INTRODUCTION TO: THERMAL KINETICS

DEVELOPMENT •••• DESIGN •••• FABRICATION
Vision Statement

Innovation Driven → Solutions Focused…

See alternatives not recognized before. Deliver best process solutions which enable the success of our customers, adds value to their enterprise, and protects our community. Rely on our internal teams and partnering with suppliers and customers to bring all the ideas to the effort. Know that blending many perspectives and talents in a trusting environment accelerates innovation and builds the best solutions. Finally by executing this vision we elevate our life work and inspire excellence.
Our Values

- **Respect** - is our priority requiring trust and accountability for staff, customers, suppliers, and the environment.
- **Integrity** - we take responsibility, accept accountability, “do the right thing”
- **Partnering** - for strong team involvement of staff, customers and suppliers
- **Team building** - help everyone strive for greatness. “Have your teammates back.”
- **Responsiveness** - urgency in action and communication. Delays breed mistrust.
- **Continuous learning** - for staff growth, highest quality of service and solutions for our customers, which sparks innovation and creativity.

We are building for the future solving energy and environmental problems for the next generation. We achieve team building through mutual respect, partnering to solve the most difficult engineering problems for the benefit of our customers and the environment.
Mission Statement

We solve a diverse range of difficult heat/mass transfer process applications, while promoting sustainability, excellence and value for our customers.
Sustainability Statement

Thermal Kinetics is committed to providing process equipment solutions that help sustain and conserve environmental resources.

Our renewable fuels initiatives offer major energy conservation benefits to our clients and support energy independence for the USA.
Development, Design, & Supply

PROCESS FACILITIES

MOLECULAR SIEVE ADSORBERS

MODULAR SKID MOUNTED PLANTS

DEVELOPMENT ••• DESIGN ••• FABRICATION
Development, Design, & Supply

Submerged Circulating Crystallizer

Falling Film Evaporator

CRISTALLIZERS
EVAPORATORS
DISTILLATION EQUIPMENT

DEVELOPMENT ••• DESIGN ••• FABRICATION
“What we do”

- System design, supplying cost effective equipment and process solutions to our customers
  - Minimizing energy input
  - Maximizing product output
  - Optimizing project value
“What we do”

- Emission control systems using absorption and adsorption technologies

- Chemical purifications systems using distillation, adsorption, and evaporation technologies

- Diverse experience in the chemical, food processing, distillery, industrial operations, including metals processing

- Customized process development through rigorous analysis, process simulation, and equipment design development
What we have done lately...

- DD&E (Distillation, Dehydration & Evaporation) system supplied for fuel ethanol production at Dakota Spirit AgEnergy
- Cellulosic ethanol plant molecular sieve system for DuPont in Iowa
- First ultra low moisture industrial alcohol MSU system achieving 150 ppm moisture consistently
- Sodium Sulfate anhydrous four effect crystallizer in Mexico. MOC are titanium and duplex stainless steel
- Thermal BioMass Conversion Process designed for extraction of organics (biofuels) from mixed waste and plastics under subcritical hydrothermal conditions
Overview and Supplied Equipment
Markets Served

- Chemical industries
- Renewable fuels and chemicals
- Food processors
- Industrial manufacturers
- Pharmaceutical processing
Renewable Fuels, Chemicals & Polymers

- Alcohols (i.e. ethanol, methanol, glycerol)
- Grain-based fuel ethanol production
- Cellulosic-based fuel ethanol production
- Biomass gasification processes
- Biopolymers (i.e. PLA, PHA, etc.)
- Chemicals recovery from algae processes
- Platform chemicals (i.e. C2-C6, succinic acid, etc.)
Services & Equipment Provided

- Fully integrated process systems development and design
- Detailed equipment design and supply
- Commissioning and start-up services
- Design/construct on-site
- Fully modularized skid mounted systems
Services & Equipment Provided – Process Modeling
Thermal Kinetics provides a number of core technologies, designs and process operations including:

- Process evaporation
- Distillation systems
- Adsorption drying systems – molecular sieves
- Scrubbers/absorbers – emission control
- Specialized chemical recovery and reaction systems
Materials of Construction

Experience in a wide variety of construction materials:

