PRETREATMENT AND EXTRACTION / CATALYSIS AT HIGH PRESSURES

Equipment	Scale	Details and comments
Customized Andritz Hastelloy C276 Pressure Reactor along with Tempest® TCU	1 x 210 L	• Thermochemical treatments with pressures varying from -14 – 150 psi and temperatures ranging from 25 to 175°C, i.e. is capable of **low temperature vacuum drying as well.** • Stirring with a helical agitator, suitable for high viscosity slurries • Indirect heating through wall from hot oil in jacket • Direct steam injection and release for faster heating and cooling mechanism (i.e. of 100 liters water varying between 25 to 175°C in ≤ 30 minutes) • MicroMotion® H-Series Mass flow meter (http://www2.emersonprocess.com/en-US/brands/micromotion/coriolis-flow-density-meters/H-Series/Pages/index.aspx) • Flowserve® and PBM® Valves to measure and control release of gases from the reactor • Cleaning by ABEC CIP cart through rotating CIP-nozzles
Customized High pressure Parr Series 4556 Reactors made of Hastelloy C276 and Carpenter Steel (http://www.parrinst.com/products/stirred-reactors/series-4555-10-20-l-floor-stand-reactors/)	3 x 10 L	• Thermochemical treatments with pressures varying from 0 – 1900 psi and temperatures varying from 25 – 350ºC. • Stirring action with two impellers – anchor and turbine with real time rpm values, which indicate changes in viscosity of the material • Indirect heating through electrical coils on the walls • Direct steam injection and release mechanism
Customized Tube Reactors heated with a Omega Fluidized Sand Bath	20 x 10 mL 20 x 25 mL	• Thermochemical treatments with pressures varying from 0 – 150 psi and temperatures ranging from 25 to 200C. • Indirect heating through wall from hot sand in Omega Sand Bath

SACCHARIFICATION AND EXTRACTION / CATALYSIS AT AMBIENT PRESSURE

Equipment	Scale	Details and comments
IKA SPP (http://cdn2.ika.com/pdf/newsletter/spp_01-08_e.pdf)	1 X 50 L	• Enzymatic or thermochemical treatments at atmospheric pressures with temperatures ranging from 4 to 100°C • Stirring with anchor impeller (RFG-02-A) with drive power of 55 kW. Flow breaker also included. • Pumping, with or without shear (Dispersing element DBI 2000/4) available. • Cleaning by means of rotating CIP-nozzles • Customized for real time torque and temperature values
IKA Reactors LR-2.ST (http://www.ika.com/owa/ika/catalog.product_detail?iProduct=8016500&iCS=1&iProductgroup=232&iSubgroup=1)	4 X 2 L	• Enzymatic or thermochemical treatments at atmospheric pressures with temperatures ranging from 4 to 200°C • Stirring with anchor impeller and flow breaker with real time rpm values • Real time temperature and pH data • Soon to be customized for real time torque data

FERMENTATION AND BIOCATALYSIS

Equipment	Scale	Details and comments
ABEC Bioreactors	2 X 300L 1 X 50L	• Batch, Fed-Batch, and Continuous Modes applicable • Can be attached to external programmed pump to control feed rate • Load Cells on all Fermenters to observe mass gain/loss • Condensers attached to avoid mass loss • Off-gas analysis through AIT Multigas Analyzer (Mass Spec) • Off-line analysis through YSI and UV-Spec • On-line analysis through FT-NIR
BioEngineering Bioreactors	1 X 15L 4 X 3.7L	• Batch, Fed-Batch, and Continuous Modes applicable • Can be attached to external programmed pump to control feed rate • Condensers attached to avoid mass loss • Off-gas analysis through AIT Multigas Analyzer (Mass Spec) • Off-line analysis through YSI and UV-Spec • On-line analysis through FT-NIR (for 15L only)
Sartorius Bioreactors	4 X 2L	• Batch, Fed-Batch, and Continuous Modes applicable • Can be attached to external programmed pump to control feed rate • Condensers attached to avoid mass loss • Off-gas analysis through AIT Multigas Analyzer (Mass Spec) • Off-line analysis through YSI and UV-Spec

