Establishing a techno-economic base case for a second generation bio-refinery: a South African perspective

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DECLARATION

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this thesis.

The author hereby confirms that he has read and understood the Dishonesty and Plagiarism Policies of the North-West University, and applicable to this body of work as submitted, confirming further same to be his own work, safe for where indicated otherwise by adequate referencing.

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Date: 25 November 2022

DEDICATION

I dedicate my dissertation work to my partner, family and steadfast friends. A special feeling of gratitude to my loving parents, whose words of encouragement will always ring in my ears.

"Eat a live frog first thing in the morning

and nothing worse will happen to you the rest of the day"

Mark Twain. American writer, 1855 - 1910

PREFACE

Very few techno-economic assessments on continuous hydrothermal liquefaction processes utilize experimental results from actual continuous processing; most are based on results from batch processes. In the literature, this is more so the case for processing of biomass feedstock, and even more so for waste-biomass feedstock.

To date, no techno-economic analyses have been reported in the literature as relating to hydrothermal liquefaction, continuous or otherwise, of biomass for an Africa-based plant. This includes waste-biomass. Likewise, no techno-economic analyses on the coprocessing of sewage waste with green waste to produce solid and liquid fuels using pilot-scale data has yet been reported in the literature.

This prompted the author to undertake the study to not only gain a deeper understanding of the science and technology, but also to address the knowledge gap in the literature. The study was specifically undertaken at the North-West University (NWU), with the university housing the African continent's first continuous hydrothermal liquefaction processing pilot plant. This allowed for generating requisite data for the investigation. Depending on results, potential policy directives related to both South Africa's waste and energy sectors were expectant.

Considering the author's aptitude: the author obtained his Master of Engineering (Chemical) degree from the NWU in 2002, which followed on his Bachelor of Engineering (Chemical) degree in 1999. Since then, he was involved with various research and development projects, and while employed as Process Engineer with the Council for Industrial and Scientific Research (CSIR, Biosciences Division). He is also a Professional Engineer, registered as such with the Engineering Council of South Africa (ECSA).

Under the premise of the research question, and the presumed aptitude of the author, an investigation was conducted over several years. In consequence, this thesis presents that work, and is submitted as fulfilment of the requirements for the Ph.D. degree at the NWU, South Arica.

The thesis is presented as a monograph, for the Reader's consideration.

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- Colleagues, friends and family

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Thank you.

ABSTRACT

A baseline techno-economic assessment for converting organic municipal waste via a novel continuous hydrothermal liquefaction (cHTL) pilot plant is presented. Feed streams, product yields, and product quality were based on real-time data. Pilot plant data was used to estimate the capital investment and operating costs, cashflow and economic indicators for a commercial-scale cHTL plant. Results showed that a return on investment of 31 %, an internal rate of return of 31 %, and a profitability index of 5.5–6.0 could be realized with a satisfactory nett cashflow over an estimated plant life of 20 years. Sensitivity analyses showed that both plant capacity and capital investment had a significant effect on product unit cost. The potential of using cHTL technology to sterilize and co-treat primary sewage with municipal waste was demonstrated for underpinning a circular economy where waste would be re-directed towards new energy products, while offsetting localized municipal operating costs.

Key terms

Biorefinery, techno-economic, waste, circular economy, liquefaction

OPSOMMING

'n Basislyn tegno-ekonomiese assessering vir die omskakeling van organiese munisipale afval via 'n nuwende deurlopende hidrotermiese vloeibaarmaking (cHTL) loodsaanleg word aangebied. Voerstrome, produkopbrengste en produkkwaliteit is op intydse data gebaseer. Loodsaanlegdata is gebruik om die kapitaalinvestering en bedryfskoste, kontantvloei en ekonomiese aanwysers vir 'n kommersiële skaal cHTL-aanleg te beraam. Resultate het getoon dat 'n opbrengs op belegging van 31 %, 'n interne opbrengskoers van 31 % en 'n winsgewendheidsindeks van 5.5–6.0 gerealiseer kan word met 'n voldoende netto kontantvloei oor 'n geskatte aanleglewe van 20 jaar. Sensitiwiteitsontledings het getoon dat beide aanlegkapasiteit en kapitaalinvestering 'n beduidende uitwerking op produkeenheidskoste het. Die potensiaal van die gebruik van cHTL-tegnologie om primêre riool met munisipale afval te steriliseer en saam te behandel, demonstreer ondersteuning van 'n sirkulêre ekonomie, waar afval na nuwe energieprodukte herlei sal word, terwyl gelokaliseerde munisipale bedryfskoste verreken word.

Sleutelterme

Bioraffinadery, tegno-ekonomies, afval, sirkulêre ekonomie, vervloeiing

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CHAPTER 1 INTRODUCTION

1.1 Background

A rapid global increase in urbanization and industrialization has led to an excessive increase in wastewater and treatment plant effluents associated with serious environmental and health concerns (Peccia and Westerhoff, 2015). The latter, coupled with increasing global energy demand (and accompanying Greenhouse Gas (GHG) emissions), have paved the way for the development of biofuels to supplement sustainable energy security, and curtail global climate change (Cherubini and Ulgiati, 2010). While the production of biofuels has received considerable attention over recent decades, the move towards the development of the broader concept of biorefineries - which produce a diverse array of products from a range of biomass feedstock - is gaining traction.

Although wind and solar energy can be used as renewable alternative energy sources, a carbon source is required to produce liquid fuels and chemicals. A significant amount of bioethanol and biodiesel (as the most prominent biofuels produced by biorefineries) are produced worldwide to partially replace fossil-based petroleum and diesel in the transportation sector. However, biofuels accounted for only approximately 4 % of the worldwide road transport fuel in 2016, with studies showing that global production growth pre-2010 was slowing to a modest 2 % year-on-year (IEA, 2017). This has primarily been attributed to policy uncertainty, technical limitations, direct and indirect land-use change issues, and economic considerations (IEA, 2017). Furthermore, biofuels require economic incentives or policy interventions to make them competitive in the fuel transportation market (Ghatak, 2011). Ghatak (2011) also found that the price of bioenergy, especially biofuels, may see a downward trend with increased market penetration and technological advancement. For these products, the future of economic sustainability lies in the comprehensive utilization of by-products and residues to improve production chain economics, i.e., the biorefinery approach. As a result, advanced biofuel projects have been announced in a growing number of developing countries such as China, India and Thailand (IEA, 2017).

As for South Africa, the government adopted its so-called Biofuels Industrial Strategy in 2007 (NCCAS, 2020). Observers have noted the strategy as largely ineffectual, being focused on promoting the interests of previously disadvantaged farming areas/communities rather than establishing a viable commercial biofuels industry, and thus failing markedly to meet fuel targets (Esterhuizen, 2009).

Studies have also found the South African government subsidy inadequate for establishing the economic feasibility of processes utilizing crop-grown biomass feedstock, in addition to limitations imposed by available croplands (with the hot, dry climate providing limited arable land and feedstock competing with feed/food) and proximity to pre-existing infrastructure. Numerous commercial undertakings saw failed attempts at processing crop-grown ("first-generation") feedstock into biofuels (Amigun et al., 2011). In addition, the country's Department of Environmental Affairs (DEA) reported that the largest contributor to the country's gross GHG emissions is the established energy industry, which is responsible for 80.1 % of total emissions (DEA, 2020). On 24 August 2021, the South African 7th National GHG Inventory Report was published. The report indicated an increase in total emissions of >10 % since 2000, and detailed the bulk of the country's gross emissions composition of carbon dioxide (CO_2, 84.5 %), methane (CH_4, 9.7 %) and nitrous oxide (N_2O, 5.0 %) (DFFE, 2021). The waste sector was found to be a significant contributor of CH_4 emissions (41.0 %), due to a 58.3 % growth in the sector over the assessment period. Total waste sector emissions were reported to have increased by 56.7 %, with solid waste disposal the main contributor (averaging 80.2 % of these emissions) (DFFE, 2021).

According to South Africa's Greenhouse Gas Mitigation Potential Analysis, abatement of up to 4 963 ktCO_2eq from waste would depend on waste-to-energy technologies. The associated cost of these mitigation strategies was projected to be as high as US$ 47.46 per ton CO_2eq by 2020, US$ 59.33 per ton CO_2eq by 2030, and US$ 74.75 per ton CO_2eq by 2050; it would negatively affect job creation and GDP growth if not related to increased revenue (DEA, 2014).

South Africa has 824 large-scale municipal and private wastewater treatment plants (WWTPs) with a combined hydraulic capacity of 6 510 ML/day (Stats SA, 2022). The 2022 Stats SA report showed that 175 of the 257 municipalities in South Africa are dysfunctional, with most having an asset-to-liability ratio of <1. Since 82.5 % of district municipalities' revenue is already from grants and subsidies, further bailout by the country's Treasury Department is unsustainable. Lowering the financial burden of sewage treatment and solid waste management using a viable, commercializable waste-to-energy technology could significantly increase municipal revenue and cashflow.

As a technology for processing biomass, hydrothermal liquefaction (HTL) has the ability to treat liquid feedstock, and is also substantially more tolerant to changes in feedstock composition and contamination compared to biological and bio-chemical processes (Zabed et al., 2017). It negates the need for expensive physical, chemical or biological pre-treatment processes and, in comparison, is much more rapid and efficient (Gollakota et al., 2018).

During HTL, biomass macro-molecule compounds are decomposed into fragments of light molecules in the presence of a suitable catalyst and a hydrogen source (such as water, which also acts as a solvent) under subcritical conditions (Akhtar et al., 2011). HTL results in better quality, more stable bio-oil (biocrude), has a lower (more cost-effective) operating temperature, higher energy efficiency, and lower tar yield compared to other thermo-chemical processes such as pyrolysis (Singh et al., 2016). For a detailed discussion of reaction mechanisms, the reader is referred to Gollokota et al. (2018). HTL characteristics, therefore, make the technology ideally suited for treating wet organic waste such as the wet discharge streams from wastewater treatment plants. Treatment of these streams may contribute toward a cleaner, safer environment without compromising fuel quality and energy content from the energy sector.

More than a decade ago, Bhattacharya and Kumar (2010) already showed that a biorefinery using sewage or animal waste could be sustainable if the technical limitations could be overcome. It is only recently that municipal waste originating from residential and non-residential sources has been considered as ideal organic feedstock. This has primarily been attributed to its wide variation in composition and microbial contamination, as well as technical constraints relating to continuous processing, notwithstanding regional development potential (Zabed et al., 2017; Bora et al., 2020). Mulchandani and Westerhoff (2016) demonstrated the enormous economic and environmental potential for HTL of aqueous municipal and industrial bio-waste to produce fuels and chemicals, to concentrate heavy-metal salts with nutrient recovery, and to eliminate pollutants and pathogens. The study was supported by Skaggs et al. (2018), who conducted a detailed analysis of the potential of waste for biofuel production via HTL on a site-specific basis. Results indicated that wastes had the potential to produce up to 22.3 GL/y of the biocrude oil intermediate. The use of wet (municipal and industrial) bio-waste as feedstock for the development of future biorefinery concepts using HTL technology was also endorsed by Dimitriadis and Bezergianni (2017) and Gollakota et al. (2018). No cultivation and harvesting costs are incurred, no carrier or logistical costs are involved, and treatment of these feedstocks has an added positive environmental impact (with a purified aqueous discharge and resultant upgraded water environment).

Nevertheless, local and global technological solutions for utilizing biomass for fuel and chemicals appear to be more limiting than for other renewables. The limitations are especially evident in terms of upscaling, and locational and regulatory context (IPCC, 2015). The associated risks are difficult to quantify, although research may serve to reduce the knowledge gaps in the state of the art.

Gollakota et al. (2018) identified several possible research areas facing investigators of HTL conversion of wet biomass. This includes setting up a continuous hydrothermal liquefaction (cHTL pilot plant), analyzing the effects of wet biomass feedstock on conversion efficiencies, and assessing the complexities of parameters (e.g., temperature, pressure and the residence times) for cHTL of a given feedstock at piloting scale. When providing an assessment of the potential of hydrothermal technologies - especially HTL - Kumar et al. (2018) stressed the need to perform techno-economic assessments for the purposes of founding viability. This study presents an assessment of a conceptual design, development, and modelling of a theoretical biorefinery processing wet municipal waste streams; this is followed by a cost analysis, which provides indicators for process development, and large-scale technology transfer. This, in turn, demonstrates the potential for continuous liquefaction technology in processing waste biofuel feedstock in South Africa, which could serve as possible policy directives.

With the established viability of processing liquid waste biomass feedstock to supplement South Africa's energy resources, the lifetime of the country's current coal reserves may be extended and its dependency on imported oil reduced. It may further assist in the country achieving its carbon emissions targets as set by the COP 21 Paris agreement (UNFCCC, 2015). The resultant effect may even be more pronounced, given the recent rise in crude oil prices due to supply shocks from the COVID-19 pandemic and the Russian invasion of Ukraine. Technology transfer could additionally benefit other crude oil and foreign-exchange deficient countries.

1.2 Aim

The aim of this study is to establish a techno-economic baseline for a biorefinery localised to South Africa. Said biorefinery concept utilizes liquid waste-biomass as feedstock, which is processed via novel cHTL technology, as developed at the North-West University, South Africa (NWU). This aim is achieved with due consideration of economically viable (combinations of) biomass feedstock (and wastes in particular), and evaluation of applying developed continuous thermo-chemical processing piloting technology within the sphere of South Africa's geographical, environmental, political, and economic conditions (and by extension, the broader frame of current global trends and technologies).

The investigation sets out an analysis of a biorefining case study within the South African context, applying piloting cHTL data generated to model a commercial-scale facility. With waste management and an upgraded water environment as principal drivers, the potential of using cHTL technology to sterilise and co-treat primary sewage with municipal solid waste is demonstrated, underpinning a circular economy where waste would be re-directed towards new energy products, while offsetting localized municipal operating costs.

1.3 Objectives

The aim set out above may be sectioned into more specific objectives, being the following:

- Consider and discuss biomass feedstocks generally, and wet organic wastes specifically. Consider and discuss biomass processing technologies in general, and hydrothermal liquefaction especially, with due consideration and appreciation of accessibility to the novel NWU cHTL piloting facility. Consider and discuss techno-economic studies generally, as well as those attaching to the thermo-chemical processing of wet biomass in particular.

- For the purposes of defining, processing and modelling wet biomass waste streams, sample (municipal) recycled activated sludge, discharged sewage sludge, and green waste streams from wastewater treatment plants, and characterizing all samples via apposite analytical methods.

- Establish a design basis for a theoretical biorefining concept suitable to the South African environment, which concept utilizes hydrothermal liquefaction of wet biomass waste. Consider published works and allow for the incorporation of generated cHTL experimental data to simulate a commercial-scale plant. Perform cHTL of wet municipal waste via the NWU-developed piloting facility, and generate cursory experimental data suitable for modelling an up-scaled plant, as based on compositional/yield results.

- Employ a deterministic steady-state chemical process simulator widely recognized in industry for modelling commercial (bio-)chemical processing plants, maintaining the basis of design, methods, and calculations consistent with published efforts insofar as practically possible and applicable.

- Employ a recognized, established chemical process cost estimator to determine capital investment and operating costs for the biorefining concept, comprising a complete commercial-scale processing plant, generating cashflow and calculating economic indicators, and evaluating economies of scale.

- Assess the developed theoretical commercial-scale biorefinery based on economic results, present an economic analysis, and provide recommendations regarding expectant applied research efforts, and related plant development.

The anticipated outcomes of this study, when regarding the objectives set out above, will assist in providing the NWU's Biofuels Research Chair with a platform for further research and development, especially for the purposes of potential commercialisation.

1.4 Methodology

With the cHTL demonstration piloting facility located at the NWU established, and the need for a techno-economic analysis of a theoretical commercial synthesis plant utilizing the technology on a potential commercial-scale identified, a process design was conceptualised.

The study proceeded with an inclusive literature review, setting out various biomass feedstocks and competing processing technologies, but motivated, in particular, by the need to process wet waste-biomass feedstock, to provide for an ameliorated water environment and produce energy products to offset operating costs. The potential of economic viability of wet waste-biomass feedstock have not yet been proven on commercial-scale – this objective (albeit to establish a baseline of comparison for future endeavours) was deemed achievable given local environmental (water environments and emissions), economic (oil deficient, exchange rate challenged) and political (COP 21 commitment) concerns. The review was narrowed, and economic assessment studies discussed, as pertaining to thermo-chemical processes treating wet biomass (waste) streams.

Collection of (municipal) recycled activated sludge, discharged sewage sludge, and green waste stream samples proceeded at the primary settling stage of the Potchefstroom wastewater treatment facility, South Africa. Collected samples were then characterized using standardised analytical methods. Collected bulk samples were blended, allowing for optimal carbon content, and subjected to hydrothermal liquefaction in the cHTL NWU-piloting plant, generating data suitable for modelling hypothetical commercial plant streams. Discharged product streams were sampled, and similarly characterized for the purposes of modelling. Significantly, data generated for modelling a theoretical continuous processing facility differed from established efforts in the literature, which relied almost exclusively on batch data.

In developing the conceptualized process design, reference studies from literature were consulted, which modelled HTL of wet biomass waste using (a) deterministic steady-state chemical process simulator/s. The various approaches to modelling were considered, adapted, and applied to the present concept. Employing an industry-standard, recognized chemical process simulator, the hypothetical processing plant was modelled, importing experimental data from the sampled feedstock and cHTL product streams. This allowed for a first-level or baseline techno-economic analysis to be carried out, using cost estimation modelling software.

The biorefining concept was modelled, applying empirical and theoretical data and parameters obtained from the literature as well as the NWU cHTL piloting facility, integrating various thermodynamic and kinetic models and/or properties in the design, for producing various (solid, gaseous, and/or (aqueous and organic) liquid) streams. The theoretical synthesis plant comprised several operations. These comprised biomass conversion (hydrothermal liquefaction), separation and product isolation operations. Stream and block results from the design simulations were considered, and the design iteratively reviewed, adapted, and improved, so as to allow for a feasible concept.

Final process cost analyses were performed on the adopted designs, comprising modelling and calculation of various cost indicators based on sized equipment and running costs. Following consideration of simulation results and economic indicators, recommendations were proposed as relating to anticipated avenues of future research and development. The study concluded with a statement of contribution to the state of the art.

1.5 Thesis outline

- Chapter 1: Introduction

  This chapter provides context to the study, its relevance, as well as formulates the study's scope. A brief discussion is provided on the approach followed, together with an outline of how the study was approached and presented.

- Chapter 2: Literature review

  Chapter 2 examines biomass feedstock relating to various generational biorefineries. Biomass processing technologies are briefly discussed, with HTL being highlighted (given accessibility to the cHTL NWU piloting plant, and scope of the study). Wet biomass waste as feedstock for the HTL is stressed, and techno-economic studies pertaining to HTL of (wet) biomass waste streams detailed.

- Chapter 3: Materials and methods

  Chapter 3 details experimental sampling and characterization of wet municipal waste streams. The discussion is followed by the approach to the conceptual design of a theoretical biorefinery. Process simulation development and calculation methods are described, including modelling software, thermodynamic properties/models, and model compounds.

This is followed by a discussion of the approach to techno-economic analysis, describing cost analysis, and related calculations. Assumptions and parameters are detailed throughout.

- Chapter 4: Results and Discussion

  This chapter is divided into three segments, comprising a detailed account of experimental results (incl. feedstock characterization and analytical results), simulation results (incl. stream and process modelling results), and techno-economic results (incl. cost analysis and indicators), drawing comparisons and highlighting dissimilarities with the literature, as suitable.

- Chapter 5: Conclusions and Recommendations

  The study concludes with this final chapter. Based on considered results, a conclusion statement is provided as pertaining to the process' design, performance, scalability, and feasibility. This is followed by recommendations on future research and development, as especially relevant to commercialization, and potential national energy policy implications. An account of the investigation's contribution to the state of the art is also provided.

1.6 Concluding remarks on novelty

Novelty was briefly broached in the Preface to this thesis. In emphasis, to date no techno-economic analyses have been reported in the literature as relating to HTL or cHTL of biomass for an Africa-based plant. This includes waste-biomass. No such assessments on the coprocessing of sewage waste with green waste to produce solid and liquid fuels, and using pilot-scale data, have been reported in the literature at all, either.

As a result of the myriad assumptions involved in process design and simulation - and contingencies built into these designs providing for related uncertainties – no two simulation studies reported in the literature are alike. The issue is exacerbated by applying techno-economic assessments to these process designs; they rely on an altogether supplementary set of (deviating) assumptions related to socio-economic issues and governmental policies, which must eventually be evaluated against the local geo-political backdrop. It is for this reason that such investigations assume the character of case studies and make comparisons tenuous. This notwithstanding, these studies do provide insight into future areas of research and development.

In the present study, experimental results from a cHTL pilot plant were utilized. Almost all techno-economic analyses found in the literature makes use of batch data sourced from literature to model continuous processes. Even less studies attempt to generate batch data to use in process simulation, and then attempt a techno-economic analyses. This investigation generated data from the continuous piloting plant, utilized said data in process simulation of a commercial-scale plant, and applied a techno-economic assessment as it related to South Africa (an oil- and exchange rate deficient country), and its socio-economic limitations.

Building on foregoing research and development of HTL technology at the NWU, this work was undertaken to assess the potential economic viability of a commercialized process plant, supporting the UN Sustainable Development Goals for clean water, affordable energy, and sustainable cities.

CHAPTER 2 LITERATURE REVIEW

2.1 Preamble

This chapter details a review of the literature relevant to the conceptual design of a (second-generation) biorefinery, especially as pertaining to the viability of a commercial-scale facility supposedly operating in South Africa. The discussion centres around issues of novelty raised in Chapter 1 above; therefore, the literature review presented herein, as it relates to said topics, is by no means intended to be exhaustive. Given the accessibility of the NWU cHTL piloting plant for generating experimental data useful to simulation and having identified WWTP discharge streams from dysfunctional municipalities as potential feedstock, Chapter 2 concentrates the review on waste-biomass as potential biorefinery feedstock, and hydrothermal conversion (and cHTL in particular) of feedstock to streams of economic value and environmental benefit. Germane techno-economic assessments on design studies featuring some of the design choices are also included. The purpose of this chapter is to establish support for a design basis presented in Chapter 3.

The foregoing chapter alluded to the need for alternative (non-fossil-based) fuels, and the push towards biorefining (with the associated processing of renewable biomass), as incumbent technology/ies to produce (bio-)fuels, (bio-)energy and chemicals. Apart from fossils, biomass is the only other carbon-rich material suitable for producing said commodities. To date, an overwhelming emphasis has been placed on the development of these (hypothetical) biorefineries for the purposes of producing bulk fuel, whether in gaseous (e.g., biogas), solid (hydrochar), or liquid (bio- or renewable diesel, bioethanol, bio-methanol, etc.) form. Developing strategies for a diverse product portfolio and/or pursuit of a range of low-volume high-value co-/by-products has been largely peripheral. So, too, is the case with energy generated by these processes, which has seen process integration mainly for lowering plant operational costs. To the extent that some biorefinery concepts have met with commercial success, large-scale adoption has been hamstrung for sustainability reasons. Other concepts have been constrained by technical and/or economic challenges, limiting technology implementation and/or transfer to bench- or piloting scale. An abridged discussion follows herein. When considering biorefining as industrial process, a significant socio-environmental issue often relegated is the rapid growth rate of urbanization and related water quality degradation, as mentioned above. The treatment of industrial and municipal waste streams, together with nutrient content of wastewater due to eutrophication, have become significant concerns to the water environment, and public health - these concerns may likewise be addressed through biorefining processes (Gollakota et al., 2018), acting as drivers of the (design) choices of this study, which guides this review.

2.2 Biomass feedstock

Biofuels are broadly classified as primary biofuels (used in an unprocessed form) and secondary biofuels (produced by processing of biomass). Primary biofuels are utilized by way of combustion, principally for heating, cooking or electricity production (e.g. wood chips, pellets, etc.). Secondary biofuels may be applied as transport fuels or in industrial processes. Biorefineries, which produce secondary biofuels, may be classified based on their system components, namely feedstock (e.g. dedicated crops, residues, wastes), platforms (referring to intermediates connecting the biorefinery systems and their processes, e.g. syngas, C_5/C_6 sugars or biogas), conversion processes (e.g. mechanical, chemical, bio-chemical, or thermo-chemical), and products (energy products (e.g. bioethanol or biodiesel) or material products (e.g. chemicals)) (Ghatak, 2011). Generally, from literature, biorefineries (and resultant secondary biofuels) are characterized by biomass feedstock type processed (Singh et al., 2016). Depending on the nature of the biomass, three types of biorefinery are distinguishable, namely first-generation, second-generation and third-generation. First-generation biorefineries produce fuel and other products from edible biomass crops generated by the agricultural sector. Second-generation biorefineries converts non-edible biomass such as lignocellulosic biomass (e.g., agricultural and forestry residues and wastes), oils and fats (e.g., waste cooking oils and fats from slaughterhouses), and animal and municipal wastes. Third-generation biorefineries process algal matter (e.g. micro- and macro-algae) and cyanobacteria (“blue-green algae”). **Table 2-1** provides a summary of generational biofuels, detailing some distinguishing features, advantages and disadvantages. It is important to note that all the above-mentioned generational biorefineries and associated biofuels are and remain under development, founding numerous avenues of present research and development.

Challenges remain, pertaining to feedstock type (collection network, storage, food vs. fuel), technology (pre-treatment, enzyme production, efficiencies, cost, development of value-added co-products), and policy (land use, piloting demonstration, commercial-scale deployment, procurement of subsidies and tax rebates) (Dimitriadis and Bezergianni, 2017).

When selecting a biomass feedstock to be converted in a biorefinery, no universal rule applies – various factors may impact on and determine such a choice. Huang et al. (2009) showed biorefinery plant size and associated biofuel production costs to be dependent on the feedstock delivered price, as well as feedstock availability – production costs were shown to decrease with increased feedstock availability. Generally, for establishing a design basis of a hypothetical biorefining process, biomass feedstock cost, availability and sustainability are paramount motivators for design choices. Amelioration of localised water environments have, for the purposes of this investigation, been included as paramount promoter.

Table 2-1: Biofuel generations based on biomass feedstock type (adapted from Nigam and Singh, 2011)

	1ST Generation	2ND Generation	3RD Generation
Feedstock Type	Dedicated Crops	Residues/Wastes	Algal matter
Sourced	Edible biomass from agriculture/forestry sectors	Non-edible biomass from agriculture/ forestry/industrial/ municipal sectors	Non-edible aquatic biomass from agriculture/forestry sectors
Cultivation	Yes	No	Yes
Examples	Oil Crops (e.g., soybean, sunflower, rape, palm, Jatropha); Sugar Crops (e.g., sugarcane, beet); Starch Crops (e.g., corn, potato, wheat, Cassava, sorghum); Woody Plantations (e.g., hardwoods, softwoods); Grasses & Herbs (e.g., Switchgrass, Alfalfa)	Lignocellulosic (e.g., black liquor, paper mill waste sludge, timber house waste, sawmill waste, wheat straw, bagasse); Oils & Fats (Slaughterhouse fats, cooking oil waste); Vegetable/Fruit Processing Waste; Pith; Poultry Litter; Animal Waste; Molasses; Municipal Waste	*Dunaliella tertiolecta; Spirulina platensis; Entermorpha prolifera; Chlorella pyrenoidosa; Ulva fasciata; Botryococcus braunii; Microcystis viridis; Chlorella vulgaris; Nannochloropsis oculate; Porphyridium cruentum; Laminaria Saccharina; Desmodesmus sp.*
Competes for Arable Land	Yes	No	No
Availability	Limited, dependent on farming priorities (pricing), and policy (incentives)	Abundant	Dependent on cultivation using natural or artificial waterbodies
Technology	Maturing/ Commercialized	Emerging	Emerging
Supply Cost to Total Plant Operating Cost	Substantial	Marginal to Significant	Substantial
Products	Bioethanol/butanol by fermentation of starch or sugars; Biodiesel by transesterification of oils	Bioethanol/butanol by enzymatic hydrolysis; Methanol/Fischer-Tropsch fuel/Mixed alcohol/Dimethyl Ether/Bio-oil/Renewable Diesel by thermo-chemical processes; Biomethane by anaerobic digestion	Hydrogen from green algae and microbes; Biodiesel from algae; Bioethanol from algae and sea weeds

Considering feedstock cost, contributions by Nilsson (2009), Thorsell et al. (2004) and Stephen et al. (2010) showed increased economic viability with decreased feedstock delivery costs (associated with localised processing facilities). Caputo et al. (2005) established that the cost of feedstock supply contributes 40-60 % of total operating costs of a typical biorefinery. Feedstock supply costs refer not only to transportation and logistical costs for carriage of the feedstock from its source to the processing facility, but also the costs involved with cultivating and harvesting these feedstocks. The former, accounting for as much as 90 % of the delivered feedstock cost, may play a significant role in the overall profitability of a biorefinery. Feedstock cost uncertainties have typically been addressed using sensitivity analysis in literature through numerous biofuel techno-economic studies. Results from various studies show that feedstock costs have had the most substantial effect on the cost-competitiveness of biofuels (Gnansounou and Dauriat, 2010; Sarkar et al., 2011; He and Zhang, 2011; Zhang et al., 2013). Mustapha et al. (2017) reported that, apart from sustainable feedstock supplies, production costs of biorefineries are hugely dependent on feedstock supply costs, followed to a much lesser extent by capital costs. The authors showed that integrated technologies, which utilize existing infrastructure, may prove essential to cost reduction. The authors concluded that future biorefining concepts may only become economically viable with co-generation of a comprehensive co-/by-product distribution, establishing that the availability of accurate techno-economic data to be a limiting factor for obtaining certainty as regarding the entire value chain.

Impacting factors affecting feedstock availability are climatic and weather conditions, location relative to the processing facility/ies, and socioeconomic issues and governmental policies. These factors must be evaluated against the local geo-political backdrop, which will differ considerably from one country to the next. Stephen et al. (2010) found that biorefineries require a dependable supply of feedstock over its entire lifespan, which can be 10–30 years or even longer, in order to be a viable alternative to petroleum refineries. Biomass feedstock cost and availability are significant contributors to the long-term economic feasibility of the biorefining process.

The above notwithstanding, sustainability remains the primary driver for adopting the use of biomass feedstocks to produce fuels, chemicals and energy; (the choice of) biomass feedstock must therefore be sustainable. The so-called fuel vs. food debate (i.e., the use of dedicated cropland for fuel production, limiting food availability) has attracted condemnation of first-generation biomass feedstocks, while elevating the use of second- and third-generation feedstocks (Ghatak, 2011).

Presently, first-generation feedstocks are being utilized to produce bioethanol and biodiesel commercially. Bioethanol is produced from agricultural crops such as sugarcane and corn, while commercial biodiesel is produced from sunflower, palm, coconut, rapeseed, and soybean (depending on the climate conditions of the producers' locations (Mohammad et al., 2013)). The use of these feedstocks has attracted considerable criticism, most notably the negative environmental impact, including inter alia, soil erosion, loss of biodiversity, high volatile organic compound, emissions, and NO_x pollution, as well as the energy balance disadvantage (Solomon et al., 2007).

In 2008, it was already reported that increased biofuel production cannot be sustained by employing first-generation feedstocks (Licht, 2008). First-generation feedstocks must be cultivated on arable land, directly competing with cropland required for food/feed production, with global demand for the latter on the rapid increase (Cheng and Timilsina, 2011). Lange (2011) confirmed that the conversion of natural land into biofuel feedstock croplands leads to much higher GHG emissions (compared to even fossil fuels) when accounting for carbon emissions associated with land use transformation. Resultant governmental penalties promote feedstock production on (former) croplands, which again contributes to the cited food/fuel-competition predicament (and allied rise in prices). Lange (2011) identified the use of degraded grassland as the only possible exception for the sustainable conversion of natural land into biofuel feedstock croplands but questioned the profitability of any such biofuel production process; such a scenario would be heavily dependent on governmental subsidy and/or other incentives encouraging use of such grasslands.

With the use of first-generation biomass feedstocks ostensibly unsustainable, research efforts have intensified into producing so-called advanced biofuels, or biofuels produced from second-generation and third-generation feedstocks. As of 2010, advanced biofuels made up a mere 0.2 % of total biofuel production, because of significant techno-economic barriers. For this reason, the past decade has seen several studies in the fields of pyrolysis and HTL, gasification and biomass to liquid technologies (Nigam and Singh, 2011).

To date, typical research efforts on the production of advanced biofuels have concentrated on lignocellulosic materials such as agricultural and forestry/wood residues, grasses and wastes. Although these materials are in abundance worldwide, are easily degradable, and do not compete with arable crop plants for space, light and nutrients, no commercially viable option(s) have been proven beyond piloting-scale (Zabed et al., 2017; Gollakota et al., 2018).

Lignocellulosic feedstocks are comprised of variable cellulose, hemicellulose and lignin fractions; these fractions exhibit low accessibility of cellulose and hemicelluloses as a result of complex tight structures, making separation of the lignin-component from the (hemi)celluloses complicated and expensive. For this reason, commercialization has been challenging. Inflated capital investment and excessive operating costs involved in carriage/delivery as well as the (physical, chemical and/or biological) pre-treatment and processing of various lignocellulosic feedstocks, have all but curbed large-scale implementation for the purposes of biorefining (Cheng and Timilsina, 2011).

Another second-generation biomass feedstock under scrutiny for producing of fuels and/or chemicals is (recycled) animal/food waste oils and fats. Biodiesels from both used and unused oils/fats have similar properties, as both are composed of methyl esters of fatty acids. In most cases, pre-treatment (removal by filtration of solid particles, esterification process to reduce the content of free fatty acids) of used oil is suitable for subsequent transesterification (organic reactions where an ester is transformed into another form through the interchange of the alkoxy moiety). Reactions are catalysed, using base catalysis, acid catalysis, 2-step heterogeneous catalysis, enzymatic catalysis, or supercritical methanol, to mention some process alternatives. Complications limiting commercialization include high level of impurity content and/or water content in the feedstock, long reaction times, glycerol and/or methanol (as produced by-product(s)) oversupply, and product degradation. Processes also require costly separation and purification steps to meet various standards for industrial use. Marchetti et al. (2008) performed a techno-economic study for different process alternatives for biodiesel production from spent oils, reporting that 76-80 % of the operating costs were associated with feedstock cost. Apostolakou et al. (2009) provided a techno-economic cost analysis for producing biodiesel from vegetable oils, indicating that feedstock costs accounted for 75-90 % of total production costs, depending on plant capacity. Cost of the process, process adaptability, as well as feedstock renewability and sustainability are established as determinative for industrial applicability (Marx, 2016). Although well-established, there remains considerable inefficiencies in existing trans-esterification processes.

Municipal (solid) wastes originating from residential and non-residential sources have rarely been considered, until recently, as ideal (second-generation) biofuel feedstocks; as mentioned, this has chiefly been attributed to its wide diversification in composition, and microbial contamination, notwithstanding regional development potential (Zabed et al., 2017). Technical limitations in processing municipal waste materials have been the most arduous obstacle to commercialization.

As mentioned, Bhattacharya and Kumar (2010) showed that a biorefinery using human/animal waste would be sustainable only if it were insensitive to variations in feedstock composition; the authors indicated that feedstock supply uncertainty could also be reduced, if not eliminated. Because of the varying composition in municipal wastes, contamination, and associated costly (batch) pre-treatment and drying processing steps, the large-scale conversion of organic human/animal wastes using existing commercialized technologies has not been possible. Aqueous bio-waste, however, has a significant advantage over first-generation biomass feedstocks, as well as other second-generation feedstocks mentioned above (including solid wastes): processing of the wet feedstock without the need of costly physical, chemical and/or biological pre-treatment processes – this is possible through HTL (a rigorous description of HTL conversion technology is provided below, and its ability for processing wet biomass feedstocks highlighted). Aqueous bio-waste shares this attribute with third-generation feedstocks (i.e., macro-, and micro-algae). Among several possibilities of processing wet biomass, microalgae have been held as an excellent source of biofuel due to high photosynthetic efficiency, maximum biomass production, fast growth rate (compared to lignocellulosic feedstocks) and lack of arable soil requirements (Tian et al., 2014).

However, considerable obstacles remain with regards to commercialization of third-generation feedstocks, as detailed by Tian et al. (2014). These include feedstock preparation (contamination; cost of cultivation and/or harvesting; denitrogenation), scale-up (lack of understanding algal feedstock characteristics; development of specialized cHTL reactors operated with higher temperatures and pressures; nutrient recycling; lipid dependency; low production rates), and process integration (unsustainable demand of water, energy and fertilizer; development of value-added chemical by-product(s); high heat demand; product separation costs). These obstacles have led to serious concerns as to whether third-generation feedstocks are at all viable, prompting speculation for the need of so-called fourth-generation biomass feedstocks using genetically modified organisms (Singh et al., 2016).

As opposed to third-generation (and fourth-generation) biomass feedstocks, aqueous (municipal or industrial) waste does not incur costly cultivation and harvesting costs; it also negates the need of carrier and/or logistical costs in an architype scenario where waste is processed on-site. Additionally, treatment of industrial and/or municipal bio-waste would have an added positive environmental impact, with HTL treatment of waste streams resulting in amelioration of aqueous discharge and a resultant upgraded water environment. Recent developments in hydrothermal processing technologies/pathways may serve to circumvent prevailing obstacles of wet biomass feedstock processing, considering the potential of processing continuous wet waste streams (Gollakota et al., 2018).

Wet biomass feedstocks comprise lipids/fats and proteins/amino acids. Lipids/fats are predominantly non-polar compounds otherwise immiscible/hydrophobic in nature. These compounds share similarities with aliphatic compounds, especially triglycerides (TAGs) (tri-esters of fatty acids and glycerol) (Bühler et al., 2002). The fats are generally insoluble in solvents at normal temperatures and gradually tend towards polarity with temperature change. This is also observed for cellulose. Greater miscibility is obtained with the dielectric constant of the solvent, especially for water at sub-critical conditions (Peterson et al., 2008). Greater miscibility results in greater TAG structure stability, in turn resulting in the formation of glycerol. Glycerol, which is a combination of fatty acids, methanol, and salts, is a major by-product of biodiesel production. During HTL, glycerol is converted to a water-soluble compound (Lehr et al., 2007). Further degradation of glycerol results in a combination of acetaldehydes, propionaldehyde, acrolein, allyl alcohol, ethanol, formaldehyde, CO, CO_2, and H_2 (Bühler et al., 2002).

One of the major constituents of aqueous bio-waste and microbial or algal biomass is protein, which comprises several chains of peptides, in turn reducing to polymers of amino acids. Amino acids are highly heterogeneous (and degradation oftentimes difficult). During HTL, strong peptide chains of proteins undergo decarboxylation and deamination reactions, resulting in the formation of hydrocarbons, amines, aldehydes and acids. Consequent degradation leads to carboxylic acids, acetic acid, propionic acid, n-butyric acid, and iso-butyric acids (Sohail et al., 2011).

The abovementioned constituents make up various gaseous, liquid, and solid fuel/chemical products from HTL of wet biomass feedstock. As mentioned, a robust description of HTL conversion technology is provided below. Apart from lipids/fats and proteins/amino acids, municipal and/or industrial waste streams also contain heavy-metals (such as Chromium, Zinc, Copper, Silver, Cadmium), nutrients (such as Phosphorous, Nitrogen, Potassium), and organic pollutants and pathogens. As mentioned above, Mulchandani and Westerhoff (2016) demonstrated the huge economic and environmental potential for HTL of aqueous municipal/industrial bio-waste through the concentration of heavy-metal salts with nutrient recovery, and the simultaneous elimination of pollutants and pathogens (in addition to producing fuels/chemicals). Also discussed, was the findings of Skaggs et al. (2018), who affirmed the potential of diverting organic wastes, including wastewater sludge, livestock waste, and food waste, for beneficial energy use through HTL, while reducing the quantities of waste that are disposed or released to the environment. The authors conducted a detailed analysis of the wastes' potential for biofuel production on a site-specific basis using HTL, with results indicating that wastes have the potential to produce up to 22.3 GL/y of a biocrude oil intermediate.

Although very literature is available, the use of wet (municipal and/or industrial) bio-waste as feedstock for development of future biorefinery concepts (using HTL capable of converting wet biomass) was also concluded by Gollakota et al. (2018) as well as Dimitriadis and Bezergianni (2017), as discussed, and upon respective reviews of the state of the art of biorefining technologies and concepts.

2.3 Biorefining processing pathways

For the purposes of establishing a design basis for a novel biorefinery, and after settling upon a suitable biomass feedstock to be converted, a complimentary processing technology must be established. Advanced solid, liquid and/or gaseous biofuels are mainly produced by means of 2 routes, namely bio-chemical and thermo-chemical – herein follows a condensed review.

The bio-chemical conversion of biomass feedstocks involves four steps: (1) pre-treatment (physical, chemical, or biological (Lamsal et al., 2010; Szczodrak and Fiedurek, 1996; Cheng and Timilsina, 2011; Sarkar et al., 2012; Kamzon et al., 2016)); (2) hydrolysis (acid or enzymatic (Chandel et al., 2007; Duff and Murray, 1996; Lee, 1997; Lavarack et al., 2002; Lee et al., 1999; Saha, 2003; Zhang et al., 2007; Reczey et al., 1996; Wyman, 1999; Balat, 2007; Gírio et al., 2010; Balat, 2011)); (3) fermentation (Sprenger, 1996; Thomas et al., 1996; Boulton et al., 1999; Olsson and Hahn-Hägerdal, 1996; Sonderegger et al., 2004; Kuyper et al., 2005; Gnansounou and Dauriat, 2005; Lin and Tanaka, 2006; Snoek et al., 2016; Cazetta et al., 2007; Bai et al., 2008); and (4) product isolation.

Commercialized bio-chemical processing of biomass for producing advanced biofuels continue to face intractable challenges – pre-treatment of feedstocks is complicated and expensive, while concerns of acid recovery/neutralization, sugar degradation, production of reaction inhibitors and equipment corrosion plague acid hydrolysis. Similarly, with enzymatic hydrolyses, considerations of slower, selective enzymatic reactions that convert hemicellulose into pentoses (xylose and arabionose) and hexoses (glucose, galactose, and mannose) complicate the process and increase costs attached to scale-up, as these sugars cannot be fermented by natural micro-organisms (Lee et al., 1999; Saha, 2003; Zhang et al., 2007).

Scaled-up fermentation processes require an additional step for converting (hemi)cellulose to fermentable sugars, necessitating large quantities of enzymes (and increased production costs/reaction times). Natural micro-organisms producing these enzymes provide for low yields and poor enzyme quality, making them economically unattractive. Obstacles such as fuel-product tolerance limit and osmotic stress of yeast cells, fermentation broth acidity, as well as bacterial contamination must be overcome for improved fermentation efficiency (Gírio et al., 2010).

Despite various advancements centred around enhancing biofuel yield per unit of biomass, decreased production costs and process time, and minimized process steps, commercial production of advanced biofuels remains infeasible (Laopaiboon et al., 2009; Lim et al., 2013; Liang et al., 2008; Nikolić et al., 2009; Zhao and Xia, 2010; Tomás-Pejó et al., 2009; Srichuwong et al., 2009; Li et al., 2013; Nikolić et al., 2010; Erdei et al., 2013; Masiero et al., 2014; Chen et al., 2016). Sensitivity to biomass feedstock composition, contamination, and the requirement of costly, high energy consuming pre-treatment processes remain. Prospective economically viable industrial applications will be hugely dependent on advancements in genetic engineering, and the development of less expensive, stress-tolerant, and selective micro-organisms (Cheng and Timilsina, 2011).

Efforts for cost-efficient recombinant micro-organisms expressing pentose and hexose utilization pathways over expression of existent pathways, increased biofuel generating pathways, deletion of by–product producing pathways and expression of detoxifying enzymes are under development (Horisawa et al., 2015).

Thermo-chemical processes are up to a hundred times more efficient than anaerobic digestion with regards to loading rate (Zhang et al., 2010). Additionally, thermo-chemical processing technologies are less sensitive to feedstock composition and/or contamination and are not feedstock specific; micro-organisms used in bio-chemical processes are feed specific, with the slightest change potentially leading to its non-functionality – this provides for a substantial risk in the commercialisation of the process, especially treatment of wet municipal/industrial waste streams (Singh et al., 2016).

However, a major disadvantage of thermo-chemical conversion of biomass is the high cost, attributed to high temperature and pressure requirements of processing. Depending on feedstock and operating conditions, intermediaries and products may also be subject to degradation. These operating conditions also pose health risks (explosion and noise pollution) (Okolie et al., 2022).

Additionally, where bio-oil/biocrude oil is a targeted product, thermo-chemical conversion processes require upgrading, which in turn further increases processing costs (Lü et al., 2018).

Compared to bio-chemical processing, thermo-chemical processes proceed at several higher degrees in temperature (oftentimes in the presence of catalysts) to obtain products from different (biomass) sources. Generally, thermo-chemical conversions are also much more rapid than bio-chemical processes, upgrading biomass by heating under a pressurized environment in the absence of oxygen. Thermo-chemical processes are classified into gasification, carbonization, pyrolysis, and direct liquefaction (Peterson et al., 2008).

Gasification is a process that involves a reaction temperature above 350 °C in the absence of oxidants. Depending on reaction conditions, a flue gas rich in either H_2 or CH_4 is produced. The three types of thermo-chemical gasification comprise aqueous phase refining, catalytic gasification in a near-critical state, and supercritical water gasification. Products from gasification include CO_2, H_2, CO, and CH_4, with small amounts of C_2H_4 and C_2H_6 (organic liquid), and (almost) no biochar/tar, again depending on reaction conditions (Ortiz et al., 2012; Cherad et al., 2016; Güngören Madenoğlu et al., 2016).

Carbonization converts biomass into a value-added solid fuel termed biochar (similar to lignite) at a comparatively low temperature (180–250 °C) and saturated pressure (2–10 MPa). The process also yields minimal amounts of liquid product, including an aqueous phase containing most of the dissolved organics, as well as an almost negligible amount of gas (Dinjus et al., 2011; Berge et al., 2011; Ramke et al., 2012 cited by Kumar et al., 2018).

As opposed to gasification (which produces a mostly gaseous product) and carbonization (which produces a mostly solid product), pyrolysis and liquefaction produces (a) mostly liquid product(s). Mustapha et al. (2017) reported higher economic performance for fast pyrolysis and hydrothermal liquefaction (thermo-chemical pathways) when producing advanced biofuels, compared to hydrolysis and fermentation, mixed alcohol synthesis, and Fischer-Tropsch synthesis, respectively. Direct liquefaction or HTL is synonymous with hydrous pyrolysis. Referring to biomass heating rates, fast, slow, and flash pyrolysis are distinguished, producing (mostly) liquid product, together with gases and solid products, depending on operating conditions. Pyrolysis reaction temperatures range between 350-700 °C. Compared to HTL, oil obtained from pyrolysis has a relatively low heating value because of the high oxygen and water content, which require expensive upgrading. Pyrolysis oils, compared to HTL, are also found to be less stable, and less miscible in conventional fuels (Savage, 2009).

Pyrolysis of wet biomass feedstocks is not possible without costly drying pre-treatment. For this reason, as well as a better quality, more stable bio-oil (crude) containing various chemicals (including vanillin, phenols, aldehydes, and organic acids, and others), Singh et al. (2016) determined HTL as being superior to pyrolysis; as mentioned above, the authors showed that, compared to pyrolysis, HTL has a lower (more cost effective) operating temperature, higher energy efficiency, and lower tar yield.

Table 2-2 provides a comparison of HTL and pyrolysis, for biomass conversion.