- Carbon steel and austenitic stainless steels
- Duplex and specialty stainless steels
- Titanium Gr 2, Gr 7, and Gr 11
- Inconel, Nickel 200/201, Monel, Hastelloy(s) and special alloys
- Impervious graphite equipment
- Lined piping (PTFE, ETF, PVDF…)
- Fiberglass composite systems
Industrial Experience

- Agricultural chemicals and fertilizers
- Animal byproducts and rendering
- Fats, oils and soap
- Food products and processing
- Breweries and distilleries
- Inorganic chemicals
- Pharmaceutical
- Sugar and corn products
- Steel processing and metals industries
Examples

Acids:
- Hydrochloric acid absorption/well brine production by reaction of HCl & CaCO3
- Hydrochloric acid recovery from waste phosgene gas stream
- Hydrochloric acid distillation and recovery with calcium chloride dehydrator
- Recovery of HCl from a mixture of HCl and H₂SO₄
- Pickle liquor temperature control and HCl recovery
- Phosphoric acid evaporation (30% to 54% P₂O₅)
- Sulfuric acid: high purity electronics grade production facility
- Sulfuric acid concentration systems
- Citric acid fermentation, filtration, purification, evaporation, crystallization, and drying
- Gluconic acid evaporator
Examples

Caustic and Alkalies:
- Caustic Soda (NaOH): evaporation to 50% & anhydrous flake w/ material handling
- Caustic Soda (NaOH): recovery from mercerizing process (textile facility)
- Caustic Potash (KOH) concentration and flaking

Organic and Specialty Chemicals:
- ABS latex solvent recovery system and vacuum condensing operation
- Glycerin concentration and distillation systems
- Terpene resin solvent evaporation and stripping system
- Ethylene glycol distillation and purification
- Rolling oil emissions control and distillation recovery (2 mm Hg abs/360 F)
Examples

Sugar, Corn Products, Grain-based Ethanol:
• Corn/Sorghum to ethanol distillation, evaporation and dehydration
• Corn steep liquor evaporator
• Dextrose evaporator and crystallizer
• Invert sugar evaporator
• Brewery effluent alcohol recovery

Fats and Oils, Rendering, Specialty:
• Sorbitol processing – evaporation and drying
• Odor stripping of oils and fats
• Solvent stripping of fatty acid miscella
• Turkey processor wastes to renewable oils conversion
Examples

Salts and Inorganics:

- Sodium Sulfide \((\text{Na}_2\text{S})\): evaporator and flake plant
- Ammonium thiosulfate production facility and reactor design
- Calcium chloride \((\text{CaCl}_2)\): production of flake road salt
- Ammonium sulfate – reaction of ammonia and sulfuric acid with crystallization
- Calcium hypochlorite production
- Sodium sulfate production and crystallization plant from ore
Evaporation Systems

- Single/multiple effect systems
- TVR: Thermo-vapor recompression
- MVR: Mechanical vapor recompression
- Anhydrous caustic flake systems
- Salt flake systems
- Corrosives (H2SO4...)
- Crystallization systems
- Foaming and heat sensitive materials

**CONFIDENTIAL**

**EVAPORATOR DESIGN QUESTIONNAIRE**

Please supply as much information as possible. Thermal Kinetics will supply typical values based on experience when missing data is encountered.

<table>
<thead>
<tr>
<th>Inquiry Date:</th>
<th>Approximate installation date:</th>
</tr>
</thead>
</table>

**Company**

**Address**

**Telephone**

**Fax**

**E-mail**

**Contact**

**Position**

**Department**

**Price Basis**

**Order of Magnitude**

**Budget**

**Firm**

**Thermal Kinetics**

Thermal Kinetics quotation required by:

Test facilities are available for determining physical properties of process fluids if needed pilot testing can be arranged.

**PROCESS LIQUIDS**

Solution to be concentrated:

- Scaling Tendency?
- If so, what type?
- Will solute crystallize?
- Sand solubility data if this is the case
- Is solution corrosive?
- Describe:
- Is feed being concentrated now?
- By what method?

**PHYSICAL PROPERTIES**

- Total solids content
- Specific Gravity
- Viscosity
- Specific Heat in Bulk °F
- Boiling point elevation °F
- Physical samples available?

