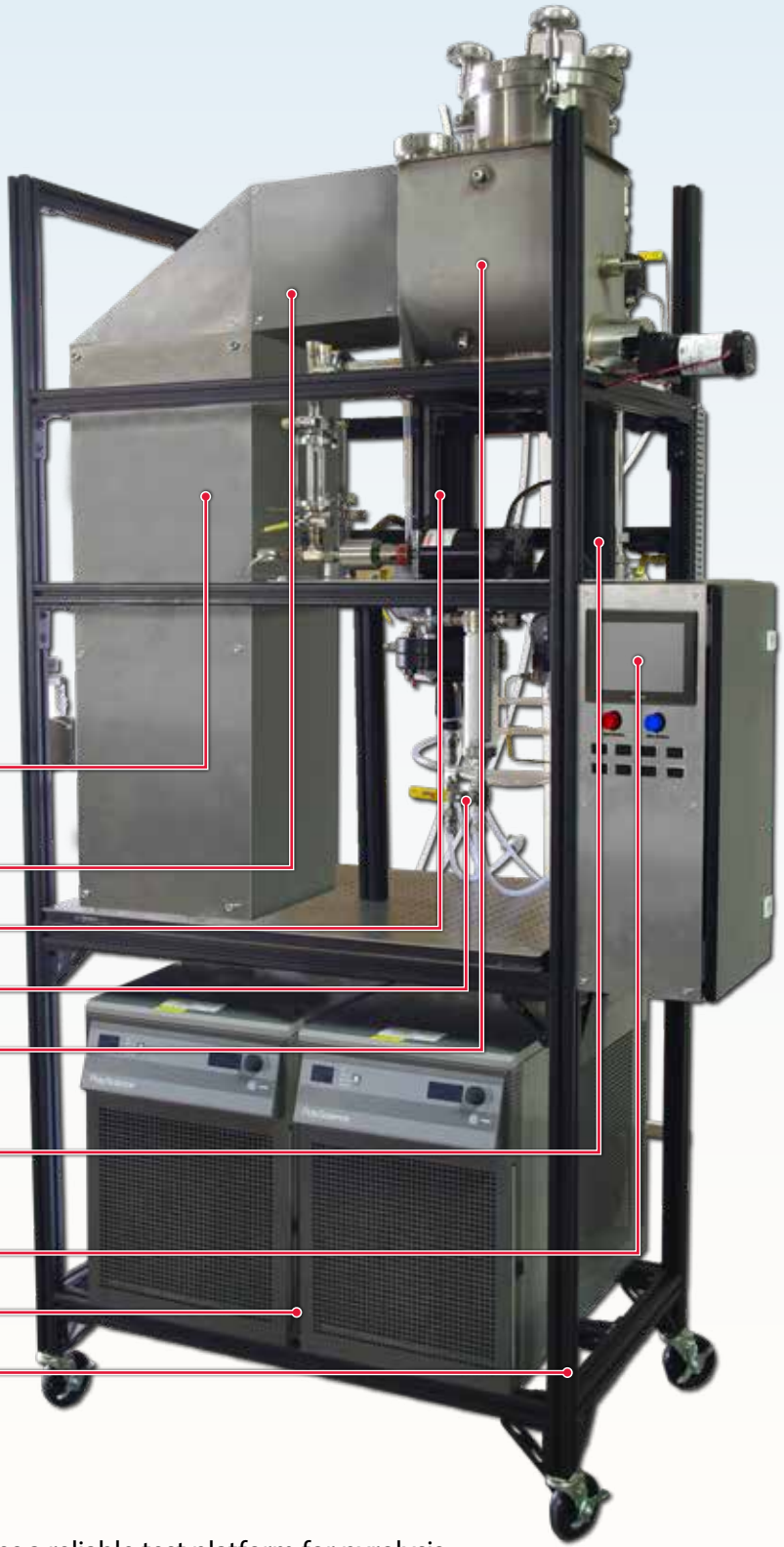
MAINSTREAM ENGINEERING CORPORATION

Continuous, Bench-Scale Pyrolysis Unit

Solutions Through Advanced Technology®
MAINSTREAM ENGINEERING

Fluidized Bed Pyrolysis Reactor

A continuous, bench-scale pyrolysis system (approximately 2 lb/h) was developed for rapid pyrolysis and bio-oil collection optimization. That bench-scale reactor serves as a valuable test bed for developing novel pyrolysis technologies and bio-oil upgrading technology. Engineering research in this area is being performed by government, industrial, and academic researchers; however, this system will extend pyrolysis technology to others. A custom two-stage cyclone system, fractional condensation system, and custom bio-oil collection components were integrated into the test bed. The unit operations in the bench-scale pyrolysis unit mirror those in the pilot-scale (approximately 100 lb/h) reactor skid; providing byproduct yields and benchmark performance data. Bench-scale optimization studies were used to accelerate the development of the pilot-sale and provide experimental data for the full scale pyrolysis reactor.



