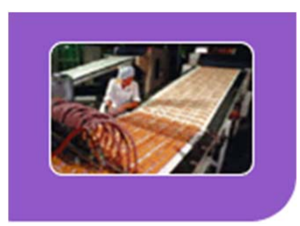
Presentation Outline

1. Market Overview
2. Decision Making
3. Technologies
4. Case Studies



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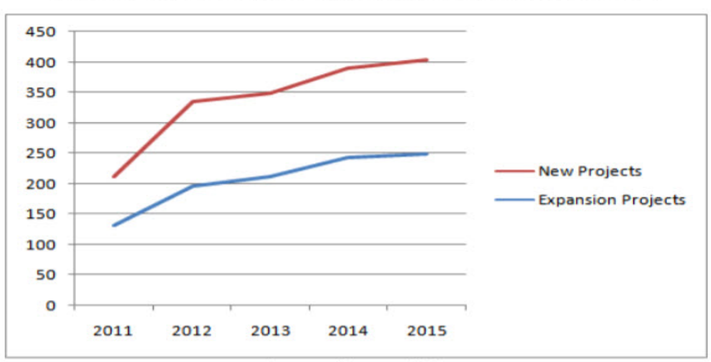
Food Processing

- Processing food is America's top business
- Processing raw fruits, vegetables, grains, meats, and dairy products into finished goods ready for the grocer or wholesaler to sell to households, restaurants, or institutional food services
- Food and beverage manufacturing plants, located throughout North America

Number of New and Expanded Food Processing Facilities in the US

Figure 1: Food Processing New and Expansion Project Trends, 2011-2015

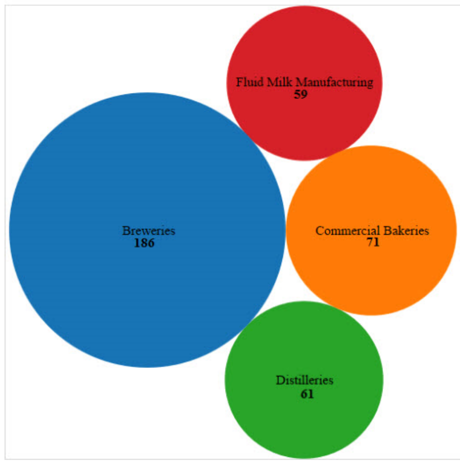


Source: Conway Data

https://whittakerassociates.com/industry-overview-food-processing/

Market Overview - Statistics

Figure 2: Sub-Sector Projects, 2011-2015



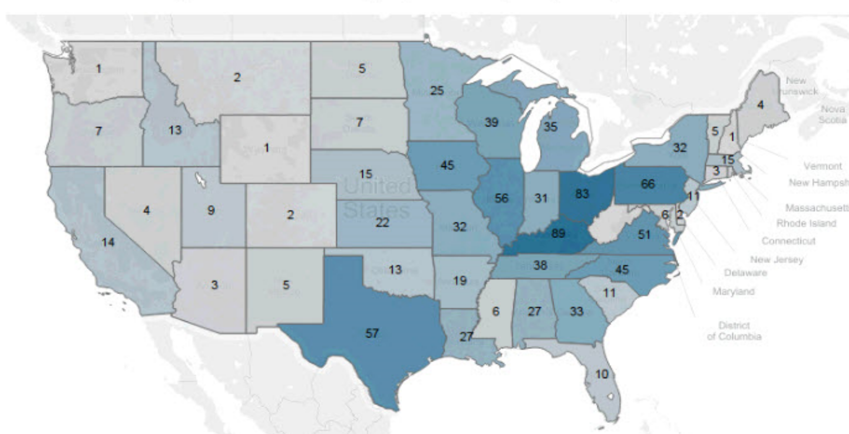
Source: Conway Data

Growth in (new & Expansion) Food Processing Sub-Sectors:

- Brewery 186
- Commercial Bakery 71
- Distilleries 61
- Fluid Milk Manufacturing 59