<table>
<thead>
<tr>
<th>Feed</th>
<th>Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EVAPORATOR DUTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed rate lb/hr</td>
</tr>
<tr>
<td>Operating time hr/day</td>
</tr>
<tr>
<td>Turn-down required</td>
</tr>
<tr>
<td>% concentrate cooled</td>
</tr>
</tbody>
</table>
Standard Evaporator Styles

Falling Film Evaporator

Rising/Falling Film Evaporator

Forced Circulation Film Evaporator
Standard Crystallizer Styles

Submerged Circulating Crystallizer

Internal Pump Circulating Crystallizer

Draft Tube Crystallizer
Thermal Kinetics Patents

- Distillation/Dehydration/Evaporation (DD&E)
  - Saves 15% of steam compared to prevalent systems

- Ethanol, methanol, solvent purification, dehydration and advanced adsorption separations technologies

- Improved methods for pressure swing adsorption for ethanol dehydration

- Ethanol drying with co-production of methanol, hydrogen, heat and chemicals from syngas
DD&E Patented Configuration
(Six Plants Constructed and Operating)
## DD&E Patent Comparison

<table>
<thead>
<tr>
<th></th>
<th>TK Patented Process</th>
<th>Plant By Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Steam Req'd</strong></td>
<td>56,210 LB/HR</td>
<td>71,525 LB/HR</td>
</tr>
<tr>
<td><strong>Equivalent Heat</strong></td>
<td>49.8 MM BTU/HR</td>
<td>63.37 MM BTU/HR</td>
</tr>
<tr>
<td><strong>Whole Stillage Flow</strong></td>
<td>247,063 LB/HR</td>
<td>296,564 LB/HR</td>
</tr>
<tr>
<td><strong>Whole Stillage Conc</strong></td>
<td>16.22 WT%</td>
<td>13.51 WT%</td>
</tr>
<tr>
<td><strong>Centrifuge Load</strong></td>
<td>430 GPM</td>
<td>529 GPM</td>
</tr>
<tr>
<td><strong>Evap Feed</strong></td>
<td>243 GPM @ 8.65%</td>
<td>232 GPM @ 7.03%</td>
</tr>
<tr>
<td><strong>Recycle to Fermentation (Backset)</strong></td>
<td>87.7 GPM</td>
<td>205.4 GPM</td>
</tr>
<tr>
<td><strong>Fusel Oil Decanter</strong></td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>Process Condensate For Recycle Recovered</strong></td>
<td>123,969 LB/HR</td>
<td>79,187 LB/HR</td>
</tr>
<tr>
<td></td>
<td>247.9 GPM</td>
<td>158.4 GPM</td>
</tr>
<tr>
<td><strong>1st Effect Evap Temp (F)</strong></td>
<td>152</td>
<td>199</td>
</tr>
<tr>
<td><strong>2nd Effect Evap Temp (F)</strong></td>
<td>127</td>
<td>185</td>
</tr>
<tr>
<td><strong>Beer Column Bottom (F)</strong></td>
<td>203</td>
<td>185</td>
</tr>
</tbody>
</table>
“The Bottom Line” - DD&E Results

Financial Benefit at 13.1 Wt% Ethanol

<table>
<thead>
<tr>
<th></th>
<th>TK Patented Process</th>
<th>Standard Plant</th>
<th>Delta</th>
<th>50 MM GPY Plant ($)</th>
<th>100 MM GPY Plant ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Steam Req'd (lb/hr)*</td>
<td>56,210</td>
<td>71,525</td>
<td>-21%</td>
<td>$836,199</td>
<td>$1,672,398</td>
</tr>
<tr>
<td><strong>Total Financial Benefit</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$836,199</strong></td>
<td><strong>$1,672,398</strong></td>
</tr>
</tbody>
</table>

*Assumption: $6.50/1000 lbs steam

**Basis:**
Beer feed of 13.1 wt % ethanol, 12.72 % total solids

Note: Reduced backset of non-fermentable solids has allowed Calgren in Pixley, CA to achieve 15.5 wt% ethanol on a consistent basis for far greater savings.
Distillation Equipment

CONFIDENTIAL
SEPARATION DESIGN QUESTIONNAIRE

MORE INFORMATION AND SPECS SHOULD BE SUPPLIED AS NEEDED TO DEFINE PROJECT

Please supply as much information as possible.
Thermal Kinetics will supply typical values based on experience when missing data is encountered.

