

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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Thermochemical treatments with pressures varying from 0 – 1900 psi and temperatures varying from 25 – 350°C. 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	<ul style="list-style-type: none"> Thermochemical treatments with pressures varying from 0 – 150 psi and temperatures ranging from 25 to 200°C. 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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/com/2011/00/01/04/10459/1/1/0/89/8621157/se-downloads-solidbowldecanter-d_en_.pdf)	6 m ³ /h (max)	<ul style="list-style-type: none"> Rapid solid liquid separation, primarily used for pretreated biomass Design flow rate of 6 m³/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)	<ul style="list-style-type: none"> S-L, L-L, & S-L-L separations
Basket Centrifuge (http://www.westernstates.com/pages/content/pilotplantcentrifuges.html)	7.4 L (batch)	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Procurement in process
Labconco FreeZone [®] 6-L bulk freeze dryer	Bulk Tray dryer with 6 x 1L port manifolds	<ul style="list-style-type: none"> Capable of drying ~ 6 liters of centrifuged biomass, protein or chemical product in one cycle
Qsonica- Q700 in-line continuous sonicator	20 L/hr	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Small & medium scale protein concentration; filter membranes with various pore sizes (50 cm² & 0.1 m²) can be used to separate & concentrate specific proteins from fermentation broth; Cogent M1 can run in fed-batch or diafiltration 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 m² to several m²
AKTA Avant 150 equipped with UNICORN 6.1 (with integrated DOE capabilities)	150 mL/min (max)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none">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	<ul style="list-style-type: none">Compositional, in process and final product analysis for water-soluble molecules
Dionex HPAEC High-performance anion-exchange chromatography	UV, Electrochemical	<ul style="list-style-type: none">Detection of low concentration sugars and other metabolites
Thermo Scientific GC - Gas chromatography	Flame ionization detector (FID)	<ul style="list-style-type: none">Volatile small molecule detection
BIOTEK microplate reader	UV/Vis	<ul style="list-style-type: none">Absorbance and fluorescence biomarker assays
IKA bomb calorimeter	UV/Vis	<ul style="list-style-type: none">Energy content and heat of combustion measurements of feedstocks and products