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Mr. Anil Prahbu, Manager, Fuels Evaluation Section
Mr. Sam Wade, Chief, Transportation Fuels Branch
California Air Resources Board
Industrial Strategies Division
P.O. Box 2815
Sacramento, CA 95812

RE: Staff Draft Discussion Paper "Co-Processing of Low Carbon Feedstocks in Petroleum Refineries"

Dear Anil and Sam,

I would like to commend the staff of the California Air Resources Board (ARB) on the conclusions and recommendations presented in their draft discussion paper, *"Co-Processing of Low Carbon Feedstocks in Petroleum Refineries"* dated May 30, 2017. In particular, I found the proposed co-processing yield methodology options as presented to be reasonable and supported by common industry practice. Prior to my current role with Ensyn Corporation, I was employed in the petroleum industry for more than 20 years, most recently as Vice President of Chevron Technology Ventures. In my professional experience, employing a standard mass balance approach based on observed yields is the most appropriate and accurate method of determining renewable gasoline and diesel co-processing yields in a refinery.

As is evident in the public domain, ARB working group presentations, and within common industrial practice, this position is broadly supported by refiners, technology providers and public research institutions. Ensyn Corporation strongly supports the use of a mass balance approach in its co-processing application, which entails co-feeding our biocrude (at up to 10% of the unit's average daily feed rate) with conventional petroleum feed in a refinery's Fluid Catalytic Cracker (FCC).

While Ensyn Corporation supports the conclusions and recommendations of the draft ARB report, for the record, I respectfully suggest clarification of some broad technical statements made in the report (and its Appendix) about biocrude and biocrude co-processing. I believe Ensyn Corporation is uniquely qualified to make these comments on the following basis:

1. Ensyn Corporation, collectively with its predecessor company and affiliates (hereinafter "Ensyn"), is the only producer in the world of fast-pyrolysis liquids on a continuous basis for commercial sale and has been selling fast-pyrolysis liquids to end-users since 1989.
2. With a 25+ year history of commercial operations, Ensyn has learned how to produce stable liquid product, and how to store, transport and utilize it worldwide in an effective manner under industry-approved specifications.

3. As a privately-held company, Ensyn protects the trade secrets around its proprietary technology, and does not publish or disseminate trade secrets that are routinely applied to produce a consistent, stable product that meets the defined specifications of its end use.
4. Ensyn uniquely developed biocrude co-processing, as defined above, and owns broad intellectual property related thereto. Furthermore, it has conducted hundreds of co-processing trials both independently and in collaboration with petroleum companies, and is therefore uniquely qualified to comment on its nature and efficacy.
5. The properties of Ensyn's commercial biocrude have been validated, warranted and published by Honeywell UOP and the efficacy of Ensyn's co-processing technology has been validated and characterized in the public domain by Honeywell UOP, Petrobras, and the U.S. Department of Energy's National Renewable Energy Laboratory.
6. To our knowledge, Ensyn's biocrude co-processing technology is the only commercial application of its kind that is both technically and economically viable at the present time. Ensyn and its partners believe that no other party possesses Ensyn's knowledge and know-how relating to biocrude production, conditioning, handling, storage and injection in FCC co-processing applications.

Based upon Ensyn's extensive technical and commercial experience in the production, transport, and use of fast-pyrolysis liquids, I offer the following comments on four technical conclusions contained in the report and its appendix:

1. Coke:

   The report states:
   "In addition, during co-processing in FCC units, pyrolysis oil may tend to preferentially precipitate as coke onto the catalyst…" (p.3, Section 4)

   "With regard to coke yields, FCC co-processing studies show mixed results. Some studies including Lindfors et al. show an increase in coke production whereas a pilot-scale study by Pinho, et. al., shows lower coke production, especially at higher conversion levels" (p.26, Appendix)

   "This is attributed to lower thermal stability of pyrolysis, resulting in the formation of larger amounts of coke … compared to cracking VGO"

   In response, Ensyn would offer:
   Several public domain biocrude co-processing studies, based on Ensyn's technology and published by Petrobras, NREL, and Honeywell UOP, clearly demonstrate that the co-processing coke yield (typically when less than 5% of

biocrude is added) is either lower or roughly equivalent to coke yields from 100% petroleum FCC feed materials. This position has been presented by NREL, Ensyn and Honeywell UOP at the ARB working group meetings. Petrobras (Pinho et al.) states explicitly that FCC processing equipment "size matters", and this reflects the experience of Ensyn and its refining partners. The wall effects of small laboratory equipment, including MAT and ACE reactors, are proportionately large and have a significant effect on the chemistry, particularly coking reactions. Furthermore, the method of contact of the cracking catalyst with the reacting feedstocks is not fully consistent with transported bed feed-catalyst contact that occurs in a pilot, demonstration, or full-scale FCC unit. Finally, proprietary biocrude conditioning and injection methodologies are very significant contributors to effective biocrude co-processing. Ensyn and its partners possess relatively simple but effective mechanical techniques to condition the biocrude prior to co-processing and render it suitable for optimal performance in FCC co-processing operations. Extensive trials have shown that coke will not preferentially precipitate on the catalyst if proper scale, biocrude conditioning and injection methods are employed.