Market Overview - Statistics

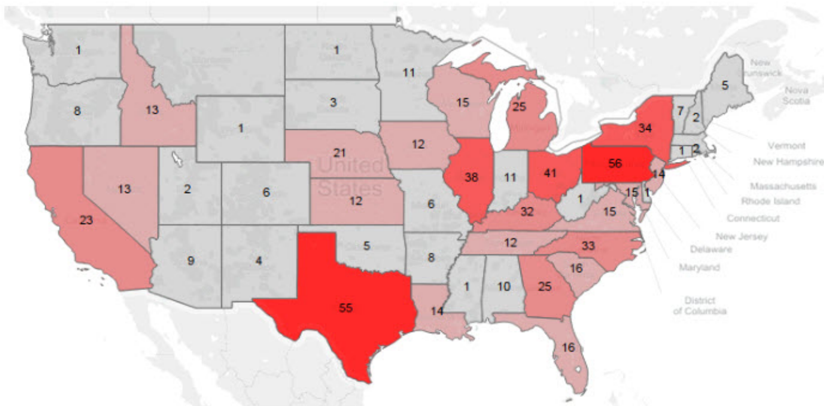
Figure 3: Food Processing Expansion Projects by State, 2011-2015



Source: Conway Data

Market Overview - Statistics

Figure 4: Food Processing New Projects by State, 2011-2015



Source: Conway Data

Innovation in Food Processing

Technology has helped companies expand production while keeping quality intact

- Robotics company produce 360 burgers per hour
- Seattle based-craft beer maker Fremont Brewing is fully automated and is estimated to produce 60,000 barrels
- Food packaging and processing technologies are recycling and using bio-degradable materials for packaging snacks and pet food, new films that have been developed to keep meat fresher longer
- Automatic bagel forming equipment provides up to 30 thousand full-size bagels per hour

Processed Food Debate

- Why people have turned against processed foods?
  - High content of sugar
  - Added chemicals
- People have turned to organic food consumption as organic food sales have tripled over the past decade
- Major brands have started changing their ingredients in their products and releasing organic brands to attract consumers.
  - Pledged to remove artificial flavors and coloring from its cereals & Chocolate bars
  - Launched of their organic soup brand
- These changes come at a time when 82% of baby boomers and 72% millennials believe that eating healthily is "extremely important,"

Future Growth in Food Processing

- U.S. food industry will have a steady growth of 2.9% CAGR through 2022
- Processed foods industry gives economic developers more opportunities to create jobs and attract projects in the future
- Trends in food production will change according to consumer demand and evolving technology
- Demand for STEM field related jobs will also increase as technical advances in sciences will require employees to be qualified to run automated machines

Market Segments

Major Market Segments

- Meat Industry
- Dairy Industry
- Canned & Frozen Food Industry
- Grain Mills
- Bakery Products
- Sugar & Confectionary Products
- Beverages
- Fat, Oils & Miscellaneous Foods
- Snack Foods & Other Industry Segments

Market Segment - Meat

- Slaughter of meat and poultry and the cutting and packaging of these meat products for sale to wholesalers and meat jobbers
- Characterized by its diversification into other fields, such as the chemical, pharmaceutical and animal feed industries, in order to capitalize on the use of all animal byproducts
- Natural gas is primarily used as boiler fuel to produce hot water & steam
  - NG provide 45-55% of total thermal energy used
  - Gas fired desiccant to control moisture and ice buildup – Frozen Food
  - Biogas, a renewable natural gas from waste food

Market Segment - Dairy

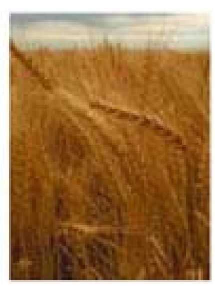
- Classified into five product types - creamery butter, cheese, condensed milk, ice cream and fluid milk
- Due to its perishable nature, processing plants are typically small, decentralized and located close to the milk source
- A considerable amount of natural gas is used to prepare the various product lines
  - 50% of the thermal energy requirements of this industry are generated by natural gas
  - Electrical energy usage by the industry is relatively small, except ice cream and frozen desserts

Market Segment – Canned & Frozen

- Scattered throughout the country
- Continuous operations, processing numerous products throughout the year
- Slow but steady growth over many years
- Production continues to undergo rapid expansion due to prepackaged meals and specialty and dietary meal programs.
- Refrigeration to freeze product prior to shipment is also important to this industry
- Natural gas satisfies approximately half of the canned and frozen foods industry's energy requirements
  - Process heat is primarily steam for blanching foods, cooking, sterilization and hot water

