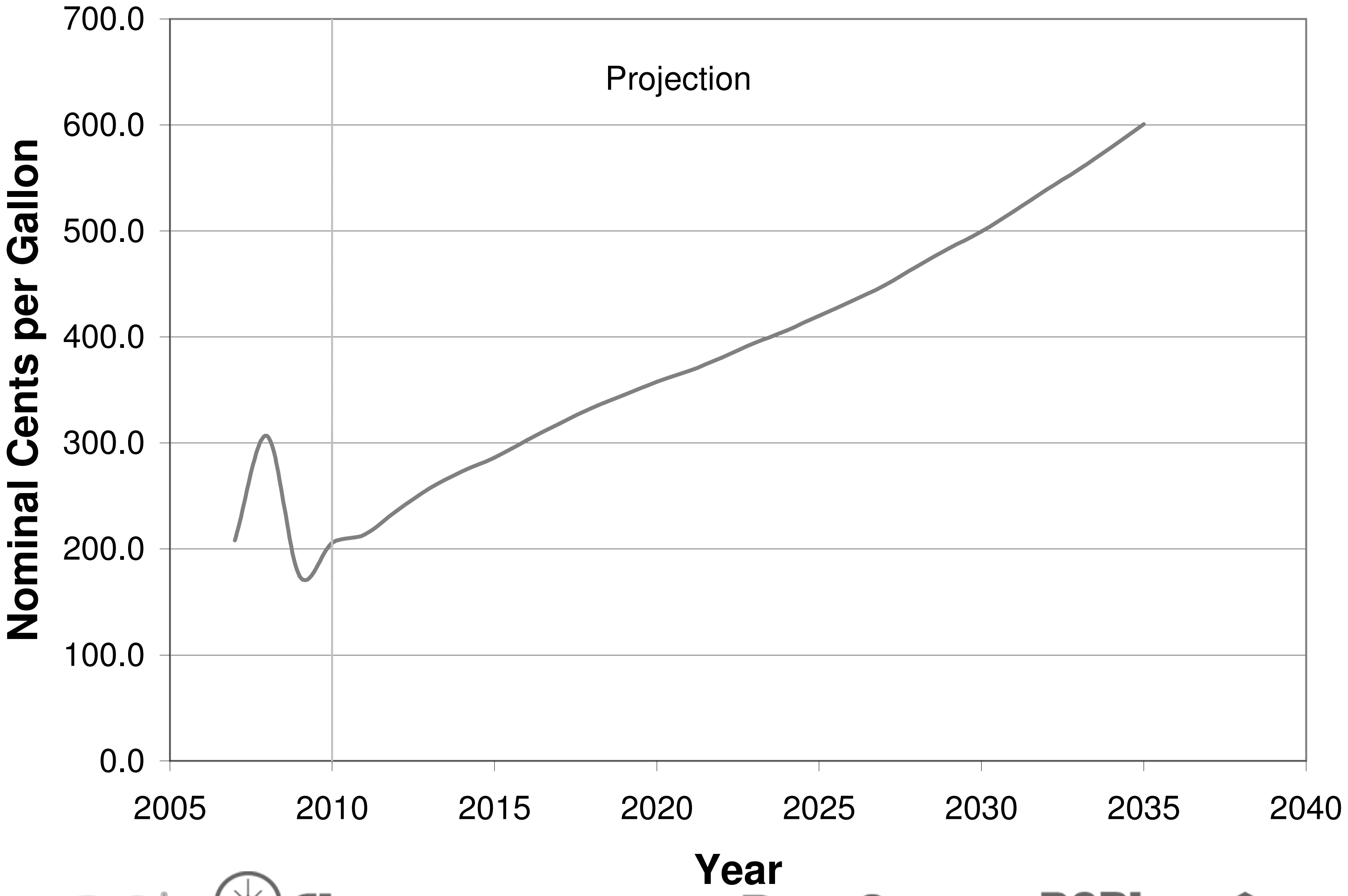
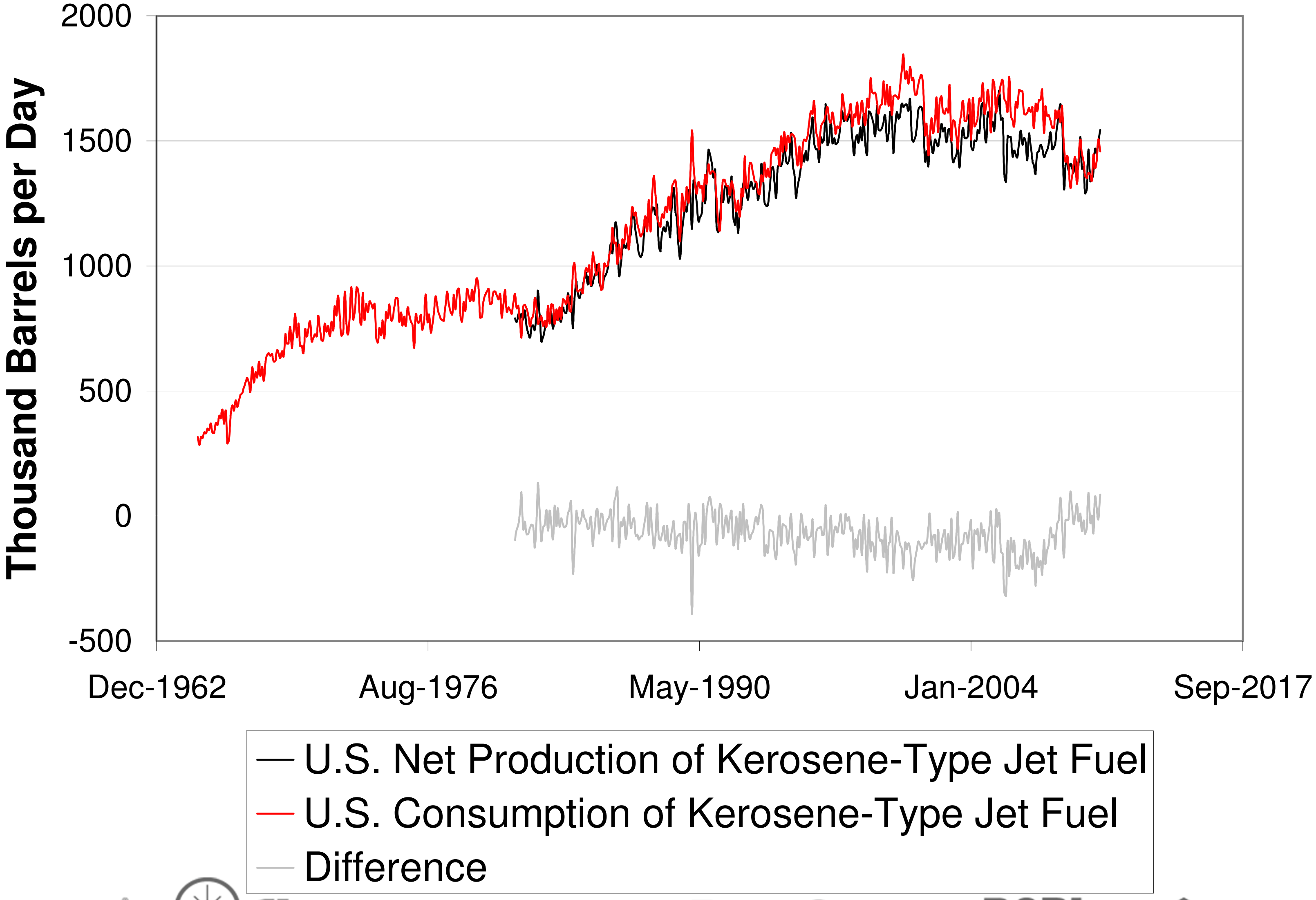
Outline

