

## HIGH PRESSURE & TEMPERATURE EXTRACTION, CATALYSIS AND BIOMASS PRETREATMENT

Equipment	Scale	Details and comments
Customized Andritz Hastelloy C276 Pressure Reactor along with Tempest® TCU <a href="https://www.andritz.com/products-en/group/separation/contact-paddle-dryers/kraus-maffei-helix-dryer">https://www.andritz.com/products-en/group/separation/contact-paddle-dryers/kraus-maffei-helix-dryer</a>	1 x 210 L	<ul style="list-style-type: none"> <li>Thermochemical treatments with pressures varying from - 14 – 150 psi and temperatures ranging from 25 to 175°C, i.e. is capable of <b>low temperature vacuum drying as well.</b></li> <li>Stirring with a helical agitator, suitable for high viscosity slurries</li> <li>Indirect heating through wall from hot oil in jacket</li> <li>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)</li> <li>MicroMotion® H-Series Mass flow meter (<a href="http://www2.emersonprocess.com/en-US/brands/micromotion/coriolis-flow-density-meters/H-Series/Pages/index.aspx">http://www2.emersonprocess.com/en-US/brands/micromotion/coriolis-flow-density-meters/H-Series/Pages/index.aspx</a>)</li> <li>Flowserve® and PBM® Valves to measure and control release of gases from the reactor</li> <li>Cleaning by ABEC CIP cart through rotating CIP-nozzles</li> </ul>
Customized High pressure Parr Series 4556 Reactors made of Hastelloy C276 and Carpenter Steel <a href="http://www.parrinst.com/products/stirred-reactors/series-4555-10-20-l-floor-stand-reactors/">(http://www.parrinst.com/products/stirred-reactors/series-4555-10-20-l-floor-stand-reactors/)</a>	3 x 10 L	<ul style="list-style-type: none"> <li>Thermochemical treatments with pressures varying from 0 – 1900 psi and temperatures varying from 25 – 350°C.</li> <li>Stirring action with two impellers – anchor and turbine with real time rpm values, which indicate changes in viscosity of the material</li> <li>Indirect heating through electrical coils on the walls</li> <li>Direct steam injection and release mechanism</li> </ul>
Customized Tube Reactors heated with a Omega Fluidized Sand Bath	20 x 10 mL 20 x 25 mL	<ul style="list-style-type: none"> <li>Thermochemical treatments with pressures varying from 0 – 150 psi and temperatures ranging from 25 to 200°C.</li> <li>Indirect heating through wall from hot sand in Omega Sand Bath</li> </ul>

## AMBIENT PRESSURE EXTRACTION, CATALYSIS AND ENZYMATIC SACCHARIFICATION

Equipment	Scale	Details and comments
IKA SPP <a href="http://cdn2.ika.com/pdf/newsletter/spp_01-08_e.pdf">http://cdn2.ika.com/pdf/newsletter/spp_01-08_e.pdf</a>	1 X 50 L	<ul style="list-style-type: none"> <li>Enzymatic or thermochemical treatments at atmospheric pressures with temperatures ranging from 4 to 100°C</li> <li>Stirring with anchor impeller (RFG-02-A) with drive power of 55 kW. Flow breaker also included.</li> <li>Pumping, with or without shear (Dispersing element DBI 2000/4) available.</li> <li>Cleaning by means of rotating CIP-nozzles</li> <li>Customized for real time torque and temperature values</li> </ul>
IKA Reactors LR-2.ST <a href="http://www.ika.com/owa/ika/catalog/product_detail?iProduct=8016500&amp;iCS=1&amp;iProductGroup=232&amp;iSubgroup=1">http://www.ika.com/owa/ika/catalog/product_detail?iProduct=8016500&amp;iCS=1&amp;iProductGroup=232&amp;iSubgroup=1</a>	4 X 2 L	<ul style="list-style-type: none"> <li>Enzymatic or thermochemical treatments at atmospheric pressures with temperatures ranging from 4 to 200°C</li> <li>Stirring with anchor impeller and flow breaker with real time rpm values</li> <li>Real time temperature and pH data</li> <li>Soon to be customized for real time torque data</li> </ul>
Customized Andritz Hastelloy C276 Ambient Pressure Reactor along with Tempest® TCU	1 x 100 L	<ul style="list-style-type: none"> <li>Enzymatic or chemical treatments at atmospheric pressures with temperatures ranging from 25 to 175°C.</li> <li>Stirring with a helical agitator, suitable for high viscosity slurries</li> <li>Indirect heating through wall from hot oil in jacket</li> </ul>