Market Segment – Grain Mills

- Grinding of wheat and other cereal grains to form flour, the blending of flours, and the preparation of animal feeds and large quantities of breakfast cereals
- Flourmills are small users of energy
  - 80% of total energy expenditure is for electricity.
- The cereal preparation industry is dominated by a small number of large establishments - by far the largest component of this industry segment



Market Segment - Bakery

- Two types of Baking:
  - Bread and similar perishable bakery products
  - Dry bakery products such as biscuits, crackers and pretzels
- Comprised of a relatively small number of quite large bakeries serving the major segment of the market and a second group of small, but very numerous, bakeries serving a narrow specialty products market
- Bakeries represent a sizeable energy market due to continuous bread making processes.
- These facilities are scattered across the country due to the longer storage and shelf life characteristics of the products
- Natural gas, fueling ovens and boilers, serves the major portion of the thermal energy requirement in the bakery products industry

Market Segment – Sugar & Confectionary

- Two distinct segments:
  - Cane sugar refining and
  - Beet sugar refining
- Both groups perform essentially the same function, but the processes vary somewhat
- The sugar and confectionary products industry is made up of a small number of large production facilities
- The candy industry is made up of many small manufacturers scattered throughout the country
- Fossil fuels and electricity represent a large portion of the total cost of the sugar produced
- Hydrocarbon fuels provide over 90% of the typical energy input for product processing

Market Segment - Beverage

- **Breweries**
  - Natural gas providing over 50% of the total energy needs
  - Requires process heat for malting, sterilizing
  - Specialty beers and microbreweries has continued to grow
  - Although continuous brewing exists, batch processing is still most prevalent
- **Wine and distilled liquors**
  - Whiskey, other spirits, distilled liquors and all types of wine.
  - Fuel and energy sales are relatively small and regionalized.
  - Most energy is used for process heating and cleaning.
- **Soft drink**
  - Primarily of franchised bottlers that purchase syrups from large soft drink companies
  - The franchised bottler will serve a regional market from a central production and warehousing facility.

Market Segment – Fat, Oils & Misc.

- Extract and refine **vegetable or animal fats or oils**
- The amount of animal fats consumed in the U.S has declined significantly, but the use of hydrogenated vegetable shortenings and cooking oils greatly increased
- Natural gas is the leading energy form for thermal energy in this industry segment
- In the miscellaneous food products industry, the **roasted coffee segment** continues to grow with the advent of specialty coffees and new blends
- **Pasta** and other food preparations continue to grow at a rate constant with the increasing population rate

Market Segment – Snack Food

- Snack Food industry is about 400 companies with combined annual revenue of $23 billion
- Major companies include PepsiCo's Frito-Lay, Kraft's Nabisco subsidiary, and Kellogg's Retail Snacks business
- The industry is concentrated: the top 50 companies account for 75 percent of industry revenue
- Snacks: roasted nuts and nut mixes; potato, tortilla, and corn chips; popped popcorn; and peanut butte
- This industry doesn't include companies that make cookies, candy, crackers, pies, or chocolate-covered snacks

Decision Making

Decision Making

- Decision Makers
- Process
- Drivers

Decision Makers - Drivers

http://siteselection.com/issues/2015/jul/food-processing.cfm

Food Processing Trends

- Trends:
  - Healthy and clean label vs. diet-friendly
  - Rise of natural and organic products
  - The anti-sugar movement
  - Adding value to products
  - Slow product innovation cycles

http://www.fooddive.com/news/8-major-challenges-facing-the-food-and-beverage-industry-in-2016/411408/

Challenges Facing Food & Beverage

- Major Challenges:
  - Consumers avoiding center of store products
  - Low to no sugar products
  - Making products more convenient
  - E-Commerce- welcome to the age of technology

- Additional Challenges
  - Phase out of R-22 Refrigerants
  - Microbial growth
  - Trade negotiations
  - Safety and quality
  - Livestock production 18% of global warming, (9% CO_2, 37% CH_4, 65%NO)

Food Processing Equipment

Food Processing Equipment

- Drying
- Washing
- Baking
- Cooking
- Refrigerating
- Freezing
- Concentrating
- Pasteurizing
- Scalding
- Rendering

Equipment – Food Drying (Batch)

Solid- Heat Sensitive

- Rotary Dryer

Solid- Not Heat Sensitive

- Bin Dryer
- Kiln Dry
- Cabinet Dryer
- Sun/Solar Dryer
- Microwave/Dielectric Dryer
- Fluidized Bed Dryer

Gas-Fired Drum Fryer

Food Drying (Batch) - Details

Food Drying- the essential principle underlying the drying of foods is dehydration, or the removal of water from food. Hot air used in various types of air dryers is a common method of food preservation.
Divided into two groups: Solids that are heat sensitive and solids that are not.