- Why synthetic jet fuels?
    - Cost saving efforts
    - Security
- Background of the different synthetic jet fuels
    - Feedstock
        - HRJ (Hydrotreated Renewable Jet) Fuels
        - Fisher-Tropsch based Fuels
    - Benefits
- Different synthetic jet fuel properties
    - Results
- Conclusions

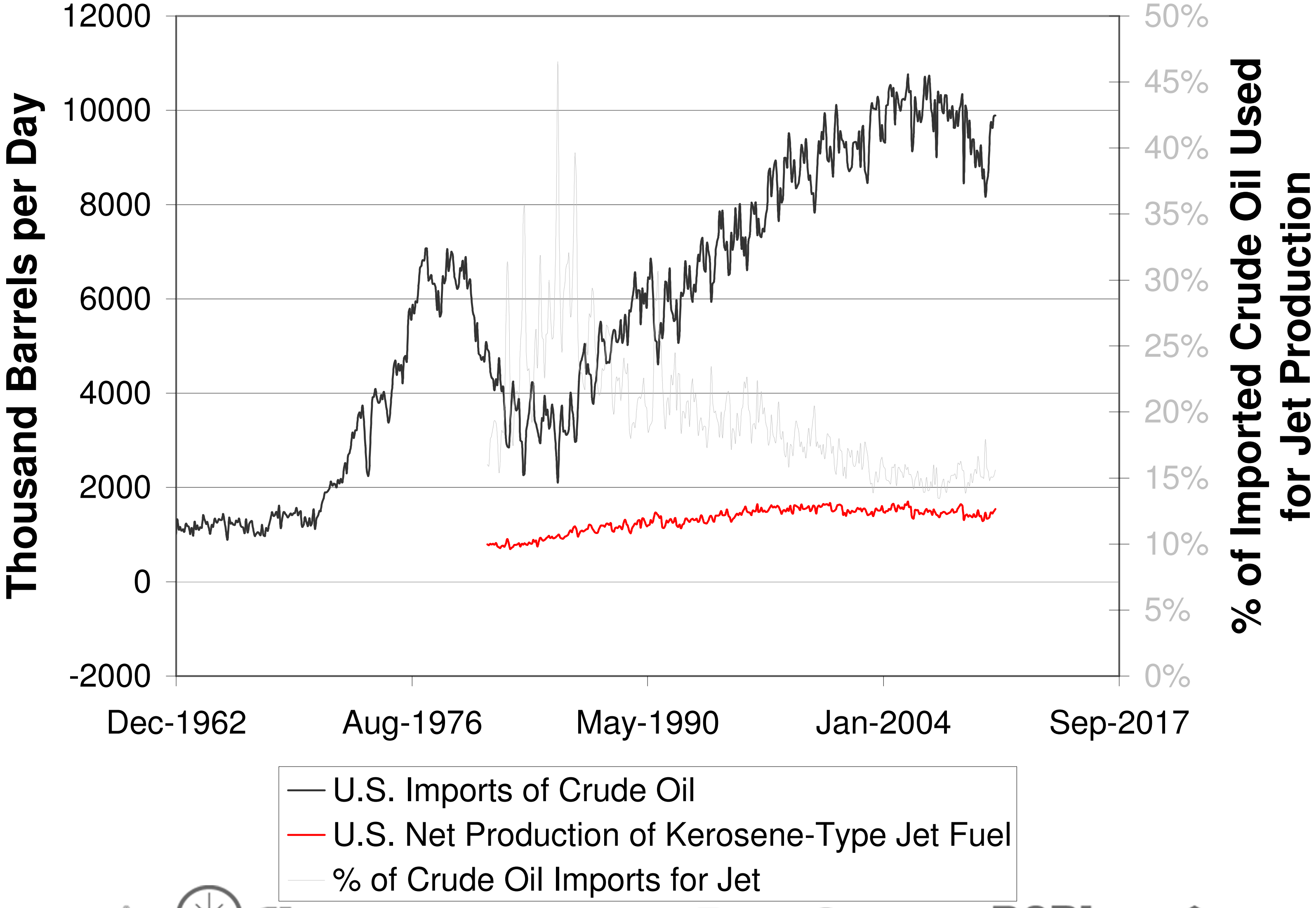
U.S. Jet Fuel Prices[1]