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## FERMENTATION AND BIOCATALYSIS

Equipment	Scale	Details and comments
ABEC Bioreactors	2 X 300L 1 X 50L	<ul style="list-style-type: none"> <li>• Batch, Fed-Batch, and Continuous Modes applicable</li> <li>• Can be attached to external programmed pump to control feed rate</li> <li>• Load Cells on all Fermenters to observe mass gain/loss</li> <li>• Condensers attached to avoid mass loss</li> <li>• Off-gas analysis through AIT Multigas Analyzer (Mass Spec)</li> <li>• Off-line analysis through YSI and UV-Spec</li> <li>• On-line analysis through FT-NIR</li> </ul>
BioEngineering Bioreactors	1 X 15L 4 X 3.7L	<ul style="list-style-type: none"> <li>• Batch, Fed-Batch, and Continuous Modes applicable</li> <li>• Can be attached to external programmed pump to control feed rate</li> <li>• Condensers attached to avoid mass loss</li> <li>• Off-gas analysis through AIT Multigas Analyzer (Mass Spec)</li> <li>• Off-line analysis through YSI and UV-Spec</li> <li>• On-line analysis through FT-NIR (for 15L only)</li> </ul>
Sartorius Bioreactors	4 X 2L 1 X 10L	<ul style="list-style-type: none"> <li>• Batch, Fed-Batch, and Continuous Modes applicable</li> <li>• Can be attached to external programmed pump to control feed rate</li> <li>• Condensers attached to avoid mass loss</li> <li>• Off-gas analysis through AIT Multigas Analyzer (Mass Spec)</li> <li>• Off-line analysis through YSI and UV-Spec</li> </ul>
Eppendorf new Brunswick Bioreactor	1 X 10L	<ul style="list-style-type: none"> <li>• Batch, Fed-Batch, and Continuous Modes applicable</li> <li>• Can be attached to external programmed pump to control feed rate</li> <li>• Condensers attached to avoid mass loss</li> <li>• Off-gas analysis through AIT Multigas Analyzer (Mass Spec) or BlueSense</li> <li>• Off-line analysis through YSI, Gallery, and UV-Spec</li> </ul>
Flownamics <a href="http://www.flownamics.com/automated_bioreactor_samplinq_4800.html">http://www.flownamics.com/automated_bioreactor_samplinq_4800.html</a>	Control 8 X 2L	<ul style="list-style-type: none"> <li>• Controlled archiving of Cell-Free and Cell-containing samples</li> <li>• Refrigerate archived samples</li> <li>• Integration with YSI and other analyzers</li> <li>• Real time feedback of glucose to control feed pumps</li> <li>• Automated cleaning and flushing of flow-paths</li> </ul>
BlueSens <a href="https://www.bluesens.com/">https://www.bluesens.com/</a>	Off-gas Analyzer	<ul style="list-style-type: none"> <li>• Gas analyzer for CO<sub>2</sub> and O<sub>2</sub>.</li> <li>• Tool for monitoring fermentations and perfect for cell growth processes.</li> <li>• Can be connected with any scale of bioreactors.</li> </ul>