- **Optimized fluidized bed pyrolysis reactor**
- **Two-stage cyclone separators**
- **Multi-stage condensers**
- **Easy bio-oil collection**
- **Automated, two-stage feeding system**
- **Controllable electrostatic precipitators**
- **Touchscreen, LabVIEW-based HMI**
- **Controlled recirculating chillers**
- **Roll-around, skidded frame**

Powerful Instrument for Pyrolysis Research

Mainstream's continuous, bench-scale pyrolysis unit provides a reliable test platform for pyrolysis research. The fluidized bed reactor has been fully optimized with biomass feedstock (bio-oil yields of 65%) and downstream components have been evaluated. This system ultimately provides the researcher the ultimate control and flexibility of process parameters (e.g. temperature, residence time) and bio-oil separation and collection.

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Features

Fluidized bed pyrolysis reactor

Generates high bio-oil yields with biomass and mixed waste.Continuous, 2 lb/h with controlled reactor and heated zone control

Two-stage cyclone separators:

Efficient separation of pyrolysis char byproduct

Multi-stage condensers

Fraction condensation of bio-oil product

Touchscreen HMI

Automated control of pyrolysis conditions and process parameters. Fluidizing gas flow, reactor temperature, heated zone control, and user-programmable

Table 1. Properties of Bio-oil from Bench-scale Pyrolysis Unit

Temperature	500	500
Flow Rate (L/min)	17.0	17.0
Residence Time (sec)	0.73	0.73
Density (g/mL)	1.20	1.14
Moisture Conent, wt%	18.1	15.0
Elemental Analysis, wet basis		
C	45.6	71.6
H	5.0	5.0
O	49.4	23.4
Elemental Analysis, dry basis		
C	55.7	84.2
H	3.6	3.9
O	40.7	11.9
ph	1.39	1.42
Heating Value	20.0	19.9

Demonstrated Performance

The development of the bench-scale pyrolysis reactor for process scale-up has resulted in a stand-alone, pyrolysis demonstrator. Most small-scale reactors operate by batch processing or handle very small amounts of feedstock material. Designing, building, and commissioning a custom bench-scale process can be extremely time consuming and costly. Mainstream has eliminated the inherent risk with developing a pyrolysis test platform and is offering the industry a standard system capable of process optimization, bio-oil upgrading, and bio-oil collection testing and research. Our system has been successfully scaled-up to a 100 lb/h pyrolysis skidded system, which has processed biomass and mixed waste feedstocks.

High Quality Bio-oil and Biochar Byproducts

The byproducts from the bench-scale pyrolysis reactor are high quality. Mainstream has processed pine and other biomass feedstocks, as well as mixed solid waste and controlled blends of biomass and plastic (e.g. 80 wt%:20 wt% pine:polystyrene mixture). The properties of bio-oil for pine feed and 80 wt%:20 wt% mixed waste feed at 500 °C are listed in Table 1. Properties of the pyrolysis char byproduct are listed in Table 2.

Table 2. Properties of Char from Bench-scale Pyrolysis Unit

Proximate Analysis	**Composition (wt%)**
Moisture	2.27-6.03
Volatile Matter	15.54
Fixed Carbon	61.76
Ash	20.43
Ultimate Analysis	**Composition (wt%)**
Carbon	68.0-82.7
Hydrogen	3.31
Nitrogen	1.79
Sulfur	0.04
Oxygen	4.12
HHV (MJ/kg)	25.5-29.7
Ash Constituents	**Composition (wt%)**
Calcium, CaO	38.50
Potassium, K_2O	16.50
Silica, SiO2	12.00
Aluminum, AL2O3	11.52
Magnesium, MgO	9.64
Phosphorus, P2O2	4.67
Ferric, Fe2O2	2.04
Sulfur, SO3	1.39

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