U.S. Jet Fuel Production and Consumption[2,3]



Percentage of U. S Imported Crude Oil Used for Jet Fuel Production[3,4]



US Military Push for Synthetic Jet Fuel

- Safety
  - Reduce the dependence on foreign oil
- Supply
  - Reduce the number of different fuels required
- Environment
  - Burns cleaner than petroleum-based fuels

- World's largest buyer of fuel
  - 8 billion gallons per year [11]

Current Limitations

- Facilities shortage [9]
  - Not enough production
  - Drives up cost
- Military role in driving synthetic fuels
  - Goal to have 50% of their domestic supply from domestic sources by 2016 [9]
  - Facilitates building up of infrastructure
  - Lowers cost

Feedstocks

- HRJ (Hydrotreated Renewable Jet) Fuels
  - Fuels based off of biomass products such as plants or animal by-products
  - Turns bio feedstocks into jet fuels
  - Produced from natural oils, fats, and grease
    - C18 oils include soy, palm, and canola
    - C12 oils include coconut, jatopha, camelina, and algal
  - Creates Synthetic Pariffinic Kerosine (SPK)
    - Can be blended directly with petroleum-derived jet fuel or with aromatics from either a renewable or petroleum source [10]
- Fischer-Tropsch (FT) based Fuels
  - Fuels from hydrogen and carbon monoxide sources
    - Coal
    - Methane
    - Biomass [11]

Camelina

- Part of the Brassicaceae plant family [14]
  - Same family as broccoli, cabbage, and canola
- Originated in Europe [16]
- Characteristics
  - Heavily branched
  - Grow 1-3 feet tall
  - Produce many small, oily seeds
    - Approximately 400,000 seeds per pound
    - Produce 40% oil compared to only 20% of oil with soybeans
    - Can realize up to 100 gallons of oil per acre
  - Can boost wheat production up by 15% [5]
  - Grows wild in the US [13]

Camelina Attributes

- Low production cost
  - Low fertilizer requirements
  - Low pesticide requirements
  - Low water requirements [15]
    - Thrives in areas with 10-17 inches of rainfall [5]
- Camelina seed content:
  - 35% - 45% omega-3 fatty acid
  - 45% - 47% crude protein
  - 10% - 11% fiber [15]
- Short growing season
  - Planted in March and harvested in late July
- Drought tolerant [12]
- Known by many names: gold-of-pleasure, false flax, wild flax, and German sesame [5]

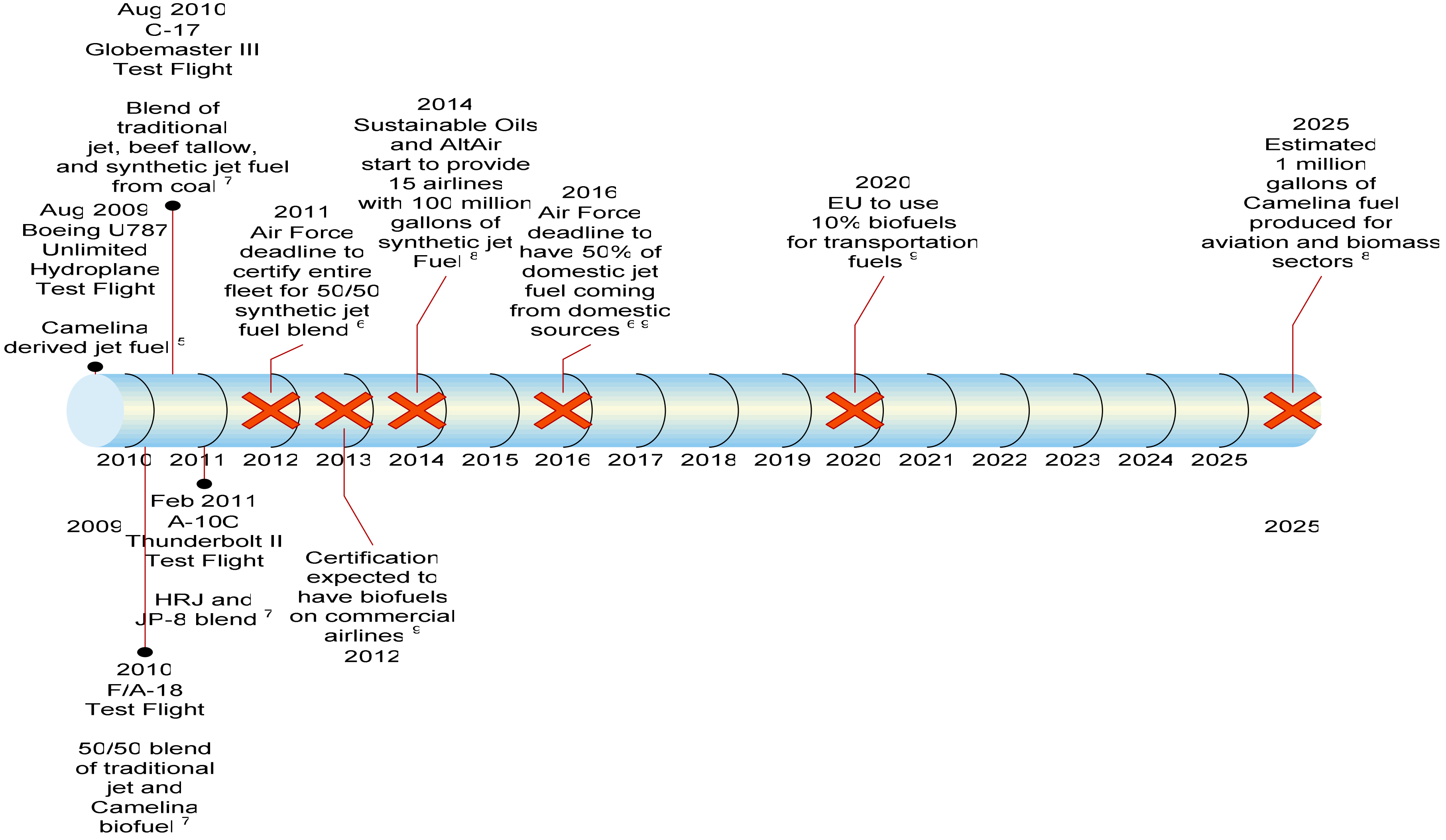
Camelina -
Attractive as Biofuel Feedstock