## PRODUCT RECOVERY AND PURIFICATION

Equipment	Throughput	Details and comments
Andritz Decanter (D2L) made of Stainless Steel <a href="http://atl.g.andritz.com/c/com2011/00/01/04/10459/1/1/0/898621157/se-downloads-solidbowldecanter-d_en_.pdf">http://atl.g.andritz.com/c/com2011/00/01/04/10459/1/1/0/898621157/se-downloads-solidbowldecanter-d_en_.pdf</a>	6 m <sup>3</sup> /h (max)	<ul style="list-style-type: none"> <li>Rapid solid liquid separation, primarily used for pretreated biomass</li> <li>Design flow rate of 6 m<sup>3</sup>/h for suspended solids with ≤ 1% w/w (feed concentration)</li> <li>Anticipated time to remove moisture from 10 – 30% to 40% w/w solids of pretreated biomass is &lt; 10 minutes</li> </ul>
Alfa Laval MBPX 404 three-phase continuous centrifuge	150 L/min (max)	<ul style="list-style-type: none"> <li>S-L, L-L, &amp; S-L-L separations</li> </ul>
Alfa Laval Labstak® M20 (Rental equipment) <a href="https://www.alfalaval.us/products/separation/membranes/labstak/labstak-m20/">https://www.alfalaval.us/products/separation/membranes/labstak/labstak-m20/</a>	Variation of cross-flow from 5 to 24 l/min	<ul style="list-style-type: none"> <li>Can be fitted with the entire range of flat sheet membranes with flexible area from 0.036 m<sup>2</sup> to 0.72 m<sup>2</sup></li> <li>Fully integrated system with module, pump, heat exchanger, valve, pressure gauges and hydraulic hand pump</li> <li>High operating temperature and pressure</li> <li>Simultaneous test of different membrane types</li> </ul>
Basket Centrifuge <a href="http://www.westernstates.com/pages/content/pilotplantcentrifuges.html">http://www.westernstates.com/pages/content/pilotplantcentrifuges.html</a>	7.4 L (batch)	<ul style="list-style-type: none"> <li>Rapid solid liquid separation for both pretreated and saccharified biomass</li> <li>Filter bags of pore size 5 – 10μ and 25 – 30μ</li> <li>Maximum rpm of 3600</li> <li>A recycle system to recycle solvent utilized for the wash has been developed and incorporated into the system</li> </ul>
Distillation / Evaporation skid <a href="http://www.popeinc.com/still-products/wiped-film-stills-evaporators">http://www.popeinc.com/still-products/wiped-film-stills-evaporators</a>	0.5-3 L/hr	<ul style="list-style-type: none"> <li>Pope Scientific 2" Hybrid Wiped-Film</li> <li>Efficient thermal separation with minimum product decomposition and maximum product quality.</li> <li>Works in 3 system configurations: evaporator/concentrator, molecular still and hybrid fractional modes.</li> </ul>
Mini DeBEE Homogenizer <a href="http://www.beei.com/high-pressure-homogenizer-products/laboratory-homogenizers/mini-debee">http://www.beei.com/high-pressure-homogenizer-products/laboratory-homogenizers/mini-debee</a>	Material Dependent	<ul style="list-style-type: none"> <li>Cell lysis or particle size reduction at high working pressure up to 45,000 psi</li> </ul>
Lab scale M-110P Homogenizer <a href="https://www.microfluidicscorp.com/microfluidizers/lab-machines/m-110p/">https://www.microfluidicscorp.com/microfluidizers/lab-machines/m-110p/</a>	Material Dependent	<ul style="list-style-type: none"> <li>Lab scale homogenizer that works with a variety of fluids, solids-in-liquid suspensions and cell disruptions with the most difficult yeasts, E.coli and mammalian cells.</li> <li>Achieves processing pressures of 30,000 psi</li> </ul>
Pilot scale M-110EH Microfluidizer <a href="https://www.microfluidicscorp.com/microfluidizer%C2%AE-processors/biopharmaceutical-manufacturing-equipment-cgmp/pilot-scale-m-110eh/">https://www.microfluidicscorp.com/microfluidizer%C2%AE-processors/biopharmaceutical-manufacturing-equipment-cgmp/pilot-scale-m-110eh/</a>	Material Dependent	<ul style="list-style-type: none"> <li>Pilot scale homogenizer that works with a variety of fluids, solids-in-liquid suspensions and cell disruptions with the most difficult yeasts and E.coli.</li> <li>Achieves processing pressures of 30,000 psi</li> <li>Produces product flow rates up to 320 ml/min at 30,000 psi</li> </ul>
Labconco FreeZone <sup>®</sup> 6-L bulk freeze dryer	Bulk Tray dryer with 6 x 1L port manifolds	<ul style="list-style-type: none"> <li>Capable of drying ~ 6 liters of centrifuged biomass, protein or chemical product in one cycle</li> </ul>
Qsonica- Q700 in-line continuous sonicator	20 L/hr	<ul style="list-style-type: none"> <li>Enables high-throughput microbial cell lysis to extract intracellular metabolites like enzymes</li> </ul>
Milipore Labscale Tangential Flow Filtration (TFF) system	500 mL & 10 L reservoir	<ul style="list-style-type: none"> <li>Small &amp; medium scale protein concentration; filter membranes with various pore sizes (50 cm<sup>2</sup> &amp; 0.1 m<sup>2</sup>) can be used to separate &amp; concentrate specific proteins from</li> </ul>