Table 2-2: Comparison of hydrothermal liquefaction and pyrolysis for biomass treatment

	Pyrolysis	HTL
Drying	*Necessary*	*Unnecessary*
Pressure (MPa)	*0.1–0.5*	*5–20*
Temperature (°C)	*350-700*	*200–400*
Catalyst	*No*	*Sometimes*
Heating Value (MJ/kg)	*Low (~17)*	*High (~30)*
Oxygen Content	*High*	*Low*
Water Content	*High*	*Low*
Viscosity	*Low*	*High*
Upgrade	*Complicated*	*Simple*
Author	Dimitriadis and Bezergianni (2017); Demirbas (2000)	Xu and Lancaster (2008); Zhang et al. (2008); Dimitriadis and Bezergianni (2017)

2.4 High temperature ("Hydrothermal") liquefaction

With HTL, biomass macro-molecule compounds are decomposed into fragments of light molecules in the presence of a suitable catalyst, as well as water as solvent, at a medium-temperature, and high-pressure (Akhtar et al., 2011; Toor et al., 2011). These fragments, which are unstable and reactive, re-polymerize into oily compounds having appropriate molecular weights (Molten et. al., 1983). The process involves complex sequences of reactions, including solvolysis, dehydration, decarboxylation, hydrogenation of functional groups, etc. (Chornet and Overend, 1985). As indicated, HTL is ideally suited to biomass from aquatic origins, in contrast to pyrolysis. Temperatures of 250-350 °C and pressures of 5-20 MPa are generally required for HTL, while pyrolysis necessitates temperatures of 370-530 °C, with pressures of 0.1-0.5 MPa (Demirbas, 2000; López Barreiro et al., 2013). The reaction mechanisms of HTL and pyrolysis are different, as reported by some investigators (Minowa et al., 1995; Demirbas, 2009). HTL has potential to create lower-oxygen oil, as compared to fast pyrolysis and other thermo-chemical methods. During the HTL process, the oxygen content of the organic material is reduced from about 40 % to between 10-15 % (He et al., 2008). Herein follows a state-of-the-art review of the processing technology:

2.4.1 Liquefaction products

HTL of biomass and its model compounds have been extensively studied in recent years. HTL of biomass feedstocks results in bio-oils and/or phenolics. Formation of various chemicals, with intact phenolic functional groups, indicates that hydrolysis plays an important role during the decomposition reaction. Phenolic compounds, such as phenol, o-cresol and catechol, are important intermediates in the chemical industry. HTL is thus an efficient way of recovering these compounds. Tymchyshyn and Xu (2010) reported the relative concentration of phenolic compounds in lignocellulosic-derived bio-oil at approximately 80 % in HTL of organosolv-lignin. Kang et al. (2011) showed that HTL of alkaline biomass provided for more than half phenolics in the oily product. Phenolics, including 28.37 Wt% of catechol, 7.53 Wt% of phenol, 7.87 Wt% of m,p-cresol and 3.80 Wt% of o-cresol, have been obtained from the methanol soluble fraction of lignocellulosic-derived HTL products (Wahyudiono Sasaki and Goto, 2008).

Zhang et al. (2008) investigated 5 types of hydrothermally treated biomass materials and residues; yields of liquid products in total products were found to be between 32.6-90.2 %. Results indicated that yields were dependent on the composition or structure of the raw materials. It was concluded that hydrothermal conversion of biomass could be a promising method for obtaining phenolics (as natural antioxidants/food additives).

Organic acid is another important product from HTL. According to Yoshida et al. (2005), the production of organic acid from HTL-treated biomass results from decomposition of the propyl chain of the phenyl propane group, but not aromatic moiety; the benzene structure is highly stable during HTL treatment. Temperature and reaction time are important factors affecting the product distribution and yield. Increased reaction time at the same conditions, results in decreased high molecular weight fractions, and an increase in low molecular weight fractions (Wahyudiono Sasaki and Goto, 2008). Guaiacol units of some HTL-treated biomass are known to produce vanillin, vanillic acid, dihydroconiferyl alcohol, and guaiacol (Tsubaki et al., 2010). Syringaldehyde, syringic acid and sinapaldehyde are usually obtained from syringyl units of some HTL-treated biomass (Ruiz et al., 2013).

Kang et al. (2011) observed more alkyl-substituted phenols and fewer methoxyl aromatic products at higher temperatures. Zhang et al. (2009) found that final liquefaction temperature, liquefaction time, as well as heating rate, were the main factors to influence the liquid yields by HTL of grassland perennials, and its extracted lignin-component. The authors indicated that, with increased heating rates, liquid yields similarly increased.

2.4.2 Liquefaction model compounds

Numerous investigations have focussed on simple model compounds to avoid complications associated with the heterogeneity and complexity of biomass. Cellulose and hemicellulose are modelled by glucose and xylose, respectively, while phenol is used to model lignin, being the corresponding main constituents of lignocellulose fractions. A few studies have used methanol in models for alcohol, while others have used 5-hydroxymethylfurfural (an intermediate for glucose gasification). Cellulose is the main component in lignocellulosic biomass fractions and mostly yields glucose (Kruse, 2013).

The hemi-cellulosic fraction is made up of five-membered carbons (e.g., xylose and arabinose and six-membered sugar units like glucose, mannose, and galactose, which may be substituted with phenolics, uronics, and acetyl groups) (Kabel et al., 2002; Nabarlatz et al., 2004). Hemicellulose undergoes hydrolysis into oligosaccharides, monosaccharides, and other products (e.g., furfural, hydroxymethylfurfural, and acetic acid) (Vegas et al., 2008). So too can xylan, as building block of hemicellulose, be cleaved into xylose oligosaccharides and intermediates (e.g., used as pre-biotics) (Carvalheiro et al., 2004; Gullón et al., 2009).

Many lignin model compounds have been used in HTL, in order to explore liquefaction mechanisms and reaction kinetics (Lawson and Kleln, 1985; Sato et al., 2002; Wahyudiono et al., 2007; Wahyudiono Sasaki and Goto, 2009). β-O-4-type lignin model compounds have been found to be easily cleaved, while biphenyl-type compounds are highly stable during supercritical water treatment (Ehara et al., 2002). Hydrothermal conversion of lignin model compound 2-isopropylphenol yields dealkylation, and rearrangement reactions (Sato et al., 2002).

Wahyudiono et al. (2007) found that decomposition of guaiacol tended to produce catechol and phenol, rather than o-cresol, and phenolic bonds were not easily cleaved at high temperatures. During the conversion of catechol, phenol is the main product, being a stable hydrolysis product containing a single ring (Wahyudiono Sasaki and Goto, 2009). Hydrothermal conversion of these low molecular phenolic model compounds (catechol, guaiacol) produces char, which indicates that char is an inevitable product in an un-catalysed lignin hydrothermal reaction; phenolics are necessary products in lignin liquefaction. These model compounds' reaction pathway suggests that some useful chemical intermediates might be recovered for appropriate reaction speed and selectivity, by changing the hydrothermal conditions (e.g., temperature).

2.4.3 Application and separation

By using active carbons (Montané et al., 2006), ultra or nano-filtration membranes (Vegas et al., 2006), and reactor configurations (Garrote et al., 2002; Makishima et al., 2009), some advancement in the recovery/purification of xylose oligosaccharides from hydrothermal processing have been observed. HTL-treated biomass yields phenolics which have particular properties, making them ideal for the synthesis of pharmaceutical products, for the production of adhesives, and for the synthesis of specialty polymers (Amen-Chen et al., 1997). Phenolic oils obtained from liquefied lignin may be useful to produce green phenol–formaldehyde resins. Xu et al. (2010) demonstrated that lignin derived phenolics had the potential to be used as substitutes for phenol in preparing novolac resins. Barclay et al. (1997) reported on the antioxidant properties of biomass-derived phenolic compounds. It was also found that phenolic compounds produced from the lignin fraction of sugarcane bagasse and olive tree prunings exhibited antioxidant activity (Conde et al., 2009; Arni et al., 2010).

Kang et al. (2011) reported that the liquid products from both black liquor lignin and ligno-sulfonate could be used as antioxidants; antioxidants' abilities showed certain relationships with the total phenol content in the liquid products. Apart from the monomeric phenolics, dimeric phenolics were also found in the biomass-derived liquefaction products (Takada et al., 2004). Dimeric phenolic compounds examined had significantly higher antioxidant properties, as compared to that of monomeric phenolics (Barclay et al., 1997). Kang et al. (2011) produced antioxidant biodiesel in supercritical methanol with the addition of lignin, highlighting that products derived from HTL-treated biomass can be used to improve biofuel antioxidant abilities. Conversely, some non-phenolic compounds, e.g., carboxylic acids and alcohols, exist in biomass-derived liquefaction products, which would modify brittleness and lead to increased flexibility of the resins produced with biomass-derived liquefaction liquids. Furthermore, the hydroxyl groups in the non-phenolic compounds would affect the antioxidant activity, as polar groups can (hydrogen) bond with lignin phenolic groups. In a separate study, Kang et al. (2011) successfully separated lignin liquefaction products into four types of substances: benzene-diols, mono-phenolic hydroxyl products, weak-polar products, and water-soluble products (low-molecular-weight organic acids, alcohols, etc.). This was done by using successive extractions with alkali solutions and organic solvents.

Several methods, such as silica-gel column chromatography (Achladas, 1991), and liquid–liquid extraction (Amen-Chen et al., 1997), have the potential to separate and obtain phenol-rich fractions. Molecular distillation has been used as an effective method for the separation of bio-oil (Wang et al., 2009). This method promises much in the way of recovering phenolics from biomass-derived liquefaction products.

2.4.4 Catalysts

Alkali, alkali salt and noble metals are common catalysts used in HTL of biomass materials. Sulfuric acid can also be used as a catalyst.

Ibbett et al. (2011) reported, however, that substrate degradation reactions occurred, and were not effectively catalysed by aqueous acid. Hepditch and Thring (2000) studied the effects of Lewis acid catalysts in HTL of biomass, finding that Lewis acid catalysts ($FeCl_3$) clearly favoured the production of catechol, whilst syringol and guaiacol were major compounds obtained from $NiCl_2$. Both catalysts could not effectively degrade the lignin-component, but favoured condensation reactions, leading to the formation of insoluble residue.

Akhtar et al. (2010) reported on the HTL of biomass for empty palm fruit bunch, noting the reactivity of the alkalis to be in the order of K_2CO_3>KOH>NaOH. The authors also found that substrate degradation was quite sensitive to K_2CO_3 concentrations; higher K_2CO_3 catalyst concentrations supported re-polymerization, which resulted in a sharp decrease in substrate degradations. Yan et al. (2008) established that Pd/C catalyst could cleave the C–O bonds without disrupting the C–C linkages in lignin, yielding four main monomers, namely guaiacyl propane, syringyl propane, guaiacyl propanol, and syringyl propanol.

The use of homogeneous catalysts provides certain advantages, such as increased biocrude yield, improved biocrude properties, and decreased solids production. Also, dehydration reactions are decreased (usually leading to unstable unsaturated molecules), with the incorporation of alkali salts in the hydrothermal media, resulting in elevated pH (Arturi et al., 2016). Déniel et al. (2016) showed that less char is produced with NaOH, with the OH^- neutralizing the molecules causing polymerization during char formation. Sugano et al. (2008) indicated that NaOH's participation is restricted in condensation reactions - polymerization reactions between the hydroxyl groups at the residue surface and the carboxylic groups in the aqueous stream produces ester bonds, which form char; NaOH cannot cause polymerization due to the neutralization of carboxylic acids.

Recent significant contributions pertaining to the development of homogenous liquefaction catalysis include studies by Mazaheri et al. (2013), Wang et al. (2013), Zhu et al. (2014), Zhu et al. (2015), Nazari et al. (2015), Shakya et al. (2015), Jindal and Jha (2016), Biller et al. (2016), Cao et al. (2016), Chang et al. (2016), Déniel et al. (2016), Durak and Aysu (2016), Bi et al. (2017), Arturi et al. (2017), and Muppaneni et al. (2017).

The most prominent disadvantage associated with the use of homogenous catalysts for catalytic HTL of biomass is expensive, energy intensive separation/recovery processes. The use of heterogeneous catalysts such as Pt, Ni and Pd have recently been reported in the HTL of biomass, specifically to improve biocrude quality – these catalysts have been more widely used in gasification (to remove oxygen), albeit at the cost of reduced biocrude yield. Saber et al. (2016) reported on using Ni nano-catalysts to improve bio-oil yield at low temperatures, indicating the potential of its use in the commercialization of HTL. Because reductive noble metal catalysts are rare and expensive, the use of metallic oxides such as ZrO_2 have also been considered; other compounds include MnO, MgO, NiO, ZnO, CeO_2, and La_2O_3 (Watanabe et al., 2006; Zhang et al., 2009; Hammerschmidt et al., 2011; Christensen et al., 2014).

Other attempts at employing heterogeneous catalysts have seen reports of using either zeolite (Bi et al., 2017) or carbon nanotubes (Chen et al., 2017) supported transition metals, which provide large surface areas and are capable of being recycled (Davari et al., 2014; Xu et al., 2015). Zhou et al. (2016) showed the potential for using CuZnAl during hydrogenation and hydrogenolysis to convert furfural into cyclopentanone. By varying the Cu or Zn oxide, the activity of such catalysts may be modified, allowing recycling through reactivation with H_2 gas. Duan and Savage (2010) cited improved biocrude quality with supported transition metal catalyst use.

2.4.5 Limitations and challenges

Presently, HTL technologies are not being widely commercialized. This is partly due to the high pressures required for processing, necessitating special reactor and separator designs for development of continuous processes, and associated capital investment associated with commercial plant construction and operation. Apart from a handful of demonstration plants (including the recently commissioned NWU pilot plant), no commercial-scale plants are presently in operation. The said specialist designs and/or processes must overcome issues related to solids loading and handling (in excess of 15-20 Wt%), feeding at high pressure and temperatures, and integrated heat recovery systems – effective heat and mass transfer is essential for competitive reaction rates and product yields. Another critical issue deterring commercialization is the need for robust, stable catalysts capable of separation and reintroduction into reaction systems. In the case of heterogeneous catalysts, catalyst deactivation due to coke formation and/or feedstock contamination must also be minimized or avoided. Finally, knowledge of synergistic interactions between biomass components, and the effect of their interactions on quantitative and qualitative product yields are lacking; to fully understand reaction chemistry and mechanisms, improvements in kinetic models and associated modelling strategies are required for integrating complex biomass feedstocks and predicting HTL behaviour (Singh et al., 2016).

As mentioned, Gollakota et al. (2018) identified the following areas of research presently facing concerned investigators, as relating to the state of the art:

- Setting up an HTL pilot plant and analysing the effects of wet biomass feedstocks on conversion efficiencies.

- Assess the complexities of parameters like temperature, pressure, and the residence times for HTL of a given feedstock, at piloting scale.

- Investigate possible pathways for optimized conversion via HTL, especially for wet biomass feedstocks, and their mixtures.

- Evaluate relationships between biocrude yield/value added chemical species, evaluating production of high value chemical co-/by-products using catalysts.

- Examine and consider reaction pathways of HTL processing of model compounds and comparing real biomass.

- Develop computational fluid dynamics models to analyse the complex inherent properties (e.g., thermodynamic properties of the biocrude, viscosity effects etc.), to optimize processing parameters.

Kumar et al. (2018), when providing an assessment of the potential of hydrothermal technologies, especially HTL, stressed the need to perform techno-economic assessments for the purposes of founding viability.

2.4.6 Significant contributions

Minowa et al. (1995) investigated the decomposition of cellulose, and the effect of adding a sodium carbonate catalyst, a reduced nickel catalyst, and no catalyst addition in hot-compressed water. It was noted that hydrolysis played an important role in forming glucose/oligomer, which quickly decomposed into non-glucose aqueous products, oil, char, and gases. Char and gases were produced as intermediates through oil in the absence of a catalyst. With an alkali catalyst, the oil intermediates were stabilized, resulting in oil production and inhibition of char production. Bio-oil production from HTL was shown to be affected by the type of biomass, due to their varying chemical compositions and physical structures. As indicated, limited research has been carried out to establish the effects of individual compounds and their interactions (e.g., ash, proteins) on HTL reactions. Cellulose, lignin and hemicelluloses have been used as individual model compounds to study the reaction pathways and decomposition mechanisms (Demirbas, 2009).

Waste materials are more complex in terms of composition. Results from laboratory investigations have been wanting regarding reaction kinetics. It is believed that any organic material, specifically carbohydrates, proteins, and fats could be converted into crude oil (Kruse and Gawlik, 2003; Fang et al., 2008; Kruse et al., 2013).

Xu and Etcheverry (2008) reported that reduced nickel was found to catalyse the steam reforming reaction of aqueous products (as intermediates), as well as the machination reaction. Typical yields of liquid products for hydrothermal conversion processes were reported to be in the range of 7–70 %, depending on various factors including substrate type, temperature, pressure, residence time, type of solvents, and type of catalysts used.

Zhang et al. (2009) studied the liquefaction of low-input high-diversity mixtures of native grassland perennials, following dilute acid pre-treatment and lignin extraction. Liquefaction yields were found to be dependent on final temperature, liquefaction time, and heating rate. The highest bio-oil yield of 82.1 % was achieved within a residence time of 1min at 374 °C.

Mazaheri et al. (2010) examined the thermal decomposition of oil palm fruit press fibre with sub/supercritical methanol, ethanol, acetone, and 1,4-dioxane treatments using a high-pressure autoclave reactor. When fruit press fibre was decomposed with methanol, ethanol, and acetone from 483-603 K, the highest liquid product yield obtained were 38.0 %, 36.9 %, and 38.5 %, while the highest degree of conversion obtained were 81.5 %, 77.8 %, and 67.9 % respectively. With 1,4-dioxane, the conversion of fruit press fibre increased from 18.30 % to 80.00 %, while liquid product yield increased from 13.30 % to 50.90 % (comprising 42.3 % bio-oil compounds), when the reaction temperature was increased from 483-563 K. When the temperature was further increased to 603 K, the authors found that the conversion of fruit press fibre and liquid product yield decreased to 69.60 % and 24.10 %, respectively. For producing the bio-oil component, subcritical 1,4-dioxane treatment was found to be the most effective for the degradation of fruit press fibre.

Akhtar and Amin (2011) examined processing conditions as affecting process performance, including final liquefaction temperature, residence time, rate of biomass heating, size of biomass particles, type of solvent media and hydrogen donor solvents. Operating parameters significantly affected bio-oil yield and quality. The authors highlighted that past investigations had focussed on maximizing overall oil yield, without paying sufficient attention to the interaction of these parameters, or their effect on the product composition and quality.

Jena et al. (2011) investigated the optimum HTL operating conditions for producing biocrude from *Spirulina platensis*. Experiments were performed at various temperatures (200–380 °C), holding times (0–120 min), and solids concentrations (10–50 %). The highest biocrude yield of 39.9 %, representing 98.3 % carbon conversion efficiency, was produced at a HTL conversion at 350 °C, 60 min holding time and 20 % solids concentration. Light fraction biocrude was observed at 300 °C and higher temperatures, representing 50–63 % of the total biocrude. Biocrude obtained at 350–380 °C had similar fuel properties as that of petroleum crude, with energy densities of 34.7–39.9 MJ/kg (compared to 42.9 MJ/kg for petroleum crude). It was also reported that the biocrude from conversion at 300 °C or above had 71–77 % elemental carbon, and 0.6-11.6 % elemental oxygen, with viscosities in the range 40–68 cP. GC/MS analysis showed the presence of higher hydrocarbons (C_{16}–C_{17}), phenolics, carboxylic acids, esters, aldehydes, amines, and amides.

Xiu and Shahbazi (2012) indicated HTL to be superior to pyrolysis, owing to higher oil yield and the higher heating value of the bio-oil products, further noting that organic waste materials being more favourable as feedstocks than woody biomass and agricultural residues, for the purposes of HTL processing. The authors emphasized the environmental and economic benefits, when disposing of large volumes of organic wastes (reducing pollutants and producing energy in the form of liquid fuel).

Toor et al. (2012) studied the combination of enzymatic bioethanol production with catalytic liquefaction of wet distiller's grains with solubles (WDGS), being a by-product from the bioethanol process. Catalytic liquefaction was carried out on WDGS at sub-critical conditions (280-370 °C, 25 MPa) in the presence of a homogenous alkaline and heterogeneous Zirconia catalyst (known as the Catliq® process). WDGS was converted to bio-oil, gases, and water-soluble organic compounds, with results indicating that, through the combination of ethanol production and catalytic liquefaction, it was possible to significantly increase liquid product yield.

Bensaid et al. (2012) focussed on the production of synthetic liquid fuels from the direct liquefaction of selected fractions of municipal solid wastes (organic, pruning residues, wood refuses and agro-industry residues). Following steam pulping pre-treatment, a pulp of organic material with a water content ranging between 50-90 % was fed to a reactor operating at approximately 330 °C and 180 bar, with residence times ranging between 4-10 min. A 50 kt/year (based on dry biomass content) was considered, and a bio-oil net production of 37.1 Wt% reached, taking account of all plant fuel needs. They noted a specific power consumption of 0.258 kWh/kg_{oil}, corresponding to the ratio between output/input energy of 35.8.

Yin and Tan (2012) reported on the HTL of biomass to bio-oil under alkaline, neutral, and acidic conditions. Comparative studies at pH = 3, 7, and 14, at temperatures ranging between 275-320 °C and residence times of 0-30 min were conducted on cellulose feedstocks. The chemical compositions of the bio-oils were reportedly different for acidic, neutral (main composition comprising 5-(Hydroxymethyl) furfural (HMF) and alkaline (main composition comprising C_{2-5} carboxylic acids) conditions. It was observed that high temperatures and long residence times impacted negatively on bio-oil yields, regardless of pH levels. They also reported different reaction pathways, specifically, polymerization of 5-HMF to solids under acidic conditions, causing a decrease in bio-oil yield; conversion of 5-HMF to solid and gaseous products under neutral conditions, causing a decrease in bio-oil yield and decomposition of bio-oil to gases under alkaline conditions, through the formation of short-chain acids and aldehydes.

Miao et al. (2012) developed a two-step sequential HTL (SEQHTL) model for simultaneous extraction of polysaccharide at the first step, followed by bio-oil in the second. Evaluation of the effects of reaction temperature, residence times, and biomass/water ratio on the product distribution of each SEQHTL step was made. Maximum yield (32 Wt%) of polysaccharides was obtained at 160 °C, 20 min and 1:9 biomass/water ratio. As ideal SEQHTL conditions for bio-oil extraction and considering the operation cost and bio-oil yield (>30 %), 240 °C, 20 min and 1:9 biomass/water ratio was preferred. SEQHTL produced approximately 5 % more bio-oil and approximately 50 % less biochar, than direct HTL. Free fatty acid content of the bio-oils decreased sharply with increased temperature. SEQHTL required approximately 5 % less MJ/kg bio-oil than direct HTL. Energy recovery rates for SEQHTL were also virtually 4 % higher, as compared to direct HTL.

Yuan et al. (2014) presented a novel small-scale HTL process adopting single nitrogen expansion with carbon dioxide pre-cooling, as a means for exploitation and transportation of stranded gas to market. Aspen HYSYS® was utilised to simulate and optimize the process. Taking unit energy consumption as the target function, results showed a liquefaction rate of 0.77, with unit energy consumption of 9.90 kW/kmol/h. The adaptability of this process under different pressure, temperature and compositions of feed gas was also studied. The exergy losses of main equipment in the process were evaluated and analysed, based on optimization results. The proposed liquefaction process proved to be suitable for the development of small gas reserves, satellite distributed fields of gas or coal-bed methane fields, having regard for the compactness of the device, safe operation, and simplicity.

Tran (2016) reported on the reactor material constraints and difficulties coupled with the formation of unwanted products as limitations to commercial application of HTL. The author also exploited heat and mass transfer limitations in the reaction system, which results in lower conversion efficiency and selectivity, the latter making product separation, purification, and/or modification difficult and expensive. The study emphasized the need for developing a special plug-flow reactor for scaling up of HTL processes.

Özdenkçi et al. (2017) proposed a concept for an integrated biorefinery from a sustainability perspective. The investigators highlighted deficiencies of present techno-economic studies, in particular limited replacement potential in co-processing with fossil sources, and high investment costs required with integration to a specific plant (resulting in a research focus of supply-chain network systems). The authors did, however, acknowledge the scope for improvement of specific product and/or feedstocks. The authors presented a novel biorefinery concept for biomass - using a sectoral integration network and implementing hydrothermal processing (specifically partial wet oxidation or simultaneous dissolution with partial wet oxidation) of solid biomass, followed by lignin recovery with acidification, the reactor performed either HTL or supercritical water gasification. The concept showcased the potential for producing multiple products, while reducing net GHG emissions.

A comprehensive summary of publications contributing towards the state of the art of HTL of biomass, including the effect of various process conditions, was provided by Dimitriadis and Bezergianni (2017), Gollakota et al. (2018) and Kumar et al. (2018). Although considerable literature exists on HTL of biomass feedstock, research efforts of wet biomass has centred mostly around the utilization of third-generation micro- and macro-algae, and seaweeds. Literature on the HTL of wet bio-waste streams such as municipal sewage or sludges is limited.

2.5 HTL of wet waste, sewage and sludges

Bora et al. (2020) provided a review on the sustainable approach of transforming sewage sludge to biofuel. The potential of high lipid-containing municipal sewage sludge as feedstock was indicated, owing to its low cost and abundant availability. Pre-treatment, pyrolysis, and transesterification processes were discussed, together with the numerous associated disadvantages complicating scale-up and commercialization. Expensive and ineffective drying methods, excessive amounts of solvent required for extraction, slow rate of transesterification reactions, and need for process intensification were highlighted, alluding to the application of HTL technology to circumvent these challenges. The benefits of using municipal sewage sludge, compared to other second-and third-generation biomass feedstocks, were detailed, with the study pointing towards minimization of environmental hazards, and economic potential prospects.

Though not wet streams, solid municipal wastes have also been considered by various authors of late, in the application of so-called waste-to-energy. Mukherjee et al. (2020) provided a review on the proposed conversion of municipal solid waste using gasification and/or pyrolysis, as opposed to conventional incineration and landfill. The authors provided a review of established techno-economic assessments, life-cycle sustainability assessments, and reverse logistics modelling (as pertaining to said proposed and established technologies) and emphasized the use of the various studies in finding industrially applicable routes to viability.

Sadhukhan and Martinez-Hernandez (2017) presented a study on the material flow and (lifecycle) sustainability analyses of a novel mechanical, biological, and chemical treatment system for completing valorisation of municipal solid waste, relying on a futuristic scenario wherein complete reuse-recycling-recovery cycles of source segregated solid municipal waste is employed. Lemoine et al. (2013) compared solid municipal waste, primary sewage sludge and microalgae subjected to HTL at different temperatures (330 °C, 380 °C and 450°C). The feeds' analyses (TDA–TGA, ICP-AES, lipids quantification) showed that solid waste and primary sludge had similar characteristics and physio-chemical properties but differed from those of microalgae. Bio-oil yields (Wt%) were reported in the order: microalgae > sewage sludge > solid waste. The conversion rate of the sludge was higher at 380 °C, while bio-oil hearting value was higher than solid waste and microalgae, regardless of operating temperature.

Watson et al. (2020) detailed pathways towards commercial viability through the valorisation of aqueous streams by HTL, including municipal wet waste. The authors reviewed the impact of HTL conditions and the feedstock composition on the energy and elemental distribution of process outputs with specific emphasis on the HTL aqueous product stream. Lifecycle sustainability analysis was performed to appraise the environmental sustainability and economic implications. The study showed that, to enhance the prospects of large-scale HTL entering the mainstream biocrude oil market, valorisation of the aqueous HTL phase to be critical, concluding that further research should be conducted to co-optimize the economic potential and GHG emissions of the different paradigms associated with HTL, including HTL biocrude oil production, and HTL aqueous valorisation. The authors eschewed findings by foregoing researchers performing life cycle sustainability assessments, who have, of late, shifted their focus from algal matter to wet biowaste as an HTL feedstock, mainly emphasizing sludge, manure, etc. These studies also showed that valorisation of the HTL aqueous discharge having a critical impact on the overall lifecycle sustainability results.

As cited above, Skaggs et al. (2018) indicated the potential of diverting organic wastes, including wastewater sludge, livestock waste, and food waste, for beneficial energy use through HTL, while reducing the quantities of waste that are disposed or released to the environment. The authors conducted a detailed analysis using data on feedstock resources, coupled with a novel biomass regression assessment tool modelling framework and reduced-form HTL conversion model. Results indicating that wastes have the potential to produce up to 22.3 GL/y of a biocrude oil intermediate.

Bertanza et al. (2018) reported on the viability of retrofitting two WWTPs of different size (50,000 and 500,000 population equivalents) and achieving either energy self-sufficiency or material recovery of upgrading existing facilities. A detailed evaluation of technical, social, economic, and administrative aspects was carried out, based on mass and energy balances. Utilizing a simplified approach, environmental aspects were also included. It was indicated that external energy supply could be reduced by approximately 10 % of the total requirement, with moderate techno-economic implications. This was especially the case where a plant is already equipped with primary sedimentation and anaerobic digestion. The potential of integral recovery of treated effluent, sludge and nitrogen in large facilities was also touted, while significant risks were identified for medium-sized plants. Considering rising urbanization and associated environmental concerns, it was emphasized that wastewater treatment plants will, in the near future, be tasked to consume less resources, while even possibly be required to produce valuable material and energy.

The stated literature clearly set out the potential of treating wet (municipal) waste streams to supplement waste treatment processes in existing wastewater treatment plants. This notwithstanding, very little research has been performed on HTL of wet waste streams.

Table 2-3 below provides a summary of investigations into HTL of sewage sludge, municipal/industrial waste and/or comparable bio-waste stream as wet biomass feedstock.

Table 2-3: Summary of the literature pertaining to HTL of wet biomass waste

Author	Description	Feed	Process Conditions	Comments
Hadhoum et al., 2016	*Hydrothermal liquefaction of oil mill wastewater for bio-oil production in subcritical conditions*	*Oil mill wastewater*	*T: 200-300 °C P: 190 bar Batch reactor*	*Max. yield of 58 Wt%, content comprised primarily of phenolics*

Author	Description	Feed	Process Conditions	Comments
Zheng et al., 2015	*Alkaline hydrothermal liquefaction of swine carcasses to bio-oil*	*Animal carcasses*	*T: 250 °C* *P: -* *Batch reactor*	*62.2 Wt% bio-oil, 22 Wt% biochar*
Malins et al., 2015	*Bio-oil from thermo-chemical hydro-liquefaction of wet sewage sludge*	*Sewage sludge*	*T: 300-350°C* *P: -* *Batch reactor*	*45 Wt% bio-oil*
Pham et al., 2013	*Effects of hydrothermal liquefaction on the fate of bioactive contaminants in manure and algal feedstocks*	*Animal manure*	*T: 250-300 °C* *P: 10-15 MPa* *Batch reactor*	*32 Wt% bio-oil, 64 Wt% biochar 4 Wt% water-soluble compounds* CO_2 *Deactivates antibiotic resistant strains*
Vardon et al., 2011	*Chemical properties of biocrude oil from the hydrothermal liquefaction of Spirulina algae, swine manure, and digested anaerobic sludge*	*Animal manure*	*T: 250-300 °C* *P: 10-15 MPa* *Batch reactor*	*41 Wt% bio-oil, 50 Wt% biochar 9 Wt% water-soluble compounds* CO_2 *Metals/nutrients concentrated in biochar*
Dong et al., 2009	*Product distribution and implication of hydrothermal conversion of swine manure at low temperatures*	*Animal Manure*	*T: 240-280 °C* *P: 0.7 MPa* *Batch reactor*	*33 Wt% bio-oil*
Xu and Lancaster, 2008	*Conversion of secondary pulp/paper sludge powder to liquid oil products for energy recovery by direct liquefaction in hot-compressed water*	*Secondary pulp/paper sludge*	*T: 250-380 °C* *P: 2 MPa* *Batch reactor*	*25 Wt% bio-oil*

Author	Description	Feed	Process Conditions	Comments
Williams and Slaney, 2007	*Analysis of products from the pyrolysis and liquefaction of single plastics and waste plastic mixtures*	*Municipal solid waste*	*T: 500 °C P: 10-15 MPa Batch reactor*	*55.8 Wt% bio-oil*
Itoh et al., 1994	*Biocrude production from sewage sludge using HTL*	*Sewage sludge*	*T: 300° C P: 10 MPa Demonstration plant*	*11 Wt% bio-oil*

2.6 Techno-economic studies: general considerations

For the purposes of evaluating advanced biofuel production pathways, techno-economic studies require designing processes at the suitable level of detail and modelling the production cost by using sets of relevant and consistent assumptions. Compared to techno-economic analysis of common products, biofuel exhibits such distinguished characteristics as significant variety of pathways (in particular, the possibility of using a large range of feedstocks), high uncertainty about economic drivers, large number of stakeholders involved in the pathways, and uncertainties relating to their interactions. Published works on advanced biofuel simplify this complexity by focusing on limited pathways, a narrow range of feedstocks, less choices of economic factors and implicit assumptions pertaining to the behaviour of the stakeholders. These assumptions change significantly from one study to the other, making it intractable to compare different techno-economic evaluations. Gnansounou et al. (2005) indicated that as long as biofuel is supposed to be used as pure fuel (or in a high blend rate), and providing that such characteristics as GHG emission reduction, renewability, absence of competition with food/feed, general policy considerations, and lack of (in)direct land-use impacts are not taken into account (neither by the market nor by the public authorities), such modelling choices are regarded as acceptable.

From the literature, techno-economic analysis of second- or third-generation biomass derived biofuel is based on one of three types of cost management systems. These strategic cost management systems comprise Value Engineering (VE), Target Costing (TC) and Combined Target Costing and Value Engineering (TC&VE). With VE, each basic function in the system is specified and analysed, including its various interactions, comprising the detailed plant design. VE-based costing entails the estimation of capital investment and production costs, incl. feedstock cost. Compared to VE, TC is a rather market-oriented method (Gnansounou and Dauriat, 2010).

Gnansounou and Dauriat (2010) provides that the supply chain of advanced biofuel feedstocks must be evaluated by using the VE-approach, given the non-integration of feedstock delivery (not at issue when using existing infrastructure of wastewater treatment plants), novel biofuel conversion processes, distribution and end-use segments. It was noted that market price projections cannot adequately consider the distinctive characteristics of sustainable advanced biofuel, and that practical applications of a VE-based approach require consideration of the specific plant construction sites (comprising i.a. political and environmental considerations). VE is more suitable to processes for converting raw materials into a diverse product portfolio (low-volume and high-value products, with co/by-products of varying value). As opposed to the VE approach, TC is preferred when producing a single high-volume commodity (e.g., renewable diesel), where development of co/by-products are peripheral (Peters et al. (2003)). With TC, being a popular approach used throughout techno-economic assessments of biorefinery processes, a minimum fuel selling price (MFSP) is calculated, and sensitivity analyses using variable economic indicators employed to compare competitiveness with conventional fuels. VE, being a more robust, comprehensive approach compared to TC, estimates actual process capital and operating costs, with associated economic parameters relating to cashflow and economic performance over the process lifetime (Landucci et al., 1994).

According to production economics literature (Ibusuki and Kaminski, 2007; Gnansounou and Dauriat, 2010), TC has been used for almost 60 years to manage production costs. Ellram (2006) investigated TC practices in the US and highlighted the more frequent application of TC and TC&VE in research and development, as opposed to the use of VE by other authors. Generally, TC and TC&VE (which provide for the calculation of a MFSP in order to demonstrate techno-economic feasibility), are favoured by U.S. authors, while authors in Eurasia and Africa (including the present study) prefer the VE approach. However, techno-economic evaluations of advanced biofuel processes, as they appear in scientific papers, are rarely in full accordance with either TC(&VE) or VE approaches. As mentioned above, these analyses take on the characteristics of case studies for the myriad of assumptions and design choices, including their approach to economics. For practical cases of future commercial biorefineries, which are considered heavy-investment processes: technical aspects of the supply chain are generally prioritised, neglecting the potential competition for resources (Ellram, 2006).

Significant research and development have been performed over the course of the past 4 decades in demonstrating a techno-economically feasible route for the commercial production of biofuel. It has only in the late 1990's/early 2000's that second- and third-generation biomass feedstocks were considered as viable for the purposes of these studies.

Moreover, nearly all the above-mentioned research efforts were focussed on bio-chemical processing pathways, some resulting in the construction and operation of piloting and (unsustainable) commercial production plants using first-generation biomass feedstocks. The most significant contributions to the state of the art include those by the U.S.'s National Renewable Energy Laboratory (NREL) (most notably Wooley et al. (1999a), Aden et al. (2002), Aden (2008), and Humbird and Aden (2009)), in conjunction with Engineers Inc., Stone and Webster Engineering Corporation, and Chem. Systems Incorporated. Other significant contributions include those by Aden and Foust (2009), Kazi et al. (2010), Sánchez-Segado et al. (2012), Treasure et al. (2012), and Quintero et al. (2013). Contributors outside of the Americas include Galbe et al. (2007), Sassner et al. (2008), Wingren et al. (2008), Franceschina et al. (2011), Shafiei et al. (2011), Li et al. (2012), Roy et al. (2012), Fornell et al. (2013), and Wang et al. (2013). Contributions relating to Sub-Saharan Africa include those by Amigun et al. (2011), Quintero et al. (2012), and Van der Merwe et al. (2013).

The abovementioned studies, pertaining primarily to production costs of advanced biofuel by means of bio-chemical pathways, provided various indicators regarding sensitivity to key parameters, including plant size (capacity), conversion efficiency (yield), the type, composition and price of feedstock (effect of (non)transport costs), and level of investment cost (fixed/variable operation costs, and variables). It was established that second-generation biomass feedstocks indeed require significantly heftier investment, compared to first-generation production pathways. The referred studies established the need for accessible, more affordable, and sustainable second- and third-generation biomass sourced biorefineries; additionally, the studies highlighted bio-chemical process' weaknesses, emphasizing the need for rapid, robust conversion technologies sufficiently resistant to variable feed compositions and/or contamination, and which would not require complex, expensive pre-treatment processes.

2.7 Techno-economic studies: HTL of wet biomass

Reviews of emerging biomass feedstock conversion pathways demonstrated that production cost estimates differ significantly between studies, particularly with regards to feedstock costs, capital cost assumptions and economies of scale, with uncertainty related to future feedstock cost development further complicating assessment (Haarlemmer et al., 2012; De Jong et al., 2015). Analyses by various authors have indicated that a designed biorefinery (which fully exploits every possible by-/co-product value chain) has great economic potential (even in the event of doubled capital investment and decreased value in low-volume co-/by-product(s)), in addition to environmental beneficiation (Van Dyne et al., 1999; Realff and Abbas, 2004; Kamm and Kamm, 2004; Luo et al., 2010).

The competitiveness and feasibility of processes may be subjected to comparison with established conventional technologies by making use of techno-economic assessments. Techno-economic investigations and/or analyses of processes employing thermo-chemical production of advanced biofuel is in its initial stages, as compared to established works on bio-chemical processing. Regarding the former, most techno-economic studies scrutinizing thermo-chemical processing of biomass have focussed almost exclusively on gasification and/or pyrolysis.

Noteworthy contributions relating to gasification technologies include those by Hamelinck et al. (2004), Phillips et al. (2007), Gasafi et al. (2008), Amigun et al. (2010), Anex et al. (2010), Clausen et al. (2010), Swanson et al. (2010), Dutta et al. (2011), Trippe et al. (2011), Voets et al. (2011), Kou and Zhou (2011), Ng and Sadhukhan (2011), He and Zhang (2011), Haro et al. (2013), Trippe et al. (2013), Lumley et al. (2014), and Patel et al. (2016).Significant contributions relating to pyrolysis include those by Wright et al. (2010), Trippe et al. (2010), Anex et al. (2010), Trippe et al. (2011), Voets et al. (2011), Bals and Dale (2012), Rogers and Brammer (2012), Brown et al. (2013), Zhang et al. (2013), Zhang et al. (2013), Brown et al. (2013), Thilakaratne et al. (2014), and Do et al. (2014).

Most techno-economic studies scrutinizing thermo-chemical processing of wet biomass have focussed almost exclusively on hydrothermal liquefaction of algae. Noteworthy contributions relating to algae HTL include those by Richardson et al. (2014), Beal et al. (2015), Barlow et al. (2016), DeRose et al. (2019), Zhu et al. (2019) and Jiang et al. (2019). Especially valuable contributions were that of Ou et al. (2015) and Hognon et al. (2015).

Ou et al. (2015) described a techno-economic analysis of transportation fuel production by HTL of defatted microalgae, followed by hydroprocessing of the resulting biocrude. The study was a development on the concept by Zhu et al. (2014), substituting woody biomass with microalgae as feedstock. A 2000 dry ton/day of defatted microalgae was processed by the theoretical plant. The authors employed ChemCAD 6.5 software by Chemstations™ for process modelling, and analyses. The process model comprised 5 areas: HTL, hydroprocessing, hydrogen generation, product refining, and a combined heat and power (CHP) plant. Waste handling and disposal facilities were not modelled. A final fuel-product-to-feed (mass) ratio of 0.36 was noted, with biomass energy efficiency at 63.5 %. Again, product heating value was based on results from literature, and not simulated. A minimum fuel selling price was calculated for the purposes of establishing economic feasibility, based on Cost Targeting analyses approach – it was shown that minimum fuel selling price was most sensitive to product fuel yield (indicating the relative importance of HTL conversion performance), and feedstock costs.

Hognon et al. (2015) compared HTL and pyrolysis of *Chlamydomonas reinhardtii* microalgae for renewable diesel production, based on energetic and economic evaluation. The study adapted a process model originally developed by Delrue et al. (2013), comprising cultivation, harvesting, dewatering (for pyrolysis), conversion (HTL or pyrolysis), and hydrotreating steps. The authors built a thermo-chemical model based on empirical results sourced from literature, providing for flow feeds of 714 m^3/day (HTL) and 105 m^3/day (pyrolysis), respectively. A final fuel-product-to-feed (mass) ratio of 0.47 was noted, with biomass energy efficiency at 73 %, using the HTL pathway. Product heating value was based on results from the literature, and not simulated. Using the VE analysis approach, the authors established various process economic indicators. The study concluded that the costs of production of renewable diesel from HTL (or pyrolysis) were significantly higher than petroleum diesel, with the most expensive step reported as microalgae cultivation (nutrients cost and raceway capital cost). It was also noted that cHTL processes could significantly improve economic balances.

Very little literature exists on the HTL of wet waste biomass, and especially for techno-economic analyses of these processes. Perkins et al. (2019) provided a summary of techno-economic analyses for various biomass liquefaction processes, showing only a single contribution for the HTL using wastewater sewage sludge – the remaining contributions, regarding processing of wet biomass, were consigned to algae. Singular notable techno-economic assessments of biorefineries processing wet biomass waste using HTL are distinguished as follows:

Hoffmann et al. (2013) presented 2 process alternatives, carried out in Aspen Plus®, for an integrated organic waste treatment/conversion process. A flowsheet and process model for a hydrothermal liquefaction plant was developed, feeding 1000 kg/h manure, consisting of four process blocks: a biogas plant, an HTL plant, H_2 production plant, and upgrading unit. The model was loosely based on a process design by Toor et al. (2012), making use of CatLiq® technology for the liquefaction of WDGS (wet distiller's grans with solubles). Digestate from the biogas plant was converted to a biocrude in the HTL plant, with biogas produced by the former feeding to the H_2 production plant, and utilities. The H_2 produced was then used in the upgrading process producing diesel-quality-fuel. According to the authors, this biorefinery concept offered a sophisticated and sustainable way of converting organic residuals into a range of high-value biofuel streams (although no co-/by-product streams were specified, other than those discharged), in addition to CHP production. Based on the said process model, Hoffmann et al. (2013) estimated yields of approximately 30–38 kg/h liquid fuel and 38–61 kg/h biogas. An estimated fuel heating value of 43 MJ/kg was reported. The study provided for various process results in motivating the plant's (economic) potential; no process cost analyses was, however, performed.

Summers et al. (2015) provided a feasibility analysis of diary effluent to renewable diesel employing yeast fermentation and HTL. A systems-model was developed using information garnered from literature, without a technical plant design, or operations modelling. The authors reported a minimum fuel selling price of US$ 4.78/gallon of renewable diesel, 0.81 net energy ratio, and GHG emissions of 30.0 g-CO_2-eq MJ^{-1}. High production costs/emissions were attributed to operational temperatures and fermentation residence times. A favourable net energy ratio was attributed to high lipid yields of the yeast, offsetting operational demands.

Van Doren et al. (2017) also presented a systems design study, reporting on the techno-economic feasibility of converting wet biomasses such as animal manure, organic waste, or algae, via HTL. Although no technical design was attempted, results showed HTL to be better suited (from an economics perspective) for converting waste biomass (including manure and wastewater sludge) to energy products, rather than for the conversion of expensive feedstocks such as algae (which incurs excessive cultivation costs). These results accorded with those of Hognon et al. (2015), who indicated that costs of microalgae cultivation are significantly higher, compared to subsequent HTL and pyrolysis operations (as referred above).

Snowden-Swan et al. (2017) reported on the conceptual biorefinery design processing wet waste to fuels via HTL. The hypothetical treatment of wastewater treatment plant sludge (being fed at no cost at a rate of 93.5 t/day, dry and ash-free) provided for a biocrude product with a theoretical heating value of 39.7 MJ/kg. Biocrude yield was calculated at 43.6 %, providing for a product stream of a reported 40.7 t/day. Total capital investment cost was estimated at US$ 362 mil. with an electricity import of 0.82 MWe (utilizing a train of 10 HTL sub-plants). The authors employed a Target Costing Method, providing for a minimum fuel selling price of US$ 0.92/L -gasoline equivalent. Apart from the HTL unit, an upgrading plant was also into the concept, providing for an overall fuel yield 33.1 Wt% (408.8 L/ ton, dry). Total Capital investment for the overall processing facility was calculated at US$ 512.4 mil., emphasizing the huge comparative investment requirement for a fuel-type product, as opposed to biocrude.

Watson et al. (2020) considered various pathways towards the commercial viability of HTL, with an emphasis on the valorisation of the aqueous HTL product. The paper provided a review on the impact of HTL conditions and the feedstock composition on the energy and elemental distribution of process outputs. The study also compared and contrasted the current state of value-added products separation, along with biological (biomass cultivation, anaerobic fermentation, and bio-electro-chemical systems) and thermo-chemical (gasification and HTL) pathways to valorise the HTL aqueous.

The authors highlighted the importance of techno-economic analyses, as well as lifecycle sustainability analyses, for the purposes of appraising economic implications and environmental sustainability of different valorisation techniques. Perspectives on the integration approaches of HTL aqueous valorisation pathways, with HTL and biorefining, were provided.

2.8 Concluding remarks on the literature

The continued use of first-generation biomass feedstocks to produce biofuel is regarded as infeasible. However, the commercial implementation and use of both second- and third-generation biomass feedstocks to produce advanced biofuels face significant challenges. The potential utilization of micro- and macro-algae and seaweeds has received much attention over the past decade. As wet biomass feedstock, waste-biomass such as municipal sewage has certain advantages over said third-generation feedstocks. The utilization of aqueous (municipal or industrial) waste would not incur slow and costly cultivation and harvesting costs and would have substantial added environmental benefits to the water and health environment. Processing of aqueous waste is, ostensibly, only economically viable via HTL. The advantages of HTL over bio-chemical processing (as well as other thermo-chemical techniques) were discussed, with noteworthy academic contributors provided.

A significant disadvantage of HTL is cost, being a hugely energy intensive process (associated with extreme operating conditions). As indicated, having accessibility to the NWU cHTL piloting facility, and motivated by environment concerns, resulted in the literature review as well as the investigation within the larger context, being pivoted towards the use of HTL, and cHTL in particular. Only sparse literature is available on the HTL of liquid waste streams. Literature on the techno-economic evaluation of a (hypothetical) biorefinery utilizing continuous processing liquid waste is near absent. This literature review established that the present study is suitably positioned to assess existing knowledge, and bridge the research gap, especially pertaining to the South African landscape.