- **Rotary:** Energy Intensity: 1,400-9,700 Btu/lb of water in product. Stainless steel cylinder rotating at slight incline with heat provided by natural gas burners or steam tubes. Used for solid, small, strong fruits/vegetables. Good mixing and rapid drying. Favored for cereals that stick together on belt or conveyor dryers. Impact and abrasion degrades some products.
- **Bin:** Energy Intensity: High compared to other dryers. Heated air blown up through wire mesh at bottom of cylindrical or rectangular vessel. Used for strong, low moisture fruits/vegetables. Quantity processing helps equalize moisture levels. Often best choice as buffer between other dryers or packaging, or as finishing step.
- **Kiln:** Energy Intensity: No data, but probably less efficient than other hot air dryers. Hot air flows through multiple product layers in tall (typically 20') chambers constructed above gas furnace. Used for fruits/vegetables such as apple rings and hops. Simple construction and low installed costs. Long drying times and uneven drying rates limit use for food processing.
- **Cabinet/Tray:** Energy Intensity: 1,575-3,200 Btu/lb of water in product. Insulated cabinet with shallow, mesh-bottomed trays. Used for moderate moisture fruits/vegetables. Variable product quality due to uneven airflow. Good for smaller operations due to low capital cost and flexibility.
- **Sun/Solar Dryers:** Systems range from simple product-filled trays stacked in outdoor fields to cabinet units with electric fans that circulate sun-heated air. Works well with high sugar, acidic fruits. Limited application due to food spoilage over lengthy drying periods.
- **Fluidized Bed:** Energy Intensity: 1,800-9,600 Btu/lb of water in product. Heated air blown up through perforated plate or screen. Used for small, strong vegetables, grains, powders, herbs. Quick, uniform drying. Requires careful control to entrain product. Higher electric costs due to fan needs.

http://foodtechinfo.com/foodpro/index_gas_technologies/dryers_-_rotary/

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Equipment – Food Drying (Continuous)

Solid- Heat Sensitive

- Rotary Dryer
- Pneumatic/Ring Dryer

Solid- Not Heat Sensitive

- Conveyor/Band Dryer
- Drum Dryer
- Microwave/Dielectric Dryer
- Fluidized Bed Dryer
- Spray Dryer
- Trough Dryer
- Tunnel Dryer
- Radiant Dryer

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Food Drying (Continuous) - Details

Pneumatic/Ring: Energy Intensity: No data available. Product dries while suspended in vertical column of hot air. Produces dried gravy/soup mixes, starches, dehydrated mashed potatoes (best for products with less than 40% water). Rapid drying rates, high production rates and low capital costs.
Conveyor/Band: Energy Intensity: 1,700-28,000 Btu/lb of water in product. Conveyor carries product through series of hot air zones (typically 10' wide by 60' long, divided into three zones). Used for cereals, fruits/vegetables, baked goods, nuts. Efficient and suited to large variety of applications. Often used in conjunction with bin dryer to complete drying.
Drum Dryers: Energy Intensity: 2,350-2,700 Btu/lb of water in product. Heated drum evaporates moisture; dried product scraped from drum. Used for liquids and slurries such as mashed potato flakes and yeast. Efficient. High throughput rates. High capital cost. Generally limited to only one product.
Microwave Dryers: Energy Intensity: 1,500 Btu/lb of water in product. Conveyor moves product through zones of electromagnetic radiation which cause water molecules to vibrate and generate heat. Mostly used for pasta; also fruits/vegetables. Efficient and rapid, but uneven drying. Quality problems result with thicker food products.
Dielectric Dryers: Energy Intensity: 1,500 Btu/lb of water in product. Plates—electrically energized with rapidly reversing, opposing polarity—cause water molecules to vibrate and rise to surface of product; automation achieved with mechanized handling system and groups of plates. Mostly used for pasta; also fruits/vegetables. Efficient and rapid, but uneven drying. Requires careful matching of plates to product shapes.
Fluidized Bed: Energy Intensity: 1,800-9,600 Btu/lb of water in product. Heated air blown up through perforated plate or screen. Used for small, strong vegetables, grains, powders, herbs. Quick, uniform drying. Requires careful control to entrain product. Higher electric costs due to fan needs. Automatic systems used to move product between trays. Recent developments include "torbed" and spin-flash designs.