ADVANCED RECOVERY AND PURIFICATION

Equipment	Throughput	Details and comments
Andritz Decanter (D2L) made of Stainless Steel (http://atl.g.andritz.com/c/com2011/00/01/04/10459/1/1/0/898621157/se-downloads-solidbowldecanter-d_en_.pdf)	6 m^3/h (max)	• Rapid solid liquid separation, primarily used for pretreated biomass • Design flow rate of 6 m^3/h for suspended solids with ≤ 1% w/w (feed concentration) • Anticipated time to remove moisture from 10 – 30% to 40% w/w solids of pretreated biomass is < 10 minutes
Alfa Laval MBPX 404 three-phase continuous centrifuge	150 L/min (max)	• S-L, L-L, & S-L-L separations
Basket Centrifuge (http://www.westernstates.com/pages/content/pilotplantcentrifuges.html)	7.4 L (batch)	• Rapid solid liquid separation for both pretreated and saccharified biomass • Filter bags of pore size 5 – 10µ and 25 – 30µ • Maximum rpm of 3600 • A recycle system to recycle solvent utilized for the wash has been developed and incorporated into the system
Distillation / evap skid	TBD	• Procurement in process
Labconco FreeZone ® 6-L bulk freeze dryer	Bulk Tray dryer with 6 x 1L port manifolds	• Capable of drying ~ 6 liters of centrifuged biomass, protein or chemical product in one cycle
Qsonica- Q700 in-line continuous sonicator	20 L/hr	• Enables high-throughput microbial cell lysis to extract intracellular metabolites like enzymes
Milipore Labscale Tangential Flow Filtration (TFF) system & Cogent M1 TFF system	500 mL & 10 L reservoir capacity, respectively	• Small & medium scale protein concentration; filter membranes with various pore sizes (50 cm^2 & 0.1 m^2) can be used to separate & concentrate specific proteins from fermentation broth; Cogent M1 can run in fed-batch or diafilitration mode, which enables system to process up to 100 L or more based on product & filter characteristics. Supports a total membrane area from 0.1 m^2 to several m^2
AKTA Avant 150 equipped with UNICORN 6.1 (with integrated DOE capabilities)	150 mL/min (max)	• Fast & secure development of scalable chromatographic processes for protein purification, as well as fine-tuning & robustness testing of optimized process; capable of yielding gram quantities of pure protein using a variety of chromatographic modes; easy DOE planning for scale-up
KARR® Reciprocating Plate Extraction Column	250 mL/min (max)	• 25 mm diameter; retention volume of ~ 2L; agitator for 0-400 spm; explosion-proof motor; metal/PTFE plate stack • L-L separations; continuous & efficient recovery of immiscible & partially miscible liquid biofuels, like butanol & bisabolene, from fermentation broth

ANALYTICAL CHEMISTRY AND MATERIALS HANDLING / SOLIDS CHARACTERIZATION

Equipment	Detection modes	Typical uses
Malvern stress- controlled oscillating rheometer / viscometer	N/A	• Characterizing visco-elastic and rheological properties of liquids, solids, and liquid-solid mixtures
Thermo Scientific HPLCs High-performance liquid chromatography	Refractive index (RI), UV, charged aerosol	• Compositional, in process and final product analysis for water-soluble molecules
Dionex HPAEC High-performance anion-exchange chromatography	UV, Electrochemical	• Detection of low concentration sugars and other metabolites
Thermo Scientific GC - Gas chromatography	Flame ionization detector (FID)	• Volatile small molecule detection
BIOTEK microplate reader	UV/Vis	• Absorbance and fluorescence biomarker assays
IKA bomb calorimeter	UV/Vis	• Energy content and heat of combustion measurements of feedstocks and products