- 80% lower emissions than petroleum-derived jet fuel
- Does not compete for food crops [12]
  - Can be grown on land unsuitable for food crops [13]
- Can be used in rotation with wheat crops instead of fallow years
  - Can increase the amount of wheat production
  - Reduces erosion of topsoil
- Most readily available feedstock
- Leftover meal after crushing can be used for livestock feed [12]
  - High in omega-3 fatty acids [13]

Fischer-Tropsch (FT) Fuels

- Process developed by German scientists
  - Used to make fuel during World War II [11]
- Keys to successful coal hydrogenation
  - Sulfur resistant catalysts
  - Two stage liquid-vapor phase hydrogenation [17]

Synthetic Jet Fuel Timeline



Aug 2010
C-17
Globemaster III
Test Flight

Blend of
traditional
jet, beef tallow,
and synthetic jet fuel
from coal [7]

Aug 2009
Boeing U787
Unlimited
Hydroplane
Test Flight

Camelina
derived jet fuel [5]

2011
Air Force
deadline to
certify entire
fleet for 50/50
synthetic jet
fuel blend [6]

2014
Sustainable Oils
and AltAir
start to provide
15 airlines
with 100 million
gallons of
synthetic jet
Fuel [8]

2016
Air Force
deadline to
have 50% of
domestic jet
fuel coming
from domestic
sources [6 9]

2020
EU to use
10% biofuels
for transportation
fuels [9]

2025
Estimated
1 million
gallons of
Camelina fuel
produced for
aviation and biomass
sectors [8]

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025

2009

Feb 2011
A-10C
Thunderbolt II
Test Flight

HRJ and
JP-8 blend [7]

Certification
expected to
have biofuels
on commercial
airlines [9]
2012

2025

2010
F/A-18
Test Flight

50/50 blend
of traditional
jet and
Camelina
biofuel [7]

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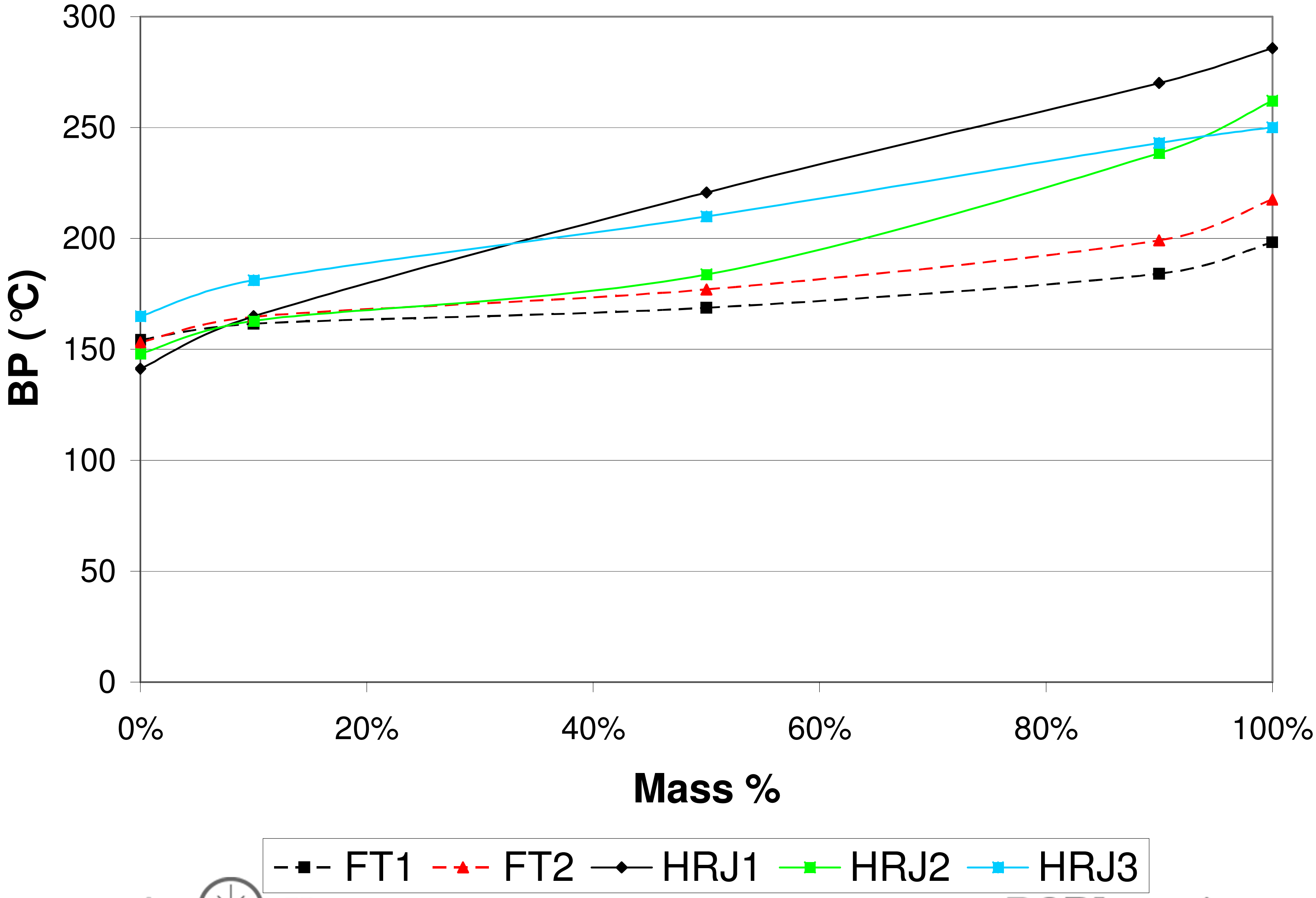
Fuels Used in Study