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<p>&amp; Cogent M1 TFF system</p>	<p>capacity, respectively</p>	<p>fermentation broth.</p> <ul style="list-style-type: none"> <li>• Cogent M1 can run in fed-batch or diafiltration mode, which enables system to process up to 100 L or more based on product &amp; filter characteristics. Supports a total membrane area from 0.1 m<sup>2</sup> to several m<sup>2</sup></li> </ul>
<p>AKTA Avant 150 equipped with UNICORN 6.1 (with integrated DOE capabilities) <a href="https://www.gelifesciences.com/shop/chromatography/chromatography-systems/akta-avant-p-06264?current=28976337">https://www.gelifesciences.com/shop/chromatography/chromatography-systems/akta-avant-p-06264?current=28976337</a></p>	<p>150 mL/min (max)</p>	<ul style="list-style-type: none"> <li>• Fast &amp; secure development of scalable chromatographic processes for protein purification, as well as fine-tuning &amp; robustness testing of optimized process</li> <li>• Capable of yielding gram quantities of pure protein using a variety of chromatographic modes;</li> <li>• Easy DOE planning for scale-up</li> </ul>
<p>KARR® Reciprocating Plate Extraction Column <a href="https://kochmodular.com/liquid-liquid-extraction/extraction-column-types/karr-columns/">https://kochmodular.com/liquid-liquid-extraction/extraction-column-types/karr-columns/</a></p>	<p>250 mL/min (max)</p>	<ul style="list-style-type: none"> <li>• 25 mm diameter; retention volume of ~ 2L; agitator for 0-400 spm; explosion-proof motor; metal/PTFE plate stack</li> <li>• L-L separations; continuous &amp; efficient recovery of immiscible &amp; partially miscible liquid biofuels, like butanol &amp; bisabolene, from fermentation broth</li> </ul>
<p>Filter press <a href="https://ertelalsop.com/depth-filtration-equipment/plate-and-frame-filter/12-inch-plate-and-frame-filter-press/">https://ertelalsop.com/depth-filtration-equipment/plate-and-frame-filter/12-inch-plate-and-frame-filter-press/</a></p>	<p>Depended on material</p>	<ul style="list-style-type: none"> <li>• 12" plate and frame filter</li> <li>• Fabricated in 316L SS, cart mounted used for ultra-fine filter applications</li> </ul>
<p>GEA Crystallizers (on request) <a href="https://www.gea.com/en/products/groups/evaporators_crystallizers/crystallizers/index.jsp">https://www.gea.com/en/products/groups/evaporators_crystallizers/crystallizers/index.jsp</a></p>	<p>Depended on material</p>	<ul style="list-style-type: none"> <li>• GEA offers pilot scale crystallizer for application development or sample purity for the food and the chemical applications.</li> <li>• Alternatively, we can use 50L bioreactor at low temperatures with gentle mixing.</li> </ul>
<p>Pilot scale Evaporation /Concentration</p>		<ul style="list-style-type: none"> <li>• Andritz Vacuum capability of 0.1 torr with external vacuum pump, maximum vacuum reading at 1 bar.</li> <li>• Ability to work as a vacuum evaporation vessel with capability of 100 kg per batch. Condensates can be collected in a 120L receiving tank.</li> </ul>
<p>Spray drying (on request) <a href="https://www.gea.com/en/products/mobile-minor.jsp">https://www.gea.com/en/products/mobile-minor.jsp</a></p>	<p>0.5-6 kg/h</p>	<ul style="list-style-type: none"> <li>• We don't have Spray drying on site but we can rent to meet our client needs. One of the spray drying company that offer rented equipment is GEA MOBILE MINOR™.</li> <li>• GEA MOBILE MINOR™ – small quantities of solutions, suspensions or emulsions can be dried into powder solutions.</li> <li>• Available in 3 different atomization techniques: Rotary atomization, atomization by a co-current or counter-current two-fluid nozzle</li> </ul>
<p>Simulated moving bed chromatography (SMBC) (on request) <a href="http://sembabio.com/simulated-moving-bed-chromatography/">http://sembabio.com/simulated-moving-bed-chromatography/</a></p>	<p>Up to 20-fold vs. batch systems</p>	<ul style="list-style-type: none"> <li>• We don't have SMBC on site but we can rent to meet our client needs.</li> <li>• Efficient utilization of solid and liquid phases with lower solvent consumption.</li> <li>• Scalable from mg to tons of purified materials with target compounds can vary from sugars, sugar alcohols, amino acids, oligosaccharides, organic acids, fatty acids and recombinant proteins.</li> </ul>