Company
Address
Telephone
Fax
E-mail

THERMAL KINETICS QUOTATION

Your reference: ____________________________
Thermal Kinetics quotation required by: 
Price Basis:  ○ Order of Magnitude  ○ Budget  ○ Firm

Inquiry Date:
Approximate installation date: ____________________________

FORMULA LIQUIDS FOR DISTILLATION, ABSORPTION, OR OTHER MASS TRANSFER OPERATION

Feed Composition:
Scaling Tendency:  No  If so, what type?
Foaming Tendency:  Yes  Describe:
Is solution corrosive?  Yes  Add description:
Is this a new or retrofit project?  Yes  Describe:
Prefered materials of construction (G316L, etc.):

SPECIAL PHYSICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Feed</th>
<th>Bottoms Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Acid-soluble solids content</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity</td>
<td>cps at°F</td>
<td>cps at°F</td>
</tr>
<tr>
<td>Specific Heat in Btu/F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Conductivity (Btu/F°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are quartz samples available?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

COMPOSITION OF PRODUCTS

<table>
<thead>
<tr>
<th>Product</th>
<th>Overhead Product</th>
<th>Bottoms Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component and purity, Separation #1</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Component and purity, Separation #2</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Component and purity, Separation #3</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Component and purity, Separation #4</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

PROCESS DUTY, RATES, CONDITIONS

Feed rate:  lbs/hr
Feed temperature:  °F
Operating time:  hrs/day
Turn-down required:  %
Maximum processing time:  hrs

DEVELOPMENT  ••• DESIGN  ••• FABRICATION
Services & Equipment Provided –
Detailed Process Development
Renewable Fuels Initiative – Technology for Energy Independence

Innovation:
• Science-centered technology, development and innovative engineering
• Advanced solutions for energy independence
• Scientific publications reporting TK advances in molecular sieve ethanol dehydration
• Patented inventions for renewable fuels production

Successful Operating Facilities:
• Engineered, supplied and commissioned – traditional DD&E plants and TK process
• Experienced engineering resources to support construction, start-up and optimization

Effective Project Development Partner:
• Thermal Kinetics works with our clients to build successful projects in traditional dry mill ethanol plants and emerging cellulosic and thermo-chemical technologies
Thermal Kinetics excels in the development of innovative processes for the conversion of biomass to chemicals and fuel.

It is our ability to understand, adapt to and design for the various challenging physical properties associated with biomass derived mixtures that sets us apart.
Molecular Sieve Ethanol Dehydration Module
Molecular Sieve Dehydration Simulation

Material flows around the PSA unit

FLOW [lbs/hr]

Pressure [Psia]

FEED
Bottom product
Net Product
Purge + Pressurization
Regen Flow
Pressure

0 100 200 300 400 500

0 5 10 15 20 25 30

12000
14000

0 2000 4000 6000 8000 10000 12000

0 2000 4000 6000 8000 10000 12000
DSA Plant – North Dakota

Utilizing Thermal Kinetics Patented:

- Distillation
- Dehydration
- Evaporation
Calgren Renewable Fuels – Pixley, CA
50 MMGPY (US Patent 7,867,365 B2)
Most efficient ethanol plant in the U.S.
Sunoco Renewable Energy – Fulton, NY
100 MMGPY (US Patent 7,867,365 B2)
Example Projects – Cellulosic Based Fuel Ethanol

Pilot Plant Scale - Molecular Sieve Dehydration System
Unique low pressure adsorption to 8 psig with low moisture < 0.5% achieved
Example Projects – Cellulosic Based Fuel Ethanol

Demonstration Scale - Molecular Sieve Dehydration Module
Sodium Sulfate Crystallizer System
Chemicals Recovery from Waste Streams

- Steel processors
  - Chemicals recovery and associated chemical services

- Aluminum rolling mills
  - Emissions control systems

- Recovery of chemicals and waste streams from manufacturing processes
High Vacuum (2mm Hg abs 360 °F)
Oil Separation – Modular Construction
Ethylene Glycol Purification System
Food Processing Industry

- Fruit juice processors
- Animal byproducts and rendering
- Fats and oil processors
- Food products and processing
- Breweries and distilleries
- Dairy processing
Example Projects – Sorbitol Concentration System
Bone Gelatin Concentration System

10,000 cps Final Product Viscosity
Thank You very much for allowing us to present our technology and expertise to you. We look forward to sharing our passion for process solutions with you on your next project...

Contact Us Today!