- Two Fischer-Tropsch Fuels and Three Hydrotreated Renewable Jet Fuels
  - One Camelina feedstock
  - One Tallow feedstock

Distillation (ASTM D86)



Distillation (ASTM D86)

	FT1	FT2	HRJ1	HRJ2	HRJ3
IBP (℃)	154.3	153.2	141.3	148	164.9
T10 (℃) (max 205)	161.5	164.7	164.9	162.9	181.2
T50 (℃)	168.7	177	220.7	183.8	209.9
T90 (℃)	184.1	199.1	270	238.5	243.0
FBP (℃) (max 300)	198.3	217.5	285.7	262.1	250.1
T90 - T10 (℃) (min 22)	22.6	34.4	105.1	75.6	61.8

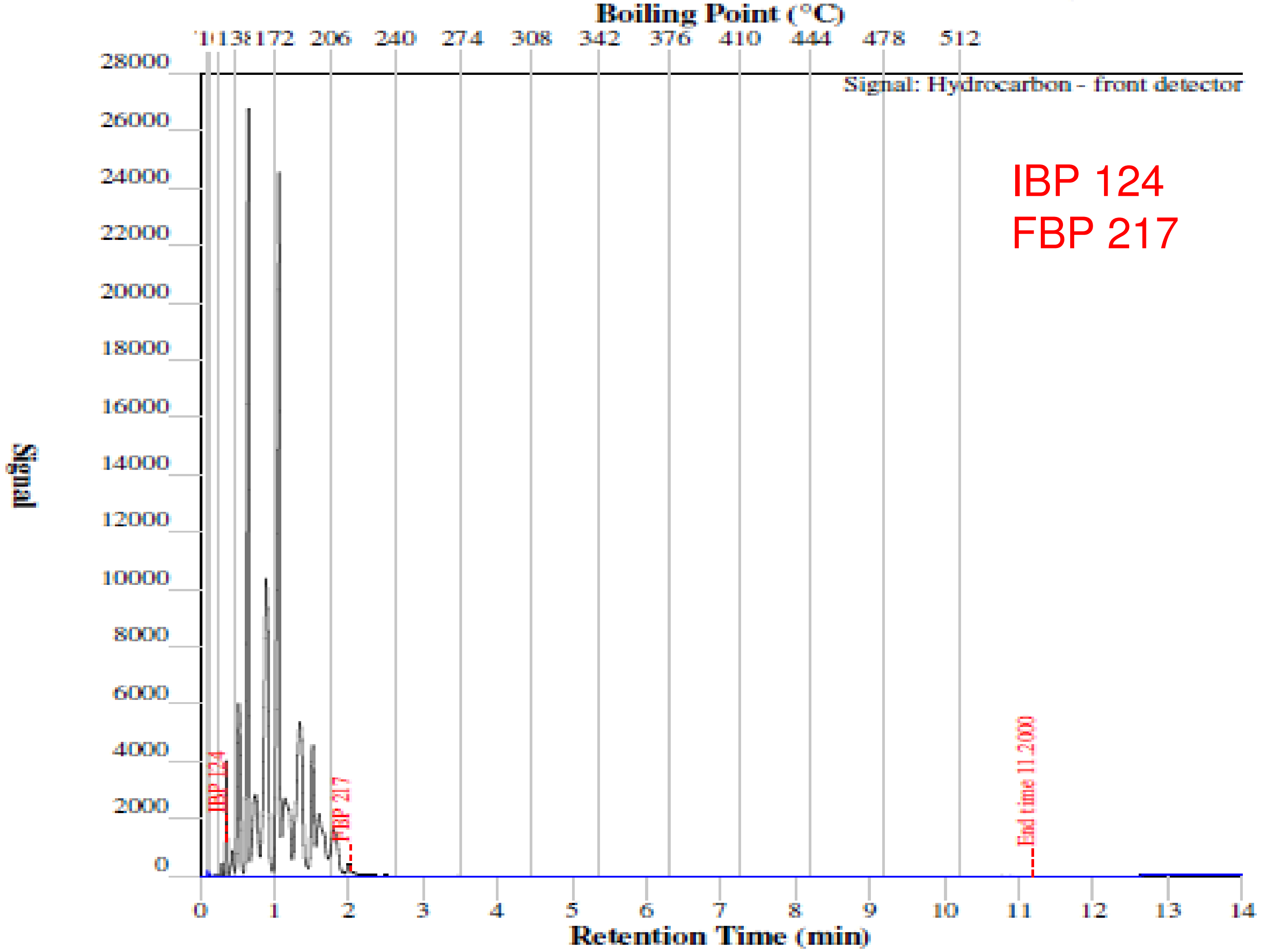
Sulfur (ASTM D5453)
Nitrogen (ASTM D4629)