Stressing Mulchandani and Westerhoff (2016), who recognized the knowledge gap, and commended the potential use of HTL treatment of municipal sewage, especially in consideration of the health and environmental benefits, if not economic gain. The authors presented a review on limitations of present (biological) wastewater treatment processes and solids disposal options, highlighting HTL as a promising option for replacing/augmenting extensive dewatering, anaerobic digestion, and off-site disposal processes. Implementation of HTL (with liquid extraction) for converting WWTPs into resource recovery facilities was proposed. HTL was regarded to better recover energy and metals, while inactivating pathogens and destroying organic pollutants.

Mulchandani and Westerhoff (2016) supplemented assumptions with experimental data from the literature, providing for a rudimentary concept facility (with limited direct comparisons between different sludge types). It was noted that HTL technology occupies a minimal land footprint and operates 100 times faster than anaerobic digestion employed in established WWTPs. Although no technical design was attempted, results showed a 50 % reduction in sludge mass, with 30 % of liquefaction products converted to bio-oil, and most metals sequestered within a small mass of solid bio-char residue. As human-generated wastes consist of i.a., nutrients and organics, the enormous potential environmental, economic, and societal benefits were emphasized in the recovery and recycling of these components, as opposed to disposal by existing WWTP technologies. The authors recounted that, for a community of 1 million people, metals in bio-solids were valued up to US$ 13 million per year, amounting to a relative potential economic value of US$ 280/ton of sludge, when extracting the 13 most valuable elements (including Ag, Au, Fe, Pd, Ti, Ga, and Cr).

Presently, sewage sludge treatment and disposal comprise land application, incineration, and landfill disposal. Land application (by which approx. 55 % of sludge is disposed) has been widely encouraged (assuming that the organic content would promote soil enrichment, stabilization and crop growth) – the presence of non-regulated metals and contaminants of emerging concern (CEC's) has raised substantial public health and environmental concerns (as noted Peccia and Westerhoff, 2015, cited above). Incineration (by which approx. 15 % of sludge is disposed) leads to human toxification associated with the release of heavy metals and particulates into the atmosphere. Landfilling (by which approx. 30 % of sludge is disposed) is increasingly becoming the only available method of treating sludges with high metals/CEC content.

Growing urbanization have led to increased carriage costs required to transport sludges to ever remote (and lesser available) disposal sites (Hong et al., 2009).

GHG emissions and potential groundwater contamination from the leachate with landfilling has prompted debate as to the suitability of existing treatment technologies, which have, over past decades, merely slowly adapted to increasing environmental regulation (Giusti, 2009). These technologies include O_2 demand reduction, phosphorous precipitation, and biological treatment trains (e.g. (de)-nitrification, enhanced phosphorous removal)) – these processes produce large volumes of low density (98 % water) biological solids, chemicals, and inert particles associated with the lipid-rich bio-cellular materials, requiring longer solids retention times for anaerobic digestion (i.e., large reactor volumes/increased costs).

The potential of and need for applying HTL technology to aqueous waste-biomass streams are clear. HTL is an energy intensive, costly technology which (together with technical challenges associated with i.a., continuous processing) have seen past efforts at commercialization hampered. However, given the reduction of GHG emissions as well as the necessity for the amelioration of water environments as primary drivers, economic viability of a commercial-scale biorefinery may yet be established, especially within the unique Southern African geo-political, and economic environment. Accessibility to the novel NWU cHTL facility would serve to generate real-time data serviceable to eventual cost modelling, and assessment.

CHAPTER 3 MATERIALS AND METHODS

3.1 Preamble

This chapter details the materials and methods utilized in conceptualizing a design of a commercial-scale hypothetical biorefinery, processing wet municipal waste streams. The discussion distinguishes between experimental methodology, process simulation methodology, and techno-economic analysis methodology, respectively. Unless appearing otherwise from the context, any reference to Aspen Plus® refers to Advanced System for Process Engineering Plus, Version 8.6, a deterministic steady-state chemical process simulator employed in process modelling and cost analysis (Aspen Technology Inc., 2012).

The Department of Science and Innovation / National Research Foundation Biofuels Research Chair is seated at the NWU and houses South Africa's first cHTL pilot plant. For this study, the pilot plant was used to generate pilot-scale data to model a biorefinery converting readily available wet municipal bio-waste streams to fuel and chemicals without extensive pre-treatment. This, in turn, allowed for the techno-economic analysis (TEA) of the process, utilizing actual experimental data (as opposed to a wholly theoretical desktop assessment), which is seldom observed for TEAs of biomass-based processes. Comparatively, very little pilot-scale data is available on the cHTL of wet biomass. To date, no TEA on coprocessing sewage waste with green waste to produce solid and liquid fuels using pilot-scale data has been reported in the literature. Although the potential for processing wet organic waste is well recognized, few attempts have been made toward piloting facilities, mainly because of technical constraints relating to continuous reactor design and pumping of slurries at relatively high temperatures (300 °C to 360 °C) and pressures (9 to 13 MPa).

The NWU cHTL piloting facility used to generate data for this study is shown in **Figure 3-1**. It comprises a preheater section (1), a continuous pipe reactor section (2), and a heat transfer oil heating plant (3). The latter supplies heat to the preheater sections, and the reactor section. The working reactor volume is 20 L, providing a residence time of 10 minutes. Four interconnected tanks (with a collective capacity of approximately 150 L) feed into the intake manifold, which is connected to the circulation slurry pump, that pumps the slurry back into the feed tanks. The feed slurry is circulated at the requisite pressure for the reactor section to keep solids in suspension and ensure a uniform feed to the preheater and reactor sections. Flow through the reactor is driven by the pressure difference between the feed and product tanks. The preheater initiates the initial increase in temperature to ensure the feed is at the same temperature as the oil-heated reactor.

Figure 3-1: The NWU continuous HTL reactor.

3.2 Experimental methodology

A cHTL reactor feed was blended from various WWTP discharges, namely, a Recycled Activated Sludge (RAS) stream and a Discharged Sewage Sludge (DSS) stream collected from the primary settling stage at the wastewater treatment plant at Potchefstroom (-26° 43' 0.01" S, 27° 06' 0.00" E), South Africa.

Photographs of the RAS and DSS sampling points are provided in **Figure 3-2** and **Figure 3-3**, respectively. Each sampling point provided for the collection of 1,000 L sample. The DSS tailings dam is shown in **Figure 3-4**.

To model the concept, green waste (comprising sugarcane bagasse obtained from the sugarcane industry) was also included to allow for an increased carbon content in the feed (SCB).

Figure 3-2: Recycled Activated Sludge (RAS) dam.

Figure 3-3: DSS sampling point.

Figure 3-4: Municipal Discharged Sewage Sludge (DSS) dam.

Permitting varied blends of these stream components further established an economically robust process design. The optimal feedstock blend (based on sensitivity analyses of feedstock composition and reactor residence time vs product yields) was reacted in the cHTL plant at temperatures of approximately 190 - 195 °C and pressures of approximately 90 - 95 bar, without the addition of any additional catalysts.

Reaction products were recovered from the plant product tanks, and solids and liquids were separated using acetone as a solvent to quantitatively transfer the reaction mixture to a filtering press. The hydrochar solid product was washed with acetone to remove all residual oil residues, and then oven-dried overnight at 105 °C before the hydrochar yield was gravimetrically determined. The oil and water phases were separated by gravity-settling, and the oil subsequently recovered from the organic layer through evaporation. The recovered biocrude oil was oven-dried overnight at 60 °C, and the yield gravimetrically determined. Compositional analyses of intermediary streams and final products were determined by Inductively Coupled Plasma Analysis (ICP analysis), elemental analysis, and Gas Chromatography–Mass Spectrometry (GC-MS). The higher heating value of the biocrude product was also established using a bomb calorimeter.

3.2.1 Inductive coupled plasma-optical emission spectroscopy (ICP-OES) analysis

The concentration of inorganic components and metals in the wastewater samples were quantified using an Agilent Technologies 725-ES ICP-OES instrument equipped with a radical torch. Preparation involved filtering samples using a 0.45 µm syringe filter, followed by the tenfold dilution of each sample (with ultra-pure water) in a centrifuge tube, which was then carefully mixed (vortexed) before each analysis. The argon flow to the plasma was 15 L/min with auxiliary and nebulizer flow rates of 1.50 L/min and 0.75 L/min respectively, and a viewing height of 12 mm. A 1% nitric acid solution was used as the mobile phase for analysis. The instrument was calibrated for the detection and quantification of Ca, K, Mg, Na, Si, S, Zn, Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Tl and V before one blank sample with deionized water. Results were read against standards as calibrated.

3.2.2 Elemental analysis

The carbon, hydrogen, and nitrogen content of the hydrochar samples were analyzed with an Exeter CE-440 Elemental Analyzer based on the ISO 12902–CHN Instrumental method. Sample preparation was performed according to IDO 13909-4:2001, and oxygen was calculated as a percentage difference.

3.2.3 Gas Chromatography–Mass Spectrometry (GC-MS) analysis

GC-MS was used to analyze for the presence of organic components with a boiling range below 500 °C (limited by column and analysis technique) in the biocrude oil. An Agilent 7890 GC-MSD gas chromatograph with a 5975 Triple Axis MSD detector was used. The instrument was fitted with a 30 m VF-5ht Ulti-metal column with a diameter of 0.25 mm and a film thickness of 0.1 µm. An inlet temperature of 250 °C was used. Preparation involved filtering samples using a 0.45 µm and 0.2 µm syringe filter, followed by the dilution of each 250 µL sample (with 1mL dichloromethane, after addition of 25 µL of internal standard), which was then carefully dissolved in an ultrasonic bath for 20 minutes at 30 °C before each analysis. The oven temperature was initially kept constant at 45 °C for 8 minutes and then ramped to 100 °C at 2 °C/min. The temperature was then again ramped up to 162 °C at 7 °C/min and kept constant for 5 minutes. The temperature was then ramped up to 300 °C at 7 °C/min, and again to 350 °C at 20 °C/min. The injection volume was 1 µL (auto-injection). Helium (He) served as carrier gas with a total flow rate of 13.3 mL/min, and split ratio of 5:1.

3.2.4 Bomb calorimetry analysis

The higher heating value was determined using an IKA C5003 calorific analyzer. The analysis was performed according to the SANS 1928:2009 ISO 1928:2009 standard.

3.2.5 Proximate analysis

The ash content of samples was determined according to the NREL/TP-510-42622 standard method. Specifically, porcelain crucibles were weighed to the nearest 0.1 mg, and the mass was recorded before the crucibles were loaded with approximately 0.5 g of the sample. The samples were ashed using a muffle furnace with the temperature controlled by means of a ramping program. The furnace was heated from room temperature to 105 °C and held for 12 minutes, then further heated to 250 °C and held for 30 minutes, and finally heated to 575 °C and held for 180 minutes, after which the crucibles were removed from the furnace and placed in a desiccator to cool. The mass of the crucibles and ash was recorded to the nearest 0.1 mg. The volatile matter of the MW was determined according to the SANS 50 standard method, and fixed carbon was determined by difference. Porcelain crucibles were weighed to the nearest 0.1 mg, and the mass was recorded before the crucibles were loaded with approximately 0.5 g of the sample. The crucibles with their lids were placed inside a muffle furnace at approximately 900 °C for 7 minutes. The crucibles were removed and allowed to cool to room temperature in a desiccator. The crucibles were weighed, and the weight was recorded. The moisture content of the MW was determined according to the NREL/TP-510-42621 standard method. Porcelain crucibles were weighed to the nearest 0.1 mg, and the mass was recorded before the crucibles were loaded with approximately 0.5 g of the sample. The crucibles were placed inside a muffle furnace at approximately 105 °C until a dry constant weight. The crucibles were removed and allowed to cool to room temperature in a desiccator. The crucibles were weighed, and the weight was recorded until a ± 0.1 mg change was detected.

3.2.6 Pathogen analysis

Both the sewage and aqueous product streams were tested for harmful pathogens to test the hypothesis that HTL sufficiently sterilizes primary sewage. The analyses were performed according to standardized ISO methods. A specific growth medium was used for each micro-organism. Colonies were counted after 24 or 48 hours, depending on the standardized incubation period specified.

For the aqueous product, testing was conducted for *Escherichia coli* (*E. coli*)[1], *Staphylococcus aureus* (*S. aureus*)[2], *Salmonella*[3], *Pseudomonas aeruginosa* (*Pseudomonas*)[4], and sulphate-reducing bacteria[5], respectively.

Testing was also conducted for generic *Listeria* (*Listeria spp.*)[6] and a specific strain of *E. coli* (*E. coli 0157*)[7], with the latter responsible for causing severe intestinal infection in humans.

Testing methods for the *Salmonella* and sulphur-reducing bacteria are not specific to a species, with further characterization considered beyond the scope of the hypothesis.

3.3 Process simulation methodology

Figure 3-5 provides a schematic layout of the biorefinery concept. It was assumed that the SCB would be air-dried and milled to an average size of 1.77 mm before mixing with the RAS and DSS streams. The assumed pre-treatment of the SCB was the same as that performed for the pilot plant experiments.

Because experimental data showed a relatively high concentration of recoverable alkali and alkali earth metals (AAEMs) in the aqueous product, a separation section was included in the process design to recover these metals using a hydrochar adsorption step. Adsorption capacity data for AAEMs onto the hydrochar was taken from Marx et al. (2021) and used to calculate removal efficiencies. To wash adsorbed AAEMs from the hydrochar, hydrochloric acid (HCL) was introduced into the process design to yield chlorine salts according to reported de-adsorption kinetics.

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[1] using Standard Test Method TEC-27, SANS 4832:2007 Colony Count Technique

[2] using Standard Test Method TEC-23, SANS 6888-1:1999; SANS 5221:2018 Horizontal Method

[3] using Standard Test Method TEC-31, SANS 6579:2003 Oxoid Salmonella Rapid Culture Method

[4] using Standard Test Method TEC-30, SANS 13720:2017; SANS 5221:2018 Enumeration Method

[5] using Standard Test Method TEC-40, SANS 6133-2007; SANS 5221:2018 Most Probable Number Technique

[6] using Standard Test Method TEC-32, SANS 11290-2:1998, SANS 5221:2018 Oxoid Brilliance Chromogenic Listeria Method

[7] using Standard Test Method TEC-44, SANS16654:2003SANS5221:2018 Horizontal Method

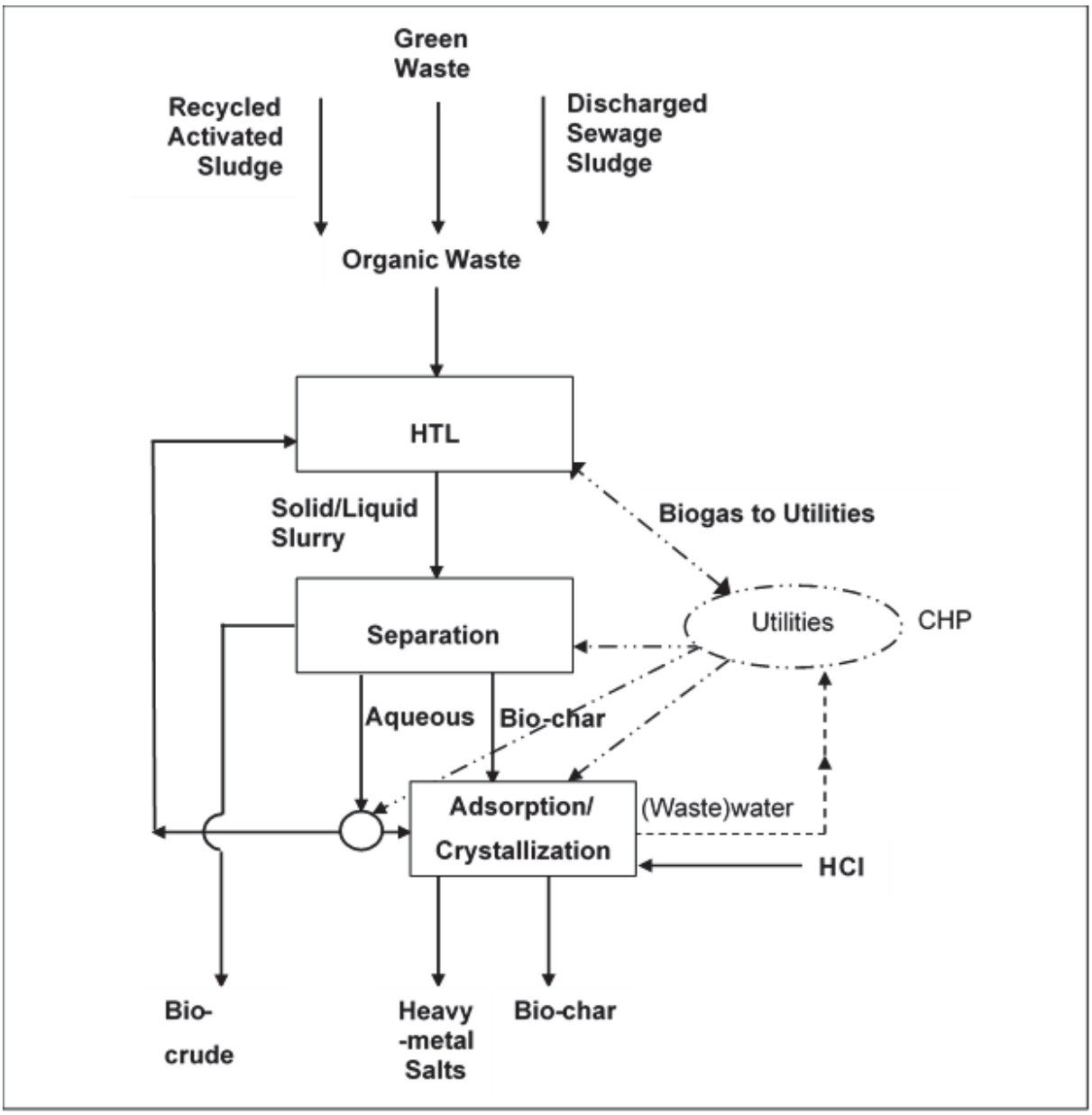


Figure 3-5: Schematic layout of simulation strategy for the proposed waste-based biorefinery.

The process strategy further utilized biogas in a CHP utility network to supplement plant heat and energy requirements. The aqueous product stream was also used to supply heating and cooling duties as part of the utility network. The design further included the recycling of a fraction of the aqueous product back to the reactor section to supplement the solvent in the cHTL reactor. The remaining aqueous product was contacted with the hydrochar product to recover AAEMs. The separation section consisted of consecutive solid separation and two-phase separation steps, resulting in final organic biocrude and aqueous products.

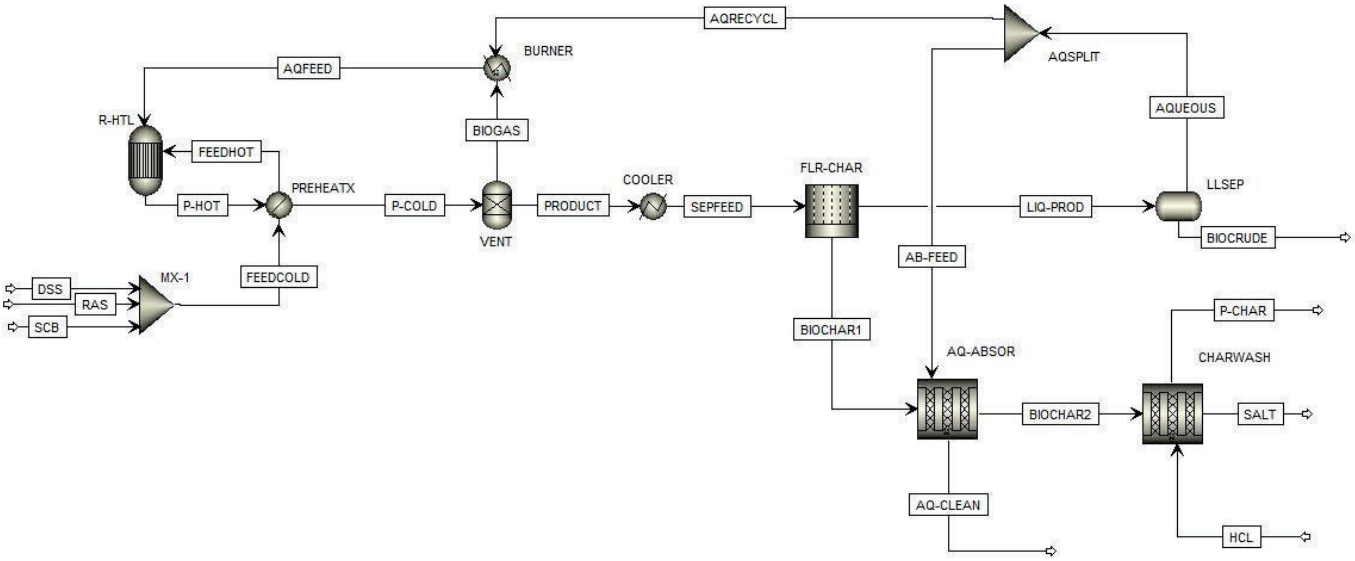
The hydrochar product, acting as filter and adsorbent, was washed with the filtrate from the aqueous split phase-separated stream and then fed to the integrated utility supply. In commercial applications, the filtrate may be split to supplement purified water reservoirs (as a value product sold back to municipalities/WWTPs). Following the aqueous wash, the solid product was subjected to an acid wash with HCL, removing various metals and impurities as crystallized salts. This step provided for a purified hydrochar (high-value adsorbent) product, as well as various chloride salts.

Following the establishment of the process design strategy, the biorefinery was modelled using an industry-standard deterministic steady-state chemical process simulator, Aspen Plus®. Input assumptions were specified for unit operation blocks and streams, based on information from the design basis and experimental piloting results. Final product yields, energy efficiency, and economic performance of the systems were calculated based on modelled results.

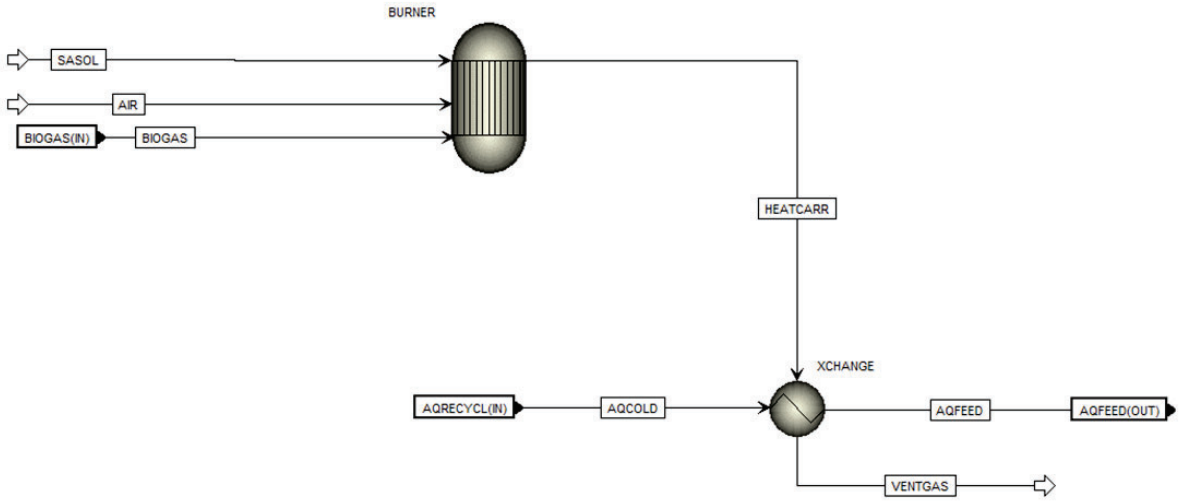
The Soave-Redlich-Kwong (SRK) cubic equation of state was used as a thermodynamic model applied in the synthesis plant, as verified with Eric Carlson's (Carlson, 1996) and Bob Seader's (Seader et al., 2006) decision trees. Accordingly, biomass feedstock was modelled as non-conventional solids. The HCOALGEN model was used to calculate the enthalpy of the said components, while the DCOALIGT model was used in modelling the density. These models were developed and are usually applied for coal-derived substances, making them especially suitable for carbon-containing species such as biomass (Hoffmann et al., 2013).

The HCOALGEN model includes several different correlations, using the heat of combustion, the heat of formation and heat capacity, the Boie correlation and the Kirov correlation, based on entered elemental attributes of the components. Therefore, the model requires the input of the ultimate, proximate and sulphonate analysis of components. Ultimate, proximate and sulphonate analytic data generated from sampled local municipal sewage streams were utilized, with elements assumed to be in their standard states for calculation (i.e., 298.15 K and 1 atm). The lower heating values (LHV) of the feedstock(s) were calculated using the ultimate analysis and the Boie correlation (Boie, 1957).

The DCOALIGT model is based on equations of state from the Institute of Gas Technology (Aspen Technology Inc., 2012). The model utilizes ultimate and sulphonate analysis to calculate densities. The Aspen Plus® simulation flowsheet of the biorefinery is shown in **Figure 3-6(a)**.



(a)



(b)

Figure 3-6: Aspen Plus® flowsheet of the waste-based biorefinery (a), together with [BURNER], inside the hierarchy block (b).

3.4 Techno-economic analysis methodology

In performing the cost analysis, Aspen Process® Economic Analyzer (APEA) was utilized as a process cost estimator, performing equipment sizing and using developed costing algorithms and databases to prepare detailed lists of bulk materials and process equipment costs. Each function in the modelled system (including its various interactions) comprising the detailed theoretical synthesis plant, was specified and analyzed. This was followed by an estimation of capital investment (installed equipment) and (variable and fixed) production costs, including feedstock cost and utilities. Following calculation, cashflow projections were determined, allowing for sensitivity analyses to establish the effect of economies of scale, capital investment, and plant efficiency on product unit cost (PUC). This was followed by an estimation of Internal Rate of Return (IRR) and Net Present Value (NPV).

To report capital, operational, and other costs associated with an estimation of the feasibility of the process, all values were reported in US Dollars ($). The currency was selected based on the South African Rand exchange rate, averaged for 2021 as on 15/08/2021, with US$ 1.00 / ZAR 14.75 (or US$ 0.068 / ZAR 1.00) (CEIC, 2021).

Sizing calculations provided attaching costs of material and labor required to fabricate and install process equipment, as well as the materials and quantities required for foundations, supporting structures and process piping, instrumentation, electrical wiring, structural steel, etc. Costs for an African-based project were specified, providing for an associated cost evaluation basis, specifically Capital and Operating Cost Basis and Assumptions for Cash-Flow Analysis respectively. APEA's default assumptions and settings for calculating the economics of a novel biochemical processing plant in Africa were left unchanged and was assumed to be accurate.

For a plant capacity of 645.8 kg/h over an analysis period (plant life) of 20 years, the time difference between the system cost base date and start date for engineering was specified at 4.75 years. 52 weeks and 8000 hours per period were assumed, with a 3-year duration set for the engineering, procurement, and construction phases. The construction phase was estimated at 57 weeks, together with a 20-week period for start-up. Working capital was assumed to be 15 % of the total capital investment. Operating charges were specified as a function of total variable costs and labor costs over the analysis period. Plant overheads were specified by the APEA as a function of maintenance, research and development, taxation, and licensing costs over the analysis period.

General and administrative expenses were similarly quantified as a function of total capital investment and variable costs over the analysis period. Escalation on project capital as well as product price over the analysis period were based on a Consumer Pricing Index (CPI) of 6.4 % (IDC, 2020). Escalation on operating, maintenance, labor, and utilities over the analysis period was based on a CPI of 3 % (IDC, 2020).

Concerning assumptions for the cashflow analysis, 50 % capital expenditure was assumed for Year 1, with 25 % expenditure for Years 2 and 3 respectively. Plant production was assumed at 25 % of full capacity in the first 6 months of operation; 50 % of full capacity between months 6 to 12; 50 % of full capacity during Year 2, with 100 % operational capacity assumed from Year 3 onwards. The reducing balance depreciation method was applied at a taxation rate of 28 %.

Artificial tools in the flowsheet and simulation were included for modelling but excluded from component mapping when calculating unit operations or equipment costs. Indirect field costs comprised office costs, field supervision, start-up, and commissioning. Non-field costs comprised freight, taxes and permits, basic and detailed engineering, procurement, overheads, and contract fees. A contingency of 15 % was specified, allowing for variance in process costs. Utility costs were calculated based on local rates reported for December 2020, as indicated in **Table 3-1**. The rates noted in the table were applied for commercial and industrial usage at maximum scales, discarding municipal rebates or governmental subsidy.

Calculated capital and variable costs were used in generating a cashflow analysis to estimate the IRR as well as NPV over the period of analysis. Variable operating costs were calculated based on the consumption of raw materials, chemicals, wastes, and utilities from simulation results, with related unit prices obtained from the literature or vendor quotations. The prices set out in **Table 3-1** were utilized in the process design for the feed and product streams. Biomass feedstock prices were assumed to be US$ 0.00/kg, including the cost of procurement overheads; this was based on the concept of an add-on commercial facility using of existing WWTP infrastructure. Electricity, water, and heat utilities were defined in the flowsheets. Quoted at maximum commercial and industrial rates (or the literature, where indicated), electricity was based on the purchase price, water was based on the purchase price and calculated side film-coefficient, and the heat was based on the coal purchase price, calculated side film-coefficient, and heating value.

Table 3-1: Feedstock, product and utility costs used in the techno-economic analysis.

Item	Value (US$/kg)	Notes/Source
Feedstock		US$ /ZAR exchange rate from 12/08/2019 to 06/02/2020 (Reuters, 2020)
DSS	0	
RAS	0	
SCB	0	
HCL	42	
Products		
Biodiesel	0.77	Based on 65 % Wholesale Diesel Price by the South African Dept. of Energy, Feb. 2020: ZAR 14.57/L (Zone 9C (Inland)) (0.05% Sulphur content)
Biocrude	0.59	Per kg. Based on average Brent Crude 2020, US$ 59.13/barrel at 119.24 L/barrel (bbl US) (Reuters, 2020)
Hydrochar	2.47	Per kg. Based on Jirka and Tomlinson (2014)
Treated water	2.72	US$/$m^3$ Based on 90 % of Fresh Water Price
Sodium Chloride (NaCl)	84.40	Sigma-Aldrich Corporation (2019)
Potassium Chloride (KCl)	176.10	Sigma-Aldrich Corporation (2019)
Calcium Chloride (CaCl2)	144.10	Sigma-Aldrich Corporation (2019)
Magnesium Chloride (MgCl2)	56.50	Sigma-Aldrich Corporation (2019)
Utilities		
Electricity	0.15	US$/kWh. Based on Eskom Tariff Quotation calculated at 216.77 c/kWh
Fresh water	3.02	US$/$m^3$ Based on Business / Industrial for consumption exceeding 200 kL, ZAR 44.50/kL, Gauteng Province 2019/2020
Heat (Coal Price)	76.03	US$/ton. Based on Coal Export Price (RSA), Dec. 2019: US$ 76.03/ton (Bituminous Coal Heating Value ≈ 25 kJ/kg)

As the capital cost of a project rarely varies linearly with plant capacity, cost capacity or scale-up factors are generally used for approximating the costs of projects of different sizes. The ratio of the capacities of two similar projects is generally not the same as the ratio of their costs, in contrast to inflation and location indexes (which are accounted for with APEA simulation).

Based on Amigun et al. (2010) and Remer and Mattos (2003), the following correlation provides for the adjustment,

$$Cost_2 = Cost_1 \left(\frac{Size_2}{Size_1}\right)^n$$

where n = scale exponent or cost capacity factor. This formula was applied by the authors to establish the effect of scale-up for a biomass-fed hydrothermal plant located in (South) Africa.

South Africa is defined as a technologically advanced developing country with well-diversified and comprehensive industrial, energy, and research and development infrastructures (Amigun et al., 2010). The reported synthesis plant is not an nth plant, as no commercial HTL plants utilizing biomass as feedstock are available on the African continent (i.e., not an established technology). This qualifies it as a Type A country, with n = 0.7.

The cost and size were utilized to establish the effect of economies of scale, based on a plant efficiency of 60 %, as adopted from Anastasakis et al. (2018), who assessed process efficiency for cHTL of sewage sludge at a nominal flow of 100 L/hr.

3.5 Concluding remarks on materials and methodology

Chapter 3 set out materials and methods utilized in the sampling and characterization of WWTP waste streams, as feedstock for the piloting NWU cHTL facility. Detailed standardized analytical methods, together with associated calculations, were similarly applied to cHTL product streams, establishing product compositions and yields. Experimental results were used during simulation, with the approach to process design modelling, including related assumptions and parameters, discussed. The chapter also provided inputs and assumptions pertaining to the techno-economic analysis methodology (as relying on results from process simulation), disclosing the approach to cost modelling. The information provided in this chapter is intended to enable the Reader to duplicate results, presuming access to the same materials, piloting and analytical equipment, and process and costing software.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Preamble

This chapter sets out the results obtained following utilization of materials and methods detailed in Chapter 3. Results are discussed and interpreted against the background of the established literature, to the extent possible. As mentioned, this is due to the diverging assumptions related to a multitude of technical and economic factors relied on by authors when performing techno-economic analyses; reasons are detailed below. It is for these reasons that published works involving techno-economic analyses on process simulations take on the format of case studies, as they apply in a particular geo-political environment.

The present study sets forth a baseline design and economic assessment as pertaining to the South African situation (and similar oil deficient, exchange rate challenged counties facing compromised health environments), providing a base case for comparison for future research efforts. The discussion presented in this chapter distinguishes between experimental results, process simulation results, and techno-economic analysis results, respectively.

4.2 Experimental results

4.2.1 Feedstock characterization

Table 4-1 provides some of the properties and characteristics of the feedstock streams used in the experimentation and simulation. The sugarcane bagasse was the largest source of carbon in the feed, with the sewage streams containing the most metals that were concentrated in the ash.

As noted by Michalska et al. (2022), due to the wide-ranging characteristics of incoming wastewater as well as varying treatment technologies, the composition of raw sewage sludge discharged during the wastewater treatment process varies significantly among WWTPs. The authors also noted that processing methods might affect, i.a., the stage of organic matter decomposition in this residue and thus its overall carbon content, which makes direct comparisons between WTTP discharges tenuous. This notwithstanding, the results provided in **Table 4-1** fell within the limits reported by Michalska et al. (2022). The authors provided an overview of sewage sludge compositions from various WTTPs which, in turn, was obtained from numerous literature sources. To model the cHTL plant and estimate the eventual economic indicators, the results shown in **Table 4-1** were regarded as sufficiently representative of a typical South African WWTP sewage sludge composition.

Table 4-1: Characteristics of feedstock.

Property	Value ± Standard Deviation		
	RAS	DSS	SCB
Moisture (mass %)	93 ± 0.2	98 ± 0.1	6.3 ± 0.1
Proximate analysis (mass %) (db)			
Volatile matter	66 ± 0.5	52 ± 1.6	74.3 ± 0.7
Ash	22 ± 1.7	38 ± 1.8	11.6 ± 0.1
Fixed Carbon	10 ± 2	12 ± 3.2	14.0 ± 0.8
Elemental analysis (mass %, daf)			
Carbon (C)	35.3 ± 0.1	18.6 ± 0.3	36.4 ± 1.3
Hydrogen (H)	5.6 ± 0.1	3.8 ±0.1	4.7 ± 0.1
Nitrogen (N)	6.1 ± 0.3	4.0 ± 0.5	0.6 ± 0.03
Oxygen	53.0 ± 0.4	73.6 ±0.3	58.3 ± 1.4
Higher heating value (HHV) (MJ/kg)	18 ± 0.2	19 ± 0.4	9.2 ± 1
Metal content (mass %)			
Calcium (Ca)	3.5 ± 0.2	2.5 ± 0.06	0.9
Potassium (K)	0.005 ± 0.1	1.0 ± 0.02	1.4
Magnesium (Mg)	30.3 ± 2.2	1.8 ± 0.03	0.5
Sodium (Na)	13.8 ± 0.8	0.3 ± 0.01	-
Aluminum (Al)	0.05 ± 0.01	0.48 ± 0.01	3.6
Manganese (Mn)	0.1 ± 0.03	0.1 ± 0.002	-
Iron (Fe)	13.8 ± 1.4	1.0 ± 0.01	8.4

4.2.2 Analytical results

Table 4-2 provides cHTL product yields as well as some characteristics of the products.

Most of the metals report to the aqueous product and could thus be recovered by adsorption using a suitable adsorbent. The gas product mainly comprised carbon dioxide (CO_2) and methane gas (CH_4).

Table 4-2: cHTL product yields and characteristics.

Property	Biocrude	Hydrochar	Gas	Aq. product
Yield (mass %) (wet)	0.7 ± 0.4	9.2 ± 0.3	23.4 ± 7.2	66.7 ± 6.9
Proximate analysis (mass %) (wet)				
Moisture		0.9 ± 0.07	-	-
Volatile matter		44.2 ± 0.09	-	-
Ash		22.2 ± 0.08	-	-
Fixed Carbon		32.8 ± 0.07	-	-
Elemental analysis (mass %, dab)				
C	67.9 ± 0.2	53.8 ± 0.5	-	-
H	7.7 ± 0.07	4.4 ± 0.1	-	-
N	2.39 ± 0.5	3 ± 0.6	-	-
O	22 ± 0.3	38.8 ± 0.7	-	-
HHV (MJ/kg)	30.3 ± 0.6	22.1 ± 0.6	-	-
Metals (mg/L)				
Ca	-	0.7 ± 0.07	-	33 ± 1.2
K	-	0.1 ± 0.02	-	7.1 ± 1
Mg	-	0.3 ± 0.02	-	50.7 ± 1.7
Na	-	0.04 ± 0.007	-	58.2 ± 2
Al	-	0.3 ± 0.06	-	0.1 ± 0.01
Mn	-	0.03 ± 0.004	-	1.9 ± 0.02
Fe	-	0.3 ± 0.05	-	19.6 ± 0.7
Total phenol content	38 ± 3 mass %	-	-	3.6 ± 0.3 g/L

Results compared favorably to that of Marx et al. (2021), who investigated the co-adsorption of AAEMs and phenolic components onto hydrochar prepared from the organic fraction of municipal solid waste. The authors reported yields of 0.7 ± 0.4 for the biocrude oil product, 14.1 ± 0.6 for the hydrochar product, 22.9 ± 7.5 for process gas, and 56 ± 7 for the aqueous product (mass fraction %, wet basis). The HHV of the biocrude oil product was determined at 31.5 ± 0.3, with that of the hydrochar product reported as 28.3 ± 0.3. Similarly, adjusting for feedstock composition and operating conditions, proximate, elemental, and ICP-OES analyses were analogous for the cHTL products. Although other reports of lab-scale or batch HTL of varying sludge have been noted, all were conducted for optimal biocrude yield (versus hydrochar coproduction, with AAEM recovery), with most utilizing catalysts and solvents other than water (Fan et al., 2022) – biocrude HVVs of 26.6–39.7 MJ/kg were observed.

While some examples of cHTL piloting plants for sewage sludge treatment are under development, limited information on reactor designs, operating conditions and capacities are available. Itoh et al. (1994) reported on a demonstration plant with a capacity for processing 15 kg/h dewatered sludge, resulting in biocrude yields of 40–53 %, having an HHV of 37–39 MJ/kg. Anastasakis et al. (2018) presented results on a novel cHTL reactor, treating, i.a., sewage sludge feeding at 100 L/h and providing a biocrude yield of 25 % and HHV of 26.8 MJ/kg. Marrone et al. (2018) provided a proof of concept of a bench-scale cHTL reactor, feeding primary and secondary sewage sludge at a flow rate of 1.5 kg/h resulting in biocrude yields of 25-37 % and HHVs of 34.8–37.8 MJ/kg. As with reported batch efforts, operation strived for optimal biocrude production, with little to no data provided on hydrochar and aqueous streams.

In the present study, both the sewage feed and aqueous product streams were tested for harmful pathogens to test the hypothesis that cHTL would be sufficient to sterilize primary sewage.

For the aqueous product, the results showed <10 Cfu/mL for *E. coli*[1], *S. aureus*[2], *Salmonella*[3], *Pseudomonas*[4], and sulphate-reducing bacteria[5], respectively. The results also showed the absence of *Listeria spp.*[6] and *E. coli 0157*[7] in the aqueous product. Similar results were obtained with identical standard test methods for the RAS and DSS streams, specifically for the *S. aureus*, *Salmonella*, *Listeria spp.* and sulphate-reducing bacteria pathogens. However, *E. coli 0157* was detected in these sewage streams, with the DSS additionally exhibiting 90 Cfu/mL of *E. coli* and 30 Cfu/mL of *Pseudomonas*. The RAS stream also exhibited 300 Cfu/mL of *E. coli* and less than 10 Cfu/mL *Pseudomonas*. The occurrence of pathogens in the sewage feed fell within ranges reported by Fijałkowski et al. (2017), who reviewed the quality of sewage sludges worldwide.

Results show that the cHTL process managed to sterilize all harmful pathogens in the sewage feeds to below harmful levels, supporting the hypothesis for using HTL technology as a sterilization step while producing high-energy products.

4.3 Simulation results

Referring to **Figure 3-6**, **Table 4-3** provides the stream table as obtained from the Aspen® simulation with the flow rates, temperature and pressure of each stream indicated.

The feed streams for discharged sewage sludge, recycled activated sludge, and green waste were designated as Streams [DSS], [RAS], and [SCB], respectively. Streams [DSS], [RAS], and [SCB] were mixed in mixer [MX-1], pre-heated by the reactor effluent stream [P-HOT] in a heat exchanger [PREHEATX] and charged as stream [FEEDHOT] to the cHTL reactor, shown as [R-HTL]. Proximate and elemental analysis of dried samples of the DSS, RAS and SCB feedstock showed that the SCB feed component had the highest carbon content, and the wet DSS feed the lowest. For this reason, Streams [DSS], [RAS], and [SCB] were fed to mixer [MX-1] in the ratio of 0.60:0.25:0.15, with a total biomass feed to the reactor chosen as at 640 kg/hr, based on chosen reactor capacity. The recycled aqueous product stream [AQFEED] was recycled back to the reactor for the correct biomass-to-liquid ratio.

The cHTL reactor [R-HTL] was modelled as a yield-type reactor, with values for the reactor taken from product yields following experimental runs on the NWU cHTL pilot plant. Product discharge from the reactor was cooled and then transferred to a vent, where biogas produced during liquefaction was vented and fed to a burner for utility application. The burner ([BURNER]) was represented by a hierarchy block. The slurry exiting the vent was cooled and charged to a solid separator (Block [FLR-CHAR]). In the separator, the solid product (hydrochar) was separated from the aqueous/organic liquid product, with the liquid stream feeding to a two-phase separator (Block [LLSEP]).

During phase separation, the organic product comprising biocrude oil was isolated from the aqueous product and discharged from the separator as the final product ([BIOCRUDE]). The aqueous product from the phase separation was discharged from the separator to a splitter ([AQSPLIT]), recycling 40% of the aqueous stream to the reactor unit to improve product yields. The reactor feed stream comprising the recycled aqueous product ([AQRECYCL]) was heated to the desired temperature via burner and fed back to the cHTL reactor. The temperature of the recycled aqueous was increased from 25 °C to 280 °C, due to cost concerns.

Table 4-3: Stream table generated by Aspen Plus® flowsheet simulation.

Stream ID	Flow rate (kg/hr)	Temperature (°C)	Pressure (bar)
DSS	380	25	1
RAS	160	25	1
SCB	105.8	25	1
FEEDCOLD	645.8	25	1
P-HOT	925.5	195	95
FEEDHOT	645.8	102.1	1
P-COLD	925.5	87.3	95
AQFEED	279.8	261.1	1
BIOGAS	204.4	87.3	95
PRODUCT	721.2	87.3	95
SEPFEED	721.2	25	1
AQRECYCL	279.8	25	1
BIOCHAR1	14.9	25	1.2
AB-FEED	419.6	25	1
AQ-CLEAN	415.6	25	1
LIQ-PROD	706.3	25	1.2
BIOCHAR2	18.9	25	1
AQUEOUS	699.4	25	1
BIOCRUDE	6.9	25	1
P-CHAR	14.5	14.5	1
SALT	1270.9	14.5	1
HCL	1266.5	25	1
SASOL	100	25	1
AIR	590	25	1
HEATCARR	894.4	575.2	1
AQFEED (AQFEED (OUT))	279.8	261.1	1
BIOGAS (BIOGAS (IN))	204.4	87.3	95
VENTGAS	894.4	51.4	1
AQCOLD (AQRECYCL (IN))	279.8	25	1

In defining the hierarchy block, it was assumed that gas was provided by a local utility supplier, with the stream chiefly comprising methane. The burner feed streams were burned as fuel to reheat the aqueous recycle stream. Air was utilized for complete combustion of the gas in the burner. Gas discharge from the burner was vented into the atmosphere. **Figure 3-6(b)** shows the simulation flowsheet of the hierarchy block, with simulation results included in **Table 4-3.**

Figure 3-6(b) indicates the gas from the local utilities supplier, air and process biogas being fed to the burner, and the burner discharge feeding to a heat exchanger. Here, stream [AQCOLD] was heated prior to being fed to the reaction as stream [AQFEED]. To model the hierarchy block, the following streams were synonymous: [BIOGAS(IN)] = [BIOGAS]; [AQRECYCL(IN)] = [AQCOLD]; [AQFEED(OUT)] = [AQFEED].

The remaining 60 % of the aqueous product from the splitter ([AB-FEED]) was transferred to an adsorber (Block [AQ-ABSOR]), where hydrochar product obtained from the solid separator was used as the adsorbent. Here, sodium, calcium, potassium, and magnesium were removed from the aqueous product through adsorption onto the hydrochar. The adsorber was modelled as a black box, with metal recoveries ranging between 86-99 % (Marx et al., 2021). Following removal of the metals onto the biochar, the purified water was discharged from the adsorber (and may be recycled back to WWTP at a premium). Hydrochar from the adsorber was washed with hydrochloric acid ([HCl]) to remove the sodium, calcium, potassium, and magnesium (as well as impurities) as chloride salts.

A crystallizer/filtration ([CHARWASH]) step was similarly modelled as a black box, assuming respective sodium chloride, magnesium chloride, potassium chloride and calcium chloride salts crystallized with a purity of >99 Wt%, with trace metals. The amount of HCL required for the filtration/crystallization operation was calculated by utilizing mass balance. Complete reaction was assumed, resulting in the complete removal of all metals from the biochar. Two product streams from this last process step comprised the hydrochar adsorbent product and the chlorine salts stream. These streams, together with the biocrude oil and clean aqueous discharge, comprised the main biorefinery commodities.

When conceptualizing a biorefinery process design, assumptions vary substantially from one design study to the next due to biomass feedstock diversity and costs (with considerations of sustainable availability, collection network, storage, food vs. fuel, etc.); pre-treatment techniques (mechanical, chemical, biological, etc.); processing technologies and varied operating conditions (e.g. biochemical or thermo-chemical, and in the case of the latter, pyrolysis, HTL, gasification, carbonization, etc.); downstream processing and associated costs (with considerations of high-value product isolation and associated unit operations, and utilization of waste streams, e.g. utility networks); and other implicit assumptions.

As a result of the significant variations of assumptions, in addition to high uncertainty about economic drivers, the large number of local, regional, and even global stakeholders involved, and further uncertainties attaching to their interactions, design studies diverge markedly, with no two pathways alike, as shown from the literature. It is for this reason that these design studies and the TEAs evaluating these process designs are considered on a case-by-case basis. Direct comparisons are simply intractable.

However, the current approach to process simulation mirrored that of Hoffmann et al. (2013). Although the authors did not perform a TEA on their process design simulation, they hinted at economic viability. The authors presented two process alternatives carried out in Aspen Plus® for an integrated organic waste treatment/conversion process. A flowsheet and process model for a hydrothermal liquefaction plant were developed, feeding 1000 kg/h of animal manure, consisting of four process blocks: a biogas plant, a cHTL plant, a H_2 production plant, and an upgrading unit. The model was loosely based on a process design by Toor et al. (2012), making use of CatLiq® technology for the liquefaction of wet distiller's grains with solubles. Digestate from the biogas plant was converted to a biocrude in the cHTL plant, with biogas produced by the former feeding to the H_2 production plant and utilities. The H_2 produced was then used in the upgrading process to produce diesel-quality fuel. According to the authors, this biorefinery concept offered a sophisticated and sustainable way of converting organic residuals into a range of high-value biofuel streams (although no co-/by-product streams were specified, other than those discharged), in addition to CHP production. The process design did not cater for a solid product stream nor AEEM recovery, electing instead for an upgrading step treating the biocrude. Based on said process model, Hoffmann et al. (2013) estimated yields of approximately 33.7 kg/h biocrude intermediary product with a calculated heating value of 43 MJ/kg. Normalizing for the feed flow rate of the present study, simulation results provided for 10.8 kg/h of the biocrude product (with an experimentally validated HHV of 30.3 MJ/kg) as well as 22.7 kg/h hydrochar (having an experimentally validated HHV of 22.1 MJ/kg).