## ANALYTICAL CHEMISTRY AND MATERIALS HANDLING / SOLIDS CHARACTERIZATION

Equipment	Detection modes	Typical uses
Malvern stress- controlled oscillating rheometer / viscometer <a href="https://www.malvern.com/en/products/product-range/kinexus-range/kinexus-pro-plus/index.html">https://www.malvern.com/en/products/product-range/kinexus-range/kinexus-pro-plus/index.html</a>	N/A	<ul style="list-style-type: none"> <li>Characterizing visco-elastic and rheological properties of liquids, solids, and liquid-solid mixtures</li> </ul>
Thermo Scientific Ultimate 3000 HPLCS High-performance liquid chromatography <a href="https://www.thermofisher.com/us/en/home/industrial/chromatography/liquid-chromatography-lc/hplc-uhplc-systems/ultimate-3000-hplc-uhplc-systems.html">https://www.thermofisher.com/us/en/home/industrial/chromatography/liquid-chromatography-lc/hplc-uhplc-systems/ultimate-3000-hplc-uhplc-systems.html</a>	Refractive index (RI), UV, charged aerosol	<ul style="list-style-type: none"> <li>Compositional, in process and final product analysis for water-soluble molecules</li> </ul>
Dionex ICS-5000+ Capillary HPLC System <a href="https://www.thermofisher.com/order/catalog/product/072243">https://www.thermofisher.com/order/catalog/product/072243</a>	UV, Electrochemical	<ul style="list-style-type: none"> <li>Detection of low concentration sugars and other metabolites</li> </ul>
Thermo Scientific GC - Gas chromatography	Flame ionization detector (FID)	<ul style="list-style-type: none"> <li>Volatile small molecule detection</li> </ul>
BIOTEK microplate reader <a href="https://www.biotek.com/products/detection-multi-mode-microplate-readers/synergy-htx-multi-mode-reader/">https://www.biotek.com/products/detection-multi-mode-microplate-readers/synergy-htx-multi-mode-reader/</a>	UV/Vis	<ul style="list-style-type: none"> <li>Absorbance and fluorescence biomarker assays</li> </ul>
IKA bomb calorimeter <a href="https://www.ika.com/laboratory-equipment/products/calorimeters/products/2679/c-200">https://www.ika.com/laboratory-equipment/products/calorimeters/products/2679/c-200</a>	Temperature Sensor	<ul style="list-style-type: none"> <li>Energy content and heat of combustion measurements of feedstocks and products</li> </ul>
Bio-Rad Gel Doc™ EZ System <a href="http://www.bio-rad.com/en-us/product/gel-doc-ez-gel-documentation-system">http://www.bio-rad.com/en-us/product/gel-doc-ez-gel-documentation-system</a>	SDS-PAGE	<ul style="list-style-type: none"> <li>Automated Gel imaging and yield publication-quality data with stain-free technology</li> </ul>
YSI 2900 Biochemistry Analyzer with Sitini Autosampler	Enzyme Sensor	<ul style="list-style-type: none"> <li>Analyze specific results in 60 seconds or less</li> <li>Proprietary immobilized enzyme electrodes</li> <li>Unique fluidics resist clogging</li> <li>Trusted measurement technology</li> <li>Automated sample handling</li> <li>Linear analytical range: Glucose: 0.05-25 g/L, Ethanol: 0.04-3.2 g/L and etc.</li> </ul>
Gallery™ Automated Photometric Analyzer <a href="https://www.thermofisher.com/order/catalog/product/98610001">https://www.thermofisher.com/order/catalog/product/98610001</a>	Photometric	<ul style="list-style-type: none"> <li>Spectral range: 275-880 nm</li> <li>Up to 200 photometric tests per hour, Maximum of 45 samples and 30 reagents loading.</li> <li>Electrochemical unit available for conductivity and pH tests</li> </ul>

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		<ul style="list-style-type: none"><li>• Can analyze: D-glucose, D-fructose, glycerol, Magnesium, phosphate, nitrogen, acetic acid, ammonia, calcium, ethanol and etc.</li></ul>
On-line FT-NIR Analysis <a href="https://www.bruker.com/products/infrared-near-infrared-and-raman-spectroscopy/ft-nir/matrix-f/overview.html">https://www.bruker.com/products/infrared-near-infrared-and-raman-spectroscopy/ft-nir/matrix-f/overview.html</a>	Fiber optics technology	<ul style="list-style-type: none"><li>• Monitoring tool used in-line with process reactors</li></ul>