	FT1	FT2	HRJ1	HRJ2	HRJ3
Sulfur (mg/kg) max 15	1.082	0.584	0.120	0.260	0.034
Nitrogen (mg/kg) Max 2	0.098	0.110	0.074	0.092	0.103

JFTOT (ASTM D3241)
Freeze Point (ASTM D7153)

	FT1	FT2	HRJ1	HRJ2	HRJ3
JFTOT (325℃) Tube Deposit Rating (less than 3, no peacock or abnormal)	1	<2	1	1	1
JFTOT (325℃) Differential Pressure (max 25)	0	0	0	0	0
Freeze Point (℃)	-52.6	-120	-49.4	-64.9	-60.5

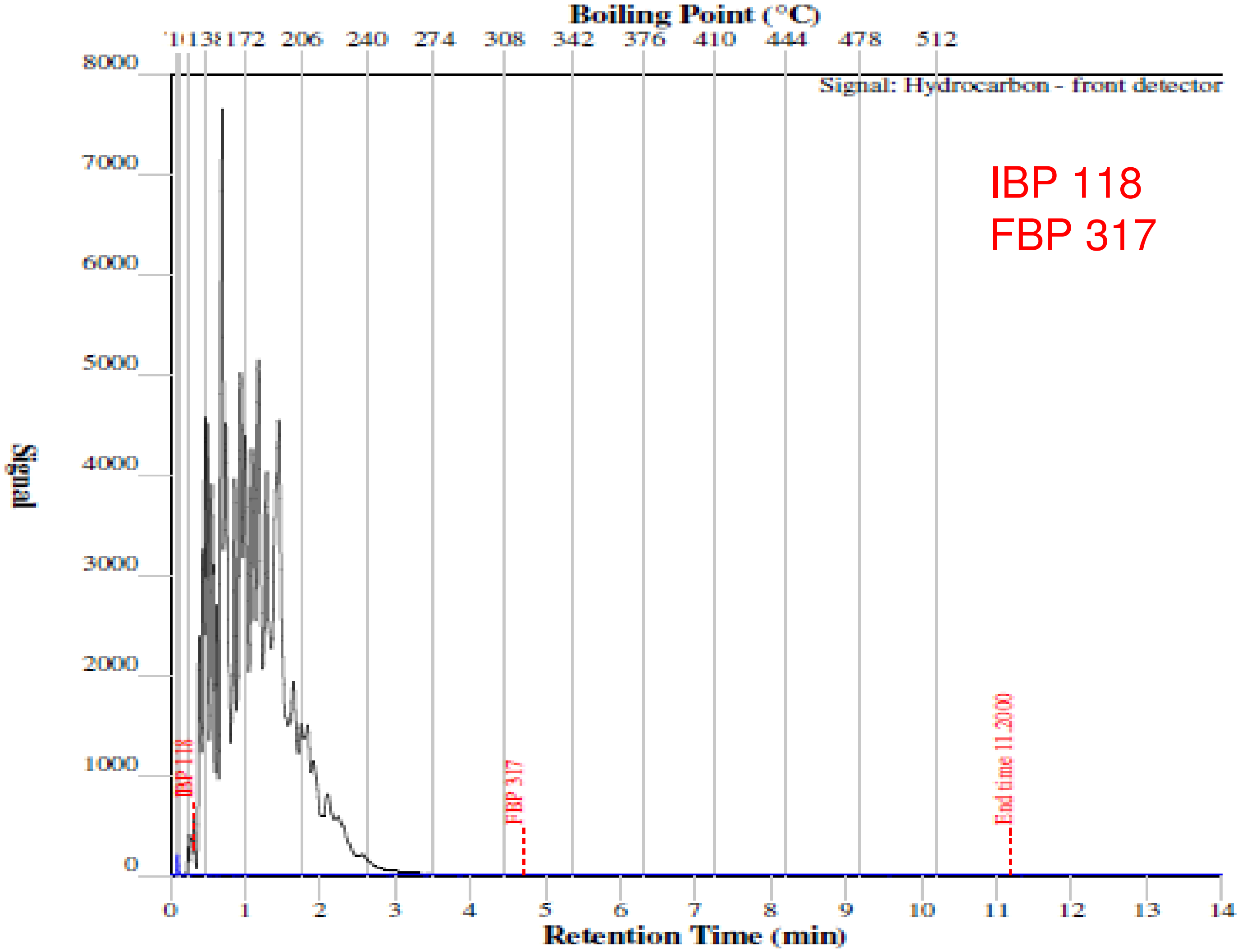
Boiling Range Distribution by GC
FT1 (ASTM D2287)