Although energy results may appear comparatively similar to that provided by Hoffmann et al. (2013), it is most significant that the present study relied on actual cHTL piloting results (as opposed to a purely theoretical investigation reported by the referred authors). In addition, the authors' simulation did not provide for a solid product, utilizing process conditions for optimizing (upgraded) biocrude oil product – with the price of the hydrochar solid product approximately four times that of the liquid biocrude, and as TEA results below show, the present process design provides for a relatively more attractive economic prospect.

4.4 Techno-economic results

Following the simulation of the synthesis plant in Aspen Plus®, APEA was initiated, unit operations mapped, and associated equipment and utility costs calculated. Generated simulation data was then exported from APEA and analyzed according to established industry methods and practices presented by Peters et al. (2003). The value engineering approach was observed to perform the TEA, calculate capital investment and operating costs, and generate cashflow with associated economic indicators. **Table 4-4** details the calculated total (direct and indirect) capital investment cost (TCI, or total cost of investment) for the synthesis plant.

With reference to the feedstock cost discussion, the literature has shown capital investment costs to be fractional compared to operational costs (Luo et al., 2010; Mustapha, 2017). Economies of scale play a crucial role in establishing economically viable processes, particularly in the calculation of imperative economic indicators, such as IRR (discount rate making the NPV of all cashflow for the biorefinery concept equal to zero) and Return on Investment (ROI, ratio of profit/loss in a fiscal year expressed in terms of the investment costs, shown as a percentage increase/decrease in the value of the investment cost during the year under consideration). For emerging biomass-based processes, the authors indicated that a smaller processing facility would meet economic targets for the particular settings and associated assumptions.

Regarding manufacturing costs in general and labor costs in particular, the basis for calculation comprised a plant crew contingent of nine operators (three operators per shift) and one supervisor. The cost per operator was calculated at US$ 20/h, while the cost per shift supervisor was calculated at US$ 35/h, subject to specified escalation. **Table 4-5** details the biorefinery's estimated operating cost, including Variable Costs, Maintenance, Research and Development Costs, Plant Overheads, Licensing/Royalties, and Taxation and Insurance Costs. A positive cashflow was calculated from the assumptions and costing factors set out above and utilizing the estimated calculated cost values detailed in **Table 4-4** and **Table 4-5**.

Table 4-4: Biorefinery capital investment.

Fixed Capital Investment Cost	$US million
Direct costs	
On-site	
Purchased equipment	1.26
Installation	0.59
Instrumentation	0.45
Piping	0.85
Electrical	0.14
Off-site	
Buildings	0.23
Yard improvements	0.13
Service facilities	0.88
Land	0.08
Indirect costs	
Engineering	0.38
Construction	0.51
Contractor fees	0.28
Total capital investment	5.76
Working capital	0.86

Table 4-5: Biorefinery operating costs.

Operating costs	$US million
Total Variable Costs	
Materials and Chemicals	
Feed to plant	0
HCl	0.1
Utilities	
Heat/Power	3.80
Fresh water	0.23
Maintenance	0.3
Research and Development	0.4
Plant Overheads	0.2
Licensing/Royalties	0.2
Taxes and Insurance	0.1
Labour	2.3
Total operating costs	7.63

Figure 4-1 provides the cashflow analysis for the biorefinery. The cashflow analysis for the biorefining concept indicated a nett cash flow of $US 11.67 million generated over an assessment period of 20 years. ROI was calculated at 31 %, with the IRR calculated at 31 %. For the criteria set, a payback period (PBP) of 3 years was established. A Profitability Index for the concept was determined to be 5.45-5.94, which is >1 and indicative of a profitable process with relatively low TCI and PBP.

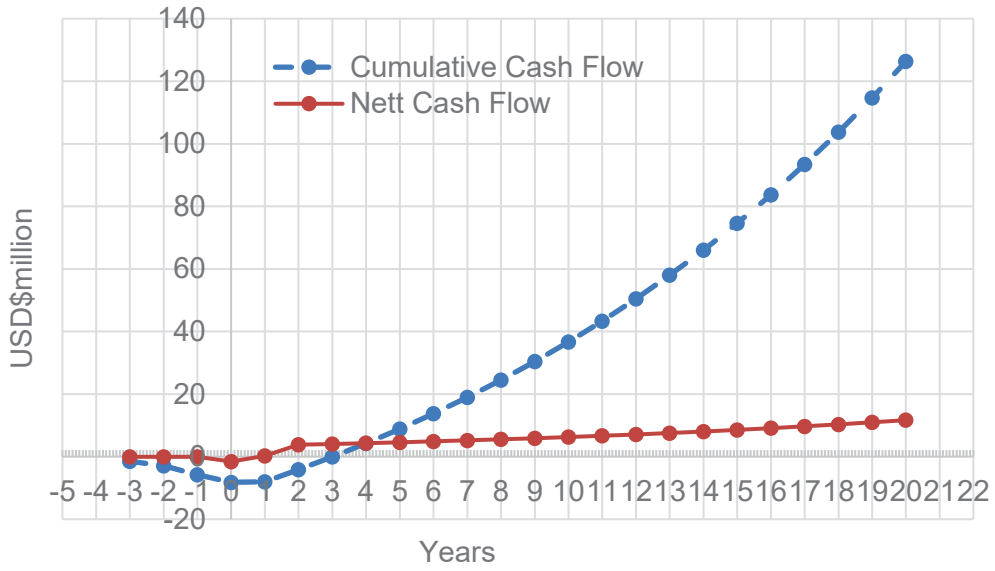
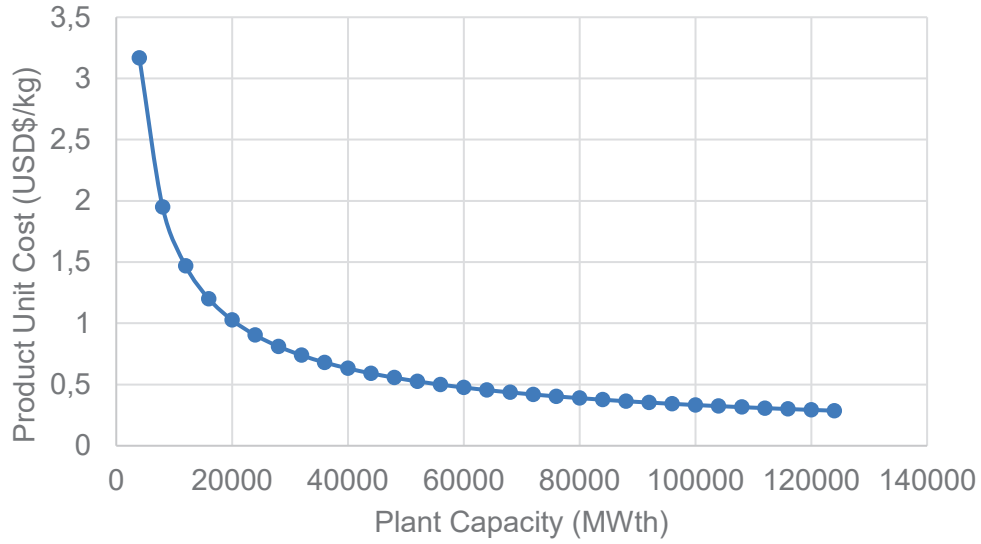


Figure 4-1: Cash flow analysis of the cHTL biorefinery.

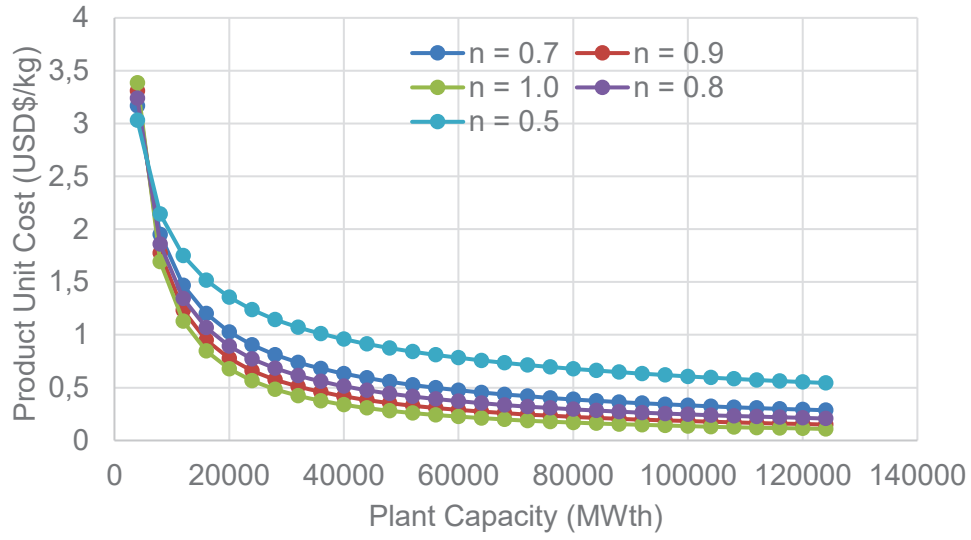
As discussed above, due to the myriad assumptions involved in process design and simulation - and contingencies built into these designs providing for related uncertainties - direct comparisons are tenuous at best (although these case studies do contribute to a larger body of the literature, allowing insights into further avenues of development).

The issue is exacerbated by applying TEAs to these process designs; they rely on an altogether supplementary set of (deviating) assumptions related to socio-economic issues and governmental policies, which must eventually be evaluated against the local geo-political backdrop. Furthermore, the approach to TEAs differs from one study to the next, being based on value engineering, target costing, or a combination of the methods (Dimitriadis and Bezergianni, 2017).

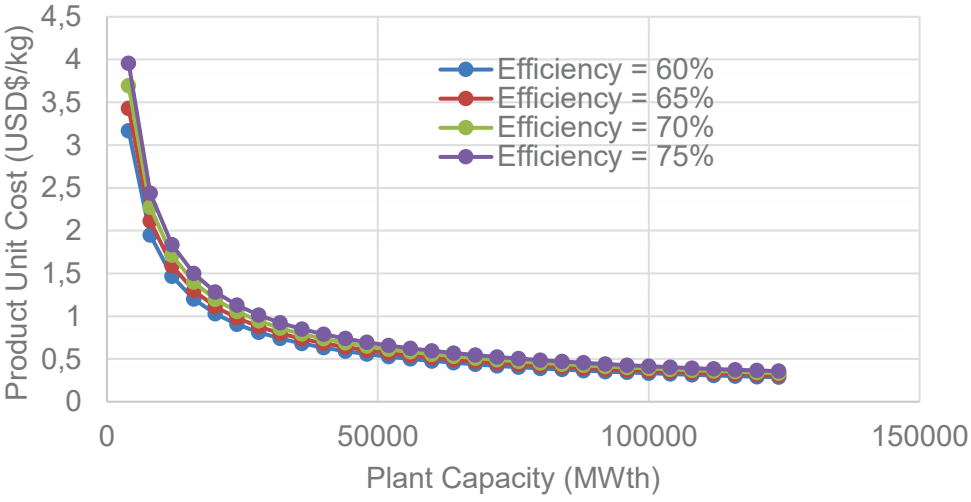
Figure 4-2 shows the affect of plant capacity, capital cost and plant efficiency on product unit cost.



(a)



(b)



(c)

Figure 4-2: Effect of economy of scale (a), plant capacity (b), and plant efficiency (c) on PUC.

South Africa is a developing country, deficient in foreign exchange and crude oil much like Sri Lanka. Additionally, the country has a dry, arid climate, limited arable land and inadequate government subsidies and tax rebates, the latter pertaining to the establishment of a fledgling biofuels industry. As a technologically advanced country in Africa, with no commercial HTL/cHTL plants utilizing biomass as feedstock operating on the continent, APEA provided cost estimations based on proprietary datasets applicable to the setting, technology, and economic environment. This, in turn, allowed for the calculation of the above-mentioned economic indicators.

Figure 4-2(a) shows the effect of plant capacity (in MW thermal) on PUC (in US$/kg), indicating how product unit costs are reduced with increased plant size. A scaling exponent of n = 0.7 was used in calculations (for a South Africa-based plant). The PUC was found to decrease from US$ 3.17/kg for a 4 GWth plant to US$ 0.29/kg for a 124 GWth plant (based on both a biocrude and biochar total product value).

The profile provided in **Figure 4-2(a)** may be utilized when electing a practical mean for establishing base assumptions of further rigorous TEA or related process development. Because of the possibility of a reduction in costs associated with technological innovation or learning curve, or both, as well as uncertainty relating to the associated equipment compliment, the sensitivity of PUC to changing fixed-capital investment was also scrutinized.

Figure 4-2(b) illustrates the impact of capital cost on overall production cost. **Figure 4-2(b)** indicates the substantial effect of capital cost on product unit cost. Calculated indicators were based on a plant efficiency of 60 % for a synthesis plant of like type.

Figure 4-2(c) illustrates the effect of plant efficiency on unit product cost, indicating that efficiency becomes less determinative with increasing plant capacity.

To date, no TEAs have been reported in the literature as relating to HTL or cHTL of biomass for an Africa-based plant. This includes waste-biomass. Likewise, no TEA on the coprocessing of sewage waste with green waste to produce solid and liquid fuels using pilot-scale data has yet been reported in literature. With most reported TEAS utilizing batch HTL data during simulation and cost calculation of continuous processes, the use of cHTL piloting results in the present design study serves to suitably influence policy on future development.

Only Amigun et al. (2010) also reported on the economic performance indicators for a South Africa-based biorefining plant using thermo-chemical processing technology. The study considered gasification (as opposed to cHTL) of non-woody plants, to produce bio-methanol (as opposed to biocrude and hydrocar). Profiles provided in **Figure 4-2(a)-(c)** were similarly observed by the authors, although for significantly different thermal outputs. Substantially higher PUC values were observed in the present study, to produce biocrude and hydrochar. This was attributed to the higher cost of operation under more extreme operating conditions, as well as inflation over the past 12 years. Amigun et al. (2010) did not provide a rigorous TEA and, as a result, did not report on the process' ROI, IRR, PBP, or profitability index.

Despite this, values reported in the current investigation were economically attractive, especially in the light of the improved water environment and lowered GHG goals associated with waste treatment. Long-term cost reduction may be possible through large(r) scale application of the presented novel technology. Sensitivity analyses indicated that investment cost had a definite effect on product unit cost, if only initially. With transportation costs having no impact on biomass feedstock cost and supposed sustainable biomass (waste) supply providing no limitation, the pursuit of technological learning and development of scaled-up HTL technology appears serviceable.

4.5 Concluding remarks on results and discussion

Sampled WWTP streams were characterized and, together with cHTL product streams, analyzed using cited standardised analytical methods, and calculations. WWTP discharge streams were not dissimilar to that reported in the literature. Experimental results were utilized in process simulation, and similarly compared with that available in the literature (notwithstanding similar approaches to simulation employing wholly batch, theoretical data (as opposed to experimental cHTL (piloting) data). Significantly, not many process studies to date have considered hydrochar as high-value energy product, instead optimizing for biocrude/renewable diesel production. Cost analysis built on process simulation, with techno-economic results compared to the gasification of non-woody biomass to produce bio-methanol (the only other TEA of a commercial-scale thermo-chemical biorefinery localised to (South) Africa reported in the literature). Results obtained in the present study were, comparatively, encouraging.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A biorefinery based in South Africa, converting localized municipal bio-waste using novel continuous hydrothermal liquefaction has been assessed. Supported by piloting data, positive economic indicators were shown for the synthesis plant, with sensitivity analyses relating the effects of economies of scale, plant efficiency and plant capacity on product unit cost. Although the plant operates at relatively excessive thermal outputs compared to other thermo-chemical processes, feedstock security and an improved local water environment may offset cost concerns. Techno-economic assessment of the concept points to a representative, long-term alternative for producing fuel and chemicals, while addressing GHG concerns associated with waste treatment.

5.2 Recommendations

Given positive economic indicators observed for the modelled synthesis plant resulting from the baseline assessment, it is recommended that a more rigorous, high-level techno-economic analysis be attempted. Considering accuracy shortcomings associated with early-stage (base case) concept evaluation, a comprehensive, if not exhaustive, examination of assumptions and parameters related to process design and modelling may prove invaluable to efforts at commercialization. These may include considerations of exploiting (upgraded) co-/by-product streams, the use of a more extensive range of model compounds during process simulation, and the effect of governmental subsidy or rebate on cost modelling. Expanded use of sensitivity analyses (including for optimal reactor operation, and production) may aid in establishing economically viable operating limits, which would in turn be determinative for policy requirements.

5.3 Concluding remarks on contribution to the state of the art

Referring back to the discussion above, noting novelty attaching to this study: a techno-economic analysis has been presented on the cHTL of biomass for an Africa-based plant, and more specifically, continuous thermo-chemical treatment of wet waste-biomass feedstock for a localised commercial-scale South African facility (and within the country's unique economic and geo-political setting). This study utilized experimental results from a novel cHTL pilot plant (as opposed to laboratory batch data used almost exclusively in TEA case studies found the literature). Further, the present assessment provided results on the coprocessing of sewage waste with green waste to produce solid and liquid fuels, which have, similarly, not been reported in the literature to date.

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ANNEXURES

A.1 Publication

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Techno-economic baseline study for a waste-based biorefinery in South Africa

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ABSTRACT

A baseline techno-economic assessment for converting organic municipal waste via a novel continuous hydrothermal liquefaction (cHTL) pilot plant is presented. Feed streams, product yields, and product quality were based on real-time data. Pilot plant data was used to estimate the capital investment and operating costs, cashflow and economic indicators for a commercial-scale cHTL plant. Results showed that a return on investment of 31 %, an internal rate of return of 31 %, and a profitability index of 5.5–6.0 could be realized with a satisfactory nett cashflow over an estimated plant life of 20 years. Sensitivity analyses showed that both plant capacity and capital investment had a significant effect on product unit cost. The potential of using cHTL technology to sterilize and co-treat primary sewage with municipal waste was demonstrated for underpinning a circular economy where waste would be re-directed toward new energy products, while offsetting localized municipal operating costs.

1. Introduction

A rapid global increase in urbanization and industrialization has led to an excessive increase in wastewater and treatment plant effluents associated with serious environmental and health concerns (Peccia and Westerhoff, 2015). The latter, coupled with increasing global energy demand (and accompanying Greenhouse Gas (GHG) emissions), have paved the way for the development of biofuels to supplement sustainable energy security, and curtail global climate change (Cherubini and Ulgiati, 2013). While the production of biofuels has received considerable attention over recent decades, the move toward the development of the broader concept of biorefineries - which produce a diverse array of products from a range of biomass feedstock - is gaining traction.

Although wind and solar energy can be used as renewable alternative energy sources, a carbon source is required to produce liquid fuels and chemicals. A significant amount of bioethanol and biodiesel (as the most prominent biofuels produced by biorefineries) are produced worldwide to partially replace fossil-based petroleum and diesel in the transportation sector. However, biofuels accounted for only approximately 4 % of the worldwide road transport fuel in 2016, with studies showing that global production growth pre-2010 was slowing to a modest 2 % year-on-year (IEA, 2017). This has primarily been attributed to policy uncertainty, technical limitations, direct and indirect land-use change issues, and economic considerations (IEA, 2017). Furthermore, biofuels require economic incentives or policy interventions to make them competitive in the fuel transportation market (Ghatak, 2011). Ghatak (2011) also found that the price of bioenergy, especially biofuels, may see a downward trend with increased market penetration and technological advancement. For these products, the future of economic sustainability lies in the comprehensive utilization of by-products and residues to improve production chain economics, i.e., the biorefinery approach. As a result, advanced biofuel projects have been announced in a growing number of developing countries such as China, India and Thailand (IEA, 2017).

As for South Africa, the government adopted its so-called Biofuels Industrial Strategy in 2007 (NCCAS, 2020). Observers have noted the strategy as largely ineffectual, being focused on promoting the interests of previously disadvantaged farming areas/communities rather than establishing a viable commercial biofuels industry, and thus failing markedly to meet fuel targets (Esterhuizen, 2008). Studies have also found the South African government subsidy inadequate for establishing the economic feasibility of processes utilizing crop-grown biomass feedstock, in addition to limitations imposed by available croplands (with the hot, dry climate providing limited arable land and feedstock

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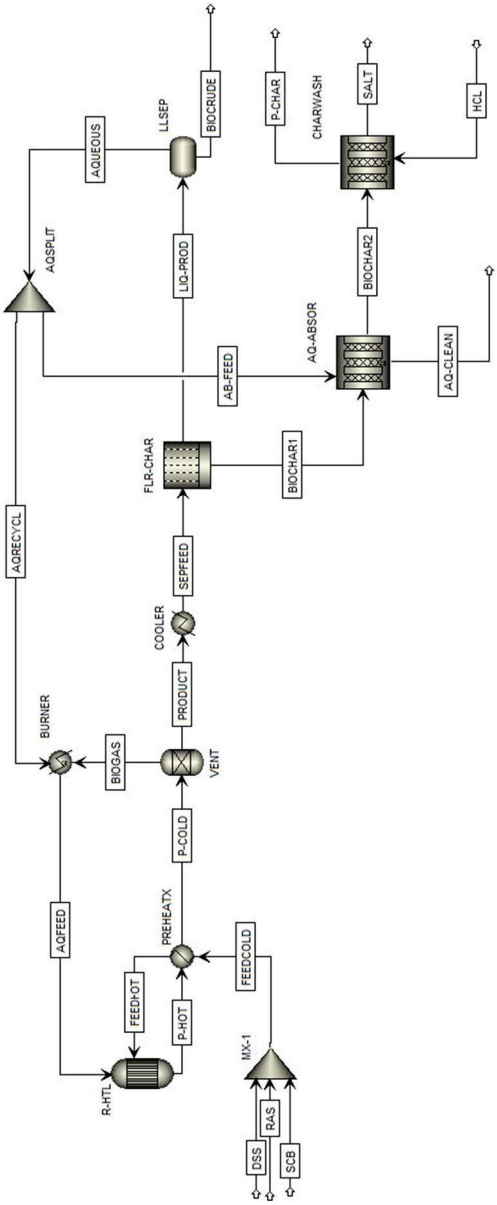
Appendix B Complete Synthesis Plant Flowsheet (B1)



Annexure B Flowsheet Balance (B2)

OVERALL FLOWSHEET BALANCE

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
CONVENTIONAL COMPONENTS (KMOL/HR)			
H20	28.7099	28.5332	0.615241E-02
CO2	0.00000	2.48737	-1.00000
CH4	6.23334	2.87825	0.538249
CARBO-01	0.00000	2.13756	-1.00000
HYDRO-01	0.00000	14.1732	-1.00000
BIOCRUDE	0.00000	0.797237E-01	-1.00000
CHAR	0.00000	8.66156	-1.00000
N2	16.6384	16.6384	-0.854099E-15
O2	3.87202	0.110540E-23	1.00000
HCL	34.7369	34.7369	0.00000
SUBTOTAL(KMOL/HR)	90.1905	110.326	-0.182510
(KG/HR)	2473.75	2602.29	-0.493965E-01
NON-CONVENTIONAL COMPONENTS (KG/HR)			
RAS	3.61600	0.00000	1.00000
DSS	24.9280	0.00000	1.00000
SCB	100.000	0.00000	1.00000
SUBTOTAL(KG/HR)	128.544	0.00000	1.00000
TOTAL BALANCE			
MASS(KG/HR)	2602.29	2602.29	-0.171196E-09
ENTHALPY(GCAL/HR)	-3.19540	-3.01854	-0.553485E-01

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	43704.0	KG/HR
PRODUCT STREAMS CO2E	1263.85	KG/HR
NET STREAMS CO2E PRODUCTION	-42440.1	KG/HR
UTILITIES CO2E PRODUCTION	92.9818	KG/HR
TOTAL CO2E PRODUCTION	-42347.1	KG/HR

Annexure B Stream Results (B3 - B172)

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

8 AQUEOUS2 BIOCHAR BIOCHAR2 S1

STREAM ID	8	AQUEOUS2	BIOCHAR	BIOCHAR2	S1
FROM :	$C-5	B2	$C-4	B2	B1
TO :	B1	$C-7	B1	$C-6	B2
CLASS:	MIXCINC	MIXCINC	MIXCINC	MIXCINC	MIXCINC
TOTAL STREAM:					
KG/HR	419.6441	415.5981	14.9009	18.9469	434.5450
GCAL/HR	-1.6037	-1.5877	-5.6563-06	-1.6037-02	-1.6037
SUBSTREAM: MIXED					
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
COMPONENTS: KMOL/HR					
H20	23.2404	23.0080	8.1751-05	0.2324	23.2405
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.0225-02	1.0123-02	1.8257-07	1.0225-04	1.0225-02
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	418.6818	414.4964	1.4728-03	4.1868	418.6832
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.9623	0.9527	1.7182-05	9.6235-03	0.9624
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.9977	0.9977	0.9885	0.9977	0.9977
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0

HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	2.2932-03	2.2932-03	1.1532-02	2.2932-03	2.2932-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.4195	0.4153	1.4756-06	4.1949-03	0.4195
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	9.1738-04	9.0823-04	1.6379-08	9.1740-06	9.1740-04
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.4204	0.4162	1.4920-06	4.2041-03	0.4204
COMPONENTS: STD VOL FRAC					
H20	0.9978	0.9978	0.9890	0.9978	0.9978
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	2.1821-03	2.1822-03	1.0978-02	2.1822-03	2.1822-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.4204	0.4162	1.4920-06	4.2041-03	0.4204
TOTAL FLOW:					
KMOL/HR	23.2506	23.0182	8.1933-05	0.2325	23.2507
KG/HR	419.6441	415.4491	1.4899-03	4.1965	419.6456
CUM/HR	0.4365	0.4322	1.5483-06	4.3653-03	0.4365
STATE VARIABLES:					
TEMP C	25.0000	25.0000	24.9956	25.0000	25.0000
PRES BAR	1.0000	1.0000	1.2000	1.0000	1.0000
VFRAC	0.0	0.0	0.0	0.0	0.0
LFRAC	1.0000	1.0000	1.0000	1.0000	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
KCAL/MOL	-68.9754	-68.9754	-68.9021	-68.9754	-68.9754
KCAL/KG	-3821.6147	-3821.6146	-3788.9838	-3821.6146	-3821.6146
GCAL/HR	-1.6037	-1.5877	-5.6454-06	-1.6037-02	-1.6037
ENTROPY:					
CAL/MOL-K	-38.9789	-38.9789	-39.0328	-38.9789	-38.9789
CAL/GM-K	-2.1596	-2.1596	-2.1464	-2.1596	-2.1596
DENSITY:					
MOL/CC	5.3262-02	5.3262-02	5.2918-02	5.3262-02	5.3262-02
KG/CUM	961.3196	961.3196	962.3115	961.3196	961.3196
AVG MW	18.0487	18.0487	18.1848	18.0487	18.0487

SUBSTREAM: CISOLID	STRUCTURE: CONVENTIONAL				
COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	1.2405-02	1.2405	1.2281	1.2405
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.1490	14.8994	14.7504	14.8994
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	1.0000	1.0000	1.0000	1.0000
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	6.4308-05	6.4308-03	6.3665-03	6.4308-03
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	6.4308-05	6.4308-03	6.3665-03	6.4308-03
COMPONENTS: STD VOL FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0

BIOCRUDE			0.0	0.0	0.0	0.0	0.0
CHAR			0.0	1.0000	1.0000	1.0000	1.0000
N2			0.0	0.0	0.0	0.0	0.0
O2			0.0	0.0	0.0	0.0	0.0
HCL			0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR			0.0	6.4308-05	6.4308-03	6.3665-03	6.4308-03
TOTAL FLOW:							
KMOL/HR			0.0	1.2405-02	1.2405	1.2281	1.2405
KG/HR			0.0	0.1490	14.8994	14.7504	14.8994
CUM/HR			0.0	6.6219-05	6.6219-03	6.5557-03	6.6219-03
STATE VARIABLES:							
TEMP	C	M -		25.0000	24.9956	25.0000	25.0000
PRES	BAR		1.0000	1.0000	1.2000	1.0000	1.0000
VFRAC		M -		0.0	0.0	0.0	0.0
LFRAC		M -		0.0	0.0	0.0	0.0
SFRAC		M -		1.0000	1.0000	1.0000	1.0000
ENTHALPY:							
KCAL/MOL		M -		-4.5856-08	-8.8387-06	-4.5856-08	-4.5856-08
KCAL/KG		M -		-3.8178-06	-7.3588-04	-3.8178-06	-3.8178-06
GCAL/HR		M -		-5.6884-13	-1.0964-08	-5.6315-11	-5.6884-11
ENTROPY:							
CAL/MOL-K		M -		-1.5380-07	-2.9645-05	-1.5380-07	-1.5380-07
CAL/GM-K		M -		-1.2805-08	-2.4682-06	-1.2805-08	-1.2805-08
DENSITY:							
MOL/CC		M -		0.1873	0.1873	0.1873	0.1873
KG/CUM		M -		2250.0206	2250.0206	2250.0206	2250.0206
AVG MW		M -		12.0110	12.0110	12.0110	12.0110

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW	KG/HR					
H20		418.6818	414.4964	1.4728-03	4.1868	418.6832
CO2		0.0	0.0	0.0	0.0	0.0
CH4		0.0	0.0	0.0	0.0	0.0
CARBO-01		0.0	0.0	0.0	0.0	0.0
HYDRO-01		0.0	0.0	0.0	0.0	0.0
BIOCRUDE		0.9623	0.9527	1.7182-05	9.6235-03	0.9624
CHAR		0.0	0.1490	14.8994	14.7504	14.8994
N2		0.0	0.0	0.0	0.0	0.0
O2		0.0	0.0	0.0	0.0	0.0
HCL		0.0	0.0	0.0	0.0	0.0
RAS		0.0	0.0	0.0	0.0	0.0
DSS		0.0	0.0	0.0	0.0	0.0
SCB		0.0	0.0	0.0	0.0	0.0
VOLFLMX	CUM/HR	0.4365	0.4322	6.6235-03	1.0921-02	0.4432
MASSVFRA		0.0	0.0	0.0	0.0	0.0
MASSSFRA		0.0	3.5851-04	0.9999	0.7785	3.4287-02
RHOMX	KG/CUM	961.3196	961.5171	2249.7196	1734.9049	980.5763
TEMP	C	25.0000	25.0000	24.9956	25.0000	25.0000
PRES	BAR	1.0000	1.0000	1.2000	1.0000	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

8
-

STREAM ID	8
FROM :	$C-5
TO :	B1
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	419.6441
GCAL/HR	-1.6037
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	23.2404
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0225-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	418.6818
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.9623
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0

```
  BIOCRUDE            2.2932-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.4195
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            9.1738-04
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.4204
COMPONENTS: STD VOL FRAC
  H20                    0.9978
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.1821-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.4204
TOTAL FLOW:
  KMOL/HR               23.2506
  KG/HR                419.6441
  CUM/HR                 0.4365
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6147
  GCAL/HR               -1.6037
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

TOTAL STREAM PROPERTIES:
```

```
***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                418.6818
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.9623
    CHAR                 0.0
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR          0.4365
MASSVFRA                 0.0
MASSSFRA                 0.0
RHOMX    KG/CUM        961.3196
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                          COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

AQUEOUS2
--------

STREAM ID               AQUEOUS2
FROM :                  B2
TO   :                  $C-7
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR                415.5981
  GCAL/HR               -1.5877
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  H20                   23.0080
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
```

HYDRO-01	0.0
BIOCRUDE	1.0123-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	414.4964
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.9527
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.4153
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.0823-04
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.4162
COMPONENTS: STD VOL FRAC	
H20	0.9978
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.1822-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.4162

```
TOTAL FLOW:
  KMOL/HR               23.0182
  KG/HR                415.4491
  CUM/HR                 0.4322
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6146
  GCAL/HR               -1.5877
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                1.2405-02
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.1490
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
```

```
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                 6.4308-05
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR         6.4308-05
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR         6.4308-05
TOTAL FLOW:
  KMOL/HR              1.2405-02
  KG/HR                   0.1490
  CUM/HR               6.6219-05
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL            -4.5856-08
  KCAL/KG             -3.8178-06
  GCAL/HR             -5.6884-13
ENTROPY:
  CAL/MOL-K           -1.5380-07
  CAL/GM-K            -1.2805-08
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:
```

```
***  ALL PHASES
MASSFLOW KG/HR
    H20                414.4964
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.9527
    CHAR                 0.1490
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR          0.4322
MASSVFRA                 0.0
MASSSFRA              3.5851-04
RHOMX    KG/CUM        961.5171
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                        2.7000-02   $/KG                    2.7000

BIOCHAR
-------

STREAM ID              BIOCHAR
FROM :                 $C-4
TO   :                 B1
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR                14.9009
  GCAL/HR           -5.6563-06
SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: KMOL/HR
  H20                8.1751-05
  CO2                  0.0
  CH4                  0.0
  CARBO-01             0.0
  HYDRO-01             0.0
```

BIOCRUDE	1.8257-07
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	1.4728-03
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.7182-05
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9885
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.1532-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	1.4756-06
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.6379-08
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	1.4920-06
COMPONENTS: STD VOL FRAC	
H20	0.9890
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0978-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	1.4920-06
TOTAL FLOW:	

```
  KMOL/HR             8.1933-05
  KG/HR               1.4899-03
  CUM/HR              1.5483-06
STATE VARIABLES:
  TEMP   C              24.9956
  PRES   BAR             1.2000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9021
  KCAL/KG            -3788.9838
  GCAL/HR            -5.6454-06
ENTROPY:
  CAL/MOL-K            -39.0328
  CAL/GM-K              -2.1464
DENSITY:
  MOL/CC              5.2918-02
  KG/CUM               962.3115
AVG MW                 18.1848

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2405
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.8994
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
```

```
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                 6.4308-03
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR         6.4308-03
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR         6.4308-03
TOTAL FLOW:
  KMOL/HR                 1.2405
  KG/HR                  14.8994
  CUM/HR               6.6219-03
STATE VARIABLES:
  TEMP   C               24.9956
  PRES   BAR              1.2000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL            -8.8387-06
  KCAL/KG             -7.3588-04
  GCAL/HR             -1.0964-08
ENTROPY:
  CAL/MOL-K           -2.9645-05
  CAL/GM-K            -2.4682-06
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
```

```
MASSFLOW KG/HR
    H20                1.4728-03
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE           1.7182-05
    CHAR                 14.8994
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR        6.6235-03
MASSVFRA                  0.0
MASSSFRA                  0.9999
RHOMX    KG/CUM       2249.7196
TEMP     C              24.9956
PRES     BAR             1.2000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
HCL                                  4.6107   $/KG                  5839.6504
P-CHAR                               0.9315   $/KG                  1183.8191
SALT                                10.3983   $/KG                   151.8457
BURNER.CH4                       2.7000-02   $/KG                     2.7000

BIOCHAR2
--------

STREAM ID              BIOCHAR2
FROM :                 B2
TO   :                 $C-6
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR                18.9469
  GCAL/HR           -1.6037-02
SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: KMOL/HR
  H20                   0.2324
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE           1.0225-04
```

CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	4.1868
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.6235-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	4.1949-03
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.1740-06
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	4.2041-03
COMPONENTS: STD VOL FRAC	
H20	0.9978
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.1822-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	4.2041-03
TOTAL FLOW:	
KMOL/HR	0.2325

```
  KG/HR                  4.1965
  CUM/HR              4.3653-03
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6146
  GCAL/HR            -1.6037-02
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                 18.0487

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2281
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.7504
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
```

```
  O2                        0.0
  HCL                       0.0
COMPONENTS: STD CUM/HR
  H20                       0.0
  CO2                       0.0
  CH4                       0.0
  CARBO-01                  0.0
  HYDRO-01                  0.0
  BIOCRUDE                  0.0
  CHAR                  6.3665-03
  N2                        0.0
  O2                        0.0
  HCL                       0.0
  TOTAL CUM/HR          6.3665-03
COMPONENTS: STD VOL FRAC
  H20                       0.0
  CO2                       0.0
  CH4                       0.0
  CARBO-01                  0.0
  HYDRO-01                  0.0
  BIOCRUDE                  0.0
  CHAR                      1.0000
  N2                        0.0
  O2                        0.0
  HCL                       0.0
  TOTAL CUM/HR          6.3665-03
TOTAL FLOW:
  KMOL/HR                   1.2281
  KG/HR                    14.7504
  CUM/HR                6.5557-03
STATE VARIABLES:
  TEMP   C                 25.0000
  PRES   BAR                1.0000
  VFRAC                     0.0
  LFRAC                     0.0
  SFRAC                     1.0000
ENTHALPY:
  KCAL/MOL             -4.5856-08
  KCAL/KG              -3.8178-06
  GCAL/HR              -5.6315-11
ENTROPY:
  CAL/MOL-K            -1.5380-07
  CAL/GM-K             -1.2805-08
DENSITY:
  MOL/CC                    0.1873
  KG/CUM                 2250.0206
AVG MW                     12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
```

```
    H20                    4.1868
    CO2                    0.0
    CH4                    0.0
    CARBO-01               0.0
    HYDRO-01               0.0
    BIOCRUDE           9.6235-03
    CHAR                 14.7504
    N2                     0.0
    O2                     0.0
    HCL                    0.0
    RAS                    0.0
    DSS                    0.0
    SCB                    0.0
VOLFLMX  CUM/HR        1.0921-02
MASSVFRA                   0.0
MASSSFRA                   0.7785
RHOMX    KG/CUM       1734.9049
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

S1
--

STREAM ID              S1
FROM :                 B1
TO   :                 B2
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR              434.5450
  GCAL/HR             -1.6037
SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: KMOL/HR
  H20                  23.2405
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE          1.0225-02
  CHAR                  0.0
```

N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	418.6832
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.9624
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.4195
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.1740-04
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.4204
COMPONENTS: STD VOL FRAC	
H20	0.9978
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.1822-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.4204
TOTAL FLOW:	
KMOL/HR	23.2507
KG/HR	419.6456

```
  CUM/HR                0.4365
STATE VARIABLES:
  TEMP   C             25.0000
  PRES   BAR            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KCAL/MOL            -68.9754
  KCAL/KG           -3821.6146
  GCAL/HR              -1.6037
ENTROPY:
  CAL/MOL-K           -38.9789
  CAL/GM-K             -2.1596
DENSITY:
  MOL/CC             5.3262-02
  KG/CUM              961.3196
AVG MW                18.0487

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                  1.2405
  N2                    0.0
  O2                    0.0
  HCL                   0.0
COMPONENTS: KG/HR
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                 14.8994
  N2                    0.0
  O2                    0.0
  HCL                   0.0
COMPONENTS: MASS FRAC
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                  1.0000
  N2                    0.0
  O2                    0.0
```

```
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                6.4308-03
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4308-03
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4308-03
TOTAL FLOW:
  KMOL/HR                 1.2405
  KG/HR                  14.8994
  CUM/HR              6.6219-03
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL           -4.5856-08
  KCAL/KG            -3.8178-06
  GCAL/HR            -5.6884-11
ENTROPY:
  CAL/MOL-K          -1.5380-07
  CAL/GM-K           -1.2805-08
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                418.6832
```

	CO2	0.0
	CH4	0.0
	CARBO-01	0.0
	HYDRO-01	0.0
	BIOCRUDE	0.9624
	CHAR	14.8994
	N2	0.0
	O2	0.0
	HCL	0.0
	RAS	0.0
	DSS	0.0
	SCB	0.0
VOLFLMX	CUM/HR	0.4432
MASSVFRA		0.0
MASSSFRA		3.4287-02
RHOMX	KG/CUM	980.5763
TEMP	C	25.0000
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

AIR BIOGAS CH4 S1 S2

STREAM ID	AIR	BIOGAS	CH4	S1	S2
FROM :	----	$C-1	----	B1	B2
TO :	B1	B1	B1	B2	$C-3
CLASS:	MIXCINC	MIXCINC	MIXCINC	MIXCINC	MIXCINC
TOTAL STREAM:					
KG/HR	590.0000	204.3554	100.0000	894.3554	279.7627
GCAL/HR	-3.2306-05	-0.3298	-0.1110	-0.4408	-0.8650
$/HR	M -	M -	2.7000	M -	M -
SUBSTREAM: MIXED					
PHASE:	VAPOR	VAPOR	VAPOR	VAPOR	VAPOR
COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	5.2751	15.4936
CO2	0.0	2.3217	0.0	2.4874	0.0
CH4	0.0	6.3691	6.2333	2.8783	0.0
CARBO-01	0.0	0.0	0.0	2.1376	0.0
HYDRO-01	0.0	0.0	0.0	14.1732	0.0
BIOCRUDE	0.0	0.0	0.0	2.2046-19	6.8169-03
CHAR	0.0	0.0	0.0	0.0	0.0

N2	16.6384	0.0	0.0	16.6384	0.0
O2	3.8720	0.0	0.0	1.1054-24	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	95.0333	279.1212
CO2	0.0	102.1777	0.0	109.4687	0.0
CH4	0.0	102.1777	100.0000	46.1751	0.0
CARBO-01	0.0	0.0	0.0	59.8739	0.0
HYDRO-01	0.0	0.0	0.0	28.5715	0.0
BIOCRUDE	0.0	0.0	0.0	2.0748-17	0.6416
CHAR	0.0	0.0	0.0	0.0	0.0
N2	466.1000	0.0	0.0	466.1000	0.0
O2	123.9000	0.0	0.0	3.5372-23	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.1180	0.9977
CO2	0.0	0.5000	0.0	0.1359	0.0
CH4	0.0	0.5000	1.0000	5.7345-02	0.0
CARBO-01	0.0	0.0	0.0	7.4357-02	0.0
HYDRO-01	0.0	0.0	0.0	3.5483-02	0.0
BIOCRUDE	0.0	0.0	0.0	2.5767-20	2.2932-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.7900	0.0	0.0	0.5788	0.0
O2	0.2100	0.0	0.0	4.3928-26	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	9.5216-02	0.2797
CO2	0.0	0.1243	0.0	0.1332	0.0
CH4	0.0	0.3411	0.3338	0.1542	0.0
CARBO-01	0.0	0.0	0.0	0.1145	0.0
HYDRO-01	0.0	0.0	0.0	0.7591	0.0
BIOCRUDE	0.0	0.0	0.0	1.9779-20	6.1159-04
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.8911	0.0	0.0	0.8911	0.0
O2	0.2074	0.0	0.0	5.9203-26	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	1.0985	0.4655	0.3338	2.1473	0.2803
COMPONENTS: STD VOL FRAC					
H20	0.0	0.0	0.0	4.4343-02	0.9978
CO2	0.0	0.2671	0.0	6.2041-02	0.0
CH4	0.0	0.7329	1.0000	7.1790-02	0.0
CARBO-01	0.0	0.0	0.0	5.3316-02	0.0
HYDRO-01	0.0	0.0	0.0	0.3535	0.0
BIOCRUDE	0.0	0.0	0.0	9.2113-21	2.1821-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.8112	0.0	0.0	0.4150	0.0
O2	0.1888	0.0	0.0	2.7571-26	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	1.0985	0.4655	0.3338	2.1473	0.2803
TOTAL FLOW:					
KMOL/HR	20.5104	8.6908	6.2333	43.5900	15.5004
KG/HR	590.0000	204.3554	100.0000	805.2224	279.7627

CUM/HR	508.3647	2.5060	154.2577	3035.2264	686.4554
STATE VARIABLES:					
TEMP C	25.0000	87.2690	25.0000	575.1892	261.0608
PRES BAR	1.0000	95.0000	1.0000	1.0133	1.0000
VFRAC	1.0000	1.0000	1.0000	1.0000	1.0000
LFRAC	0.0	0.0	0.0	0.0	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
KCAL/MOL	-1.5751-03	-37.9427	-17.8028	-10.5029	-55.8064
KCAL/KG	-5.4756-02	-1613.6182	-1109.7065	-568.5645	-3091.9823
GCAL/HR	-3.2306-05	-0.3298	-0.1110	-0.4578	-0.8650
ENTROPY:					
CAL/MOL-K	0.9832	-20.8618	-19.2340	9.5705	-5.8158
CAL/GM-K	3.4179-02	-0.8872	-1.1989	0.5181	-0.3222
DENSITY:					
MOL/CC	4.0346-05	3.4680-03	4.0409-05	1.4361-05	2.2580-05
KG/CUM	1.1606	81.5474	0.6483	0.2653	0.4075
AVG MW	28.7658	23.5140	16.0428	18.4727	18.0487

SUBSTREAM: CISOLID	STRUCTURE: CONVENTIONAL				
COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	7.4209	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	89.1330	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	1.0000	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0

HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	3.8471-02	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	0.0	0.0	3.8471-02	0.0
COMPONENTS: STD VOL FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	1.0000	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	0.0	0.0	3.8471-02	0.0
TOTAL FLOW:					
KMOL/HR	0.0	0.0	0.0	7.4209	0.0
KG/HR	0.0	0.0	0.0	89.1330	0.0
CUM/HR	0.0	0.0	0.0	3.9614-02	0.0
STATE VARIABLES:					
TEMP C	M -	M -	M -	575.1892	M -
PRES BAR	1.0000	95.0000	1.0000	1.0133	1.0000
VFRAC	M -	M -	M -	0.0	M -
LFRAC	M -	M -	M -	0.0	M -
SFRAC	M -	M -	M -	1.0000	M -
ENTHALPY:					
KCAL/MOL	M -	M -	M -	2.2997	M -
KCAL/KG	M -	M -	M -	191.4682	M -
GCAL/HR	M -	M -	M -	1.7066-02	M -
ENTROPY:					
CAL/MOL-K	M -	M -	M -	3.9861	M -
CAL/GM-K	M -	M -	M -	0.3319	M -
DENSITY:					
MOL/CC	M -	M -	M -	0.1873	M -
KG/CUM	M -	M -	M -	2250.0206	M -
AVG MW	M -	M -	M -	12.0110	M -

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW KG/HR					
H20	0.0	0.0	0.0	95.0333	279.1212

CO2		0.0	102.1777	0.0	109.4687	0.0
CH4		0.0	102.1777	100.0000	46.1751	0.0
CARBO-01		0.0	0.0	0.0	59.8739	0.0
HYDRO-01		0.0	0.0	0.0	28.5715	0.0
BIOCRUDE		0.0	0.0	0.0	2.0748-17	0.6416
CHAR		0.0	0.0	0.0	89.1330	0.0
N2		466.1000	0.0	0.0	466.1000	0.0
O2		123.9000	0.0	0.0	3.5372-23	0.0
HCL		0.0	0.0	0.0	0.0	0.0
RAS		0.0	0.0	0.0	0.0	0.0
DSS		0.0	0.0	0.0	0.0	0.0
SCB		0.0	0.0	0.0	0.0	0.0
VOLFLMX	CUM/HR	508.3647	2.5060	154.2577	3035.2660	686.4554
MASSVFRA		1.0000	1.0000	1.0000	0.9003	1.0000
MASSSFRA		0.0	0.0	0.0	9.9662-02	0.0
RHOMX	KG/CUM	1.1606	81.5474	0.6483	0.2947	0.4075
TEMP	C	25.0000	87.2690	25.0000	575.1892	261.0608
PRES	BAR	1.0000	95.0000	1.0000	1.0133	1.0000