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Food Drying (Continuous) – Details

Spray Dryers: Energy Intensity: 1,520-3,000 Btu/lb of water in product. Stream of hot gases evaporates moisture from an atomized mist of liquid product; dried solids separated from gas stream. Used in production of powdered milk, instant coffee, cornstarch. Produces highly uniform powdered product. High production rates; process times of 10 seconds or less. Appropriate only for high-moisture products.
Trough: Energy Intensity: 1,700-28,608 Btu/lb of water in product. Trough-shaped, mesh conveyor belt passes over rollers and hot air that constantly re-mix and dry product. Used to dehydrate peas and small vegetable pieces. Significantly increases throughput rates compared to older tunnel dryers.
Tunnel: Energy Intensity: 1,700-28,608 Btu/lb of water in product. Food-laden trays on moveable trucks move through insulated, heated tunnel. Flexible to accommodate a variety of fruits/vegetables. Labor intensive to load/unload trays. Older, outdated version of conveyor/band dryer.
Radiant: Energy Intensity: 1,700-2,730 Btu/lb of water in product. Infrared radiation—generated by natural gas burners or electric resistance heating elements—evaporates moisture in product. Used for pasta. Assures little product contamination. Requires high product temperatures and results in uneven drying and product degradation
http://foodtechinfo.com/foodpro/index_gas_technologies/dryers_-_pneumatic_ring_continuous/
http://foodtechinfo.com/foodpro/index_gas_technologies/dryers_-_conveyor-2/

Equipment – Food Drying (Continuous)

Liquid- Heat Sensitive

- Foam Mat Dryer
- Spin Flash Dryer

Liquid- Not Heat Sensitive

- Vacuum Band
- Shelf Dryer

Food Drying (Continuous) – Details

Liquid Heat Sensitive and Non Heat Sensitive

Foam Mat

- Energy Intensity: 1,700-28,608 Btu/lb of water in product. Perforated conveyor carries a 1/10th-inch foam layer of product through dryer. Processes fruit juice that is first converted to a foam. Dries juice three times faster than unfoamed juice. High capital costs. Requires large surface area. Limited to production of powdered fruit juices. Variation of conveyor dryer

Spin Flash

- Energy Intensity: 1,800-9,600 Btu/lb of water in product. Similar to a fluidized bed dryer, but with a rotating base to assist entrainment of dried product. Used for small and powdered products. Quick, uniform drying. Improves product entrainment

Vacuum Band

- Energy Intensity: No data available. Steel band containing spread of product is passed over two drums—one heated, second cooled—then scraped from band when dry; use of partial vacuum during process speeds evaporation. Used for high-moisture foods that can be slurried. Wide range of products, especially puff-dried foods. High capital cost. Low production rates

Shelf

- Energy Intensity: No data available. Product spread on trays and heated in partial vacuum to speed evaporation, then scraped from trays; more closely resembles batch process. Used for high-moisture foods that can be slurried. Wide range of products, especially puff-dried foods. High capital cost. Low production rates

http://foodtechinfo.com/foodpro/index_gas_technologies/dryers_-_spin_flash_continuous/

Equipment - Washing

Batch

- Vegetable Washer

Continuous

- Belt Vegetable Washer
- Basket/Cylinder Vegetable Washer

Washing - Details

Washing- vegetable washers use an intensive, but gentle water rinse or bath to remove surface dirt from root vegetables such as carrots, potatoes, turnips, radishes as well as fruits and nuts.