IBP 124
FBP 217

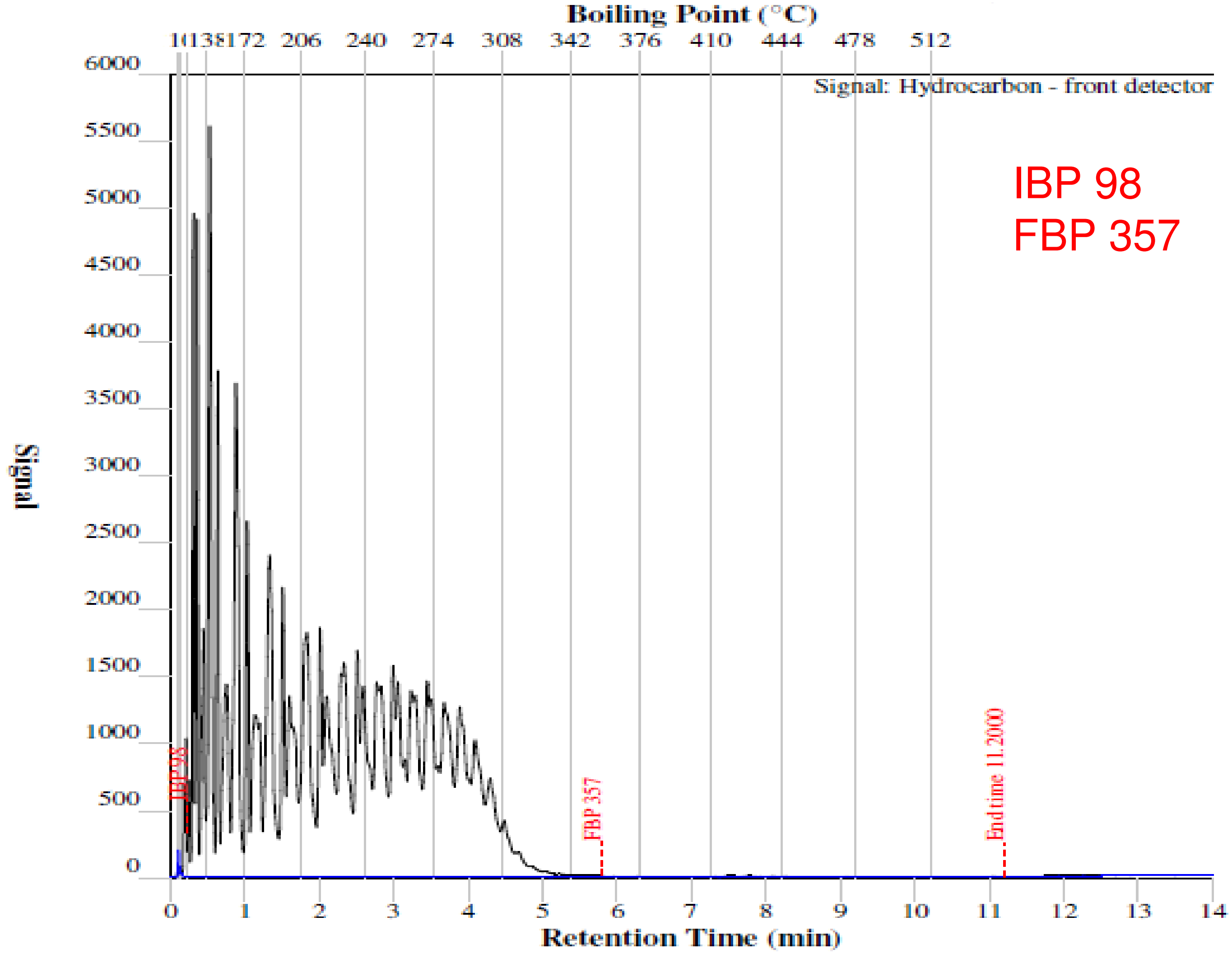
Boiling Range Distribution by GC

FT2 (ASTM D2287)



IBP 118
FBP 317

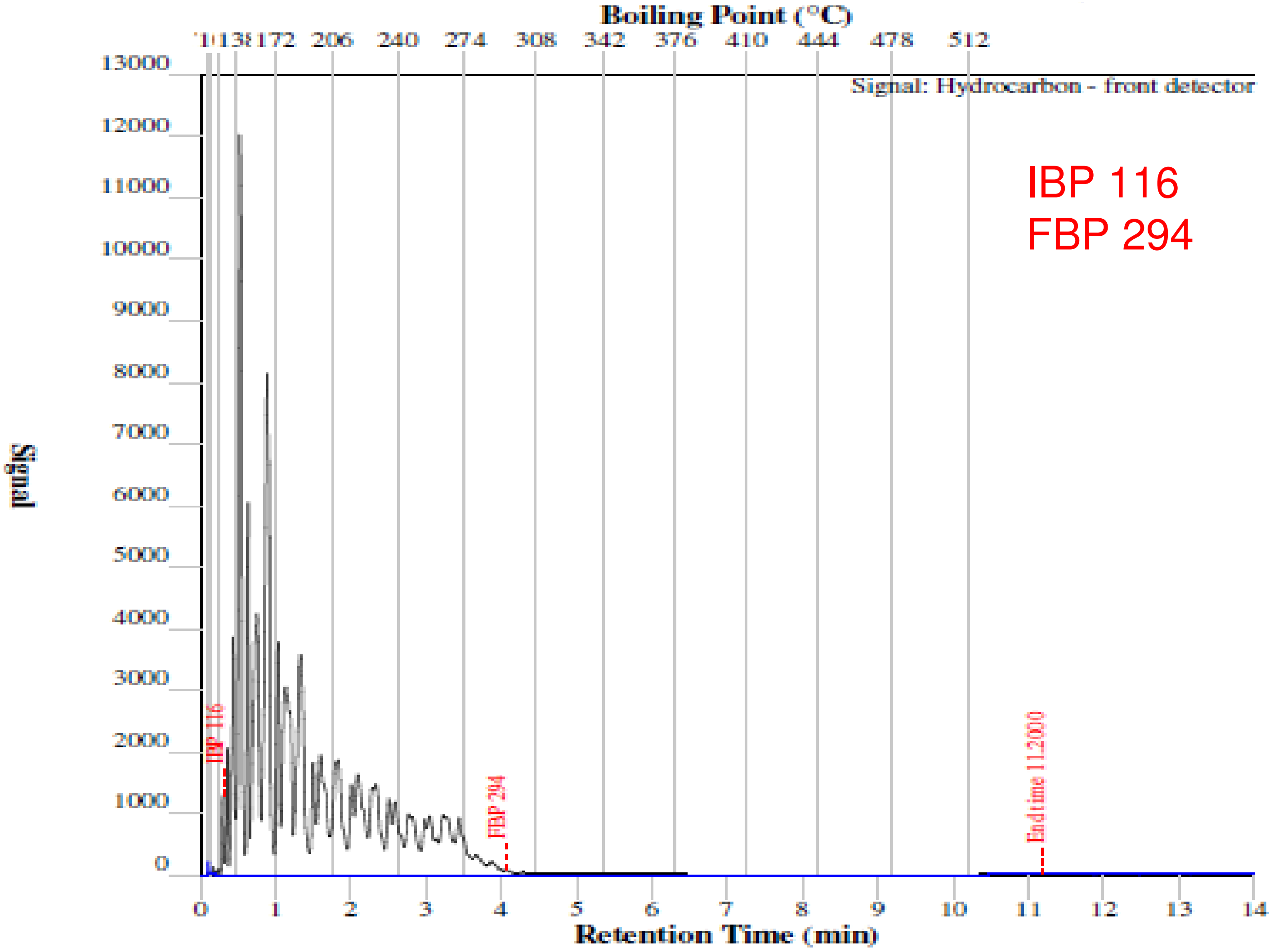
Boiling Range Distribution by GC
HRJ1 (ASTM D2287)