S3 S4

STREAM ID	S3	S4
FROM :	B2	$C-2
TO :	----	B2
CLASS:	MIXCINC	MIXCINC
TOTAL STREAM:		
KG/HR	894.3554	279.7627
GCAL/HR	-0.6449	-1.0691
SUBSTREAM: MIXED		
PHASE:	MIXED	LIQUID
COMPONENTS: KMOL/HR		
H20	5.2751	15.4936
CO2	2.4874	0.0
CH4	2.8783	0.0
CARBO-01	2.1376	0.0
HYDRO-01	14.1732	0.0
BIOCRUDE	2.2046-19	6.8169-03
CHAR	0.0	0.0
N2	16.6384	0.0
O2	1.1054-24	0.0
HCL	0.0	0.0
COMPONENTS: KG/HR		
H20	95.0333	279.1212
CO2	109.4687	0.0
CH4	46.1751	0.0
CARBO-01	59.8739	0.0
HYDRO-01	28.5715	0.0
BIOCRUDE	2.0748-17	0.6416
CHAR	0.0	0.0
N2	466.1000	0.0
O2	3.5372-23	0.0

HCL	0.0	0.0
COMPONENTS: MASS FRAC		
H20	0.1180	0.9977
CO2	0.1359	0.0
CH4	5.7345-02	0.0
CARBO-01	7.4357-02	0.0
HYDRO-01	3.5483-02	0.0
BIOCRUDE	2.5767-20	2.2932-03
CHAR	0.0	0.0
N2	0.5788	0.0
O2	4.3928-26	0.0
HCL	0.0	0.0
COMPONENTS: STD CUM/HR		
H20	9.5216-02	0.2797
CO2	0.1332	0.0
CH4	0.1542	0.0
CARBO-01	0.1145	0.0
HYDRO-01	0.7591	0.0
BIOCRUDE	1.9779-20	6.1159-04
CHAR	0.0	0.0
N2	0.8911	0.0
O2	5.9203-26	0.0
HCL	0.0	0.0
TOTAL CUM/HR	2.1473	0.2803
COMPONENTS: STD VOL FRAC		
H20	4.4343-02	0.9978
CO2	6.2041-02	0.0
CH4	7.1790-02	0.0
CARBO-01	5.3316-02	0.0
HYDRO-01	0.3535	0.0
BIOCRUDE	9.2113-21	2.1821-03
CHAR	0.0	0.0
N2	0.4150	0.0
O2	2.7571-26	0.0
HCL	0.0	0.0
TOTAL CUM/HR	2.1473	0.2803
TOTAL FLOW:		
KMOL/HR	43.5900	15.5004
KG/HR	805.2224	279.7627
CUM/HR	1142.1747	0.2910
STATE VARIABLES:		
TEMP C	51.4080	25.0000
PRES BAR	1.0133	1.0000
VFRAC	0.9842	0.0
LFRAC	1.5785-02	1.0000
SFRAC	0.0	0.0
ENTHALPY:		
KCAL/MOL	-14.8038	-68.9754
KCAL/KG	-801.3896	-3821.6147
GCAL/HR	-0.6453	-1.0691
ENTROPY:		
CAL/MOL-K	1.5796	-38.9789

CAL/GM-K	8.5511-02	-2.1596
DENSITY:		
MOL/CC	3.8164-05	5.3262-02
KG/CUM	0.7050	961.3196
AVG MW	18.4727	18.0487

SUBSTREAM: CISOLID	STRUCTURE: CONVENTIONAL	
COMPONENTS: KMOL/HR		
H20	0.0	0.0
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	0.0
CHAR	7.4209	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
COMPONENTS: KG/HR		
H20	0.0	0.0
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	0.0
CHAR	89.1330	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
COMPONENTS: MASS FRAC		
H20	0.0	0.0
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	0.0
CHAR	1.0000	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
COMPONENTS: STD CUM/HR		
H20	0.0	0.0
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	0.0
CHAR	3.8471-02	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
TOTAL CUM/HR	3.8471-02	0.0

```
COMPONENTS: STD VOL FRAC

   H20                    0.0        0.0
   CO2                    0.0        0.0
   CH4                    0.0        0.0
   CARBO-01               0.0        0.0
   HYDRO-01               0.0        0.0
   BIOCRUDE               0.0        0.0
   CHAR                   1.0000     0.0
   N2                     0.0        0.0
   O2                     0.0        0.0
   HCL                    0.0        0.0
   TOTAL CUM/HR        3.8471-02     0.0
 TOTAL FLOW:
   KMOL/HR                7.4209     0.0
   KG/HR                 89.1330     0.0
   CUM/HR              3.9614-02     0.0
 STATE VARIABLES:
   TEMP   C              51.4080    M  -
   PRES   BAR             1.0133     1.0000
   VFRAC                  0.0       M  -
   LFRAC                  0.0       M  -
   SFRAC                  1.0000    M  -
 ENTHALPY:
   KCAL/MOL            5.6344-02    M  -
   KCAL/KG                4.6910    M  -
   GCAL/HR             4.1813-04    M  -
 ENTROPY:
   CAL/MOL-K              0.1809    M  -
   CAL/GM-K            1.5065-02    M  -
 DENSITY:
   MOL/CC                 0.1873    M  -
   KG/CUM              2250.0206    M  -
 AVG MW                  12.0110    M  -

 TOTAL STREAM PROPERTIES:

 ***  ALL PHASES   ***
 MASSFLOW KG/HR
     H20                  95.0333   279.1212
     CO2                 109.4687     0.0
     CH4                  46.1751     0.0
     CARBO-01             59.8739     0.0
     HYDRO-01             28.5715     0.0
     BIOCRUDE              0.0        0.6416
     CHAR                 89.1330     0.0
     N2                  466.1000     0.0
     O2                    0.0        0.0
     HCL                   0.0        0.0
     RAS                   0.0        0.0
     DSS                   0.0        0.0
     SCB                   0.0        0.0
 VOLFLMX  CUM/HR       1142.2143     0.2910
```

MASSVFRA		0.8865	0.0
MASSSFRA		9.9662-02	0.0
RHOMX	KG/CUM	0.7830	961.3196
TEMP	C	51.4080	25.0000
PRES	BAR	1.0133	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

AIR

STREAM ID	AIR
FROM :	----
TO :	B1
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	590.0000
GCAL/HR	-3.2306-05
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	16.6384
O2	3.8720
HCL	0.0
COMPONENTS: KG/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	466.1000
O2	123.9000
HCL	0.0

```
COMPONENTS: MASS FRAC

   H20                    0.0
   CO2                    0.0
   CH4                    0.0
   CARBO-01               0.0
   HYDRO-01               0.0
   BIOCRUDE               0.0
   CHAR                   0.0
   N2                     0.7900
   O2                     0.2100
   HCL                    0.0
 COMPONENTS: STD CUM/HR
   H20                    0.0
   CO2                    0.0
   CH4                    0.0
   CARBO-01               0.0
   HYDRO-01               0.0
   BIOCRUDE               0.0
   CHAR                   0.0
   N2                     0.8911
   O2                     0.2074
   HCL                    0.0
   TOTAL CUM/HR           1.0985
 COMPONENTS: STD VOL FRAC
   H20                    0.0
   CO2                    0.0
   CH4                    0.0
   CARBO-01               0.0
   HYDRO-01               0.0
   BIOCRUDE               0.0
   CHAR                   0.0
   N2                     0.8112
   O2                     0.1888
   HCL                    0.0
   TOTAL CUM/HR           1.0985
 TOTAL FLOW:
   KMOL/HR               20.5104
   KG/HR                590.0000
   CUM/HR               508.3647
 STATE VARIABLES:
   TEMP   C              25.0000
   PRES   BAR             1.0000
   VFRAC                  1.0000
   LFRAC                  0.0
   SFRAC                  0.0
 ENTHALPY:
   KCAL/MOL          -1.5751-03
   KCAL/KG           -5.4756-02
   GCAL/HR           -3.2306-05
 ENTROPY:
   CAL/MOL-K              0.9832
   CAL/GM-K           3.4179-02
```

```
DENSITY:
  MOL/CC              4.0346-05
  KG/CUM                1.1606
AVG MW                 28.7658

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  0.0
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.0
    CHAR                 0.0
    N2                 466.1000
    O2                 123.9000
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR        508.3647
MASSVFRA                 1.0000
MASSSFRA                 0.0
RHOMX    KG/CUM          1.1606
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                          COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
HCL                                  4.6107   $/KG                  5839.6504
P-CHAR                               0.9315   $/KG                  1183.8191
SALT                                10.3983   $/KG                   151.8457
BURNER.CH4                       2.7000-02   $/KG                     2.7000

BIOGAS
------

STREAM ID              BIOGAS
FROM :                 $C-1
TO   :                 B1
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR              204.3554
  GCAL/HR             -0.3298
SUBSTREAM: MIXED
```

PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.0
CO2	2.3217
CH4	6.3691
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	0.0
CO2	102.1777
CH4	102.1777
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.0
CO2	0.5000
CH4	0.5000
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.0
CO2	0.1243
CH4	0.3411
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.4655
COMPONENTS: STD VOL FRAC	
H20	0.0
CO2	0.2671
CH4	0.7329
CARBO-01	0.0
HYDRO-01	0.0

```
  BIOCRUDE              0.0
  CHAR                  0.0
  N2                    0.0
  O2                    0.0
  HCL                   0.0
  TOTAL CUM/HR          0.4655
TOTAL FLOW:
  KMOL/HR               8.6908
  KG/HR               204.3554
  CUM/HR                2.5060
STATE VARIABLES:
  TEMP   C             87.2690
  PRES   BAR           95.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  KCAL/MOL            -37.9427
  KCAL/KG           -1613.6182
  GCAL/HR              -0.3298
ENTROPY:
  CAL/MOL-K           -20.8618
  CAL/GM-K             -0.8872
DENSITY:
  MOL/CC             3.4680-03
  KG/CUM               81.5474
AVG MW                 23.5140

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 0.0
    CO2               102.1777
    CH4               102.1777
    CARBO-01            0.0
    HYDRO-01            0.0
    BIOCRUDE            0.0
    CHAR                0.0
    N2                  0.0
    O2                  0.0
    HCL                 0.0
    RAS                 0.0
    DSS                 0.0
    SCB                 0.0
VOLFLMX  CUM/HR         2.5060
MASSVFRA                1.0000
MASSSFRA                0.0
RHOMX    KG/CUM        81.5474
TEMP     C             87.2690
PRES     BAR           95.0000
```

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

CH4

STREAM ID	CH4
FROM :	----
TO :	B1
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	100.0000
GCAL/HR	-0.1110
$/HR	2.7000
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.0
CO2	0.0
CH4	6.2333
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	0.0
CO2	0.0
CH4	100.0000
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.0
CO2	0.0
CH4	1.0000
CARBO-01	0.0

```
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.3338
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.3338
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    1.0000
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.3338
TOTAL FLOW:
  KMOL/HR                6.2333
  KG/HR                100.0000
  CUM/HR               154.2577
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -17.8028
  KCAL/KG            -1109.7065
  GCAL/HR               -0.1110
ENTROPY:
  CAL/MOL-K            -19.2340
  CAL/GM-K              -1.1989
DENSITY:
  MOL/CC              4.0409-05
  KG/CUM                0.6483
AVG MW                 16.0428
```

TOTAL STREAM PROPERTIES:

```
 ***  ALL PHASES   ***
 MASSFLOW KG/HR
     H20                  0.0
     CO2                  0.0
     CH4                100.0000
     CARBO-01             0.0
     HYDRO-01             0.0
     BIOCRUDE             0.0
     CHAR                 0.0
     N2                   0.0
     O2                   0.0
     HCL                  0.0
     RAS                  0.0
     DSS                  0.0
     SCB                  0.0
 VOLFLMX  CUM/HR        154.2577
 MASSVFRA                 1.0000
 MASSSFRA                 0.0
 RHOMX    KG/CUM          0.6483
 TEMP     C              25.0000
 PRES     BAR             1.0000

 STREAM COSTS
 ------------

 ID                                PRICE                          COST $/HR

 -----------                       ------------------------------   ------------
 BIOCRUDE                             0.8200   $/KG                    5.6248
 HCL                                  4.6107   $/KG                 5839.6504
 P-CHAR                               0.9315   $/KG                 1183.8191
 SALT                                10.3983   $/KG                  151.8457
 BURNER.CH4                       2.7000-02   $/KG                    2.7000

 S1
 --

 STREAM ID              S1
 FROM :                 B1
 TO   :                 B2
 CLASS:                 MIXCINC
 TOTAL STREAM:
   KG/HR              894.3554
   GCAL/HR             -0.4408
 SUBSTREAM: MIXED
 PHASE:                 VAPOR
 COMPONENTS: KMOL/HR
   H20                  5.2751
   CO2                  2.4874
   CH4                  2.8783
```

CARBO-01	2.1376
HYDRO-01	14.1732
BIOCRUDE	2.2046-19
CHAR	0.0
N2	16.6384
O2	1.1054-24
HCL	0.0
COMPONENTS: KG/HR	
H20	95.0333
CO2	109.4687
CH4	46.1751
CARBO-01	59.8739
HYDRO-01	28.5715
BIOCRUDE	2.0748-17
CHAR	0.0
N2	466.1000
O2	3.5372-23
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.1180
CO2	0.1359
CH4	5.7345-02
CARBO-01	7.4357-02
HYDRO-01	3.5483-02
BIOCRUDE	2.5767-20
CHAR	0.0
N2	0.5788
O2	4.3928-26
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	9.5216-02
CO2	0.1332
CH4	0.1542
CARBO-01	0.1145
HYDRO-01	0.7591
BIOCRUDE	1.9779-20
CHAR	0.0
N2	0.8911
O2	5.9203-26
HCL	0.0
TOTAL CUM/HR	2.1473
COMPONENTS: STD VOL FRAC	
H20	4.4343-02
CO2	6.2041-02
CH4	7.1790-02
CARBO-01	5.3316-02
HYDRO-01	0.3535
BIOCRUDE	9.2113-21
CHAR	0.0
N2	0.4150
O2	2.7571-26
HCL	0.0

```
  TOTAL CUM/HR           2.1473
TOTAL FLOW:
  KMOL/HR               43.5900
  KG/HR                805.2224
  CUM/HR              3035.2264
STATE VARIABLES:
  TEMP   C             575.1892
  PRES   BAR             1.0133
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -10.5029
  KCAL/KG              -568.5645
  GCAL/HR               -0.4578
ENTROPY:
  CAL/MOL-K              9.5705
  CAL/GM-K               0.5181
DENSITY:
  MOL/CC              1.4361-05
  KG/CUM                 0.2653
AVG MW                  18.4727

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   7.4209
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  89.1330
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
```

```
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                3.8471-02
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        3.8471-02
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        3.8471-02
TOTAL FLOW:
  KMOL/HR                7.4209
  KG/HR                 89.1330
  CUM/HR              3.9614-02
STATE VARIABLES:
  TEMP   C             575.1892
  PRES   BAR             1.0133
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL               2.2997
  KCAL/KG              191.4682
  GCAL/HR             1.7066-02
ENTROPY:
  CAL/MOL-K              3.9861
  CAL/GM-K               0.3319
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:
```

```
***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 95.0333
    CO2                109.4687
    CH4                 46.1751
    CARBO-01            59.8739
    HYDRO-01            28.5715
    BIOCRUDE          2.0748-17
    CHAR                89.1330
    N2                 466.1000
    O2                3.5372-23
    HCL                    0.0
    RAS                    0.0
    DSS                    0.0
    SCB                    0.0
VOLFLMX  CUM/HR        3035.2660
MASSVFRA                   0.9003
MASSSFRA                9.9662-02
RHOMX    KG/CUM            0.2947
TEMP     C               575.1892
PRES     BAR               1.0133

STREAM COSTS
------------

ID                                PRICE                          COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

S2
--

STREAM ID                 S2
FROM :                    B2
TO   :                    $C-3
CLASS:                    MIXCINC
TOTAL STREAM:
  KG/HR                 279.7627
  GCAL/HR                -0.8650
SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: KMOL/HR
  H20                    15.4936
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
```

```
  HYDRO-01               0.0
  BIOCRUDE            6.8169-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                  279.1212
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.6416
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.9977
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.2932-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.2797
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            6.1159-04
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.2803
COMPONENTS: STD VOL FRAC
  H20                    0.9978
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.1821-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.2803
```

```
TOTAL FLOW:
  KMOL/HR               15.5004
  KG/HR                279.7627
  CUM/HR               686.4554
STATE VARIABLES:
  TEMP   C             261.0608
  PRES   BAR             1.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -55.8064
  KCAL/KG            -3091.9823
  GCAL/HR               -0.8650
ENTROPY:
  CAL/MOL-K            -5.8158
  CAL/GM-K             -0.3222
DENSITY:
  MOL/CC              2.2580-05
  KG/CUM                 0.4075
AVG MW                  18.0487

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                279.1212
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.6416
    CHAR                 0.0
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR        686.4554
MASSVFRA                 1.0000
MASSSFRA                 0.0
RHOMX    KG/CUM          0.4075
TEMP     C             261.0608
PRES     BAR             1.0000

STREAM COSTS
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ID                              PRICE                           COST $/HR

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BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

S3
--

STREAM ID	S3
FROM :	B2
TO :	----
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	894.3554
GCAL/HR	-0.6449
SUBSTREAM: MIXED	
PHASE:	MIXED
COMPONENTS: KMOL/HR	
H20	5.2751
CO2	2.4874
CH4	2.8783
CARBO-01	2.1376
HYDRO-01	14.1732
BIOCRUDE	2.2046-19
CHAR	0.0
N2	16.6384
O2	1.1054-24
HCL	0.0
COMPONENTS: KG/HR	
H20	95.0333
CO2	109.4687
CH4	46.1751
CARBO-01	59.8739
HYDRO-01	28.5715
BIOCRUDE	2.0748-17
CHAR	0.0
N2	466.1000
O2	3.5372-23
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.1180
CO2	0.1359
CH4	5.7345-02
CARBO-01	7.4357-02
HYDRO-01	3.5483-02
BIOCRUDE	2.5767-20
CHAR	0.0
N2	0.5788
O2	4.3928-26
HCL	0.0
COMPONENTS: STD CUM/HR	

```
  H20                 9.5216-02
  CO2                    0.1332
  CH4                    0.1542
  CARBO-01               0.1145
  HYDRO-01               0.7591
  BIOCRUDE            1.9779-20
  CHAR                   0.0
  N2                     0.8911
  O2                  5.9203-26
  HCL                    0.0
  TOTAL CUM/HR           2.1473
COMPONENTS: STD VOL FRAC
  H20                 4.4343-02
  CO2                 6.2041-02
  CH4                 7.1790-02
  CARBO-01            5.3316-02
  HYDRO-01               0.3535
  BIOCRUDE            9.2113-21
  CHAR                   0.0
  N2                     0.4150
  O2                  2.7571-26
  HCL                    0.0
  TOTAL CUM/HR           2.1473
TOTAL FLOW:
  KMOL/HR              43.5900
  KG/HR               805.2224
  CUM/HR             1142.1747
STATE VARIABLES:
  TEMP   C              51.4080
  PRES   BAR             1.0133
  VFRAC                  0.9842
  LFRAC               1.5785-02
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL            -14.8038
  KCAL/KG            -801.3896
  GCAL/HR              -0.6453
ENTROPY:
  CAL/MOL-K              1.5796
  CAL/GM-K            8.5511-02
DENSITY:
  MOL/CC              3.8164-05
  KG/CUM                 0.7050
AVG MW                  18.4727

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
```

```
  BIOCRUDE               0.0
  CHAR                   7.4209
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  89.1330
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                3.8471-02
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        3.8471-02
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        3.8471-02
TOTAL FLOW:
```

```
  KMOL/HR                7.4209
  KG/HR                 89.1330
  CUM/HR              3.9614-02
STATE VARIABLES:
  TEMP   C              51.4080
  PRES   BAR             1.0133
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL            5.6344-02
  KCAL/KG                4.6910
  GCAL/HR             4.1813-04
ENTROPY:
  CAL/MOL-K              0.1809
  CAL/GM-K            1.5065-02
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  95.0333
    CO2                 109.4687
    CH4                  46.1751
    CARBO-01             59.8739
    HYDRO-01             28.5715
    BIOCRUDE              0.0
    CHAR                 89.1330
    N2                  466.1000
    O2                     0.0
    HCL                    0.0
    RAS                    0.0
    DSS                    0.0
    SCB                    0.0
VOLFLMX  CUM/HR        1142.2143
MASSVFRA                  0.8865
MASSSFRA               9.9662-02
RHOMX    KG/CUM           0.7830
TEMP     C              51.4080
PRES     BAR             1.0133

STREAM COSTS
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ID                              PRICE                           COST $/HR

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BIOCRUDE                            0.8200   $/KG                   5.6248
```

HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

S4
--

STREAM ID	S4
FROM :	$C-2
TO :	B2
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	279.7627
GCAL/HR	-1.0691
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	15.4936
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	6.8169-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	279.1212
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.6416
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.2797

```
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            6.1159-04
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.2803
COMPONENTS: STD VOL FRAC
  H20                    0.9978
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.1821-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.2803
TOTAL FLOW:
  KMOL/HR               15.5004
  KG/HR                279.7627
  CUM/HR                 0.2910
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6147
  GCAL/HR               -1.0691
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                279.1212
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
```

```
    HYDRO-01              0.0
    BIOCRUDE              0.6416
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR           0.2910
MASSVFRA                  0.0
MASSSFRA                  0.0
RHOMX    KG/CUM         961.3196
TEMP     C               25.0000
PRES     BAR              1.0000

STREAM COSTS
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ID                                PRICE                              COST $/HR

-----------                       -----------------------------   ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
HCL                                  4.6107   $/KG                  5839.6504
P-CHAR                               0.9315   $/KG                  1183.8191
SALT                                10.3983   $/KG                   151.8457
BURNER.CH4                        2.7000-02   $/KG                     2.7000

BIOCHAR2 S1 S2 SALT WASTE
-------------------------

STREAM ID               BIOCHAR2   S1         S2         SALT       WASTE
FROM :                  $C-8       $C-9       B1         B2         B2
TO   :                  B1         B1         B2         $C-10      $C-11
CLASS:                  MIXCINC    MIXCINC    MIXCINC    MIXCINC    MIXCINC
TOTAL STREAM:
  KG/HR                 18.9469  1266.5300  1285.4769    14.6029  1270.8740
  GCAL/HR            -1.6037-02    -0.7662    -0.7822 -2.5425-05    -0.7822
SUBSTREAM: MIXED
PHASE:                  LIQUID     VAPOR      VAPOR      M -        VAPOR
COMPONENTS: KMOL/HR
  H20                    0.2324     0.0        0.2324     0.0        0.2324
  CO2                    0.0        0.0        0.0        0.0        0.0
  CH4                    0.0        0.0        0.0        0.0        0.0
  CARBO-01               0.0        0.0        0.0        0.0        0.0
  HYDRO-01               0.0        0.0        0.0        0.0        0.0
  BIOCRUDE            1.0225-04     0.0     1.0225-04     0.0     1.0225-04
  CHAR                   0.0        0.0        0.0        0.0        0.0
  N2                     0.0        0.0        0.0        0.0        0.0
  O2                     0.0        0.0        0.0        0.0        0.0
  HCL                    0.0       34.7369    34.7369     0.0       34.7369
COMPONENTS: KG/HR
```

H20	4.1868	0.0	4.1868	0.0	4.1868
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	9.6235-03	0.0	9.6235-03	0.0	9.6235-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	1266.5300	1266.5300	0.0	1266.5300
COMPONENTS: MASS FRAC					
H20	0.9977	0.0	3.2948-03	0.0	3.2948-03
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	2.2932-03	0.0	7.5732-06	0.0	7.5732-06
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	1.0000	0.9967	0.0	0.9967
COMPONENTS: STD CUM/HR					
H20	4.1949-03	0.0	4.1949-03	0.0	4.1949-03
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	9.1740-06	0.0	9.1740-06	0.0	9.1740-06
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	1.8604	1.8604	0.0	1.8604
TOTAL CUM/HR	4.2041-03	1.8604	1.8646	0.0	1.8646
COMPONENTS: STD VOL FRAC					
H20	0.9978	0.0	2.2497-03	0.0	2.2497-03
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	2.1822-03	0.0	4.9200-06	0.0	4.9200-06
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	1.0000	0.9977	0.0	0.9977
TOTAL CUM/HR	4.2041-03	1.8604	1.8646	0.0	1.8646
TOTAL FLOW:					
KMOL/HR	0.2325	34.7369	34.9694	0.0	34.9694
KG/HR	4.1965	1266.5300	1270.7265	0.0	1270.7265
CUM/HR	4.3653-03	856.5029	831.2721	0.0	831.2721
STATE VARIABLES:					
TEMP C	25.0000	25.0000	14.4839	M -	14.4839
PRES BAR	1.0000	1.0000	1.0000	1.0000	1.0000

VFRAC	0.0	1.0000	1.0000	M -	1.0000
LFRAC	1.0000	0.0	0.0	M -	0.0
SFRAC	0.0	0.0	0.0	M -	0.0
ENTHALPY:					
KCAL/MOL	-68.9754	-22.0573	-22.3685	M -	-22.3685
KCAL/KG	-3821.6146	-604.9625	-615.5650	M -	-615.5650
GCAL/HR	-1.6037-02	-0.7662	-0.7822	M -	-0.7822
ENTROPY:					
CAL/MOL-K	-38.9789	2.4003	2.1409	M -	2.1409
CAL/GM-K	-2.1596	6.5832-02	5.8915-02	M -	5.8915-02
DENSITY:					
MOL/CC	5.3262-02	4.0557-05	4.2067-05	M -	4.2067-05
KG/CUM	961.3196	1.4787	1.5287	M -	1.5287
AVG MW	18.0487	36.4606	36.3382	M -	36.3382

SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL

COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.2281	0.0	1.2281	1.2158	1.2281-02
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	14.7504	0.0	14.7504	14.6029	0.1475
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.0000	0.0	1.0000	1.0000	1.0000
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0

CH4		0.0		0.0	0.0	0.0
CARBO-01		0.0		0.0	0.0	0.0
HYDRO-01		0.0		0.0	0.0	0.0
BIOCRUDE		0.0		0.0	0.0	0.0
CHAR		6.3665-03		0.0	6.3665-03	6.3028-03	6.3665-05
N2		0.0		0.0	0.0	0.0
O2		0.0		0.0	0.0	0.0
HCL		0.0		0.0	0.0	0.0
TOTAL CUM/HR		6.3665-03		0.0	6.3665-03	6.3028-03	6.3665-05
COMPONENTS: STD VOL FRAC						
H20		0.0		0.0	0.0	0.0
CO2		0.0		0.0	0.0	0.0
CH4		0.0		0.0	0.0	0.0
CARBO-01		0.0		0.0	0.0	0.0
HYDRO-01		0.0		0.0	0.0	0.0
BIOCRUDE		0.0		0.0	0.0	0.0
CHAR		1.0000		0.0	1.0000	1.0000	1.0000
N2		0.0		0.0	0.0	0.0
O2		0.0		0.0	0.0	0.0
HCL		0.0		0.0	0.0	0.0
TOTAL CUM/HR		6.3665-03		0.0	6.3665-03	6.3028-03	6.3665-05
TOTAL FLOW:						
KMOL/HR		1.2281		0.0	1.2281	1.2158	1.2281-02
KG/HR		14.7504		0.0	14.7504	14.6029	0.1475
CUM/HR		6.5557-03		0.0	6.5557-03	6.4901-03	6.5557-05
STATE VARIABLES:						
TEMP	C	25.0000	M	-	14.4839	14.4839	14.4839
PRES	BAR	1.0000		1.0000	1.0000	1.0000	1.0000
VFRAC		0.0	M	-	0.0	0.0	0.0
LFRAC		0.0	M	-	0.0	0.0	0.0
SFRAC		1.0000	M	-	1.0000	1.0000	1.0000
ENTHALPY:						
KCAL/MOL		-4.5856-08	M	-	-2.0912-02	-2.0912-02	-2.0912-02
KCAL/KG		-3.8178-06	M	-	-1.7411	-1.7411	-1.7411
GCAL/HR		-5.6315-11	M	-	-2.5681-05	-2.5425-05	-2.5681-07
ENTROPY:						
CAL/MOL-K		-1.5380-07	M	-	-7.1396-02	-7.1396-02	-7.1396-02
CAL/GM-K		-1.2805-08	M	-	-5.9443-03	-5.9443-03	-5.9443-03
DENSITY:						
MOL/CC		0.1873	M	-	0.1873	0.1873	0.1873
KG/CUM		2250.0206	M	-	2250.0206	2250.0206	2250.0206
AVG MW		12.0110	M	-	12.0110	12.0110	12.0110

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW KG/HR						
H20		4.1868		0.0	4.1868	0.0	4.1868
CO2		0.0		0.0	0.0	0.0	0.0
CH4		0.0		0.0	0.0	0.0	0.0
CARBO-01		0.0		0.0	0.0	0.0	0.0
HYDRO-01		0.0		0.0	0.0	0.0	0.0

BIOCRUDE		9.6235-03	0.0	9.6235-03	0.0	9.6235-03
CHAR		14.7504	0.0	14.7504	14.6029	0.1475
N2		0.0	0.0	0.0	0.0	0.0
O2		0.0	0.0	0.0	0.0	0.0
HCL		0.0	1266.5300	1266.5300	0.0	1266.5300
RAS		0.0	0.0	0.0	0.0	0.0
DSS		0.0	0.0	0.0	0.0	0.0
SCB		0.0	0.0	0.0	0.0	0.0
VOLFLMX	CUM/HR	1.0921-02	856.5029	831.2786	6.4901-03	831.2721
MASSVFRA		0.0	1.0000	0.9885	0.0	0.9999
MASSSFRA		0.7785	0.0	1.1475-02	1.0000	1.1607-04
RHOMX	KG/CUM	1734.9049	1.4787	1.5464	2250.0206	1.5288
TEMP	C	25.0000	25.0000	14.4839	14.4839	14.4839
PRES	BAR	1.0000	1.0000	1.0000	1.0000	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

BIOCHAR2

STREAM ID	BIOCHAR2
FROM :	$C-8
TO :	B1
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	18.9469
GCAL/HR	-1.6037-02
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	0.2324
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0225-04
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	4.1868

```
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE             9.6235-03
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: MASS FRAC
  H20                      0.9977
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE             2.2932-03
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: STD CUM/HR
  H20                  4.1949-03
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE             9.1740-06
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR         4.2041-03
COMPONENTS: STD VOL FRAC
  H20                      0.9978
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE             2.1822-03
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR         4.2041-03
TOTAL FLOW:
  KMOL/HR                  0.2325
  KG/HR                    4.1965
  CUM/HR               4.3653-03
STATE VARIABLES:
  TEMP   C                25.0000
  PRES   BAR               1.0000
  VFRAC                    0.0
```

```
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6146
  GCAL/HR            -1.6037-02
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                  1.2281
  N2                    0.0
  O2                    0.0
  HCL                   0.0
COMPONENTS: KG/HR
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                 14.7504
  N2                    0.0
  O2                    0.0
  HCL                   0.0
COMPONENTS: MASS FRAC
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                  1.0000
  N2                    0.0
  O2                    0.0
  HCL                   0.0
COMPONENTS: STD CUM/HR
  H20                   0.0
  CO2                   0.0
  CH4                   0.0
```

```
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.3665-03
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3665-03
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3665-03
TOTAL FLOW:
  KMOL/HR                1.2281
  KG/HR                 14.7504
  CUM/HR              6.5557-03
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL           -4.5856-08
  KCAL/KG            -3.8178-06
  GCAL/HR            -5.6315-11
ENTROPY:
  CAL/MOL-K          -1.5380-07
  CAL/GM-K           -1.2805-08
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  4.1868
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE          9.6235-03
```

```
    CHAR                14.7504
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR       1.0921-02
MASSVFRA                 0.0
MASSSFRA                 0.7785
RHOMX    KG/CUM      1734.9049
TEMP     C             25.0000
PRES     BAR            1.0000

STREAM COSTS
------------

ID                                PRICE                          COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

S1
--

STREAM ID              S1
FROM :                 $C-9
TO   :                 B1
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR             1266.5300
  GCAL/HR             -0.7662
SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: KMOL/HR
  H20                  0.0
  CO2                  0.0
  CH4                  0.0
  CARBO-01             0.0
  HYDRO-01             0.0
  BIOCRUDE             0.0
  CHAR                 0.0
  N2                   0.0
  O2                   0.0
  HCL                 34.7369
COMPONENTS: KG/HR
  H20                  0.0
  CO2                  0.0
```

```
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                  1266.5300
COMPONENTS: MASS FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     1.0000
COMPONENTS: STD CUM/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     1.8604
  TOTAL CUM/HR            1.8604
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     1.0000
  TOTAL CUM/HR            1.8604
TOTAL FLOW:
  KMOL/HR                34.7369
  KG/HR                1266.5300
  CUM/HR                856.5029
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   1.0000
  LFRAC                   0.0
```

```
  SFRAC                    0.0
ENTHALPY:
  KCAL/MOL              -22.0573
  KCAL/KG              -604.9625
  GCAL/HR                -0.7662
ENTROPY:
  CAL/MOL-K               2.4003
  CAL/GM-K             6.5832-02
DENSITY:
  MOL/CC               4.0557-05
  KG/CUM                  1.4787
AVG MW                   36.4606

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                    0.0
    CO2                    0.0
    CH4                    0.0
    CARBO-01               0.0
    HYDRO-01               0.0
    BIOCRUDE               0.0
    CHAR                   0.0
    N2                     0.0
    O2                     0.0
    HCL                 1266.5300
    RAS                    0.0
    DSS                    0.0
    SCB                    0.0
VOLFLMX  CUM/HR          856.5029
MASSVFRA                   1.0000
MASSSFRA                   0.0
RHOMX    KG/CUM            1.4787
TEMP     C                25.0000
PRES     BAR               1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

S2
--
```

STREAM ID	S2
FROM :	B1
TO :	B2
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	1285.4769
GCAL/HR	-0.7822
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.2324
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0225-04
CHAR	0.0
N2	0.0
O2	0.0
HCL	34.7369
COMPONENTS: KG/HR	
H20	4.1868
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.6235-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	1266.5300
COMPONENTS: MASS FRAC	
H20	3.2948-03
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	7.5732-06
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.9967
COMPONENTS: STD CUM/HR	
H20	4.1949-03
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.1740-06
CHAR	0.0
N2	0.0
O2	0.0

```
  HCL                     1.8604
  TOTAL CUM/HR            1.8646
COMPONENTS: STD VOL FRAC
  H20                  2.2497-03
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             4.9200-06
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.9977
  TOTAL CUM/HR            1.8646
TOTAL FLOW:
  KMOL/HR                34.9694
  KG/HR                1270.7265
  CUM/HR                831.2721
STATE VARIABLES:
  TEMP   C               14.4839
  PRES   BAR              1.0000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -22.3685
  KCAL/KG              -615.5650
  GCAL/HR                -0.7822
ENTROPY:
  CAL/MOL-K               2.1409
  CAL/GM-K             5.8915-02
DENSITY:
  MOL/CC               4.2067-05
  KG/CUM                  1.5287
AVG MW                   36.3382

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.2281
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: KG/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
```

```
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.7504
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.3665-03
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3665-03
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3665-03
TOTAL FLOW:
  KMOL/HR                1.2281
  KG/HR                 14.7504
  CUM/HR              6.5557-03
STATE VARIABLES:
  TEMP   C              14.4839
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
```

```
ENTHALPY:
  KCAL/MOL           -2.0912-02
  KCAL/KG               -1.7411
  GCAL/HR            -2.5681-05
ENTROPY:
  CAL/MOL-K          -7.1396-02
  CAL/GM-K           -5.9443-03
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                   4.1868
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE           9.6235-03
    CHAR                 14.7504
    N2                    0.0
    O2                    0.0
    HCL                1266.5300
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR         831.2786
MASSVFRA                  0.9885
MASSSFRA               1.1475-02
RHOMX    KG/CUM           1.5464
TEMP     C               14.4839
PRES     BAR              1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

SALT
----

STREAM ID              SALT
```

```
FROM :                   B2
TO   :                   $C-10
CLASS:                   MIXCINC
TOTAL STREAM:
  KG/HR                  14.6029
  GCAL/HR             -2.5425-05

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.2158
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: KG/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                   14.6029
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                 6.3028-03
  N2                      0.0
  O2                      0.0
  HCL                     0.0
```

```
TOTAL CUM/HR        6.3028-03
COMPONENTS: STD VOL FRAC

  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3028-03
TOTAL FLOW:
  KMOL/HR                1.2158
  KG/HR                 14.6029
  CUM/HR              6.4901-03
STATE VARIABLES:
  TEMP   C              14.4839
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL           -2.0912-02
  KCAL/KG               -1.7411
  GCAL/HR            -2.5425-05
ENTROPY:
  CAL/MOL-K          -7.1396-02
  CAL/GM-K           -5.9443-03
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                    0.0
    CO2                    0.0
    CH4                    0.0
    CARBO-01               0.0
    HYDRO-01               0.0
    BIOCRUDE               0.0
    CHAR                  14.6029
    N2                     0.0
    O2                     0.0
    HCL                    0.0
    RAS                    0.0
    DSS                    0.0
    SCB                    0.0
```

VOLFLMX	CUM/HR	6.4901-03
MASSVFRA		0.0
MASSSFRA		1.0000
RHOMX	KG/CUM	2250.0206
TEMP	C	14.4839
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

WASTE

STREAM ID	WASTE
FROM :	B2
TO :	$C-11
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	1270.8740
GCAL/HR	-0.7822
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.2324
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0225-04
CHAR	0.0
N2	0.0
O2	0.0
HCL	34.7369
COMPONENTS: KG/HR	
H20	4.1868
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	9.6235-03
CHAR	0.0
N2	0.0
O2	0.0

```
  HCL                 1266.5300
COMPONENTS: MASS FRAC
  H20                 3.2948-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            7.5732-06
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.9967
COMPONENTS: STD CUM/HR
  H20                 4.1949-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            9.1740-06
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    1.8604
  TOTAL CUM/HR           1.8646
COMPONENTS: STD VOL FRAC
  H20                 2.2497-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            4.9200-06
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.9977
  TOTAL CUM/HR           1.8646
TOTAL FLOW:
  KMOL/HR              34.9694
  KG/HR              1270.7265
  CUM/HR              831.2721
STATE VARIABLES:
  TEMP   C             14.4839
  PRES   BAR            1.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  KCAL/MOL            -22.3685
  KCAL/KG             -615.5650
  GCAL/HR              -0.7822
ENTROPY:
  CAL/MOL-K             2.1409
```

```
  CAL/GM-K            5.8915-02
DENSITY:
  MOL/CC              4.2067-05
  KG/CUM                 1.5287
AVG MW                  36.3382

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                1.2281-02
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.1475
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.3665-05
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3665-05
```

```
COMPONENTS: STD VOL FRAC

   H20                    0.0
   CO2                    0.0
   CH4                    0.0
   CARBO-01               0.0
   HYDRO-01               0.0
   BIOCRUDE               0.0
   CHAR                   1.0000
   N2                     0.0
   O2                     0.0
   HCL                    0.0
   TOTAL CUM/HR        6.3665-05
 TOTAL FLOW:
   KMOL/HR             1.2281-02
   KG/HR                  0.1475
   CUM/HR              6.5557-05
 STATE VARIABLES:
   TEMP   C              14.4839
   PRES   BAR             1.0000
   VFRAC                  0.0
   LFRAC                  0.0
   SFRAC                  1.0000
 ENTHALPY:
   KCAL/MOL           -2.0912-02
   KCAL/KG               -1.7411
   GCAL/HR            -2.5681-07
 ENTROPY:
   CAL/MOL-K          -7.1396-02
   CAL/GM-K           -5.9443-03
 DENSITY:
   MOL/CC                 0.1873
   KG/CUM              2250.0206
 AVG MW                  12.0110

 TOTAL STREAM PROPERTIES:

 ***  ALL PHASES   ***
 MASSFLOW KG/HR
     H20                    4.1868
     CO2                    0.0
     CH4                    0.0
     CARBO-01               0.0
     HYDRO-01               0.0
     BIOCRUDE           9.6235-03
     CHAR                   0.1475
     N2                     0.0
     O2                     0.0
     HCL                 1266.5300
     RAS                    0.0
     DSS                    0.0
     SCB                    0.0
 VOLFLMX  CUM/HR         831.2721
```

MASSVFRA		0.9999
MASSSFRA		1.1607-04
RHOMX	KG/CUM	1.5288
TEMP	C	14.4839
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

AB-FEED AQ-CLEAN AQFEED AQRECYCL AQUEOUS

STREAM ID	AB-FEED	AQ-CLEAN	AQFEED	AQRECYCL	AQUEOUS
FROM :	AQSPLIT	$C-7	$C-3	AQSPLIT	LLSEP
TO :	$C-5	----	R-HTL	$C-2	AQSPLIT
CLASS:	MIXCINC	MIXCINC	MIXCINC	MIXCINC	MIXCINC
TOTAL STREAM:					
KG/HR	419.6441	415.5981	279.7627	279.7627	699.4068
GCAL/HR	-1.6037	-1.5877	-0.8650	-1.0691	-2.6729
SUBSTREAM: MIXED					
PHASE:	LIQUID	LIQUID	VAPOR	LIQUID	LIQUID
COMPONENTS: KMOL/HR					
H20	23.2404	23.0080	15.4936	15.4936	38.7339
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.0225-02	1.0123-02	6.8169-03	6.8169-03	1.7042-02
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	418.6818	414.4964	279.1212	279.1212	697.8029
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.9623	0.9527	0.6416	0.6416	1.6039
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0

COMPONENTS: MASS FRAC					
H20	0.9977	0.9977	0.9977	0.9977	0.9977
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	2.2932-03	2.2932-03	2.2932-03	2.2932-03	2.2932-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.4195	0.4153	0.2797	0.2797	0.6991
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	9.1738-04	9.0823-04	6.1159-04	6.1159-04	1.5290-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.4204	0.4162	0.2803	0.2803	0.7007
COMPONENTS: STD VOL FRAC					
H20	0.9978	0.9978	0.9978	0.9978	0.9978
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	2.1821-03	2.1822-03	2.1821-03	2.1821-03	2.1821-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.4204	0.4162	0.2803	0.2803	0.7007
TOTAL FLOW:					
KMOL/HR	23.2506	23.0182	15.5004	15.5004	38.7510
KG/HR	419.6441	415.4491	279.7627	279.7627	699.4068
CUM/HR	0.4365	0.4322	686.4554	0.2910	0.7275
STATE VARIABLES:					
TEMP C	25.0000	25.0000	261.0608	25.0000	25.0000
PRES BAR	1.0000	1.0000	1.0000	1.0000	1.0000
VFRAC	0.0	0.0	1.0000	0.0	0.0
LFRAC	1.0000	1.0000	0.0	1.0000	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
KCAL/MOL	-68.9754	-68.9754	-55.8064	-68.9754	-68.9754
KCAL/KG	-3821.6147	-3821.6146	-3091.9823	-3821.6147	-3821.6147
GCAL/HR	-1.6037	-1.5877	-0.8650	-1.0691	-2.6729
ENTROPY:					
CAL/MOL-K	-38.9789	-38.9789	-5.8158	-38.9789	-38.9789
CAL/GM-K	-2.1596	-2.1596	-0.3222	-2.1596	-2.1596

DENSITY:					
MOL/CC	5.3262-02	5.3262-02	2.2580-05	5.3262-02	5.3262-02
KG/CUM	961.3196	961.3196	0.4075	961.3196	961.3196
AVG MW	18.0487	18.0487	18.0487	18.0487	18.0487
SUBSTREAM: CISOLID	STRUCTURE: CONVENTIONAL				
COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	1.2405-02	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.1490	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	1.0000	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	6.4308-05	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	6.4308-05	0.0	0.0	0.0
COMPONENTS: STD VOL FRAC					

H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	1.0000	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	6.4308-05	0.0	0.0	0.0
TOTAL FLOW:					
KMOL/HR	0.0	1.2405-02	0.0	0.0	0.0
KG/HR	0.0	0.1490	0.0	0.0	0.0
CUM/HR	0.0	6.6219-05	0.0	0.0	0.0
STATE VARIABLES:					
TEMP C	M -	25.0000	M -	M -	M -
PRES BAR	1.0000	1.0000	1.0000	1.0000	1.0000
VFRAC	M -	0.0	M -	M -	M -
LFRAC	M -	0.0	M -	M -	M -
SFRAC	M -	1.0000	M -	M -	M -
ENTHALPY:					
KCAL/MOL	M-	-4.5856-08	M -	M -	M -
KCAL/KG	M-	-3.8178-06	M -	M -	M -
GCAL/HR	M-	-5.6884-13	M -	M -	M -
ENTROPY:					
CAL/MOL-K	M-	-1.5380-07	M -	M -	M -
CAL/GM-K	M-	- 1.2805-08	M -	M -	M -
DENSITY:					
MOL/CC	M -	0.1873	M -	M -	M -
KG/CUM	M -	2250.0206	M -	M -	M -
AVG MW	M -	12.0110	M -	M -	M -

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW KG/HR					
H20	418.6818	414.4964	279.1212	279.1212	697.8029
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.9623	0.9527	0.6416	0.6416	1.6039
CHAR	0.0	0.1490	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
RAS	0.0	0.0	0.0	0.0	0.0
DSS	0.0	0.0	0.0	0.0	0.0
SCB	0.0	0.0	0.0	0.0	0.0
VOLFLMX CUM/HR	0.4365	0.4322	686.4554	0.2910	0.7275
MASSVFRA	0.0	0.0	1.0000	0.0	0.0

MASSSFRA		0.0	3.5851-04	0.0	0.0	0.0
RHOMX	KG/CUM	961.3196	961.5171	0.4075	961.3196	961.3196
TEMP	C	25.0000	25.0000	261.0608	25.0000	25.0000
PRES	BAR	1.0000	1.0000	1.0000	1.0000	1.0000

BIOCHAR1 BIOCHAR2 BIOCRUDE BIOGAS DSS

STREAM ID	BIOCHAR1	BIOCHAR2	BIOCRUDE	BIOGAS	DSS
FROM :	FLR-CHAR	$C-6	LLSEP	VENT	----
TO :	$C-4	$C-8	----	$C-1	MX-1
CLASS:	MIXCINC	MIXCINC	MIXCINC	MIXCINC	MIXCINC
TOTAL STREAM:					
KG/HR	14.9009	18.9469	6.8596	204.3554	380.0000
GCAL/HR	-5.6563-06	-1.6037-02	-3.7295-03	-0.3298	-1.4163
$/HR	M -	M -	5.6248	M -	M -
SUBSTREAM: MIXED					
PHASE:	LIQUID	LIQUID	LIQUID	VAPOR	LIQUID
COMPONENTS: KMOL/HR					
H20	8.1751-05	0.2324	1.7617-02	0.0	19.7095
CO2	0.0	0.0	0.0	2.3217	0.0
CH4	0.0	0.0	0.0	6.3691	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.8257-07	1.0225-04	6.9498-02	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	1.4728-03	4.1868	0.3174	0.0	355.0720
CO2	0.0	0.0	0.0	102.1777	0.0
CH4	0.0	0.0	0.0	102.1777	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.7182-05	9.6235-03	6.5407	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.9885	0.9977	4.6278-02	0.0	1.0000
CO2	0.0	0.0	0.0	0.5000	0.0
CH4	0.0	0.0	0.0	0.5000	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.1532-02	2.2932-03	0.9537	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					

H20	1.4756-06	4.1949-03	3.1799-04	0.0	0.3558
CO2	0.0	0.0	0.0	0.1243	0.0
CH4	0.0	0.0	0.0	0.3411	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.6379-08	9.1740-06	6.2352-03	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	1.4920-06	4.2041-03	6.5532-03	0.4655	0.3558
COMPONENTS: STD VOL FRAC					
H20	0.9890	0.9978	4.8525-02	0.0	1.0000
CO2	0.0	0.0	0.0	0.2671	0.0
CH4	0.0	0.0	0.0	0.7329	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	1.0978-02	2.1822-03	0.9515	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	1.4920-06	4.2041-03	6.5532-03	0.4655	0.3558
TOTAL FLOW:					
KMOL/HR	8.1933-05	0.2325	8.7115-02	8.6908	19.7095
KG/HR	1.4899-03	4.1965	6.8581	204.3554	355.0720
CUM/HR	1.5483-06	4.3653-03	6.1573-03	2.5060	0.3695
STATE VARIABLES:					
TEMP C	24.9956	25.0000	25.0000	87.2690	25.0000
PRES BAR	1.2000	1.0000	1.0000	95.0000	1.0000
VFRAC	0.0	0.0	0.0	1.0000	0.0
LFRAC	1.0000	1.0000	1.0000	0.0	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
KCAL/MOL	-68.9021	-68.9754	-42.8108	-37.9427	-68.9934
KCAL/KG	-3788.9838	-3821.6146	-543.8090	-1613.6182	-3829.7161
GCAL/HR	-5.6454-06	-1.6037-02	-3.7295-03	-0.3298	-1.3598
ENTROPY:					
CAL/MOL-K	-39.0328	-38.9789	-72.4994	-20.8618	-38.9675
CAL/GM-K	-2.1464	-2.1596	-0.9209	-0.8872	-2.1630
DENSITY:					
MOL/CC	5.2918-02	5.3262-02	1.4148-02	3.4680-03	5.3348-02
KG/CUM	962.3115	961.3196	1113.8076	81.5474	961.0757
AVG MW	18.1848	18.0487	78.7239	23.5140	18.0153

SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL

COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0

BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.2405	1.2281	1.2406-04	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	14.8994	14.7504	1.4901-03	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.0000	1.0000	1.0000	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	6.4308-03	6.3665-03	6.4314-07	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	6.4308-03	6.3665-03	6.4314-07	0.0	0.0
COMPONENTS: STD VOL FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.0000	1.0000	1.0000	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	6.4308-03	6.3665-03	6.4314-07	0.0	0.0
TOTAL FLOW:					

KMOL/HR	1.2405	1.2281	1.2406-04	0.0	0.0	
KG/HR	14.8994	14.7504	1.4901-03	0.0	0.0	
CUM/HR	6.6219-03	6.5557-03	6.6226-07	0.0	0.0	
STATE VARIABLES:						
TEMP C	24.9956	25.0000	25.0000	0.0	M -	
PRES BAR	1.2000	1.0000	1.0000	95.0000	1.0000	
VFRAC	0.0	0.0	0.0	0.0	M -	
LFRAC	0.0	0.0	0.0	0.0	M -	
SFRAC	1.0000	1.0000	1.0000	0.0	M -	
ENTHALPY:						
KCAL/MOL	-8.8387-06	-4.5856-08	1.2444-16	0.0	M -	
KCAL/KG	-7.3588-04	-3.8178-06	1.0361-14	0.0	M -	
GCAL/HR	-1.0964-08	-5.6315-11	1.5438-23	0.0	M -	
ENTROPY:						
CAL/MOL-K	-2.9645-05	-1.5380-07	3.1187-16	0.0	M -	
CAL/GM-K	-2.4682-06	-1.2805-08	2.5966-17	0.0	M -	
DENSITY:						
MOL/CC	0.1873	0.1873	0.1873	0.0	M -	
KG/CUM	2250.0206	2250.0206	2250.0206	0.0	M -	
AVG MW	12.0110	12.0110	12.0110	0.0	M -	

SUBSTREAM: NC	STRUCTURE: NON CONVENTIONAL				
COMPONENTS: KG/HR					
RAS	0.0	0.0	0.0	0.0	0.0
DSS	0.0	0.0	0.0	0.0	24.9280
SCB	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
RAS	0.0	0.0	0.0	0.0	0.0
DSS	0.0	0.0	0.0	0.0	1.0000
SCB	0.0	0.0	0.0	0.0	0.0
TOTAL FLOW:					
KG/HR	0.0	0.0	0.0	0.0	24.9280
STATE VARIABLES:					
TEMP C	M -	M -	M -	M -	25.0000
PRES BAR	1.2000	1.0000	1.0000	95.0000	1.0000
VFRAC	M -	M -	M -	M -	0.0
LFRAC	M -	M -	M -	M -	0.0
SFRAC	M -	M -	M -	M -	1.0000
ENTHALPY:					
KCAL/KG	M -	M -	M -	M -	-2264.4495
GCAL/HR	M -	M -	M -	M -	-5.6448-02
DENSITY:					
KG/CUM	M -	M -	M -	M -	1394.1653
AVG MW	M -	M -	1.0000	1.0000	1.0000
COMPONENT ATTRIBUTES:					
RAS PROXANAL					
ULTANAL					
SULFANAL					
DSS PROXANAL					
MOISTURE	M -	M -	M -	M -	9.7262
FC	M -	M -	M -	M -	0.6838
VM	M -	M -	M -	M -	52.0400

	ASH	M -	M -	M -	M -	37.5500
	ULTANAL					
	ASH	M -	M -	M -	M -	0.0
	CARBON	M -	M -	M -	M -	18.5500
	HYDROGEN	M -	M -	M -	M -	3.8360
	NITROGEN	M -	M -	M -	M -	4.0220
	CHLORINE	M -	M -	M -	M -	0.0
	SULFUR	M -	M -	M -	M -	0.0
	OXYGEN	M -	M -	M -	M -	0.0
	SULFANAL					
	PYRITIC	M -	M -	M -	M -	0.0
	SULFATE	M -	M -	M -	M -	0.0
	ORGANIC	M -	M -	M -	M -	0.0
SCB	PROXANAL					
	ULTANAL					
	SULFANAL					

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***						
MASSFLOW	KG/HR					
	H20	1.4728-03	4.1868	0.3174	0.0	355.0720
	CO2	0.0	0.0	0.0	102.1777	0.0
	CH4	0.0	0.0	0.0	102.1777	0.0
	CARBO-01	0.0	0.0	0.0	0.0	0.0
	HYDRO-01	0.0	0.0	0.0	0.0	0.0
	BIOCRUDE	1.7182-05	9.6235-03	6.5407	0.0	0.0
	CHAR	14.8994	14.7504	1.4901-03	0.0	0.0
	N2	0.0	0.0	0.0	0.0	0.0
	O2	0.0	0.0	0.0	0.0	0.0
	HCL	0.0	0.0	0.0	0.0	0.0
	RAS	0.0	0.0	0.0	0.0	0.0
	DSS	0.0	0.0	0.0	0.0	24.9280
	SCB	0.0	0.0	0.0	0.0	0.0
VOLFLMX	CUM/HR	6.6235-03	1.0921-02	6.1580-03	2.5060	0.3873
MASSVFRA		0.0	0.0	0.0	1.0000	0.0
MASSSFRA		0.9999	0.7785	2.1723-04	0.0	6.5600-02
RHOMX	KG/CUM	2249.7196	1734.9049	1113.9298	81.5474	981.0682
TEMP	C	24.9956	25.0000	25.0000	87.2690	25.0000
PRES	BAR	1.2000	1.0000	1.0000	95.0000	1.0000

FEEDCOLD FEEDHOT HCL LIQ-PROD P-CHAR

STREAM ID	FEEDCOLD	FEEDHOT	HCL	LIQ-PROD	P-CHAR
FROM :	MX-1	PREHEATX	----	FLR-CHAR	$C-11
TO :	PREHEATX	R-HTL	$C-9	LLSEP	----
CLASS:	MIXCINC	MIXCINC	MIXCINC	MIXCINC	MIXCINC
TOTAL STREAM:					
KG/HR	645.7600	645.7600	1266.5300	706.2664	1270.8740
GCAL/HR	-2.3182	-2.1999	-0.7662	-2.6760	-0.7822
$/HR	M -	M -	5839.6504	M -	1183.8191

SUBSTREAM: MIXED					
PHASE:	LIQUID	MIXED	VAPOR	LIQUID	VAPOR
COMPONENTS: KMOL/HR					
H20	28.7099	28.7099	0.0	38.7516	0.2324
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	8.6540-02	1.0225-04
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	34.7369	0.0	34.7369
COMPONENTS: KG/HR					
H20	517.2160	517.2160	0.0	698.1203	4.1868
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	8.1446	9.6235-03
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	1266.5300	0.0	1266.5300
COMPONENTS: MASS FRAC					
H20	1.0000	1.0000	0.0	0.9885	3.2948-03
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	1.1532-02	7.5732-06
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	1.0000	0.0	0.9967
COMPONENTS: STD CUM/HR					
H20	0.5182	0.5182	0.0	0.6995	4.1949-03
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	7.7642-03	9.1740-06
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	1.8604	0.0	1.8604
TOTAL CUM/HR	0.5182	0.5182	1.8604	0.7072	1.8646
COMPONENTS: STD VOL FRAC					
H20	1.0000	1.0000	0.0	0.9890	2.2497-03
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0

HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	1.0978-02	4.9200-06
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	1.0000	0.0	0.9977
TOTAL CUM/HR	0.5182	0.5182	1.8604	0.7072	1.8646
TOTAL FLOW:					
KMOL/HR	28.7099	28.7099	34.7369	38.8381	34.9694
KG/HR	517.2160	517.2160	1266.5300	706.2649	1270.7265
CUM/HR	0.5382	207.1554	856.5029	0.7339	831.2721
STATE VARIABLES:					
TEMP C	25.0000	102.0834	25.0000	24.9956	14.4839
PRES BAR	1.0000	1.0000	1.0000	1.2000	1.0000
VFRAC	0.0	0.2327	1.0000	0.0	1.0000
LFRAC	1.0000	0.7673	0.0	1.0000	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
KCAL/MOL	-68.9934	-65.0098	-22.0573	-68.9021	-22.3685
KCAL/KG	-3829.7161	-3608.5940	-604.9625	-3788.9838	-615.5650
GCAL/HR	-1.9808	-1.8664	-0.7662	-2.6760	-0.7822
ENTROPY:					
CAL/MOL-K	-38.9675	-28.7571	2.4003	-39.0328	2.1409
CAL/GM-K	-2.1630	-1.5963	6.5832-02	-2.1464	5.8915-02
DENSITY:					
MOL/CC	5.3348-02	1.3859-04	4.0557-05	5.2918-02	4.2067-05
KG/CUM	961.0757	2.4968	1.4787	962.3115	1.5287
AVG MW	18.0153	18.0153	36.4606	18.1848	36.3382

SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL

COMPONENTS: KMOL/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	1.2406-04	1.2281-02
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	1.4901-03	0.1475
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0

COMPONENTS: MASS FRAC

H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	1.0000	1.0000
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	6.4314-07	6.3665-05
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	0.0	0.0	6.4314-07	6.3665-05
COMPONENTS: STD VOL FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	0.0	0.0	0.0	1.0000	1.0000
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	0.0	0.0	0.0	6.4314-07	6.3665-05
TOTAL FLOW:					
KMOL/HR	0.0	0.0	0.0	1.2406-04	1.2281-02
KG/HR	0.0	0.0	0.0	1.4901-03	0.1475
CUM/HR	0.0	0.0	0.0	6.6226-07	6.5557-05
STATE VARIABLES:					
TEMP C	M -	M -	M -	24.9956	14.4839
PRES BAR	1.0000	1.0000	1.0000	1.2000	1.0000
VFRAC	M -	M -	M -	0.0	0.0
LFRAC	M -	M -	M -	0.0	0.0
SFRAC	M -	M -	M -	1.0000	1.0000
ENTHALPY:					
KCAL/MOL	M -	M -	M -	-8.8401-06	-2.0912-02
KCAL/KG	M -	M -	M -	-7.3600-04	-1.7411
GCAL/HR	M -	M -	M -	-1.0967-12	-2.5681-07
ENTROPY:					
CAL/MOL-K	M -	M -	M -	-2.9650-05	-7.1396-02
CAL/GM-K	M -	M -	M -	-2.4686-06	-5.9443-03

DENSITY:						
MOL/CC	M -	M -	M -	0.1873	0.1873	
KG/CUM	M -	M -	M -	2250.0206	2250.0206	
AVG MW	M -	M -	M -	12.0110	12.0110	
SUBSTREAM: NC	STRUCTURE: NON CONVENTIONAL					
COMPONENTS: KG/HR						
RAS	3.6160	3.6160	0.0	0.0	0.0	
DSS	24.9280	24.9280	0.0	0.0	0.0	
SCB	100.0000	100.0000	0.0	0.0	0.0	
COMPONENTS: MASS FRAC						
RAS	2.8130-02	2.8130-02	0.0	0.0	0.0	
DSS	0.1939	0.1939	0.0	0.0	0.0	
SCB	0.7779	0.7779	0.0	0.0	0.0	
TOTAL FLOW:						
KG/HR	128.5440	128.5440	0.0	0.0	0.0	
STATE VARIABLES:						
TEMP C	25.0000	102.0834	M -	M -	M -	
PRES BAR	1.0000	1.0000	1.0000	1.2000	1.0000	
VFRAC	0.0	0.0	M -	M -	M -	
LFRAC	0.0	0.0	M -	M -	M -	
SFRAC	1.0000	1.0000	M -	M -	M -	
ENTHALPY:						
KCAL/KG	-2624.7739	-2593.9594	M -	M -	M -	
GCAL/HR	-0.3374	-0.3334	M -	M -	M -	
DENSITY:						
KG/CUM	1970.4079	1970.4079	M -	M -	M -	
AVG MW	1.0000	1.0000	1.0000	M -	M -	
COMPONENT ATTRIBUTES:						
RAS PROXANAL						
MOISTURE	11.8188	11.8188	M -	M -	M -	
FC	0.2812	0.2812	M -	M -	M -	
VM	66.3200	66.3200	M -	M -	M -	
ASH	21.5800	21.5800	M -	M -	M -	
ULTANAL						
ASH	0.0	0.0	M -	M -	M -	
CARBON	35.2800	35.2800	M -	M -	M -	
HYDROGEN	5.6800	5.6800	M -	M -	M -	
NITROGEN	6.1160	6.1160	M -	M -	M -	
CHLORINE	0.0	0.0	M -	M -	M -	
SULFUR	0.0	0.0	M -	M -	M -	
OXYGEN	0.0	0.0	M -	M -	M -	
SULFANAL						
PYRITIC	0.0	0.0	M -	M -	M -	
SULFATE	0.0	0.0	M -	M -	M -	
ORGANIC	0.0	0.0	M -	M -	M -	
DSS PROXANAL						
MOISTURE	9.7262	9.7262	M -	M -	M -	
FC	0.6838	0.6838	M -	M -	M -	
VM	52.0400	52.0400	M -	M -	M -	
ASH	37.5500	37.5500	M -	M -	M -	
ULTANAL						

	ASH	0.0	0.0	M	-	M	-	M -
	CARBON	18.5500	18.5500	M	-	M	-	M -
	HYDROGEN	3.8360	3.8360	M	-	M	-	M -
	NITROGEN	4.0220	4.0220	M	-	M	-	M -
	CHLORINE	0.0	0.0	M	-	M	-	M -
	SULFUR	0.0	0.0	M	-	M	-	M -
	OXYGEN	0.0	0.0	M	-	M	-	M -
	SULFANAL							
	PYRITIC	0.0	0.0	M	-	M	-	M -
	SULFATE	0.0	0.0	M	-	M	-	M -
	ORGANIC	0.0	0.0	M	-	M	-	M -
SCB	PROXANAL							
	MOISTURE	0.0	0.0	M	-	M	-	M -
	FC	9.6100	9.6100	M	-	M	-	M -
	VM	76.2900	76.2900	M	-	M	-	M -
	ASH	7.6200	7.6200	M	-	M	-	M -
	ULTANAL							
	ASH	0.0	0.0	M	-	M	-	M -
	CARBON	0.3636	0.3636	M	-	M	-	M -
	HYDROGEN	4.7100-02	4.7100-02	M	-	M	-	M -
	NITROGEN	5.7600-03	5.7600-03	M	-	M	-	M -
	CHLORINE	0.0	0.0	M	-	M	-	M -
	SULFUR	0.0	0.0	M	-	M	-	M -
	OXYGEN	0.0	0.0	M	-	M	-	M -
	SULFANAL							
	PYRITIC	0.0	0.0	M	-	M	-	M -
	SULFATE	0.0	0.0	M	-	M	-	M -
	ORGANIC	0.0	0.0	M	-	M	-	M -

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW	KG/HR					
H20		517.2160	517.2160	0.0	698.1203	4.1868
CO2		0.0	0.0	0.0	0.0	0.0
CH4		0.0	0.0	0.0	0.0	0.0
CARBO-01		0.0	0.0	0.0	0.0	0.0
HYDRO-01		0.0	0.0	0.0	0.0	0.0
BIOCRUDE		0.0	0.0	0.0	8.1446	9.6235-03
CHAR		0.0	0.0	0.0	1.4901-03	0.1475
N2		0.0	0.0	0.0	0.0	0.0
O2		0.0	0.0	0.0	0.0	0.0
HCL		0.0	0.0	1266.5300	0.0	1266.5300
RAS		3.6160	3.6160	0.0	0.0	0.0
DSS		24.9280	24.9280	0.0	0.0	0.0
SCB		100.0000	100.0000	0.0	0.0	0.0
VOLFLMX	CUM/HR	0.6034	207.2206	856.5029	0.7339	831.2721
MASSVFRA		0.0	0.1864	1.0000	0.0	0.9999
MASSSFRA		0.1991	0.1991	0.0	2.1098-06	1.1607-04
RHOMX	KG/CUM	1070.2006	3.1163	1.4787	962.3126	1.5288
TEMP	C	25.0000	102.0834	25.0000	24.9956	14.4839
PRES	BAR	1.0000	1.0000	1.0000	1.2000	1.0000

P-COLD P-HOT PRODUCT RAS SALT

STREAM ID	P-COLD	P-HOT	PRODUCT	RAS	SALT
FROM :	PREHEATX	R-HTL	VENT	----	$C-10
TO :	VENT	PREHEATX	COOLER	MX-1	----
CLASS:	MIXCINC	MIXCINC	MIXCINC	MIXCINC	MIXCINC
MAX CONV. ERROR:	0.0	1.1978-10	0.0	0.0	0.0
TOTAL STREAM:					
KG/HR	925.5227	925.5227	721.1673	160.0000	14.6029
GCAL/HR	-2.9527	-2.8344	-2.6241	-0.6054	-2.5425-05
$/HR	M -	M -	M -	M -	151.8457
SUBSTREAM: MIXED					
PHASE:	MIXED	MIXED	LIQUID	LIQUID	MIX
COMPONENTS: KMOL/HR					
H20	38.7516	38.7516	38.7516	8.6806	0.0
CO2	2.3217	2.3217	0.0	0.0	0.0
CH4	6.3691	6.3691	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	8.6541-02	8.6541-02	8.6541-02	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	698.1218	698.1218	698.1218	156.3840	0.0
CO2	102.1777	102.1777	0.0	0.0	0.0
CH4	102.1777	102.1777	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	8.1446	8.1446	8.1446	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.7666	0.7666	0.9885	1.0000	0.0
CO2	0.1122	0.1122	0.0	0.0	0.0
CH4	0.1122	0.1122	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	8.9440-03	8.9440-03	1.1532-02	0.0	0.0
CHAR	0.0	0.0	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.6995	0.6995	0.6995	0.1567	0.0
CO2	0.1243	0.1243	0.0	0.0	0.0

CH4		0.3411	0.3411	0.0	0.0	0.0
CARBO-01		0.0	0.0	0.0	0.0	0.0
HYDRO-01		0.0	0.0	0.0	0.0	0.0
BIOCRUDE		7.7642-03	7.7642-03	7.7642-03	0.0	0.0
CHAR		0.0	0.0	0.0	0.0	0.0
N2		0.0	0.0	0.0	0.0	0.0
O2		0.0	0.0	0.0	0.0	0.0
HCL		0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR		1.1727	1.1727	0.7072	0.1567	0.0
COMPONENTS: STD VOL FRAC						
H20		0.5965	0.5965	0.9890	1.0000	0.0
CO2		0.1060	0.1060	0.0	0.0	0.0
CH4		0.2909	0.2909	0.0	0.0	0.0
CARBO-01		0.0	0.0	0.0	0.0	0.0
HYDRO-01		0.0	0.0	0.0	0.0	0.0
BIOCRUDE		6.6208-03	6.6208-03	1.0978-02	0.0	0.0
CHAR		0.0	0.0	0.0	0.0	0.0
N2		0.0	0.0	0.0	0.0	0.0
O2		0.0	0.0	0.0	0.0	0.0
HCL		0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR		1.1727	1.1727	0.7072	0.1567	0.0
TOTAL FLOW:						
KMOL/HR		47.5290	47.5290	38.8382	8.6806	0.0
KG/HR		910.6218	910.6218	706.2664	156.3840	0.0
CUM/HR		3.2776	4.9564	0.7792	0.1627	0.0
STATE VARIABLES:						
TEMP	C	87.2690	195.0000	87.2690	25.0000	M -
PRES	BAR	95.0000	95.0000	95.0000	1.0000	1.0000
VFRAC		0.1835	0.2245	0.0	0.0	M -
LFRAC		0.8165	0.7755	1.0000	1.0000	M -
SFRAC		0.0	0.0	0.0	0.0	M -
ENTHALPY:						
KCAL/MOL		-62.1288	-59.6475	-67.5707	-68.9934	M -
KCAL/KG		-3242.7500	-3113.2381	-3715.7694	-3829.7161	M -
GCAL/HR		-2.9529	-2.8350	-2.6243	-0.5989	M -
ENTROPY:						
CAL/MOL-K		-32.8667	-27.5623	-35.6348	-38.9675	M -
CAL/GM-K		-1.7154	-1.4386	-1.9596	-2.1630	M -
DENSITY:						
MOL/CC		1.4501-02	9.5895-03	4.9842-02	5.3348-02	M -
KG/CUM		277.8325	183.7280	906.3761	961.0757	M -
AVG MW		19.1593	19.1593	18.1848	18.0153	M -

SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL

COMPONENTS: KMOL/HR						
H20		0.0	0.0	0.0	0.0	0.0
CO2		0.0	0.0	0.0	0.0	0.0
CH4		0.0	0.0	0.0	0.0	0.0
CARBO-01		0.0	0.0	0.0	0.0	0.0
HYDRO-01		0.0	0.0	0.0	0.0	0.0
BIOCRUDE		0.0	0.0	0.0	0.0	0.0
CHAR		1.2406	1.2406	1.2406	0.0	1.2158

N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: KG/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	14.9009	14.9009	14.9009	0.0	14.6029
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.0000	1.0000	1.0000	0.0	1.0000
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
COMPONENTS: STD CUM/HR					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	6.4314-03	6.4314-03	6.4314-03	0.0	6.3028-03
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	6.4314-03	6.4314-03	6.4314-03	0.0	6.3028-03
COMPONENTS: STD VOL FRAC					
H20	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CH4	0.0	0.0	0.0	0.0	0.0
CARBO-01	0.0	0.0	0.0	0.0	0.0
HYDRO-01	0.0	0.0	0.0	0.0	0.0
BIOCRUDE	0.0	0.0	0.0	0.0	0.0
CHAR	1.0000	1.0000	1.0000	0.0	1.0000
N2	0.0	0.0	0.0	0.0	0.0
O2	0.0	0.0	0.0	0.0	0.0
HCL	0.0	0.0	0.0	0.0	0.0
TOTAL CUM/HR	6.4314-03	6.4314-03	6.4314-03	0.0	6.3028-03
TOTAL FLOW:					
KMOL/HR	1.2406	1.2406	1.2406	0.0	1.2158
KG/HR	14.9009	14.9009	14.9009	0.0	14.6029

CUM/HR		6.6226-03	6.6226-03	6.6226-03		0.0		6.4901-03
STATE VARIABLES:								
TEMP	C	87.2690	195.0000	87.2690	M	-		14.4839
PRES	BAR	95.0000	95.0000	95.0000		1.0000		1.0000
VFRAC		0.0	0.0	0.0	M	-		0.0
LFRAC		0.0	0.0	0.0	M	-		0.0
SFRAC		1.0000	1.0000	1.0000	M	-		1.0000
ENTHALPY:								
KCAL/MOL		0.1416	0.4581	0.1416	M	-		-2.0912-02
KCAL/KG		11.7876	38.1382	11.7876	M	-		-1.7411
GCAL/HR		1.7565-04	5.6829-04	1.7565-04	M	-		-2.5425-05
ENTROPY:								
CAL/MOL-K		0.4298	1.1933	0.4298	M	-		-7.1396-02
CAL/GM-K		3.5783-02	9.9352-02	3.5783-02	M	-		-5.9443-03
DENSITY:								
MOL/CC		0.1873	0.1873	0.1873	M	-		0.1873
KG/CUM		2250.0206	2250.0206	2250.0206	M	-		2250.0206
AVG MW		12.0110	12.0110	12.0110	M	-		12.0110
SUBSTREAM: NC		STRUCTURE: NON CONVENTIONAL						
COMPONENTS: KG/HR								
RAS		0.0	0.0	0.0		3.6160		0.0
DSS		0.0	0.0	0.0		0.0		0.0
SCB		0.0	0.0	0.0		0.0		0.0
COMPONENTS: MASS FRAC								
RAS		0.0	0.0	0.0		1.0000		0.0
DSS		0.0	0.0	0.0		0.0		0.0
SCB		0.0	0.0	0.0		0.0		0.0
TOTAL FLOW:								
KG/HR		0.0	0.0	0.0		3.6160		0.0
STATE VARIABLES:								
TEMP	C	M -	M -	M -		25.0000	M	-
PRES	BAR	95.0000	M -	95.0000		1.0000		1.0000
VFRAC		M -	M -	M -		0.0	M	-
LFRAC		M -	M -	M -		0.0	M	-
SFRAC		M -	M -	M -		1.0000	M	-
ENTHALPY:								
KCAL/KG		M -	M -	M -		-1793.6870	M	-
GCAL/HR		M -	M -	M -		-6.4860-03	M	-
DENSITY:								
KG/CUM		M -	M -	M -		1284.6460	M	-
AVG MW		1.0000	1.0000	1.0000		1.0000	M	-
COMPONENT ATTRIBUTES:								
RAS	PROXANAL							
	MOISTURE	M -	M -	M -		11.8188	M	-
	FC	M -	M -	M -		0.2812	M	-
	VM	M -	M -	M -		66.3200	M	-
	ASH	M -	M -	M -		21.5800	M	-
	ULTANAL							
	ASH	M -	M -	M -		0.0	M	-
	CARBON	M -	M -	M -		35.2800	M	-
	HYDROGEN	M -	M -	M -		5.6800	M	-

		NITROGEN	M	-	M	-	M	-	6.1160	M	-
		CHLORINE	M	-	M	-	M	-	0.0	M	-
		SULFUR	M	-	M	-	M	-	0.0	M	-
		OXYGEN	M	-	M	-	M	-	0.0	M	-
	SULFANAL										
		PYRITIC	M	-	M	-	M	-	0.0	M	-
		SULFATE	M	-	M	-	M	-	0.0	M	-
		ORGANIC	M	-	M	-	M	-	0.0	M	-
DSS	PROXANAL										
	ULTANAL										
	SULFANAL										
SCB	PROXANAL										
	ULTANAL										
	SULFANAL										

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW	KG/HR				
H20		698.1218	698.1218	698.1218	156.3840	0.0
CO2		102.1777	102.1777	0.0	0.0	0.0
CH4		102.1777	102.1777	0.0	0.0	0.0
CARBO-01		0.0	0.0	0.0	0.0	0.0
HYDRO-01		0.0	0.0	0.0	0.0	0.0
BIOCRUDE		8.1446	8.1446	8.1446	0.0	0.0
CHAR		14.9009	14.9009	14.9009	0.0	14.6029
N2		0.0	0.0	0.0	0.0	0.0
O2		0.0	0.0	0.0	0.0	0.0
HCL		0.0	0.0	0.0	0.0	0.0
RAS		0.0	0.0	0.0	3.6160	0.0
DSS		0.0	0.0	0.0	0.0	0.0
SCB		0.0	0.0	0.0	0.0	0.0
VOLFLMX	CUM/HR	3.2842	4.9630	0.7858	0.1655	6.4901-03
MASSVFRA		0.2199	0.2566	0.0	0.0	0.0
MASSSFRA		1.6100-02	1.6100-02	2.0662-02	2.2600-02	1.0000
RHOMX	KG/CUM	281.8094	186.4853	917.6995	966.5779	2250.0206
TEMP	C	87.2690	195.0000	87.2690	25.0000	14.4839
PRES	BAR	95.0000	95.0000	95.0000	1.0000	1.0000

SCB SEPFEED

STREAM ID	SCB	SEPFEED
FROM :	----	COOLER
TO :	MX-1	FLR-CHAR
CLASS:	MIXCINC	MIXCINC
TOTAL STREAM:		
KG/HR	105.7600	721.1673
GCAL/HR	-0.2965	-2.6760
SUBSTREAM: MIXED		
PHASE:	LIQUID	LIQUID
COMPONENTS: KMOL/HR		

H20	0.3197	38.7516
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	8.6541-02
CHAR	0.0	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
COMPONENTS: KG/HR		
H20	5.7600	698.1218
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	8.1446
CHAR	0.0	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
COMPONENTS: MASS FRAC		
H20	1.0000	0.9885
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	1.1532-02
CHAR	0.0	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
COMPONENTS: STD CUM/HR		
H20	5.7711-03	0.6995
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	7.7642-03
CHAR	0.0	0.0
N2	0.0	0.0
O2	0.0	0.0
HCL	0.0	0.0
TOTAL CUM/HR	5.7711-03	0.7072
COMPONENTS: STD VOL FRAC		
H20	1.0000	0.9890
CO2	0.0	0.0
CH4	0.0	0.0
CARBO-01	0.0	0.0
HYDRO-01	0.0	0.0
BIOCRUDE	0.0	1.0978-02
CHAR	0.0	0.0

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  N2                      0.0        0.0
  O2                      0.0        0.0
  HCL                     0.0        0.0
  TOTAL CUM/HR        5.7711-03     0.7072
TOTAL FLOW:
  KMOL/HR                 0.3197    38.8382
  KG/HR                   5.7600   706.2664
  CUM/HR              5.9933-03     0.7339
STATE VARIABLES:
  TEMP   C               25.0000    25.0000
  PRES   BAR              1.0000     1.0000
  VFRAC                   0.0        0.0
  LFRAC                   1.0000     1.0000
  SFRAC                   0.0        0.0
ENTHALPY:
  KCAL/MOL              -68.9934   -68.9021
  KCAL/KG             -3829.7161 -3788.9838
  GCAL/HR             -2.2059-02    -2.6760
ENTROPY:
  CAL/MOL-K             -38.9675   -39.0325
  CAL/GM-K               -2.1630    -2.1464
DENSITY:
  MOL/CC               5.3348-02  5.2918-02
  KG/CUM                961.0757   962.3040
AVG MW                   18.0153    18.1848

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                     0.0        0.0
  CO2                     0.0        0.0
  CH4                     0.0        0.0
  CARBO-01                0.0        0.0
  HYDRO-01                0.0        0.0
  BIOCRUDE                0.0        0.0
  CHAR                    0.0        1.2406
  N2                      0.0        0.0
  O2                      0.0        0.0
  HCL                     0.0        0.0
COMPONENTS: KG/HR
  H20                     0.0        0.0
  CO2                     0.0        0.0
  CH4                     0.0        0.0
  CARBO-01                0.0        0.0
  HYDRO-01                0.0        0.0
  BIOCRUDE                0.0        0.0
  CHAR                    0.0       14.9009
  N2                      0.0        0.0
  O2                      0.0        0.0
  HCL                     0.0        0.0
COMPONENTS: MASS FRAC
  H20                     0.0        0.0
  CO2                     0.0        0.0
```

CH4		0.0	0.0
CARBO-01		0.0	0.0
HYDRO-01		0.0	0.0
BIOCRUDE		0.0	0.0
CHAR		0.0	1.0000
N2		0.0	0.0
O2		0.0	0.0
HCL		0.0	0.0
COMPONENTS: STD CUM/HR			
H20		0.0	0.0
CO2		0.0	0.0
CH4		0.0	0.0
CARBO-01		0.0	0.0
HYDRO-01		0.0	0.0
BIOCRUDE		0.0	0.0
CHAR		0.0	6.4314-03
N2		0.0	0.0
O2		0.0	0.0
HCL		0.0	0.0
TOTAL CUM/HR		0.0	6.4314-03
COMPONENTS: STD VOL FRAC			
H20		0.0	0.0
CO2		0.0	0.0
CH4		0.0	0.0
CARBO-01		0.0	0.0
HYDRO-01		0.0	0.0
BIOCRUDE		0.0	0.0
CHAR		0.0	1.0000
N2		0.0	0.0
O2		0.0	0.0
HCL		0.0	0.0
TOTAL CUM/HR		0.0	6.4314-03
TOTAL FLOW:			
KMOL/HR		0.0	1.2406
KG/HR		0.0	14.9009
CUM/HR		0.0	6.6226-03
STATE VARIABLES:			
TEMP C	M	-	25.0000
PRES BAR		1.0000	1.0000
VFRAC	M	-	0.0
LFRAC	M	-	0.0
SFRAC	M	-	1.0000
ENTHALPY:			
KCAL/MOL	M	-	1.2444-16
KCAL/KG	M	-	1.0361-14
GCAL/HR	M	-	1.5438-19
ENTROPY:			
CAL/MOL-K	M	-	3.1187-16
CAL/GM-K	M	-	2.5966-17
DENSITY:			
MOL/CC	M	-	0.1873
KG/CUM	M	-	2250.0206

```
AVG MW                  M  -       12.0110

SUBSTREAM: NC           STRUCTURE: NON CONVENTIONAL
COMPONENTS: KG/HR
  RAS                     0.0        0.0
  DSS                     0.0        0.0
  SCB                   100.0000     0.0
COMPONENTS: MASS FRAC
  RAS                     0.0        0.0
  DSS                     0.0        0.0
  SCB                     1.0000     0.0
TOTAL FLOW:
  KG/HR                 100.0000     0.0
STATE VARIABLES:
  TEMP   C                25.0000   M  -
  PRES   BAR              1.0000     1.0000
  VFRAC                   0.0       M  -
  LFRAC                   0.0       M  -
  SFRAC                   1.0000    M  -
ENTHALPY:
  KCAL/KG              -2744.6477   M  -
  GCAL/HR                 -0.2745   M  -
DENSITY:
  KG/CUM                2245.0600   M  -
AVG MW                    1.0000     1.0000
COMPONENT ATTRIBUTES:
RAS       PROXANAL
          ULTANAL
          SULFANAL
DSS       PROXANAL
          ULTANAL
          SULFANAL
SCB       PROXANAL
            MOISTURE      0.0       M  -
            FC            9.6100    M  -
            VM           76.2900    M  -
            ASH           7.6200    M  -
          ULTANAL
            ASH           0.0       M  -
            CARBON        0.3636    M  -
            HYDROGEN   4.7100-02    M  -
            NITROGEN   5.7600-03    M  -
            CHLORINE      0.0       M  -
            SULFUR        0.0       M  -
            OXYGEN        0.0       M  -
          SULFANAL
            PYRITIC       0.0       M  -
            SULFATE       0.0       M  -
            ORGANIC       0.0       M  -

TOTAL STREAM PROPERTIES:
```

```
***  ALL PHASES
MASSFLOW KG/HR
    H20                  5.7600   698.1218
    CO2                  0.0        0.0
    CH4                  0.0        0.0
    CARBO-01             0.0        0.0
    HYDRO-01             0.0        0.0
    BIOCRUDE             0.0        8.1446
    CHAR                 0.0       14.9009
    N2                   0.0        0.0
    O2                   0.0        0.0
    HCL                  0.0        0.0
    RAS                  0.0        0.0
    DSS                  0.0        0.0
    SCB                100.0000     0.0
VOLFLMX  CUM/HR       5.0536-02     0.7406
MASSVFRA                 0.0        0.0
MASSSFRA                 0.9455  2.0662-02
RHOMX    KG/CUM       2092.7853   973.8197
TEMP     C              25.0000    25.0000
PRES     BAR             1.0000     1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
HCL                                  4.6107   $/KG                  5839.6504
P-CHAR                               0.9315   $/KG                  1183.8191
SALT                                10.3983   $/KG                   151.8457
BURNER.CH4                         2.7000-02   $/KG                     2.7000

AB-FEED
-------

STREAM ID              AB-FEED
FROM :                 AQSPLIT
TO   :                 $C-5
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR              419.6441
  GCAL/HR             -1.6037
SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: KMOL/HR
  H20                 23.2404
  CO2                  0.0
  CH4                  0.0
  CARBO-01             0.0
  HYDRO-01             0.0
```

```
  BIOCRUDE            1.0225-02
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                  418.6818
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.9623
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.9977
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.2932-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.4195
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            9.1738-04
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.4204
COMPONENTS: STD VOL FRAC
  H20                    0.9978
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.1821-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.4204
TOTAL FLOW:
```

```
  KMOL/HR               23.2506
  KG/HR                419.6441
  CUM/HR                 0.4365
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6147
  GCAL/HR               -1.6037
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                418.6818
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.9623
    CHAR                 0.0
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR          0.4365
MASSVFRA                 0.0
MASSSFRA                 0.0
RHOMX    KG/CUM        961.3196
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       -----------------------------    ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
```

HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

AQ-CLEAN

STREAM ID	AQ-CLEAN
FROM :	$C-7
TO :	----
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	415.5981
GCAL/HR	-1.5877
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	23.0080
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0123-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	414.4964
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.9527
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.4153

```
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            9.0823-04
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.4162
COMPONENTS: STD VOL FRAC
  H20                    0.9978
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            2.1822-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.4162
TOTAL FLOW:
  KMOL/HR               23.0182
  KG/HR                415.4491
  CUM/HR                 0.4322
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9754
  KCAL/KG            -3821.6146
  GCAL/HR               -1.5877
ENTROPY:
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
```

CHAR	1.2405-02
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.1490
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	1.0000
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	6.4308-05
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	6.4308-05
COMPONENTS: STD VOL FRAC	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	1.0000
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	6.4308-05
TOTAL FLOW:	
KMOL/HR	1.2405-02

```
  KG/HR                  0.1490
  CUM/HR              6.6219-05
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL           -4.5856-08
  KCAL/KG            -3.8178-06
  GCAL/HR            -5.6884-13
ENTROPY:
  CAL/MOL-K          -1.5380-07
  CAL/GM-K           -1.2805-08
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                414.4964
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.9527
    CHAR                 0.1490
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR          0.4322
MASSVFRA                 0.0
MASSSFRA              3.5851-04
RHOMX    KG/CUM        961.5171
TEMP     C              25.0000
PRES     BAR            1.0000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                              0.8200   $/KG                     5.6248
HCL                                   4.6107   $/KG                  5839.6504
```

P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

AQFEED

STREAM ID	AQFEED
FROM :	$C-3
TO :	R-HTL
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	279.7627
GCAL/HR	-0.8650
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	15.4936
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	6.8169-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	279.1212
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.6416
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.2797
CO2	0.0

```
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE             6.1159-04
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR             0.2803
COMPONENTS: STD VOL FRAC
  H20                      0.9978
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE             2.1821-03
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR             0.2803
TOTAL FLOW:
  KMOL/HR                 15.5004
  KG/HR                  279.7627
  CUM/HR                 686.4554
STATE VARIABLES:
  TEMP   C               261.0608
  PRES   BAR               1.0000
  VFRAC                    1.0000
  LFRAC                    0.0
  SFRAC                    0.0
ENTHALPY:
  KCAL/MOL               -55.8064
  KCAL/KG              -3091.9823
  GCAL/HR                 -0.8650
ENTROPY:
  CAL/MOL-K               -5.8158
  CAL/GM-K                -0.3222
DENSITY:
  MOL/CC               2.2580-05
  KG/CUM                   0.4075
AVG MW                    18.0487

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  279.1212
    CO2                    0.0
    CH4                    0.0
    CARBO-01               0.0
    HYDRO-01               0.0
```

```
    BIOCRUDE              0.6416
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR         686.4554
MASSVFRA                  1.0000
MASSSFRA                  0.0
RHOMX    KG/CUM           0.4075
TEMP     C              261.0608
PRES     BAR              1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

AQRECYCL
--------

STREAM ID               AQRECYCL
FROM :                  AQSPLIT
TO   :                  $C-2
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR                279.7627
  GCAL/HR               -1.0691
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  H20                   15.4936
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            6.8169-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                  279.1212
```

```
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.6416
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.9977
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             2.2932-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.2797
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             6.1159-04
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.2803
COMPONENTS: STD VOL FRAC
  H20                     0.9978
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             2.1821-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.2803
TOTAL FLOW:
  KMOL/HR                15.5004
  KG/HR                 279.7627
  CUM/HR                  0.2910
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
```

```
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -68.9754
  KCAL/KG             -3821.6147
  GCAL/HR                -1.0691
ENTROPY:
  CAL/MOL-K             -38.9789
  CAL/GM-K               -2.1596
DENSITY:
  MOL/CC               5.3262-02
  KG/CUM                961.3196
AVG MW                   18.0487

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 279.1212
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              0.6416
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR           0.2910
MASSVFRA                  0.0
MASSSFRA                  0.0
RHOMX    KG/CUM         961.3196
TEMP     C               25.0000
PRES     BAR              1.0000

STREAM COSTS
------------

ID                              PRICE                           COST $/HR

-----------                     ------------------------------  ------------
BIOCRUDE                           0.8200   $/KG                    5.6248
HCL                                4.6107   $/KG                 5839.6504
P-CHAR                             0.9315   $/KG                 1183.8191
SALT                              10.3983   $/KG                  151.8457
BURNER.CH4                     2.7000-02   $/KG                    2.7000

AQUEOUS
-------
```

STREAM ID	AQUEOUS
FROM :	LLSEP
TO :	AQSPLIT
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	699.4068
GCAL/HR	-2.6729
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	38.7339
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.7042-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	697.8029
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.6039
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9977
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	2.2932-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.6991
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.5290-03
CHAR	0.0
N2	0.0

```
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.7007
COMPONENTS: STD VOL FRAC
  H20                     0.9978
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             2.1821-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.7007
TOTAL FLOW:
  KMOL/HR                38.7510
  KG/HR                 699.4068
  CUM/HR                  0.7275
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -68.9754
  KCAL/KG             -3821.6147
  GCAL/HR                -2.6729
ENTROPY:
  CAL/MOL-K             -38.9789
  CAL/GM-K               -2.1596
DENSITY:
  MOL/CC               5.3262-02
  KG/CUM                961.3196
AVG MW                   18.0487

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 697.8029
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              1.6039
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
```

```
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR           0.7275
MASSVFRA                  0.0
MASSSFRA                  0.0
RHOMX    KG/CUM         961.3196
TEMP     C               25.0000
PRES     BAR              1.0000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
HCL                                  4.6107   $/KG                  5839.6504
P-CHAR                               0.9315   $/KG                  1183.8191
SALT                                10.3983   $/KG                   151.8457
BURNER.CH4                       2.7000-02    $/KG                     2.7000

BIOCHAR1
--------

STREAM ID                BIOCHAR1
FROM :                   FLR-CHAR
TO   :                   $C-4
CLASS:                   MIXCINC
TOTAL STREAM:
  KG/HR                  14.9009
  GCAL/HR             -5.6563-06
SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: KMOL/HR
  H20                 8.1751-05
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            1.8257-07
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                 1.4728-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            1.7182-05
  CHAR                   0.0
```

```
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.9885
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            1.1532-02
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                 1.4756-06
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            1.6379-08
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        1.4920-06
COMPONENTS: STD VOL FRAC
  H20                     0.9890
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            1.0978-02
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        1.4920-06
TOTAL FLOW:
  KMOL/HR             8.1933-05
  KG/HR               1.4899-03
  CUM/HR              1.5483-06
STATE VARIABLES:
  TEMP   C              24.9956
  PRES   BAR             1.2000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9021
  KCAL/KG            -3788.9838
  GCAL/HR            -5.6454-06
```

```
ENTROPY:
  CAL/MOL-K            -39.0328
  CAL/GM-K              -2.1464
DENSITY:
  MOL/CC              5.2918-02
  KG/CUM               962.3115
AVG MW                  18.1848

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2405
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.8994
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.4308-03
  N2                     0.0
  O2                     0.0
```

```
 HCL                    0.0

  TOTAL CUM/HR        6.4308-03
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.4308-03
TOTAL FLOW:
  KMOL/HR                1.2405
  KG/HR                 14.8994
  CUM/HR              6.6219-03
STATE VARIABLES:
  TEMP   C              24.9956
  PRES   BAR             1.2000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL           -8.8387-06
  KCAL/KG            -7.3588-04
  GCAL/HR            -1.0964-08
ENTROPY:
  CAL/MOL-K          -2.9645-05
  CAL/GM-K           -2.4682-06
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20               1.4728-03
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE          1.7182-05
    CHAR                14.8994
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
```

```
    SCB                    0.0
VOLFLMX  CUM/HR        6.6235-03
MASSVFRA                   0.0
MASSSFRA                   0.9999
RHOMX    KG/CUM       2249.7196
TEMP     C              24.9956
PRES     BAR             1.2000

STREAM COSTS
------------

ID                                  PRICE                            COST $/HR

-----------                         ------------------------------   ------------
BIOCRUDE                               0.8200   $/KG                     5.6248
HCL                                    4.6107   $/KG                  5839.6504
P-CHAR                                 0.9315   $/KG                  1183.8191
SALT                                  10.3983   $/KG                   151.8457
BURNER.CH4                         2.7000-02   $/KG                     2.7000

BIOCHAR2
--------

STREAM ID               BIOCHAR2
FROM :                  $C-6
TO   :                  $C-8
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR                 18.9469
  GCAL/HR            -1.6037-02
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  H20                    0.2324
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            1.0225-04
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    4.1868
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            9.6235-03
  CHAR                   0.0
  N2                     0.0
```

```
  O2                       0.0
  HCL                      0.0
COMPONENTS: MASS FRAC
  H20                      0.9977
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE              2.2932-03
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: STD CUM/HR
  H20                   4.1949-03
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE              9.1740-06
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR          4.2041-03
COMPONENTS: STD VOL FRAC
  H20                      0.9978
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE              2.1822-03
  CHAR                     0.0
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR          4.2041-03
TOTAL FLOW:
  KMOL/HR                  0.2325
  KG/HR                    4.1965
  CUM/HR                4.3653-03
STATE VARIABLES:
  TEMP   C                25.0000
  PRES   BAR               1.0000
  VFRAC                    0.0
  LFRAC                    1.0000
  SFRAC                    0.0
ENTHALPY:
  KCAL/MOL               -68.9754
  KCAL/KG              -3821.6146
  GCAL/HR              -1.6037-02
ENTROPY:
```

```
  CAL/MOL-K            -38.9789
  CAL/GM-K              -2.1596
DENSITY:
  MOL/CC              5.3262-02
  KG/CUM               961.3196
AVG MW                  18.0487

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2281
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.7504
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.3665-03
  N2                     0.0
  O2                     0.0
  HCL                    0.0
```

```
TOTAL CUM/HR         6.3665-03
COMPONENTS: STD VOL FRAC

  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR         6.3665-03
TOTAL FLOW:
  KMOL/HR                1.2281
  KG/HR                 14.7504
  CUM/HR               6.5557-03
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/MOL            -4.5856-08
  KCAL/KG             -3.8178-06
  GCAL/HR             -5.6315-11
ENTROPY:
  CAL/MOL-K           -1.5380-07
  CAL/GM-K            -1.2805-08
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  4.1868
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE           9.6235-03
    CHAR                14.7504
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  0.0
    DSS                  0.0
    SCB                  0.0
```

VOLFLMX	CUM/HR	1.0921-02
MASSVFRA		0.0
MASSSFRA		0.7785
RHOMX	KG/CUM	1734.9049
TEMP	C	25.0000
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