Ensyn would be pleased to supply the referenced public domain reports to the California ARB upon request.

As a general comment, during any analysis of co-processing, it is important to define the term and the processing parameters. As biocrude proportion increases above 10%, and in some cases above 5%, many of the conclusions in the ARB draft are correct. Hydrogen becomes deficient, the chemistry changes and extreme coking and conversion to non-condensable gases is largely evident. With proper conditioning, handling, biocrude injection and catalyst-feed contact, this is not the case in the 'sweet spot' of biocrude co-processing (i.e., less than 10% and preferably less than 5% biocrude addition). In the view of Ensyn and its petroleum partners, the California ARB has correctly made this distinction at less than 10% addition.

2. Biocrude Stability

The report states:
"The higher oxygen content of pyrolysis oil is responsible for its lower stability …" (p.24, Appendix)

"..and pyrolysis oil have lower thermal and oxidative stability which may pose storage problems …" (p.30, Appendix)

In response, Ensyn would offer:

In Ensyn's experience, the oxygen content is not primarily responsible for any observed stability issues. Instability arises from nucleation sites (where polymerization can occur, and subsequent phase separation) that are present as a consequence of the presence of various solids and high-molecular weight species. This instability is effectively eliminated, for commercial purposes, by proprietary conditioning methods that have been developed by Ensyn over decades of commercial biocrude production. Honeywell UOP (through Envergent Technologies LLC, a Honeywell company) has published a validation of the stability of Ensyn's biocrude.

3. Biocrude Product Yields and Product Characterization

The report states:
"… co-processing of pyrolysis oil in FCC units results in higher amounts of oxygenated and phenolic compounds in the liquid products" (p.24 Appendix)

"Research also demonstrates that it is possible to improve gasoline yields to levels comparable to that of 100% VGO, if raw pyrolysis is upgraded to hydrodeoxygenated oil (HDO) and then co-processed with VGO" (p.26, Appendix)

In response, Ensyn would offer:
As stated above, it is important to define and characterize the parameters of co-processing when making these broad statements.

Within the parameters of Ensyn co-processing (i.e., less than 10% and preferably less than 5%, biocrude conditioning and effective biocrude injection and catalyst contact, at commercial scale), Ensyn and its partners have observed that the biocrude oxygenates end up in the dry gas and as product water, and do not show up as oxygenated and phenolic compounds in the liquid transportation fuel (gasoline and diesel) streams. This has also been disclosed publicly by Petrobras and NREL, including in the ARB co-processing working group meetings.

In addition, without the parameters of commercial Ensyn biocrude co-processing, it is not necessary nor even desirable to hydrodeoxygenate the biocrude prior to FCC co-processing. The results of co-processing trials have been published by NREL, Petrobras, Honeywell UOP, and Ensyn, consistently demonstrating that the yields of transportation fuels (i.e., gasoline and diesel) from biocrude co-processing in an FCC (at biocrude addition typically less than 5%) are either equivalent to, or greater than, the transportation fuel yields from 100% VGO processing in the same FCC unit.

Biocrude hydrodeoxygenation is complex, expensive and technically unproven. It is projected by Ensyn and its partners that the costs associated with HDO would render co-processing uneconomical and that there would be no observable benefit in this specific application.

4. Renewable Carbon in Pyrolysis Oil

The report states:
"Recently, a pilot scale study by Pinho et. al., utilized a tracer technique to quantify the relative proportion of pyrolysis oil originating products in a pilot scale FCC unit. The study found that 30% of renewable carbon…" (pp.24-25, Appendix)

In response, Ensyn would offer:
Please note that the above-referenced study by Pinho (Petrobras) was authored in 2014 and published in 2015. Pinho subsequently co-authored the NREL/PETROBRAS/ENSYN presentation entitled, *"Analysis for co-processing fast pyrolysis oil with VGO in FCC units for second generation fuel production"* that was submitted to the California ARB at the December 13, 2016 co-processing working group meeting. Pinho also co-authored a second NREL/PETROBRAS/ENSYN presentation to the ARB on February 7, 2017, entitled, "*Renewable product allocation methods assessed for FCC co-processing of pyrolysis oil*". As these two presentations state, upon further scrutiny of the C-14 methodology (i.e., after the 2015 publication), Petrobras, NREL and Ensyn summarily rejected the utility of C-14 methods for such quantitative conclusions. As I understand it, broad, independent, technical confirmation of this position was expressed to the California ARB by technology companies, refiners and technical laboratories during the course of the ARB co-processing workshops.

In conclusion, I thank you for the opportunity to provide these comments. Ensyn fully agrees with, and supports, the outcome of the draft ARB report. However, we believe appropriate the inclusion in the final report the results of the whole spectrum of biocrude co-processing data and would sincerely appreciate staff's consideration of our request and the information provided.

Respectfully,