IBP 98
FBP 357

Boiling Range Distribution by GC

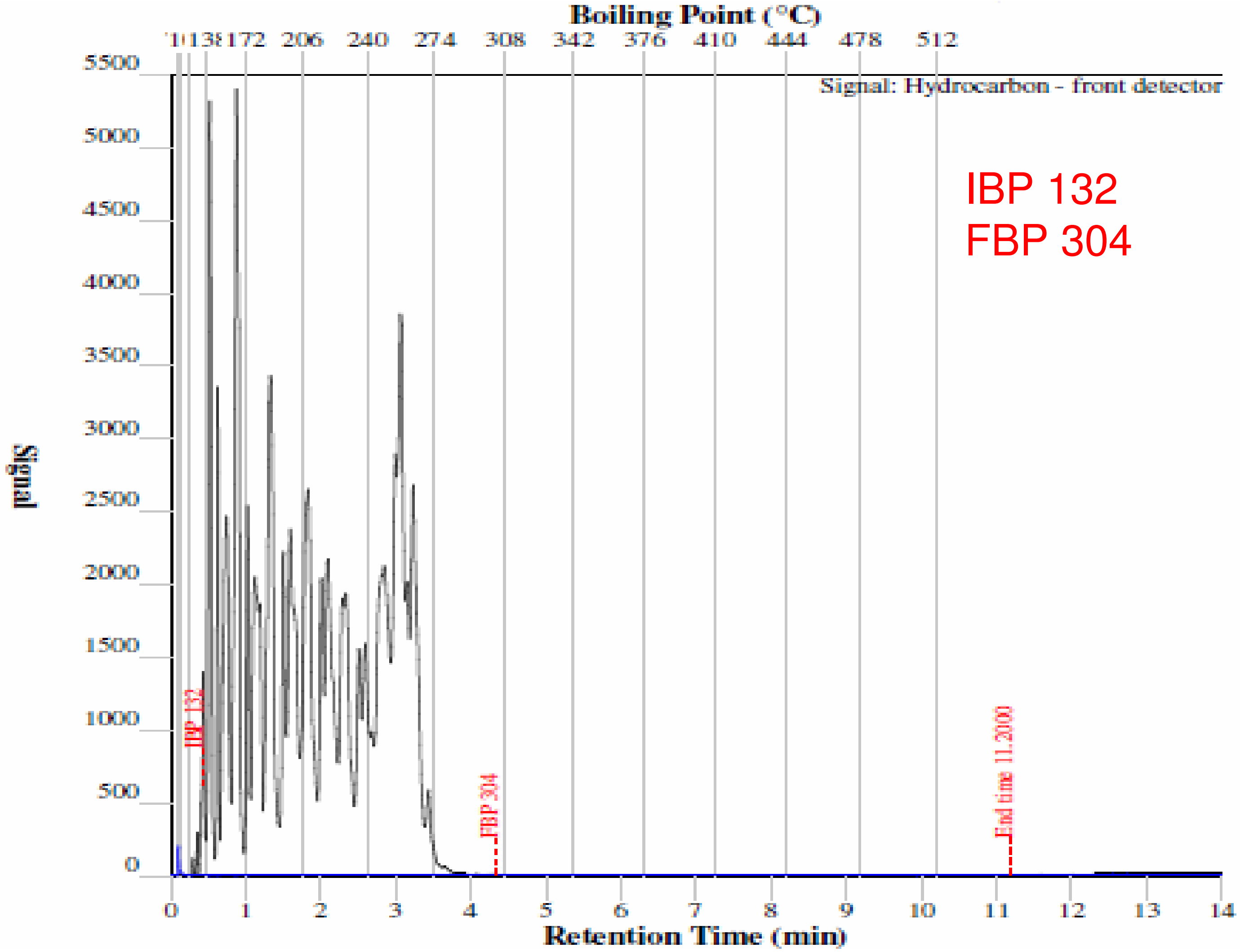
HRJ2 (ASTM D2287)



IBP 116
FBP 294

Boiling Range Distribution by GC

HRJ3 (ASTM D2287)



IBP 132
FBP 304

Conclusions

- The IBP for both of the FT Fuels are approximately equal. However, there is some variability with the IBP for the HRJ Fuels.
- The FBP has much more variability in all of the fuels no matter the feedstock.
- The Sulfur content of the Fischer-Tropsch fuels are higher than the Hydrotreated Renewable Jet fuels on a whole.
- The Nitrogen content of the fuels are comparable no matter the feedstock.
- All of the fuels display very good freeze point characteristics with the FT2 having the lowest freeze point.
- For the boiling point distributions, the FT fuels have a very narrow distribution compared to the HRJ fuels.

Special Thanks

Special thanks to the USAF/AFRL for supplying the synthetic jet fuel samples in this study.