BIOCRUDE

STREAM ID	BIOCRUDE
FROM :	LLSEP
TO :	----
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	6.8596
GCAL/HR	-3.7295-03
$/HR	5.6248
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	1.7617-02
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	6.9498-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	0.3174
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	6.5407
CHAR	0.0
N2	0.0

```
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                 4.6278-02
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.9537
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                 3.1799-04
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            6.2352-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.5532-03
COMPONENTS: STD VOL FRAC
  H20                 4.8525-02
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.9515
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.5532-03
TOTAL FLOW:
  KMOL/HR             8.7115-02
  KG/HR                  6.8581
  CUM/HR              6.1573-03
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL             -42.8108
  KCAL/KG             -543.8090
  GCAL/HR            -3.7295-03
ENTROPY:
```

```
  CAL/MOL-K            -72.4994
  CAL/GM-K              -0.9209
DENSITY:
  MOL/CC              1.4148-02
  KG/CUM              1113.8076
AVG MW                  78.7239

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                1.2406-04
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: KG/HR
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                1.4901-03
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: MASS FRAC
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                     1.0000
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: STD CUM/HR
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                6.4314-07
  N2                       0.0
  O2                       0.0
  HCL                      0.0
```

```
TOTAL CUM/HR        6.4314-07
COMPONENTS: STD VOL FRAC

  H20                   0.0
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE              0.0
  CHAR                  1.0000
  N2                    0.0
  O2                    0.0
  HCL                   0.0
  TOTAL CUM/HR        6.4314-07
TOTAL FLOW:
  KMOL/HR             1.2406-04
  KG/HR               1.4901-03
  CUM/HR              6.6226-07
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                 0.0
  LFRAC                 0.0
  SFRAC                 1.0000
ENTHALPY:
  KCAL/MOL            1.2444-16
  KCAL/KG             1.0361-14
  GCAL/HR             1.5438-23
ENTROPY:
  CAL/MOL-K           3.1187-16
  CAL/GM-K            2.5966-17
DENSITY:
  MOL/CC                0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 0.3174
    CO2                 0.0
    CH4                 0.0
    CARBO-01            0.0
    HYDRO-01            0.0
    BIOCRUDE            6.5407
    CHAR              1.4901-03
    N2                  0.0
    O2                  0.0
    HCL                 0.0
    RAS                 0.0
    DSS                 0.0
    SCB                 0.0
```

VOLFLMX	CUM/HR	6.1580-03
MASSVFRA		0.0
MASSSFRA		2.1723-04
RHOMX	KG/CUM	1113.9298
TEMP	C	25.0000
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

BIOGAS

STREAM ID	BIOGAS
FROM :	VENT
TO :	$C-1
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	204.3554
GCAL/HR	-0.3298
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.0
CO2	2.3217
CH4	6.3691
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	0.0
CO2	102.1777
CH4	102.1777
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0

```
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.0
  CO2                     0.5000
  CH4                     0.5000
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.0
  CO2                     0.1243
  CH4                     0.3411
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.4655
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.2671
  CH4                     0.7329
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.4655
TOTAL FLOW:
  KMOL/HR                 8.6908
  KG/HR                 204.3554
  CUM/HR                  2.5060
STATE VARIABLES:
  TEMP   C               87.2690
  PRES   BAR             95.0000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -37.9427
  KCAL/KG             -1613.6182
  GCAL/HR                -0.3298
ENTROPY:
  CAL/MOL-K             -20.8618
```

```
  CAL/GM-K              -0.8872
DENSITY:
  MOL/CC              3.4680-03
  KG/CUM                81.5474
AVG MW                  23.5140

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                   0.0
    CO2                 102.1777
    CH4                 102.1777
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              0.0
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR           2.5060
MASSVFRA                  1.0000
MASSSFRA                  0.0
RHOMX    KG/CUM          81.5474
TEMP     C               87.2690
PRES     BAR             95.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02   $/KG                    2.7000

DSS
---

STREAM ID               DSS
FROM :                  ----
TO   :                  MX-1
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR               380.0000
  GCAL/HR              -1.4163
```

SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	19.7095
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	355.0720
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	1.0000
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.3558
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.3558
COMPONENTS: STD VOL FRAC	
H20	1.0000
CO2	0.0
CH4	0.0
CARBO-01	0.0

```
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.3558
TOTAL FLOW:
  KMOL/HR               19.7095
  KG/HR                355.0720
  CUM/HR                 0.3695
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9934
  KCAL/KG            -3829.7161
  GCAL/HR               -1.3598
ENTROPY:
  CAL/MOL-K            -38.9675
  CAL/GM-K              -2.1630
DENSITY:
  MOL/CC              5.3348-02
  KG/CUM               961.0757
AVG MW                  18.0153

SUBSTREAM: NC           STRUCTURE: NON CONVENTIONAL
COMPONENTS: KG/HR
  RAS                    0.0
  DSS                   24.9280
  SCB                    0.0
COMPONENTS: MASS FRAC
  RAS                    0.0
  DSS                    1.0000
  SCB                    0.0
TOTAL FLOW:
  KG/HR                 24.9280
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/KG            -2264.4495
  GCAL/HR            -5.6448-02
DENSITY:
  KG/CUM              1394.1653
AVG MW                   1.0000
```

COMPONENT ATTRIBUTES:

RAS	PROXANAL		
	ULTANAL		
	SULFANAL		
DSS	PROXANAL		
		MOISTURE	9.7262
		FC	0.6838
		VM	52.0400
		ASH	37.5500
	ULTANAL		
		ASH	0.0
		CARBON	18.5500
		HYDROGEN	3.8360
		NITROGEN	4.0220
		CHLORINE	0.0
		SULFUR	0.0
		OXYGEN	0.0
	SULFANAL		
		PYRITIC	0.0
		SULFATE	0.0
		ORGANIC	0.0
SCB	PROXANAL		
	ULTANAL		
	SULFANAL		

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***		
MASSFLOW	KG/HR	
H20		355.0720
CO2		0.0
CH4		0.0
CARBO-01		0.0
HYDRO-01		0.0
BIOCRUDE		0.0
CHAR		0.0
N2		0.0
O2		0.0
HCL		0.0
RAS		0.0
DSS		24.9280
SCB		0.0
VOLFLMX	CUM/HR	0.3873
MASSVFRA		0.0
MASSSFRA		6.5600-02
RHOMX	KG/CUM	981.0682
TEMP	C	25.0000
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

FEEDCOLD

STREAM ID	FEEDCOLD
FROM :	MX-1
TO :	PREHEATX
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	645.7600
GCAL/HR	-2.3182
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	28.7099
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	517.2160
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	1.0000
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0

```
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.5182
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.5182
COMPONENTS: STD VOL FRAC
  H20                     1.0000
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.5182
TOTAL FLOW:
  KMOL/HR                28.7099
  KG/HR                 517.2160
  CUM/HR                  0.5382
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -68.9934
  KCAL/KG             -3829.7161
  GCAL/HR                -1.9808
ENTROPY:
  CAL/MOL-K             -38.9675
  CAL/GM-K               -2.1630
DENSITY:
  MOL/CC               5.3348-02
  KG/CUM                961.0757
AVG MW                  18.0153

SUBSTREAM: NC           STRUCTURE: NON CONVENTIONAL
COMPONENTS: KG/HR
  RAS                     3.6160
  DSS                    24.9280
```

```
  SCB                   100.0000
COMPONENTS: MASS FRAC
  RAS                 2.8130-02
  DSS                    0.1939
  SCB                    0.7779
TOTAL FLOW:
  KG/HR                128.5440
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/KG            -2624.7739
  GCAL/HR               -0.3374
DENSITY:
  KG/CUM               1970.4079
AVG MW                   1.0000
COMPONENT ATTRIBUTES:
RAS      PROXANAL
           MOISTURE     11.8188
           FC            0.2812
           VM           66.3200
           ASH          21.5800
         ULTANAL
           ASH           0.0
           CARBON       35.2800
           HYDROGEN      5.6800
           NITROGEN      6.1160
           CHLORINE      0.0
           SULFUR        0.0
           OXYGEN        0.0
         SULFANAL
           PYRITIC       0.0
           SULFATE       0.0
           ORGANIC       0.0
DSS      PROXANAL
           MOISTURE      9.7262
           FC            0.6838
           VM           52.0400
           ASH          37.5500
         ULTANAL
           ASH           0.0
           CARBON       18.5500
           HYDROGEN      3.8360
           NITROGEN      4.0220
           CHLORINE      0.0
           SULFUR        0.0
           OXYGEN        0.0
         SULFANAL
           PYRITIC       0.0
```

```
            SULFATE       0.0
            ORGANIC       0.0
SCB       PROXANAL
            MOISTURE      0.0
            FC            9.6100
            VM           76.2900
            ASH           7.6200
          ULTANAL
            ASH           0.0
            CARBON        0.3636
            HYDROGEN   4.7100-02
            NITROGEN   5.7600-03
            CHLORINE      0.0
            SULFUR        0.0
            OXYGEN        0.0
          SULFANAL
            PYRITIC       0.0
            SULFATE       0.0
            ORGANIC       0.0

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                517.2160
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.0
    CHAR                 0.0
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  3.6160
    DSS                 24.9280
    SCB                100.0000
VOLFLMX  CUM/HR          0.6034
MASSVFRA                 0.0
MASSSFRA                 0.1991
RHOMX    KG/CUM       1070.2006
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       ------------------------------   ------------
BIOCRUDE                              0.8200   $/KG                     5.6248
HCL                                   4.6107   $/KG                  5839.6504
```

P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

FEEDHOT

STREAM ID	FEEDHOT
FROM :	PREHEATX
TO :	R-HTL
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	645.7600
GCAL/HR	-2.1999
SUBSTREAM: MIXED	
PHASE:	MIXED
COMPONENTS: KMOL/HR	
H20	28.7099
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	517.2160
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	1.0000
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.5182
CO2	0.0

```
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.5182
COMPONENTS: STD VOL FRAC
  H20                     1.0000
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.5182
TOTAL FLOW:
  KMOL/HR                28.7099
  KG/HR                 517.2160
  CUM/HR                207.1554
STATE VARIABLES:
  TEMP   C              102.0834
  PRES   BAR              1.0000
  VFRAC                   0.2327
  LFRAC                   0.7673
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -65.0098
  KCAL/KG             -3608.5940
  GCAL/HR                -1.8664
ENTROPY:
  CAL/MOL-K             -28.7571
  CAL/GM-K               -1.5963
DENSITY:
  MOL/CC               1.3859-04
  KG/CUM                  2.4968
AVG MW                   18.0153

SUBSTREAM: NC           STRUCTURE: NON CONVENTIONAL
COMPONENTS: KG/HR
  RAS                     3.6160
  DSS                    24.9280
  SCB                   100.0000
COMPONENTS: MASS FRAC
  RAS                  2.8130-02
  DSS                     0.1939
  SCB                     0.7779
```

```
TOTAL FLOW:
  KG/HR                128.5440
STATE VARIABLES:
  TEMP   C             102.0834
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/KG            -2593.9594
  GCAL/HR               -0.3334
DENSITY:
  KG/CUM              1970.4079
AVG MW                   1.0000
COMPONENT ATTRIBUTES:
RAS      PROXANAL
           MOISTURE     11.8188
           FC            0.2812
           VM           66.3200
           ASH          21.5800
         ULTANAL
           ASH           0.0
           CARBON       35.2800
           HYDROGEN      5.6800
           NITROGEN      6.1160
           CHLORINE      0.0
           SULFUR        0.0
           OXYGEN        0.0
         SULFANAL
           PYRITIC       0.0
           SULFATE       0.0
           ORGANIC       0.0
DSS      PROXANAL
           MOISTURE      9.7262
           FC            0.6838
           VM           52.0400
           ASH          37.5500
         ULTANAL
           ASH           0.0
           CARBON       18.5500
           HYDROGEN      3.8360
           NITROGEN      4.0220
           CHLORINE      0.0
           SULFUR        0.0
           OXYGEN        0.0
         SULFANAL
           PYRITIC       0.0
           SULFATE       0.0
           ORGANIC       0.0
SCB      PROXANAL
           MOISTURE      0.0
           FC            9.6100
```

```
          VM            76.2900
          ASH            7.6200
        ULTANAL
          ASH            0.0
          CARBON         0.3636
          HYDROGEN    4.7100-02
          NITROGEN    5.7600-03
          CHLORINE       0.0
          SULFUR         0.0
          OXYGEN         0.0
        SULFANAL
          PYRITIC        0.0
          SULFATE        0.0
          ORGANIC        0.0

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                517.2160
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.0
    CHAR                 0.0
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  3.6160
    DSS                 24.9280
    SCB                100.0000
VOLFLMX  CUM/HR        207.2206
MASSVFRA                 0.1864
MASSSFRA                 0.1991
RHOMX    KG/CUM          3.1163
TEMP     C             102.0834
PRES     BAR             1.0000

STREAM COSTS
------------

ID                              PRICE                          COST $/HR

-----------                     ------------------------------   ------------
BIOCRUDE                           0.8200   $/KG                    5.6248
HCL                                4.6107   $/KG                 5839.6504
P-CHAR                             0.9315   $/KG                 1183.8191
SALT                              10.3983   $/KG                  151.8457
BURNER.CH4                     2.7000-02   $/KG                    2.7000

HCL
```

STREAM ID	HCL
FROM :	----
TO :	$C-9
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	1266.5300
GCAL/HR	-0.7662
$/HR	5839.6504
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	34.7369
COMPONENTS: KG/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	1266.5300
COMPONENTS: MASS FRAC	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	1.0000
COMPONENTS: STD CUM/HR	
H20	0.0
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0

```
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     1.8604
  TOTAL CUM/HR            1.8604
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     1.0000
  TOTAL CUM/HR            1.8604
TOTAL FLOW:
  KMOL/HR                34.7369
  KG/HR                1266.5300
  CUM/HR                856.5029
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -22.0573
  KCAL/KG              -604.9625
  GCAL/HR                -0.7662
ENTROPY:
  CAL/MOL-K               2.4003
  CAL/GM-K             6.5832-02
DENSITY:
  MOL/CC               4.0557-05
  KG/CUM                  1.4787
AVG MW                   36.4606

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                   0.0
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              0.0
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
```

```
    HCL                1266.5300
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR         856.5029
MASSVFRA                  1.0000
MASSSFRA                  0.0
RHOMX    KG/CUM           1.4787
TEMP     C               25.0000
PRES     BAR              1.0000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       -----------------------------    ------------
BIOCRUDE                              0.8200   $/KG                    5.6248
HCL                                   4.6107   $/KG                 5839.6504
P-CHAR                                0.9315   $/KG                 1183.8191
SALT                                 10.3983   $/KG                  151.8457
BURNER.CH4                         2.7000-02   $/KG                    2.7000

LIQ-PROD
--------

STREAM ID               LIQ-PROD
FROM :                  FLR-CHAR
TO   :                  LLSEP
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR                706.2664
  GCAL/HR               -2.6760
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  H20                   38.7516
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            8.6540-02
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                  698.1203
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
```

```
  BIOCRUDE               8.1446
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.9885
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            1.1532-02
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.6995
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            7.7642-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.7072
COMPONENTS: STD VOL FRAC
  H20                    0.9890
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            1.0978-02
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR           0.7072
TOTAL FLOW:
  KMOL/HR               38.8381
  KG/HR                706.2649
  CUM/HR                 0.7339
STATE VARIABLES:
  TEMP   C              24.9956
  PRES   BAR             1.2000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9021
```

```
  KCAL/KG            -3788.9838
  GCAL/HR               -2.6760
ENTROPY:
  CAL/MOL-K            -39.0328
  CAL/GM-K              -2.1464
DENSITY:
  MOL/CC              5.2918-02
  KG/CUM               962.3115
AVG MW                  18.1848

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                1.2406-04
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: KG/HR
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                1.4901-03
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: MASS FRAC
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                     1.0000
  N2                       0.0
  O2                       0.0
  HCL                      0.0
COMPONENTS: STD CUM/HR
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                6.4314-07
```

```
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4314-07
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4314-07
TOTAL FLOW:
  KMOL/HR             1.2406-04
  KG/HR               1.4901-03
  CUM/HR              6.6226-07
STATE VARIABLES:
  TEMP   C              24.9956
  PRES   BAR             1.2000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL           -8.8401-06
  KCAL/KG            -7.3600-04
  GCAL/HR            -1.0967-12
ENTROPY:
  CAL/MOL-K          -2.9650-05
  CAL/GM-K           -2.4686-06
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                698.1203
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             8.1446
    CHAR              1.4901-03
    N2                   0.0
    O2                   0.0
    HCL                  0.0
```

RAS		0.0
DSS		0.0
SCB		0.0
VOLFLMX	CUM/HR	0.7339
MASSVFRA		0.0
MASSSFRA		2.1098-06
RHOMX	KG/CUM	962.3126
TEMP	C	24.9956
PRES	BAR	1.2000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

P-CHAR

STREAM ID	P-CHAR
FROM :	$C-11
TO :	----
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	1270.8740
GCAL/HR	-0.7822
$/HR	1183.8191
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: KMOL/HR	
H20	0.2324
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0225-04
CHAR	0.0
N2	0.0
O2	0.0
HCL	34.7369
COMPONENTS: KG/HR	
H20	4.1868
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0

```
  BIOCRUDE            9.6235-03
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                 1266.5300
COMPONENTS: MASS FRAC
  H20                 3.2948-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            7.5732-06
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.9967
COMPONENTS: STD CUM/HR
  H20                 4.1949-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            9.1740-06
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    1.8604
  TOTAL CUM/HR           1.8646
COMPONENTS: STD VOL FRAC
  H20                 2.2497-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE            4.9200-06
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.9977
  TOTAL CUM/HR           1.8646
TOTAL FLOW:
  KMOL/HR              34.9694
  KG/HR              1270.7265
  CUM/HR              831.2721
STATE VARIABLES:
  TEMP   C             14.4839
  PRES   BAR            1.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  KCAL/MOL            -22.3685
```

```
  KCAL/KG             -615.5650
  GCAL/HR               -0.7822
ENTROPY:
  CAL/MOL-K              2.1409
  CAL/GM-K            5.8915-02
DENSITY:
  MOL/CC              4.2067-05
  KG/CUM                 1.5287
AVG MW                  36.3382

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                1.2281-02
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.1475
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.3665-05
```

```
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.3665-05
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.3665-05
TOTAL FLOW:
  KMOL/HR             1.2281-02
  KG/HR                  0.1475
  CUM/HR              6.5557-05
STATE VARIABLES:
  TEMP   C              14.4839
  PRES   BAR             1.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL           -2.0912-02
  KCAL/KG               -1.7411
  GCAL/HR            -2.5681-07
ENTROPY:
  CAL/MOL-K          -7.1396-02
  CAL/GM-K           -5.9443-03
DENSITY:
  MOL/CC                 0.1873
  KG/CUM              2250.0206
AVG MW                  12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                   4.1868
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE           9.6235-03
    CHAR                  0.1475
    N2                    0.0
    O2                    0.0
    HCL                1266.5300
```

RAS		0.0
DSS		0.0
SCB		0.0
VOLFLMX	CUM/HR	831.2721
MASSVFRA		0.9999
MASSSFRA		1.1607-04
RHOMX	KG/CUM	1.5288
TEMP	C	14.4839
PRES	BAR	1.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

P-COLD

STREAM ID	P-COLD
FROM :	PREHEATX
TO :	VENT
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	925.5227
GCAL/HR	-2.9527
SUBSTREAM: MIXED	
PHASE:	MIXED
COMPONENTS: KMOL/HR	
H20	38.7516
CO2	2.3217
CH4	6.3691
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	8.6541-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	698.1218
CO2	102.1777
CH4	102.1777
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	8.1446

```
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.7666
  CO2                     0.1122
  CH4                     0.1122
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             8.9440-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.6995
  CO2                     0.1243
  CH4                     0.3411
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             7.7642-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            1.1727
COMPONENTS: STD VOL FRAC
  H20                     0.5965
  CO2                     0.1060
  CH4                     0.2909
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             6.6208-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            1.1727
TOTAL FLOW:
  KMOL/HR                47.5290
  KG/HR                 910.6218
  CUM/HR                  3.2776
STATE VARIABLES:
  TEMP   C               87.2690
  PRES   BAR             95.0000
  VFRAC                   0.1835
  LFRAC                   0.8165
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -62.1288
  KCAL/KG             -3242.7500
```

```
  GCAL/HR               -2.9529
ENTROPY:
  CAL/MOL-K            -32.8667
  CAL/GM-K              -1.7154
DENSITY:
  MOL/CC              1.4501-02
  KG/CUM               277.8325
AVG MW                  19.1593

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2406
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.9009
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.4314-03
  N2                     0.0
```

```
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4314-03
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4314-03
TOTAL FLOW:
  KMOL/HR                 1.2406
  KG/HR                  14.9009
  CUM/HR              6.6226-03
STATE VARIABLES:
  TEMP   C               87.2690
  PRES   BAR             95.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL                0.1416
  KCAL/KG                11.7876
  GCAL/HR             1.7565-04
ENTROPY:
  CAL/MOL-K               0.4298
  CAL/GM-K            3.5783-02
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 698.1218
    CO2                 102.1777
    CH4                 102.1777
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              8.1446
    CHAR                 14.9009
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
```

DSS		0.0
SCB		0.0
VOLFLMX	CUM/HR	3.2842
MASSVFRA		0.2199
MASSSFRA		1.6100-02
RHOMX	KG/CUM	281.8094
TEMP	C	87.2690
PRES	BAR	95.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

P-HOT

STREAM ID	P-HOT
FROM :	R-HTL
TO :	PREHEATX
CLASS:	MIXCINC
MAX CONV. ERROR:	1.1978-10
TOTAL STREAM:	
KG/HR	925.5227
GCAL/HR	-2.8344
SUBSTREAM: MIXED	
PHASE:	MIXED
COMPONENTS: KMOL/HR	
H20	38.7516
CO2	2.3217
CH4	6.3691
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	8.6541-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	698.1218
CO2	102.1777
CH4	102.1777
CARBO-01	0.0
HYDRO-01	0.0

```
  BIOCRUDE                8.1446
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.7666
  CO2                     0.1122
  CH4                     0.1122
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             8.9440-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.6995
  CO2                     0.1243
  CH4                     0.3411
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             7.7642-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            1.1727
COMPONENTS: STD VOL FRAC
  H20                     0.5965
  CO2                     0.1060
  CH4                     0.2909
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE             6.6208-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            1.1727
TOTAL FLOW:
  KMOL/HR                47.5290
  KG/HR                 910.6218
  CUM/HR                  4.9564
STATE VARIABLES:
  TEMP   C              195.0000
  PRES   BAR             95.0000
  VFRAC                   0.2245
  LFRAC                   0.7755
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -59.6475
```

```
  KCAL/KG            -3113.2381
  GCAL/HR               -2.8350
ENTROPY:
  CAL/MOL-K            -27.5623
  CAL/GM-K              -1.4386
DENSITY:
  MOL/CC              9.5895-03
  KG/CUM               183.7280
AVG MW                  19.1593

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2406
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.9009
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.4314-03
```

```
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR         6.4314-03
COMPONENTS: STD VOL FRAC
  H20                      0.0
  CO2                      0.0
  CH4                      0.0
  CARBO-01                 0.0
  HYDRO-01                 0.0
  BIOCRUDE                 0.0
  CHAR                     1.0000
  N2                       0.0
  O2                       0.0
  HCL                      0.0
  TOTAL CUM/HR         6.4314-03
TOTAL FLOW:
  KMOL/HR                  1.2406
  KG/HR                   14.9009
  CUM/HR               6.6226-03
STATE VARIABLES:
  TEMP   C               195.0000
  PRES   BAR              95.0000
  VFRAC                    0.0
  LFRAC                    0.0
  SFRAC                    1.0000
ENTHALPY:
  KCAL/MOL                 0.4581
  KCAL/KG                 38.1382
  GCAL/HR              5.6829-04
ENTROPY:
  CAL/MOL-K                1.1933
  CAL/GM-K             9.9352-02
DENSITY:
  MOL/CC                   0.1873
  KG/CUM                2250.0206
AVG MW                     12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  698.1218
    CO2                  102.1777
    CH4                  102.1777
    CARBO-01               0.0
    HYDRO-01               0.0
    BIOCRUDE               8.1446
    CHAR                  14.9009
    N2                     0.0
    O2                     0.0
    HCL                    0.0
```

RAS		0.0
DSS		0.0
SCB		0.0
VOLFLMX	CUM/HR	4.9630
MASSVFRA		0.2566
MASSSFRA		1.6100-02
RHOMX	KG/CUM	186.4853
TEMP	C	195.0000
PRES	BAR	95.0000

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

PRODUCT

STREAM ID	PRODUCT
FROM :	VENT
TO :	COOLER
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	721.1673
GCAL/HR	-2.6241
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	38.7516
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	8.6541-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	698.1218
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	8.1446

```
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     0.9885
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            1.1532-02
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.6995
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            7.7642-03
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.7072
COMPONENTS: STD VOL FRAC
  H20                     0.9890
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE            1.0978-02
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.7072
TOTAL FLOW:
  KMOL/HR                38.8382
  KG/HR                 706.2664
  CUM/HR                  0.7792
STATE VARIABLES:
  TEMP   C               87.2690
  PRES   BAR             95.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -67.5707
  KCAL/KG             -3715.7694
```

```
  GCAL/HR               -2.6243
ENTROPY:
  CAL/MOL-K            -35.6348
  CAL/GM-K              -1.9596
DENSITY:
  MOL/CC              4.9842-02
  KG/CUM               906.3761
AVG MW                  18.1848

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2406
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.9009
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.4314-03
  N2                     0.0
```

```
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4314-03
COMPONENTS: STD VOL FRAC
  H20                     0.0
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR        6.4314-03
TOTAL FLOW:
  KMOL/HR                 1.2406
  KG/HR                  14.9009
  CUM/HR              6.6226-03
STATE VARIABLES:
  TEMP   C               87.2690
  PRES   BAR             95.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL                0.1416
  KCAL/KG                11.7876
  GCAL/HR             1.7565-04
ENTROPY:
  CAL/MOL-K               0.4298
  CAL/GM-K            3.5783-02
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                 698.1218
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              8.1446
    CHAR                 14.9009
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
```

```
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR           0.7858
MASSVFRA                  0.0
MASSSFRA               2.0662-02
RHOMX    KG/CUM         917.6995
TEMP     C               87.2690
PRES     BAR             95.0000

STREAM COSTS
------------

ID                                PRICE                            COST $/HR

-----------                       -----------------------------    ------------
BIOCRUDE                             0.8200   $/KG                     5.6248
HCL                                  4.6107   $/KG                  5839.6504
P-CHAR                               0.9315   $/KG                  1183.8191
SALT                                10.3983   $/KG                   151.8457
BURNER.CH4                       2.7000-02   $/KG                     2.7000

RAS
---

STREAM ID               RAS
FROM :                  ----
TO   :                  MX-1
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR                160.0000
  GCAL/HR               -0.6054
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  H20                    8.6806
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                  156.3840
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
```

```
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: MASS FRAC
  H20                     1.0000
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
COMPONENTS: STD CUM/HR
  H20                     0.1567
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.1567
COMPONENTS: STD VOL FRAC
  H20                     1.0000
  CO2                     0.0
  CH4                     0.0
  CARBO-01                0.0
  HYDRO-01                0.0
  BIOCRUDE                0.0
  CHAR                    0.0
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR            0.1567
TOTAL FLOW:
  KMOL/HR                 8.6806
  KG/HR                 156.3840
  CUM/HR                  0.1627
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KCAL/MOL              -68.9934
  KCAL/KG             -3829.7161
  GCAL/HR                -0.5989
```

```
ENTROPY:
  CAL/MOL-K             -38.9675
  CAL/GM-K               -2.1630
DENSITY:
  MOL/CC               5.3348-02
  KG/CUM                961.0757
AVG MW                   18.0153

SUBSTREAM: NC           STRUCTURE: NON CONVENTIONAL
COMPONENTS: KG/HR
  RAS                     3.6160
  DSS                     0.0
  SCB                     0.0
COMPONENTS: MASS FRAC
  RAS                     1.0000
  DSS                     0.0
  SCB                     0.0
TOTAL FLOW:
  KG/HR                   3.6160
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/KG              -1793.6870
  GCAL/HR              -6.4860-03
DENSITY:
  KG/CUM                1284.6460
AVG MW                     1.0000
COMPONENT ATTRIBUTES:
RAS      PROXANAL
           MOISTURE     11.8188
           FC            0.2812
           VM           66.3200
           ASH          21.5800
         ULTANAL
           ASH           0.0
           CARBON       35.2800
           HYDROGEN      5.6800
           NITROGEN      6.1160
           CHLORINE      0.0
           SULFUR        0.0
           OXYGEN        0.0
         SULFANAL
           PYRITIC       0.0
           SULFATE       0.0
           ORGANIC       0.0
DSS      PROXANAL
         ULTANAL
         SULFANAL
```

```
SCB       PROXANAL
          ULTANAL
          SULFANAL

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                156.3840
    CO2                  0.0
    CH4                  0.0
    CARBO-01             0.0
    HYDRO-01             0.0
    BIOCRUDE             0.0
    CHAR                 0.0
    N2                   0.0
    O2                   0.0
    HCL                  0.0
    RAS                  3.6160
    DSS                  0.0
    SCB                  0.0
VOLFLMX  CUM/HR          0.1655
MASSVFRA                 0.0
MASSSFRA              2.2600-02
RHOMX    KG/CUM        966.5779
TEMP     C              25.0000
PRES     BAR             1.0000

STREAM COSTS
------------

ID                                PRICE                          COST $/HR

-----------                       ----------------------------   ------------
BIOCRUDE                             0.8200   $/KG                   5.6248
HCL                                  4.6107   $/KG                5839.6504
P-CHAR                               0.9315   $/KG                1183.8191
SALT                                10.3983   $/KG                 151.8457
BURNER.CH4                       2.7000-02   $/KG                   2.7000

SALT
----

STREAM ID              SALT
FROM :                 $C-10
TO   :                 ----
CLASS:                 MIXCINC
TOTAL STREAM:
  KG/HR                14.6029
  GCAL/HR           -2.5425-05
  $/HR                151.8457
```

```
SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2158
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.6029
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                6.3028-03
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR        6.3028-03
COMPONENTS: STD VOL FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
```

```
  BIOCRUDE                0.0
  CHAR                    1.0000
  N2                      0.0
  O2                      0.0
  HCL                     0.0
  TOTAL CUM/HR         6.3028-03
TOTAL FLOW:
  KMOL/HR                 1.2158
  KG/HR                  14.6029
  CUM/HR               6.4901-03
STATE VARIABLES:
  TEMP   C               14.4839
  PRES   BAR              1.0000
  VFRAC                   0.0
  LFRAC                   0.0
  SFRAC                   1.0000
ENTHALPY:
  KCAL/MOL            -2.0912-02
  KCAL/KG                -1.7411
  GCAL/HR             -2.5425-05
ENTROPY:
  CAL/MOL-K           -7.1396-02
  CAL/GM-K            -5.9443-03
DENSITY:
  MOL/CC                  0.1873
  KG/CUM               2250.0206
AVG MW                   12.0110

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                   0.0
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              0.0
    CHAR                 14.6029
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                   0.0
VOLFLMX  CUM/HR       6.4901-03
MASSVFRA                  0.0
MASSSFRA                  1.0000
RHOMX    KG/CUM       2250.0206
TEMP     C              14.4839
PRES     BAR             1.0000
```

STREAM COSTS

ID	PRICE		COST $/HR
BIOCRUDE	0.8200	$/KG	5.6248
HCL	4.6107	$/KG	5839.6504
P-CHAR	0.9315	$/KG	1183.8191
SALT	10.3983	$/KG	151.8457
BURNER.CH4	2.7000-02	$/KG	2.7000

SCB

STREAM ID	SCB
FROM :	----
TO :	MX-1
CLASS:	MIXCINC
TOTAL STREAM:	
KG/HR	105.7600
GCAL/HR	-0.2965
SUBSTREAM: MIXED	
PHASE:	LIQUID
COMPONENTS: KMOL/HR	
H20	0.3197
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	5.7600
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	0.0
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	1.0000
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0

```
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: STD CUM/HR
  H20                5.7711-03
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR       5.7711-03
COMPONENTS: STD VOL FRAC
  H20                    1.0000
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   0.0
  N2                     0.0
  O2                     0.0
  HCL                    0.0
  TOTAL CUM/HR       5.7711-03
TOTAL FLOW:
  KMOL/HR                0.3197
  KG/HR                  5.7600
  CUM/HR             5.9933-03
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9934
  KCAL/KG            -3829.7161
  GCAL/HR            -2.2059-02
ENTROPY:
  CAL/MOL-K            -38.9675
  CAL/GM-K              -2.1630
DENSITY:
  MOL/CC             5.3348-02
  KG/CUM              961.0757
AVG MW                 18.0153

SUBSTREAM: NC          STRUCTURE: NON CONVENTIONAL
```

```
COMPONENTS: KG/HR
  RAS                    0.0
  DSS                    0.0
  SCB                  100.0000
COMPONENTS: MASS FRAC
  RAS                    0.0
  DSS                    0.0
  SCB                    1.0000
TOTAL FLOW:
  KG/HR                100.0000
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  0.0
  SFRAC                  1.0000
ENTHALPY:
  KCAL/KG            -2744.6477
  GCAL/HR               -0.2745
DENSITY:
  KG/CUM              2245.0600
AVG MW                   1.0000
COMPONENT ATTRIBUTES:
RAS      PROXANAL
         ULTANAL
         SULFANAL
DSS      PROXANAL
         ULTANAL
         SULFANAL
SCB      PROXANAL
           MOISTURE      0.0
           FC            9.6100
           VM           76.2900
           ASH           7.6200
         ULTANAL
           ASH           0.0
           CARBON        0.3636
           HYDROGEN   4.7100-02
           NITROGEN   5.7600-03
           CHLORINE      0.0
           SULFUR        0.0
           OXYGEN        0.0
         SULFANAL
           PYRITIC       0.0
           SULFATE       0.0
           ORGANIC       0.0

TOTAL STREAM PROPERTIES:

***  ALL PHASES   ***
MASSFLOW KG/HR
    H20                  5.7600
```

```
    CO2                   0.0
    CH4                   0.0
    CARBO-01              0.0
    HYDRO-01              0.0
    BIOCRUDE              0.0
    CHAR                  0.0
    N2                    0.0
    O2                    0.0
    HCL                   0.0
    RAS                   0.0
    DSS                   0.0
    SCB                 100.0000
VOLFLMX  CUM/HR        5.0536-02
MASSVFRA                  0.0
MASSSFRA                  0.9455
RHOMX    KG/CUM        2092.7853
TEMP     C               25.0000
PRES     BAR              1.0000

STREAM COSTS
------------

ID                                PRICE                           COST $/HR

-----------                       ------------------------------  ------------
BIOCRUDE                             0.8200   $/KG                    5.6248
HCL                                  4.6107   $/KG                 5839.6504
P-CHAR                               0.9315   $/KG                 1183.8191
SALT                                10.3983   $/KG                  151.8457
BURNER.CH4                       2.7000-02    $/KG                    2.7000

SEPFEED
-------

STREAM ID               SEPFEED
FROM :                  COOLER
TO   :                  FLR-CHAR
CLASS:                  MIXCINC
TOTAL STREAM:
  KG/HR               721.1673
  GCAL/HR              -2.6760
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  H20                  38.7516
  CO2                   0.0
  CH4                   0.0
  CARBO-01              0.0
  HYDRO-01              0.0
  BIOCRUDE           8.6541-02
  CHAR                  0.0
  N2                    0.0
```

O2	0.0
HCL	0.0
COMPONENTS: KG/HR	
H20	698.1218
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	8.1446
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: MASS FRAC	
H20	0.9885
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.1532-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
COMPONENTS: STD CUM/HR	
H20	0.6995
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	7.7642-03
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.7072
COMPONENTS: STD VOL FRAC	
H20	0.9890
CO2	0.0
CH4	0.0
CARBO-01	0.0
HYDRO-01	0.0
BIOCRUDE	1.0978-02
CHAR	0.0
N2	0.0
O2	0.0
HCL	0.0
TOTAL CUM/HR	0.7072
TOTAL FLOW:	
KMOL/HR	38.8382
KG/HR	706.2664
CUM/HR	0.7339

```
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   BAR             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KCAL/MOL             -68.9021
  KCAL/KG            -3788.9838
  GCAL/HR               -2.6760
ENTROPY:
  CAL/MOL-K            -39.0325
  CAL/GM-K              -2.1464
DENSITY:
  MOL/CC              5.2918-02
  KG/CUM               962.3040
AVG MW                 18.1848

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.2406
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: KG/HR
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                  14.9009
  N2                     0.0
  O2                     0.0
  HCL                    0.0
COMPONENTS: MASS FRAC
  H20                    0.0
  CO2                    0.0
  CH4                    0.0
  CARBO-01               0.0
  HYDRO-01               0.0
  BIOCRUDE               0.0
  CHAR                   1.0000
  N2                     0.0
  O2                     0.0
  HCL                    0.0
```

```
COMPONENTS: STD CUM/HR

   H20                     0.0
   CO2                     0.0
   CH4                     0.0
   CARBO-01                0.0
   HYDRO-01                0.0
   BIOCRUDE                0.0
   CHAR                6.4314-03
   N2                      0.0
   O2                      0.0
   HCL                     0.0
   TOTAL CUM/HR        6.4314-03
 COMPONENTS: STD VOL FRAC
   H20                     0.0
   CO2                     0.0
   CH4                     0.0
   CARBO-01                0.0
   HYDRO-01                0.0
   BIOCRUDE                0.0
   CHAR                    1.0000
   N2                      0.0
   O2                      0.0
   HCL                     0.0
   TOTAL CUM/HR        6.4314-03
 TOTAL FLOW:
   KMOL/HR                 1.2406
   KG/HR                  14.9009
   CUM/HR              6.6226-03
 STATE VARIABLES:
   TEMP   C               25.0000
   PRES   BAR              1.0000
   VFRAC                   0.0
   LFRAC                   0.0
   SFRAC                   1.0000
 ENTHALPY:
   KCAL/MOL            1.2444-16
   KCAL/KG             1.0361-14
   GCAL/HR             1.5438-19
 ENTROPY:
   CAL/MOL-K           3.1187-16
   CAL/GM-K            2.5966-17
 DENSITY:
   MOL/CC                  0.1873
   KG/CUM               2250.0206
 AVG MW                   12.0110

 TOTAL STREAM PROPERTIES:

 ***  ALL PHASES   ***
 MASSFLOW KG/HR
     H20                 698.1218
     CO2                   0.0
```

CH4		0.0
CARBO-01		0.0
HYDRO-01		0.0
BIOCRUDE		8.1446
CHAR		14.9009
N2		0.0
O2		0.0
HCL		0.0
RAS		0.0
DSS		0.0
SCB		0.0
VOLFLMX	CUM/HR	0.7406
MASSVFRA		0.0
MASSSFRA		2.0662-02
RHOMX	KG/CUM	973.8197
TEMP	C	25.0000
PRES	BAR	1.0000

Annexure B Unit Operation Block Results (B173 - B193)

```
BLOCK:  B1       MODEL: MIXER
------------------------------
  INLET STREAMS:         8           BIOCHAR
  OUTLET STREAM:         S1
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                    IN              OUT        RELATIVE DIFF.
     CONV. COMP.(KMOL/HR )     24.4912         24.4912          0.00000
                 (KG/HR   )    434.545         434.545         0.130811E-15
     NONCONV. COMP(KG/HR   )   0.00000         0.00000          0.00000
   TOTAL BALANCE
     MASS(KG/HR   )             434.545         434.545         0.130811E-15
     ENTHALPY(GCAL/HR )        -1.60372        -1.60372        -0.908671E-11

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/HR
   PRODUCT STREAMS CO2E          0.00000      KG/HR
   NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
   UTILITIES CO2E PRODUCTION     0.00000      KG/HR
   TOTAL CO2E PRODUCTION         0.00000      KG/HR

                          ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000
  OUTLET PRESSURE   BAR                                     1.00000

BLOCK:  B2       MODEL: FILTER
------------------------------
  INLET STREAM:          S1
  OUTLET STREAMS:        AQUEOUS2    BIOCHAR2
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                    IN              OUT        RELATIVE DIFF.
     CONV. COMP.(KMOL/HR )     24.4912         24.4912          0.00000
                 (KG/HR   )    434.545         434.545          0.00000
     NONCONV. COMP(KG/HR   )   0.00000         0.00000          0.00000
   TOTAL BALANCE
     MASS(KG/HR   )             434.545         434.545          0.00000
     ENTHALPY(GCAL/HR )        -1.60372        -1.60372          0.00000

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/HR
   PRODUCT STREAMS CO2E          0.00000      KG/HR
   NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
   UTILITIES CO2E PRODUCTION     0.00000      KG/HR
   TOTAL CO2E PRODUCTION         0.00000      KG/HR

                          ***  INPUT DATA  ***
```

```
  SELECTED TYPE                                          SOLIDS-SEPARATOR
  CLASSIFICATION CHARACTERISTIC                          PARTICLE SIZE
  FRACTION OF FLUID TO FLUID OUTLET                             0.99000
  FRACTION OF SOLIDS TO SOLID OUTLET                            0.99000
  SEPARATION SHARPNESS                                          0.0
  OFFSET OF FINES                                               0.0
  SPECIFIED PRESSURE    BAR                                     1.00000
  SPECIFIED HEAT DUTY   GCAL/HR                                 0.0
  MAXIMUM NO. ITERATIONS                                       30
  CONVERGENCE TOLERANCE                                         0.000100000

                          ***  RESULTS  ***
  FRACTION OF FLUID TO FLUID OUTLET                             0.99000
  FRACTION OF SOLIDS TO SOLID OUTLET                            0.99000
  SOLID LOAD OF FLUID OUTLET (KG/KG)                            0.00035863
  FLUID LOAD OF SOLID OUTLET (KG/KG)                            0.28450
  HEAT DUTY  GCAL/HR                                          0.40040E-15

BLOCK:  B1       MODEL: RGIBBS
------------------------------
  INLET STREAMS:         BIOGAS      AIR         CH4
  OUTLET STREAM:         S1
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                      ***  MASS AND ENERGY BALANCE  ***
                              IN          OUT       GENERATION   RELATIVE DIFF.
CONV. COMP.(KMOL/HR )    35.4346       51.0109       15.5763       0.00000
           (KG/HR   )    894.355       894.355                    -0.203386E-14
NONCONV COMP(KG/HR   )   0.00000       0.00000                      0.00000
  TOTAL BALANCE
     MASS(KG/HR   )      894.355       894.355                    -0.203386E-14
     ENTHALPY(GCAL/HR )-0.440755     -0.440755                     0.391632E-06

                      ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             5156.62      KG/HR
   PRODUCT STREAMS CO2E          1263.85      KG/HR
   NET STREAMS CO2E PRODUCTION  -3892.77      KG/HR
   UTILITIES CO2E PRODUCTION     0.00000      KG/HR
   TOTAL CO2E PRODUCTION        -3892.77      KG/HR

                          ***  INPUT DATA  ***

  EQUILIBRIUM SPECIFICATIONS:
    ONLY CHEMICAL EQUILIBRIUM IS CONSIDERED, THE FLUID PHASE IS VAPOR
    CALCULATED TEMPERATURE    C                                 575.19
    TEMPERATURE FOR FREE ENERGY EVALUATION    C               575.19
    SYSTEM PRESSURE       BAR                                 1.0132
    SPECIFIED DUTY        GCAL/HR                               0.0000

  FLUID PHASE SPECIES IN PRODUCT LIST:
    H20 CO2 CH4 CARBO-01 HYDRO-01 BIOCRUDE N2 O2 HCL
```

```
 SOLIDS IN PRODUCT LIST:

    CHAR

  ATOM MATRIX:
  ELEMENT      H    C    N    O    CL
    H20        2.00 0.00 0.00 1.00 0.00
    CO2        0.00 1.00 0.00 2.00 0.00
    CH4        4.00 1.00 0.00 0.00 0.00
    CARBO-01   0.00 1.00 0.00 1.00 0.00
    HYDRO-01   2.00 0.00 0.00 0.00 0.00
    BIOCRUDE   6.00 6.00 0.00 1.00 0.00
    CHAR       0.00 1.00 0.00 0.00 0.00
    N2         0.00 0.00 2.00 0.00 0.00
    O2         0.00 0.00 0.00 2.00 0.00
    HCL        1.00 0.00 0.00 0.00 1.00

                          ***  RESULTS  ***
  TEMPERATURE           C                                    575.19
  PRESSURE              BAR                                  1.0132
  VAPOR FRACTION                                             1.0000
  NUMBER OF FLUID PHASES                                          1

  FLUID PHASE MOLE FRACTIONS:

  PHASE              VAPOR
  OF TYPE            VAPOR
  PHASE FRACTION     1.000000
  PLACED IN STREAM   S1
    CO2              0.5706293E-01
    CH4              0.6603014E-01
    CARBO-01         0.4903790E-01
    HYDRO-01         0.3251484
    N2               0.3817031
    O2               0.2535909E-25
    BIOCRUDE         0.5057640E-20
    H20              0.1210175

  KMOL/HR            43.58995

  SOLIDS PRESENT AT EQUILIBRIUM, PLACED IN STREAM S1

  SOLID FLOW RATES   (KMOL/HR ) :

    CHAR             7.420950

BLOCK:  B2       MODEL: HEATX
------------------------------
  HOT SIDE:
  ---------
  INLET STREAM:             S1
  OUTLET STREAM:            S3
  PROPERTY OPTION SET:   SRK      SOAVE-REDLICH-KWONG EQUATION OF STATE
```

COLD SIDE:

INLET STREAM: S4
OUTLET STREAM: S2
PROPERTY OPTION SET: SRK SOAVE-REDLICH-KWONG EQUATION OF STATE

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
CONV. COMP.(KMOL/HR)	66.5113	66.5113	0.00000
(KG/HR)	1174.12	1174.12	0.00000
NONCONV. COMP(KG/HR)	0.00000	0.00000	0.00000
TOTAL BALANCE			
MASS(KG/HR)	1174.12	1174.12	0.00000
ENTHALPY(GCAL/HR)	-1.50990	-1.50990	0.120114E-07

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	1263.85	KG/HR
PRODUCT STREAMS CO2E	1263.85	KG/HR
NET STREAMS CO2E PRODUCTION	0.00000	KG/HR
UTILITIES CO2E PRODUCTION	0.00000	KG/HR
TOTAL CO2E PRODUCTION	0.00000	KG/HR

*** INPUT DATA ***

FLASH SPECS FOR HOT SIDE:
TWO PHASE FLASH
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

FLASH SPECS FOR COLD SIDE:
TWO PHASE FLASH
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

FLOW DIRECTION AND SPECIFICATION:
COUNTERCURRENT HEAT EXCHANGER
SPECIFIED EXCHANGER AREA

SPECIFIED VALUE	SQM	20.0000
AREA TOLERANCE	SQM	0.01000
MINIMUM APPROACH TEMPERATURE	C	1.00000
MAXIMUM NO. ITERATIONS		20
LMTD CORRECTION FACTOR		1.00000

PRESSURE SPECIFICATION:

HOT SIDE PRESSURE DROP	BAR	0.0000
COLD SIDE PRESSURE DROP	BAR	0.0000

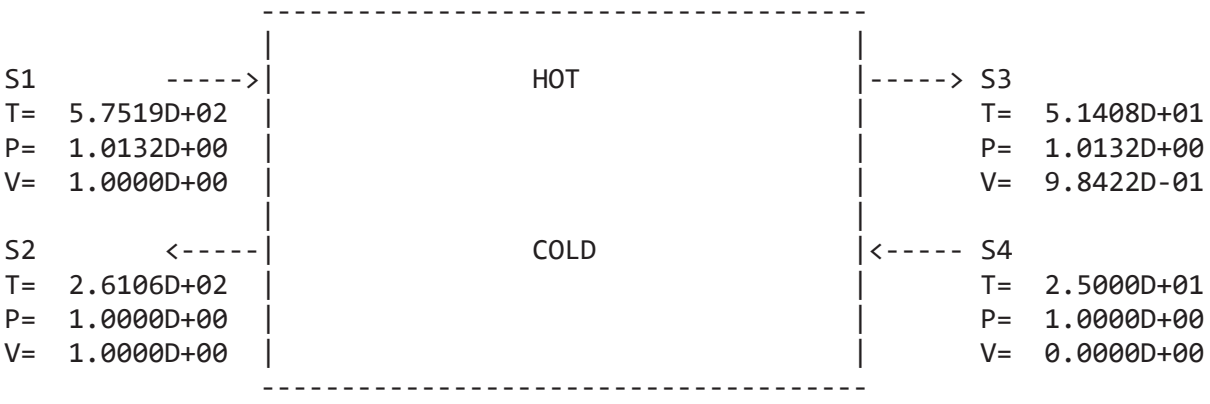
HEAT TRANSFER COEFFICIENT SPECIFICATION:

HOT LIQUID	COLD LIQUID	KCAL/HR-SQM-K	730.8684
HOT 2-PHASE	COLD LIQUID	KCAL/HR-SQM-K	730.8684
HOT VAPOR	COLD LIQUID	KCAL/HR-SQM-K	730.8684
HOT LIQUID	COLD 2-PHASE	KCAL/HR-SQM-K	730.8684

HOT 2-PHASE	COLD 2-PHASE	KCAL/HR-SQM-K	730.8684
HOT VAPOR	COLD 2-PHASE	KCAL/HR-SQM-K	730.8684
HOT LIQUID	COLD VAPOR	KCAL/HR-SQM-K	730.8684
HOT 2-PHASE	COLD VAPOR	KCAL/HR-SQM-K	730.8684
HOT VAPOR	COLD VAPOR	KCAL/HR-SQM-K	730.8684

*** OVERALL RESULTS ***

STREAMS:



DUTY AND AREA:

CALCULATED HEAT DUTY	GCAL/HR	0.2041
CALCULATED (REQUIRED) AREA	SQM	20.0010
ACTUAL EXCHANGER AREA	SQM	20.0000
PER CENT OVER-DESIGN		-0.0051

HEAT TRANSFER COEFFICIENT:

AVERAGE COEFFICIENT (DIRTY)	KCAL/HR-SQM-K	730.8684
UA (DIRTY)	CAL/SEC-K	4060.5878

LOG-MEAN TEMPERATURE DIFFERENCE:

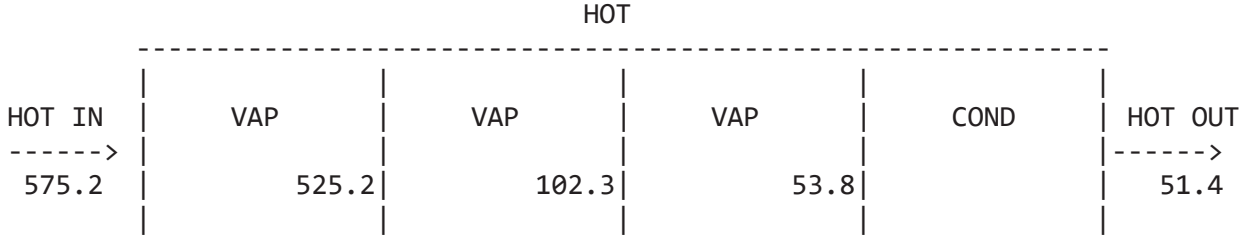
LMTD CORRECTION FACTOR		1.0000
LMTD (CORRECTED)	C	13.9638
NUMBER OF SHELLS IN SERIES		1

PRESSURE DROP:

HOTSIDE, TOTAL	BAR	0.0000
COLDSIDE, TOTAL	BAR	0.0000

*** ZONE RESULTS ***

TEMPERATURE LEAVING EACH ZONE:



```
COLDOUT |     VAP      |     BOIL     |     LIQ      |     LIQ      | COLDIN
<------ |              |              |              |              |<------
 261.1  |         102.1|         102.0|          50.9|              |   25.0
        |              |              |              |              |
        ---------------------------------------------------------------
                                    COLD
```

ZONE HEAT TRANSFER AND AREA:

ZONE	HEAT DUTY GCAL/HR	AREA SQM	LMTD C	AVERAGE U KCAL/HR-SQM-K	UA CAL/SEC-K
1	0.021	0.0771	365.9075	730.8684	15.6474
2	0.159	3.3876	64.1019	730.8684	687.7562
3	0.017	15.4757	1.4589	730.8684	3141.8621
4	0.008	1.0606	10.7069	730.8684	215.3220

HEATX COLD-TQCU B2 TQCURV INLET

PRESSURE PROFILE: CONSTANT2
PRESSURE DROP: 0.0 BAR
PROPERTY OPTION SET: SRK SOAVE-REDLICH-KWONG EQUATION OF STATE

DUTY GCAL/HR	PRES BAR	TEMP C	VFRAC
0.0	1.0000	261.0608	1.0000
9.7202-03	1.0000	186.9007	1.0000
1.9440-02	1.0000	111.2730	1.0000
2.0612-02	1.0000	102.0735	DEW>1.0000
2.9161-02	1.0000	102.0730	0.9461
3.8881-02	1.0000	102.0724	0.8849
4.8601-02	1.0000	102.0718	0.8237
5.8321-02	1.0000	102.0710	0.7624
6.8041-02	1.0000	102.0702	0.7012
7.7762-02	1.0000	102.0693	0.6400
8.7482-02	1.0000	102.0682	0.5787
9.7202-02	1.0000	102.0669	0.5175
0.1069	1.0000	102.0654	0.4562
0.1166	1.0000	102.0636	0.3950
0.1264	1.0000	102.0613	0.3338
0.1361	1.0000	102.0585	0.2725
0.1458	1.0000	102.0550	0.2113
0.1555	1.0000	102.0502	0.1500

```
!     0.1652 !     1.0000 !   102.0434 !  8.8757-02 !
!     0.1750 !     1.0000 !   102.0334 !  2.7488-02 !
!------------+------------+------------+------------!
!     0.1793 !     1.0000 !   102.0271 ! BUB>0.0    !
!     0.1847 !     1.0000 !    85.4796 !     0.0    !
!     0.1944 !     1.0000 !    55.2757 !     0.0    !
!     0.1958 !     1.0000 !    50.8502 !     0.0    !
!     0.2041 !     1.0000 !    25.0000 !     0.0    !
-----------------------------------------------------

HEATX HOT-TQCUR B2       TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         BAR
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  GCAL/HR   !  BAR       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0133 !   575.1892 !     1.0000 !
!  9.7202-03 !     1.0133 !   551.7148 !     1.0000 !
!  1.9440-02 !     1.0133 !   528.0288 !     1.0000 !
!  2.0612-02 !     1.0133 !   525.1596 !     1.0000 !
!  2.9161-02 !     1.0133 !   504.1250 !     1.0000 !
!------------+------------+------------+------------!
!  3.8881-02 !     1.0133 !   479.9968 !     1.0000 !
!  4.8601-02 !     1.0133 !   455.6379 !     1.0000 !
!  5.8321-02 !     1.0133 !   431.0415 !     1.0000 !
!  6.8041-02 !     1.0133 !   406.2011 !     1.0000 !
!  7.7762-02 !     1.0133 !   381.1102 !     1.0000 !
!------------+------------+------------+------------!
!  8.7482-02 !     1.0133 !   355.7623 !     1.0000 !
!  9.7202-02 !     1.0133 !   330.1507 !     1.0000 !
!     0.1069 !     1.0133 !   304.2689 !     1.0000 !
!     0.1166 !     1.0133 !   278.1103 !     1.0000 !
!     0.1264 !     1.0133 !   251.6684 !     1.0000 !
!------------+------------+------------+------------!
!     0.1361 !     1.0133 !   224.9362 !     1.0000 !
!     0.1458 !     1.0133 !   197.9067 !     1.0000 !
!     0.1555 !     1.0133 !   170.5723 !     1.0000 !
!     0.1652 !     1.0133 !   142.9252 !     1.0000 !
!     0.1750 !     1.0133 !   114.9567 !     1.0000 !
!------------+------------+------------+------------!
!     0.1793 !     1.0133 !   102.3050 !     1.0000 !
!     0.1847 !     1.0133 !    86.6577 !     1.0000 !
!     0.1944 !     1.0133 !    58.0188 !     1.0000 !
!     0.1958 !     1.0133 !    53.8041 ! DEW>1.0000 !
```

```
  !     0.2041 !     1.0133 !    51.4080 !     0.9842 !
-------------------------------------------------


 BLOCK:  B1       MODEL: MIXER
 ------------------------------
   INLET STREAMS:         BIOCHAR2    S1
   OUTLET STREAM:         S2
   PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                      ***  MASS AND ENERGY BALANCE  ***
                                     IN               OUT        RELATIVE DIFF.
      CONV. COMP.(KMOL/HR )     36.1975          36.1975          0.00000
                  (KG/HR   )     1285.48          1285.48         0.176879E-15
      NONCONV. COMP(KG/HR   )   0.00000          0.00000          0.00000
    TOTAL BALANCE
      MASS(KG/HR   )             1285.48          1285.48         0.176879E-15
      ENTHALPY(GCAL/HR )       -0.782240        -0.782240        -0.283947E-09

                      ***  CO2 EQUIVALENT SUMMARY ***
    FEED STREAMS CO2E             0.00000      KG/HR
    PRODUCT STREAMS CO2E          0.00000      KG/HR
    NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
    UTILITIES CO2E PRODUCTION     0.00000      KG/HR
    TOTAL CO2E PRODUCTION         0.00000      KG/HR

                          ***  INPUT DATA  ***
   TWO    PHASE      FLASH
   MAXIMUM NO. ITERATIONS                                    30
   CONVERGENCE TOLERANCE                                      0.000100000
   OUTLET PRESSURE   BAR                                    1.00000

 BLOCK:  B2       MODEL: FILTER
 ------------------------------
   INLET STREAM:          S2
   OUTLET STREAMS:        WASTE       SALT
   PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE


     **********************************************************************
     *                                                                    *
     *     CALCULATION WARNING                                            *
     *                                                                    *
     **********************************************************************


                      ***  MASS AND ENERGY BALANCE  ***
                                     IN               OUT        RELATIVE DIFF.
      CONV. COMP.(KMOL/HR )     36.1975          36.1975         0.196296E-15
                  (KG/HR   )     1285.48          1285.48          0.00000
      NONCONV. COMP(KG/HR   )   0.00000          0.00000          0.00000
    TOTAL BALANCE
      MASS(KG/HR   )             1285.48          1285.48          0.00000
```

```
      ENTHALPY(GCAL/HR )      -0.782240       -0.782240         0.00000

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/HR
   PRODUCT STREAMS CO2E          0.00000      KG/HR
   NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
   UTILITIES CO2E PRODUCTION     0.00000      KG/HR
   TOTAL CO2E PRODUCTION         0.00000      KG/HR

                          ***  INPUT DATA  ***
  SELECTED TYPE                                      SOLIDS-SEPARATOR
  CLASSIFICATION CHARACTERISTIC                      PARTICLE SIZE
  FRACTION OF FLUID TO FLUID OUTLET                         0.99000
  FRACTION OF SOLIDS TO SOLID OUTLET                        0.99000
  SEPARATION SHARPNESS                                      0.0
  OFFSET OF FINES                                           0.0
  SPECIFIED PRESSURE    BAR                                 1.00000
  SPECIFIED HEAT DUTY   GCAL/HR                             0.0
  MAXIMUM NO. ITERATIONS                                   30
  CONVERGENCE TOLERANCE                                     0.000100000

                           ***  RESULTS  ***
  FRACTION OF FLUID TO FLUID OUTLET                         0.0
  FRACTION OF SOLIDS TO SOLID OUTLET                        0.99000
  SOLID LOAD OF FLUID OUTLET (KG/KG)                       M -
  FLUID LOAD OF SOLID OUTLET (KG/KG)                        0.0
  HEAT DUTY  GCAL/HR                                       0.0000

BLOCK:  $C-1     MODEL: CONNECT
------------------------------
  INLET STREAM:          BIOGAS
  OUTLET STREAM:         BURNER.BIOGAS

BLOCK:  $C-2     MODEL: CONNECT
------------------------------
  INLET STREAM:          AQRECYCL
  OUTLET STREAM:         BURNER.S4

BLOCK:  $C-3     MODEL: CONNECT
------------------------------
  INLET STREAM:          BURNER.S2
  OUTLET STREAM:         AQFEED

BLOCK:  $C-4     MODEL: CONNECT
------------------------------
  INLET STREAM:          BIOCHAR1
  OUTLET STREAM:         AQ-ABSOR.BIOCHAR

BLOCK:  $C-5     MODEL: CONNECT
------------------------------
  INLET STREAM:          AB-FEED
  OUTLET STREAM:         AQ-ABSOR.8
```

```
BLOCK:  $C-6     MODEL: CONNECT
------------------------------
  INLET STREAM:          AQ-ABSOR.BIOCHAR2
  OUTLET STREAM:         BIOCHAR2

BLOCK:  $C-7     MODEL: CONNECT
------------------------------
  INLET STREAM:          AQ-ABSOR.AQUEOUS2
  OUTLET STREAM:         AQ-CLEAN

BLOCK:  $C-8     MODEL: CONNECT
------------------------------
  INLET STREAM:          BIOCHAR2
  OUTLET STREAM:         CHARWASH.BIOCHAR2

BLOCK:  $C-9     MODEL: CONNECT
------------------------------
  INLET STREAM:          HCL
  OUTLET STREAM:         CHARWASH.S1

BLOCK:  $C-10    MODEL: CONNECT
------------------------------
  INLET STREAM:          CHARWASH.SALT
  OUTLET STREAM:         SALT

BLOCK:  $C-11    MODEL: CONNECT
------------------------------
  INLET STREAM:          CHARWASH.WASTE
  OUTLET STREAM:         P-CHAR

BLOCK:  AQSPLIT  MODEL: FSPLIT
------------------------------
  INLET STREAM:          AQUEOUS
  OUTLET STREAMS:        AQRECYCL    AB-FEED
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                    IN              OUT        RELATIVE DIFF.
     CONV. COMP.(KMOL/HR )     38.7510         38.7510          0.00000
                (KG/HR   )     699.407         699.407       -0.162548E-15
     NONCONV. COMP(KG/HR   )   0.00000         0.00000          0.00000
   TOTAL BALANCE
     MASS(KG/HR   )            699.407         699.407       -0.162548E-15
     ENTHALPY(GCAL/HR )       -2.67286        -2.67286       -0.763946E-11

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/HR
   PRODUCT STREAMS CO2E          0.00000      KG/HR
   NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
   UTILITIES CO2E PRODUCTION     0.00000      KG/HR
   TOTAL CO2E PRODUCTION         0.00000      KG/HR
```

```
                          ***  INPUT DATA  ***

  FRACTION OF FLOW                 STRM=AQRECYCL FRAC=         0.40000

                           ***  RESULTS  ***

  STREAM= AQRECYCL       SPLIT=          0.40000     KEY=  0    STREAM-ORDER=
1
          AB-FEED                        0.60000           0
2

 BLOCK:  COOLER   MODEL: HEATER
 ------------------------------
   INLET STREAM:          PRODUCT
   OUTLET STREAM:         SEPFEED
   PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                      ***  MASS AND ENERGY BALANCE  ***
                                      IN               OUT        RELATIVE DIFF.
      CONV. COMP.(KMOL/HR )     40.0788          40.0788          0.00000
                 (KG/HR   )     721.167          721.167          0.00000
      NONCONV. COMP(KG/HR   )   0.00000          0.00000          0.00000
    TOTAL BALANCE
      MASS(KG/HR   )             721.167          721.167          0.00000
      ENTHALPY(GCAL/HR )        -2.62415         -2.67603         0.193886E-01

                      ***  CO2 EQUIVALENT SUMMARY ***
    FEED STREAMS CO2E             0.00000      KG/HR
    PRODUCT STREAMS CO2E          0.00000      KG/HR
    NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
    UTILITIES CO2E PRODUCTION     0.00000      KG/HR
    TOTAL CO2E PRODUCTION         0.00000      KG/HR

                          ***  INPUT DATA  ***
   TWO    PHASE  TP  FLASH
   SPECIFIED TEMPERATURE               C                        25.0000
   SPECIFIED PRESSURE                  BAR                       1.00000
   MAXIMUM NO. ITERATIONS                                       30
   CONVERGENCE TOLERANCE                                         0.000100000



                           ***  RESULTS  ***
   OUTLET TEMPERATURE    C                                    25.000
   OUTLET PRESSURE       BAR                                  1.0000
   HEAT DUTY             GCAL/HR                           -0.51885E-01
   OUTLET VAPOR FRACTION                                      0.0000



   V-L PHASE EQUILIBRIUM :
```

COMP	F(I)	X(I)	Y(I)	K(I)
H20	0.99777	0.99777	0.90956	0.23873E-01
BIOCRUDE	0.22282E-02	0.22282E-02	0.90435E-01	1.0629

*** ASSOCIATED UTILITIES ***

UTILITY ID FOR WATER	WATER	
RATE OF CONSUMPTION	1.0386+04	KG/HR
COST	8.8284	$/HR

BLOCK: FLR-CHAR MODEL: FILTER

INLET STREAM: SEPFEED
OUTLET STREAMS: LIQ-PROD BIOCHAR1
PROPERTY OPTION SET: SRK SOAVE-REDLICH-KWONG EQUATION OF STATE

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
CONV. COMP.(KMOL/HR)	40.0788	40.0788	0.354573E-15
(KG/HR)	721.167	721.167	0.00000
NONCONV. COMP(KG/HR)	0.00000	0.00000	0.00000
TOTAL BALANCE			
MASS(KG/HR)	721.167	721.167	0.00000
ENTHALPY(GCAL/HR)	-2.67603	-2.67603	-0.222458E-10

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	KG/HR
PRODUCT STREAMS CO2E	0.00000	KG/HR
NET STREAMS CO2E PRODUCTION	0.00000	KG/HR
UTILITIES CO2E PRODUCTION	0.00000	KG/HR
TOTAL CO2E PRODUCTION	0.00000	KG/HR

*** INPUT DATA ***

SELECTED TYPE		SOLIDS-SEPARATOR
CLASSIFICATION CHARACTERISTIC		PARTICLE SIZE
FRACTION OF SOLIDS TO SOLID OUTLET		0.99990
FLUID LOAD OF SOLID OUTLET (KG/KG)		0.000100000
SEPARATION SHARPNESS		0.0
OFFSET OF FINES		0.0
SPECIFIED PRESSURE	BAR	1.20000
SPECIFIED HEAT DUTY	GCAL/HR	0.0
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

*** RESULTS ***

FRACTION OF FLUID TO FLUID OUTLET		1.00000
FRACTION OF SOLIDS TO SOLID OUTLET		0.99990
SOLID LOAD OF FLUID OUTLET (KG/KG)		0.210982-05
FLUID LOAD OF SOLID OUTLET (KG/KG)		0.00010000
HEAT DUTY	GCAL/HR	0.59530E-10

```
BLOCK:  LLSEP    MODEL: DECANTER
--------------------------------
  INLET STREAM:          LIQ-PROD
  FIRST LIQUID OUTLET:   AQUEOUS
  SECOND LIQUID OUTLET:  BIOCRUDE
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                    IN              OUT        RELATIVE DIFF.
     CONV. COMP.(KMOL/HR )      38.8382         38.8382       -0.182949E-15
                (KG/HR   )      706.266         706.266       -0.630781E-09
     NONCONV. COMP(KG/HR   )    0.00000         0.00000         0.00000
   TOTAL BALANCE
     MASS(KG/HR   )             706.266         706.266       -0.630781E-09
     ENTHALPY(GCAL/HR )        -2.67603        -2.67659        0.211711E-03

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/HR
   PRODUCT STREAMS CO2E          0.00000      KG/HR
   NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
   UTILITIES CO2E PRODUCTION     0.00000      KG/HR
   TOTAL CO2E PRODUCTION         0.00000      KG/HR

                         ***  INPUT DATA  ***

  LIQUID-LIQUID SPLIT, TP SPECIFICATION
  SPECIFIED TEMPERATURE              C                        25.0000
  SPECIFIED PRESSURE                 BAR                     1.00000
  CONVERGENCE TOLERANCE ON EQUILIBRIUM                      0.10000E-03
  MAXIMUM NO ITERATIONS ON EQUILIBRIUM                      30
  EQUILIBRIUM METHOD                            EQUATION-SOLVING
  KLL COEFFICIENTS FROM                         OPTION SET OR EOS
  KLL BASIS                                                MOLE
  KEY COMPONENT(S):       BIOCRUDE
  SOLID SPLIT FRACTIONS:
  CISOLID SUBSTREAM
      1ST LIQUID:    0.0000     2ND LIQUID:    1.0000
  NC      SUBSTREAM
      1ST LIQUID:    0.0000     2ND LIQUID:    1.0000

                         ***  RESULTS  ***

  OUTLET TEMPERATURE      C                                  25.000
  OUTLET PRESSURE         BAR                                1.0000
  CALCULATED HEAT DUTY    GCAL/HR                         -0.56666E-03
  MOLAR RATIO 1ST LIQUID / TOTAL LIQUID                    0.99776

  L1-L2 PHASE EQUILIBRIUM :
     COMP          F             X1            X2            K
     H20        0.99777       0.99956       0.20223       0.20232
     BIOCRUDE   0.0022282     0.00043979    0.79777       1,814.00
```

```
BLOCK:  MX-1     MODEL: MIXER
------------------------------
  INLET STREAMS:          DSS          RAS          SCB
  OUTLET STREAM:          FEEDCOLD
  PROPERTY OPTION SET:    SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                     IN               OUT        RELATIVE DIFF.
     CONV. COMP.(KMOL/HR )      28.7099          28.7099          0.00000
                (KG/HR   )      517.216          517.216          0.00000
     NONCONV. COMP(KG/HR   )    128.544          128.544          0.00000
   TOTAL BALANCE
     MASS(KG/HR   )             645.760          645.760          0.00000
     ENTHALPY(GCAL/HR )        -2.31819         -2.31819        -0.161782E-10

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E              41204.0      KG/HR
   PRODUCT STREAMS CO2E           41204.0      KG/HR
   NET STREAMS CO2E PRODUCTION    0.00000      KG/HR
   UTILITIES CO2E PRODUCTION      0.00000      KG/HR
   TOTAL CO2E PRODUCTION          0.00000      KG/HR

                          ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  PREHEATX MODEL: HEATX
------------------------------
  HOT SIDE:
  ---------
  INLET STREAM:              P-HOT
  OUTLET STREAM:             P-COLD
  PROPERTY OPTION SET:    SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE
  COLD SIDE:
  ----------
  INLET STREAM:              FEEDCOLD
  OUTLET STREAM:             FEEDHOT
  PROPERTY OPTION SET:    SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                     IN               OUT        RELATIVE DIFF.
     CONV. COMP.(KMOL/HR )      77.4794          77.4794          0.00000
                (KG/HR   )      1442.74          1442.74          0.00000
     NONCONV. COMP(KG/HR   )    128.544          128.544          0.00000
   TOTAL BALANCE
     MASS(KG/HR   )             1571.28          1571.28          0.00000
     ENTHALPY(GCAL/HR )        -5.15260         -5.15260         0.313736E-08

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E              43860.6      KG/HR
```

```
 PRODUCT STREAMS CO2E          43860.6      KG/HR
 NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
 UTILITIES CO2E PRODUCTION     0.00000      KG/HR
 TOTAL CO2E PRODUCTION         0.00000      KG/HR

                      ***  INPUT DATA  ***

FLASH SPECS FOR HOT SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                  30
CONVERGENCE TOLERANCE                                    0.000100000

FLASH SPECS FOR COLD SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                  30
CONVERGENCE TOLERANCE                                    0.000100000

FLOW DIRECTION AND SPECIFICATION:
  COUNTERCURRENT   HEAT EXCHANGER
  SPECIFIED EXCHANGER AREA
  SPECIFIED VALUE                SQM                     3.0000
  AREA TOLERANCE                 SQM                     0.01000
  MINIMUM APPROACH TEMPERATURE   C                       1.00000
  MAXIMUM NO. ITERATIONS                                 20
  LMTD CORRECTION FACTOR                                  1.00000

PRESSURE SPECIFICATION:
  HOT  SIDE PRESSURE DROP        BAR                     0.0000
  COLD SIDE PRESSURE DROP        BAR                     0.0000

HEAT TRANSFER COEFFICIENT SPECIFICATION:
  HOT LIQUID    COLD LIQUID      KCAL/HR-SQM-K         730.8684
  HOT 2-PHASE   COLD LIQUID      KCAL/HR-SQM-K         730.8684
  HOT VAPOR     COLD LIQUID      KCAL/HR-SQM-K         730.8684
  HOT LIQUID    COLD 2-PHASE     KCAL/HR-SQM-K         730.8684
  HOT 2-PHASE   COLD 2-PHASE     KCAL/HR-SQM-K         730.8684
  HOT VAPOR     COLD 2-PHASE     KCAL/HR-SQM-K         730.8684
  HOT LIQUID    COLD VAPOR       KCAL/HR-SQM-K         730.8684
  HOT 2-PHASE   COLD VAPOR       KCAL/HR-SQM-K         730.8684
  HOT VAPOR     COLD VAPOR       KCAL/HR-SQM-K         730.8684

                     ***  OVERALL RESULTS  ***

STREAMS:
                ------------------------------------
                |                                  |
P-HOT     ----->|               HOT                |-----> P-COLD
T=  1.9500D+02  |                                  |       T=  8.7269D+01
P=  9.5000D+01  |                                  |       P=  9.5000D+01
V=  2.2447D-01  |                                  |       V=  1.8349D-01
                |                                  |
FEEDHOT   <-----|               COLD               |<----- FEEDCOLD
```

```
  T=  1.0208D+02  |                                    |       T=  2.5000D+01
  P=  1.0000D+00  |                                    |       P=  1.0000D+00
  V=  2.3269D-01  |                                    |       V=  0.0000D+00
                  ------------------------------------
```

DUTY AND AREA:

CALCULATED HEAT DUTY	GCAL/HR	0.1183
CALCULATED (REQUIRED) AREA	SQM	3.0001
ACTUAL EXCHANGER AREA	SQM	3.0000
PER CENT OVER-DESIGN		-0.0024

HEAT TRANSFER COEFFICIENT:

AVERAGE COEFFICIENT (DIRTY)	KCAL/HR-SQM-K	730.8685
UA (DIRTY)	CAL/SEC-K	609.0715

LOG-MEAN TEMPERATURE DIFFERENCE:

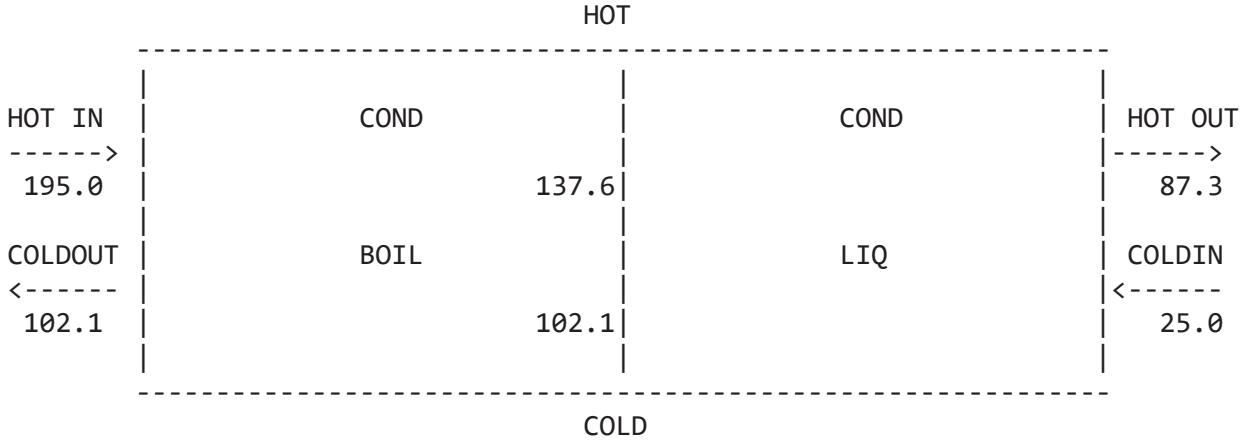
LMTD CORRECTION FACTOR		1.0000
LMTD (CORRECTED)	C	53.9660
NUMBER OF SHELLS IN SERIES		1

PRESSURE DROP:

HOTSIDE, TOTAL	BAR	0.0000
COLDSIDE, TOTAL	BAR	0.0000

*** ZONE RESULTS ***

TEMPERATURE LEAVING EACH ZONE:



ZONE HEAT TRANSFER AND AREA:

ZONE	HEAT DUTY GCAL/HR	AREA SQM	LMTD C	AVERAGE U KCAL/HR-SQM-K	UA CAL/SEC-K
1	0.068	1.5675	59.7163	730.8684	318.2393
2	0.050	1.4325	47.6738	730.8684	290.8322

```
HEATX COLD-TQCU PREHEATX TQCURV INLET
-------------------------------------
```

```
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         BAR
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

-------------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  GCAL/HR   !  BAR       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !   102.0834 !     0.2327 !
!  5.6347-03 !     1.0000 !   102.0834 !     0.2135 !
!  1.1269-02 !     1.0000 !   102.0834 !     0.1944 !
!  1.6904-02 !     1.0000 !   102.0834 !     0.1752 !
!  2.2539-02 !     1.0000 !   102.0834 !     0.1560 !
!------------+------------+------------+------------!
!  2.8174-02 !     1.0000 !   102.0834 !     0.1369 !
!  3.3808-02 !     1.0000 !   102.0834 !     0.1177 !
!  3.9443-02 !     1.0000 !   102.0834 !  9.8539-02 !
!  4.5078-02 !     1.0000 !   102.0834 !  7.9374-02 !
!  5.0712-02 !     1.0000 !   102.0834 !  6.0209-02 !
!------------+------------+------------+------------!
!  5.6347-02 !     1.0000 !   102.0834 !  4.1045-02 !
!  6.1982-02 !     1.0000 !   102.0834 !  2.1880-02 !
!  6.7617-02 !     1.0000 !   102.0834 !  2.7146-03 !
!  6.8415-02 !     1.0000 !   102.0834 ! BUB>0.0    !
!  7.3251-02 !     1.0000 !    94.6990 !     0.0    !
!------------+------------+------------+------------!
!  7.8886-02 !     1.0000 !    86.0630 !     0.0    !
!  8.4521-02 !     1.0000 !    77.3960 !     0.0    !
!  9.0155-02 !     1.0000 !    68.7025 !     0.0    !
!  9.5790-02 !     1.0000 !    59.9872 !     0.0    !
!     0.1014 !     1.0000 !    51.2547 !     0.0    !
!------------+------------+------------+------------!
!     0.1071 !     1.0000 !    42.5096 !     0.0    !
!     0.1127 !     1.0000 !    33.7564 !     0.0    !
!     0.1183 !     1.0000 !    25.0000 !     0.0    !
-------------------------------------------------------

HEATX HOT-TQCUR PREHEATX TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         BAR
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

-------------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
```

GCAL/HR	BAR	C	
0.0	95.0000	195.0000	0.2245
5.6347-03	95.0000	190.9021	0.2202
1.1269-02	95.0000	186.6856	0.2163
1.6904-02	95.0000	182.3518	0.2126
2.2539-02	95.0000	177.9022	0.2092
2.8174-02	95.0000	173.3385	0.2061
3.3808-02	95.0000	168.6628	0.2033
3.9443-02	95.0000	163.8773	0.2007
4.5078-02	95.0000	158.9845	0.1983
5.0712-02	95.0000	153.9871	0.1962
5.6347-02	95.0000	148.8883	0.1943
6.1982-02	95.0000	143.6914	0.1925
6.7617-02	95.0000	138.4000	0.1910
6.8415-02	95.0000	137.6431	0.1908
7.3251-02	95.0000	133.0180	0.1896
7.8886-02	95.0000	127.5496	0.1884
8.4521-02	95.0000	121.9995	0.1873
9.0155-02	95.0000	116.3724	0.1864
9.5790-02	95.0000	110.6734	0.1856
0.1014	95.0000	104.9078	0.1849
0.1071	95.0000	99.0814	0.1844
0.1127	95.0000	93.1998	0.1839
0.1183	95.0000	87.2690	0.1835

BLOCK: R-HTL MODEL: RYIELD

INLET STREAMS: FEEDHOT AQFEED
OUTLET STREAM: P-HOT
PROPERTY OPTION SET: SRK SOAVE-REDLICH-KWONG EQUATION OF STATE

*** MASS AND ENERGY BALANCE ***

	IN	OUT	GENERATION	RELATIVE DIFF.
CONV. COMP.(KMOL/HR)	44.2102	48.7696	4.55934	-0.145694E-15
(KG/HR)	796.979	925.523		-0.138888
NONCONV COMP(KG/HR)	128.544	0.00000		1.00000
TOTAL BALANCE				
MASS(KG/HR)	925.523	925.523		0.245671E-15
ENTHALPY(GCAL/HR)	-3.06488	-2.83441		-0.751962E-01

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	41204.0	KG/HR
PRODUCT STREAMS CO2E	2656.62	KG/HR
NET STREAMS CO2E PRODUCTION	-38547.4	KG/HR
UTILITIES CO2E PRODUCTION	92.9818	KG/HR

```
 TOTAL CO2E PRODUCTION        -38454.4      KG/HR

                          ***  INPUT DATA  ***

 TWO    PHASE  TP  FLASH
 SPECIFIED TEMPERATURE C                                  195.000
 SPECIFIED PRESSURE    BAR                                 95.0000
 MAXIMUM NO. ITERATIONS                                    30
 CONVERGENCE TOLERANCE                                      0.000100000

  MASS-YIELD
   SUBSTREAM MIXED   :
   H20       0.754        CO2       0.110        CH4       0.110
   BIOCRUDE  0.880E-02
   SUBSTREAM CISOLID :
   CHAR      0.161E-01

                          ***  RESULTS  ***
 OUTLET TEMPERATURE    C                                   195.00
 OUTLET PRESSURE       BAR                                  95.000
 HEAT DUTY             GCAL/HR                             0.23047
 VAPOR FRACTION                                            0.22447



 V-L PHASE EQUILIBRIUM :

    COMP              F(I)           X(I)           Y(I)           K(I)
    H20              0.81533        0.99234        0.20374        0.20531
    CO2              0.48848E-01    0.34943E-02    0.20555         58.822
    CH4              0.13400        0.20513E-02    0.58990         287.58
    BIOCRUDE         0.18208E-02    0.21128E-02    0.81202E-03    0.38434

                     ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                ELECT
 RATE OF CONSUMPTION                     268.0338  KW
 COST                                   8.5878+05  $/HR
 CO2 EQUIVALENT EMISSIONS                 92.9818  KG/HR

BLOCK:  VENT     MODEL: SEP
------------------------------
  INLET STREAM:          P-COLD
  OUTLET STREAMS:        BIOGAS      PRODUCT
  PROPERTY OPTION SET:   SRK       SOAVE-REDLICH-KWONG EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                    IN              OUT        RELATIVE DIFF.
      CONV. COMP.(KMOL/HR )     48.7696         48.7696          0.00000
                 (KG/HR   )     925.523         925.523          0.00000
      NONCONV. COMP(KG/HR   )   0.00000         0.00000          0.00000
   TOTAL BALANCE
      MASS(KG/HR   )            925.523         925.523          0.00000
```

```
    ENTHALPY(GCAL/HR )       -2.95274        -2.95390        0.391282E-03

                    ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             2656.62      KG/HR
  PRODUCT STREAMS CO2E          2656.62      KG/HR
  NET STREAMS CO2E PRODUCTION   0.00000      KG/HR
  UTILITIES CO2E PRODUCTION     0.00000      KG/HR
  TOTAL CO2E PRODUCTION         0.00000      KG/HR


                         ***  INPUT DATA  ***

 FLASH SPECS FOR STREAM BIOGAS
 ONE    PHASE  TP  FLASH   SPECIFIED PHASE IS  VAPOR
 PRESSURE DROP         BAR                                  0.0
 MAXIMUM NO. ITERATIONS                                    30
 CONVERGENCE TOLERANCE                                      0.000100000

 FLASH SPECS FOR STREAM PRODUCT
 TWO    PHASE  TP  FLASH
 PRESSURE DROP         BAR                                  0.0
 MAXIMUM NO. ITERATIONS                                    30
 CONVERGENCE TOLERANCE                                      0.000100000

 FRACTION OF FEED
   SUBSTREAM= MIXED
     STREAM= BIOGAS    CPT= H20       FRACTION=          0.0
                            CO2                          1.00000
                            CH4                          1.00000
                            CARBO-01                     0.0
                            HYDRO-01                     0.0
                            BIOCRUDE                     0.0


                          ***  RESULTS  ***

 HEAT DUTY             GCAL/HR                           -0.11558E-02

COMPONENT = H20
  STREAM     SUBSTREAM    SPLIT FRACTION
  PRODUCT    MIXED                1.00000

COMPONENT = CO2
  STREAM     SUBSTREAM    SPLIT FRACTION
  BIOGAS     MIXED                1.00000

COMPONENT = CH4
  STREAM     SUBSTREAM    SPLIT FRACTION
  BIOGAS     MIXED                1.00000

COMPONENT = BIOCRUDE
  STREAM     SUBSTREAM    SPLIT FRACTION
```

```
  PRODUCT    MIXED                1.00000

COMPONENT = CHAR
  STREAM     SUBSTREAM    SPLIT FRACTION
  PRODUCT    CISOLID              1.00000
```

Annexure B Conversion Criteria & Tolerances (B194 - B198)

```
 CONVERGENCE BLOCK:  $OLVER01
 ----------------------------
     Tear Stream   :  P-HOT
     Tolerance used:  0.100D-03
     Trace molefrac:  0.100D-05
     Trace substr-2:  0.100D-05
     Trace substr-3:  0.100D-05

     MAXIT=   55 WAIT   1 ITERATIONS BEFORE ACCELERATING
     QMAX =   0.0     QMIN =  -5.0
     METHOD: WEGSTEIN      STATUS: CONVERGED
     TOTAL NUMBER OF ITERATIONS:     3
     NUMBER OF ITERATIONS ON LAST OUTER LOOP:     0

                           *** FINAL VALUES ***

VAR#  TEAR STREAM VAR  STREAM   SUBSTREA COMPONEN ATTRIBUT ELEMENT      UNIT
    VALUE       PREV VALUE       ERR/TOL
----  ---------------  -------- -------- -------- -------- -------- -----------
------------   ------------   ------------
   1  TOTAL MOLEFLOW   P-HOT    MIXED                                KMOL/HR
  47.5290        47.5290      1.3139-12
   2  TOTAL MOLEFLOW   P-HOT    CISOLID                              KMOL/HR
   1.2406         1.2406      3.1461-12
   3  TOTAL MASSFLOW   P-HOT    NC                                   KG/HR
   0.0            0.0            0.0
   4  COMP-ATTR-VA     P-HOT    NC       RAS      PROXANAL MOISTURE
  M   -          M   -            0.0
   5  COMP-ATTR-VA     P-HOT    NC       RAS      PROXANAL FC
  M   -          M   -            0.0
   6  COMP-ATTR-VA     P-HOT    NC       RAS      PROXANAL VM
  M   -          M   -            0.0
   7  COMP-ATTR-VA     P-HOT    NC       RAS      PROXANAL ASH
  M   -          M   -            0.0
   8  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  ASH
  M   -          M   -            0.0
   9  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  CARBON
  M   -          M   -            0.0
  10  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  HYDROGEN
  M   -          M   -            0.0
  11  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  NITROGEN
  M   -          M   -            0.0
  12  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  CHLORINE
  M   -          M   -            0.0
  13  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  SULFUR
  M   -          M   -            0.0
  14  COMP-ATTR-VA     P-HOT    NC       RAS      ULTANAL  OXYGEN
  M   -          M   -            0.0
  15  COMP-ATTR-VA     P-HOT    NC       RAS      SULFANAL PYRITIC
  M   -          M   -            0.0
  16  COMP-ATTR-VA     P-HOT    NC       RAS      SULFANAL SULFATE
```

```
M   -          M   -          0.0
17  COMP-ATTR-VA     P-HOT    NC       RAS      SULFANAL ORGANIC
M   -          M   -          0.0
18  COMP-ATTR-VA     P-HOT    NC       DSS      PROXANAL MOISTURE
M   -          M   -          0.0
19  COMP-ATTR-VA     P-HOT    NC       DSS      PROXANAL FC
M   -          M   -          0.0
20  COMP-ATTR-VA     P-HOT    NC       DSS      PROXANAL VM
M   -          M   -          0.0
21  COMP-ATTR-VA     P-HOT    NC       DSS      PROXANAL ASH
M   -          M   -          0.0
22  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  ASH
M   -          M   -          0.0
23  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  CARBON
M   -          M   -          0.0
24  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  HYDROGEN
M   -          M   -          0.0
25  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  NITROGEN
M   -          M   -          0.0
26  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  CHLORINE
M   -          M   -          0.0
27  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  SULFUR
M   -          M   -          0.0
28  COMP-ATTR-VA     P-HOT    NC       DSS      ULTANAL  OXYGEN
M   -          M   -          0.0
29  COMP-ATTR-VA     P-HOT    NC       DSS      SULFANAL PYRITIC
M   -          M   -          0.0
30  COMP-ATTR-VA     P-HOT    NC       DSS      SULFANAL SULFATE
M   -          M   -          0.0
31  COMP-ATTR-VA     P-HOT    NC       DSS      SULFANAL ORGANIC
M   -          M   -          0.0
32  COMP-ATTR-VA     P-HOT    NC       SCB      PROXANAL MOISTURE
M   -          M   -          0.0
33  COMP-ATTR-VA     P-HOT    NC       SCB      PROXANAL FC
M   -          M   -          0.0
34  COMP-ATTR-VA     P-HOT    NC       SCB      PROXANAL VM
M   -          M   -          0.0
35  COMP-ATTR-VA     P-HOT    NC       SCB      PROXANAL ASH
M   -          M   -          0.0
36  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  ASH
M   -          M   -          0.0
37  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  CARBON
M   -          M   -          0.0
38  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  HYDROGEN
M   -          M   -          0.0
39  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  NITROGEN
M   -          M   -          0.0
40  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  CHLORINE
M   -          M   -          0.0
41  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  SULFUR
M   -          M   -          0.0
42  COMP-ATTR-VA     P-HOT    NC       SCB      ULTANAL  OXYGEN
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  M   -          M   -          0.0
  43  COMP-ATTR-VA     P-HOT    NC       SCB      SULFANAL PYRITIC
  M   -          M   -          0.0
  44  COMP-ATTR-VA     P-HOT    NC       SCB      SULFANAL SULFATE
  M   -          M   -          0.0
  45  COMP-ATTR-VA     P-HOT    NC       SCB      SULFANAL ORGANIC
  M   -          M   -          0.0
  46  MOLE-FLOW        P-HOT    MIXED    H20                       KMOL/HR
  38.7516        38.7516        0.0
  47  MOLE-FLOW        P-HOT    MIXED    CO2                       KMOL/HR
   2.3217         2.3217      3.3623-12
  48  MOLE-FLOW        P-HOT    MIXED    CH4                       KMOL/HR
   6.3691         6.3691        0.0
  49  MOLE-FLOW        P-HOT    MIXED    CARBO-01                  KMOL/HR
   0.0            0.0           0.0
  50  MOLE-FLOW        P-HOT    MIXED    HYDRO-01                  KMOL/HR
   0.0            0.0           0.0
  51  MOLE-FLOW        P-HOT    MIXED    BIOCRUDE                  KMOL/HR
8.6541-02      8.6541-02      2.8189-12
  52  MOLE-FLOW        P-HOT    MIXED    CHAR                      KMOL/HR
   0.0            0.0           0.0
  53  MOLE-FLOW        P-HOT    MIXED    N2                        KMOL/HR
   0.0            0.0           0.0
  54  MOLE-FLOW        P-HOT    MIXED    O2                        KMOL/HR
   0.0            0.0           0.0
  55  MOLE-FLOW        P-HOT    MIXED    HCL                       KMOL/HR
   0.0            0.0           0.0
  56  PRESSURE         P-HOT    MIXED                              BAR
  95.0000        95.0000        0.0
  57  MASS ENTHALPY    P-HOT    MIXED                              KCAL/KG
-3113.2381     -3113.2381      1.1978-06
  58  MOLE-FLOW        P-HOT    CISOLID  H20                       KMOL/HR
   0.0            0.0           0.0
  59  MOLE-FLOW        P-HOT    CISOLID  CO2                       KMOL/HR
   0.0            0.0           0.0
  60  MOLE-FLOW        P-HOT    CISOLID  CH4                       KMOL/HR
   0.0            0.0           0.0
  61  MOLE-FLOW        P-HOT    CISOLID  CARBO-01                  KMOL/HR
   0.0            0.0           0.0
  62  MOLE-FLOW        P-HOT    CISOLID  HYDRO-01                  KMOL/HR
   0.0            0.0           0.0
  63  MOLE-FLOW        P-HOT    CISOLID  BIOCRUDE                  KMOL/HR
   0.0            0.0           0.0
  64  MOLE-FLOW        P-HOT    CISOLID  CHAR                      KMOL/HR
   1.2406         1.2406      3.1461-12
  65  MOLE-FLOW        P-HOT    CISOLID  N2                        KMOL/HR
   0.0            0.0           0.0
  66  MOLE-FLOW        P-HOT    CISOLID  O2                        KMOL/HR
   0.0            0.0           0.0
  67  MOLE-FLOW        P-HOT    CISOLID  HCL                       KMOL/HR
   0.0            0.0           0.0
  68  PRESSURE         P-HOT    CISOLID                            BAR
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 95.0000        95.0000         0.0
 69  MASS ENTHALPY    P-HOT    CISOLID                              KCAL/KG
 38.1382        38.1382         0.0
 70  MASS-FLOW        P-HOT    NC       RAS                         KG/HR
  0.0            0.0             0.0
 71  MASS-FLOW        P-HOT    NC       DSS                         KG/HR
  0.0            0.0             0.0
 72  MASS-FLOW        P-HOT    NC       SCB                         KG/HR
  0.0            0.0             0.0
 73  PRESSURE         P-HOT    NC                                   BAR
 95.0000        95.0000         0.0
 74  MASS ENTHALPY    P-HOT    NC                                   KCAL/KG
  0.0            0.0             0.0

                          *** ITERATION HISTORY ***

    TEAR STREAMS AND TEAR VARIABLES:

    ITERATION   MAX-ERR/TOL VAR#  STREAM ID      VARIABLE         SUBSTREA
COMPONEN ATTRIBUT ELEMENT
    ---------   ----------- ----  ---------      ---------------- --------
-------- -------- -------
         1      0.1000E+07    56  P-HOT          PRESSURE         MIXED

         2       3023.        46  P-HOT          MOLE-FLOW        MIXED    H20

         3      0.1198E-05    57  P-HOT          MASS ENTHALPY    MIXED


 CONVERGENCE BLOCK:  $OLVER02
 ----------------------------
    SPECS: H20
    MAXIT=   30 STEP-SIZE=    1.0000    % OF RANGE
                MAX-STEP=       100.    % OF RANGE
                XTOL=       1.000000E-08
    THE NEW ALGORITHM WAS USED WITH BRACKETING=NO
    METHOD: SECANT        STATUS: CONVERGED
    TOTAL NUMBER OF ITERATIONS:     6
    NUMBER OF ITERATIONS ON LAST OUTER LOOP:     0

                          *** FINAL VALUES ***


VAR#  MANIPUL/TEAR-VAR VARIABLE DESCRIPTION                          UNIT
    VALUE       PREV VALUE       ERR/TOL
----  ---------------- ------------------------                      -----------
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   1  BLOCK-VAR        FLR-CHAR.PARAM.PRES                          BAR
   1.2000         1.2000        -0.1053

                          *** ITERATION HISTORY ***
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DESIGN-SPEC ID: H20

ITERATED: SENTENCE=PARAM VARIABLE=PRES IN UOS BLOCK FLR-CHAR

ITERATION	VARIABLE	ERROR	ERR/TOL
1	1.200	-0.1053E-01	-0.1053