Batch Vegetable Washer

Energy Intensity: 100-500 Btu/lb of product. Horizontal drum circulating in housing fitted with multiple spray washing nozzles. Used to wash root vegetables such as carrots, potatoes, beets; also fruits and nuts. Lower throughput. Higher material handling requirements. Use limited to smaller operations

Continuous Belt Vegetable Washer

Energy Intensity: 100-500 Btu/lb of product. Metal mesh belt transports product through tanks of water for gentle washing/rinsing. Used to wash root vegetables such as carrots, potatoes, beets; also fruits and nuts. Less product degradation than with other system. Less effective at removing surface dirt than basket systems

Continuous Basket Vegetable Washer

Energy Intensity: 100-500 Btu/lb of product. Series of tanks and mechanism to move baskets from tank to tank. Used to wash root vegetables such as carrots, potatoes, beets; also fruits and nuts. Independent tanks allow for different cleaning temperatures and chemicals. Single system adaptable to a very wide range of vegetables

Continuous Cylinder Vegetable Washer

Energy Intensity: 100-500 Btu/lb of product. Product tumbled in water bath in long, horizontal, inclined cylinders. Used to wash root vegetables such as carrots, potatoes, beets; also fruits and nuts. Inclined tank assists movement of product through washer. Product cleanliness enhanced by flowing water in opposite direction of products

Equipment – Baking Ovens

Batch

- Draw Plate/Rack
- Deck
- Rotary Hearth
- Reel/Revolving Tray

Continuous

- Lanham/Spiral
- Single Lap
- Double Lap
- Tunnel/Band/Traveling Hearth

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Food Processing Line

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Bakery Conveyor Belt

Baking Ovens - Details

Batch

- **Baking Ovens-** of all food manufacture workers, 19% work in establishments the make bakery goods. And, ovens are the heart of a baker. Baking is he process by which heat is used to remove moisture from grain-based products such as breads, cakes, cookies, and crackers.
- **Draw Plate/Rack:** Energy Intensity: 125-375 kBtu/h. Tall stainless steel box containing racks on a rotating turntable that can accommodate up to 100 trays. Used to produce bakery products. Rotating turntable assures even baking. Compact size allows for multiple ovens and variety of products. Superior temperature control. Preferred by small to mid-size bakeries. Usually fueled by natural gas, but can be propane or electric.
- **Deck Oven:** Energy Intensity: 20-120 kBtu/h; 6-12 kW. Multiple, independent baking chambers mounted on top of one another. Used for smaller quantities of specialty baked goods. Flexible – chambers can bake simultaneously at different temperatures. Minimal mechanical movement to disturb sensitive products. Natural gas and electric models available.
- **Rotary Hearth Oven:** Energy Intensity: Data unavailable. Circulates food through oven on trays; loading and unloading take place though same door using a paddle called a peel. Used to produce baked goods. Low ceiling provides solid-bottom-heat and properly proportioned top radiation heat. Requires large work area. Limited flexibility. Frequently occurring hot spots. Usually natural gas, but available for propane or electricity.
- **Reel/Revolving Tray Ovens:** Energy Intensity: 500-750 Btu/lb of product. Trays mounted Ferris-wheel style on horizontal axle and rotated in high baking chamber. Used for bakery products in operations with low-production volume, limited floor space or low-volume specialty products in large bakeries. High heat requirements. Uneven heat distribution. Limited temperature control. Difficulty maintaining product quality due to high relative humidity in upper zone.

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Baking Ovens - Detail

Continuous

- **Lanham-Spiral Oven:** Energy Intensity: 500 Btu/lb. Conveyor spirals product through proofing and baking chambers to exit at bottom of oven; direct gas-fired by ribbon burners running parallel to product travel direction. Used for fragile dough products. Reduced product loss. Multiple heating zones in oven chamber. High production rates.
- **Single Lap:** Energy Intensity: 450-1,050 Btu/lb. Trays carry product back and forth through baking chamber one time. Used for bread baking. Superior performance compared to double lap style. Simpler design, minimum ductwork. Long horizontal runs. Extensive steam zone.
- **Double Lap:** Energy Intensity: 450-1,050 Btu/lb. Similar design to single lap, but trays pass through chamber twice. Used for bread baking. Maximizes utilization of floor space. Difficult to achieve precise temperature control.
- **Tunnel/Band/Traveling Hearth Oven:** Energy Intensity: 400-2,000 Btu/lb. Solid or perforated steel or wire mesh conveyor band travels in straight line through series of baking zones with product loaded and unloaded at entry/exit ends. Used to bake cookies and crackers. Suited to variety of pan sizes. Precise top and bottom heat control and ideal steam conditions. Easy tray stabilization. Higher initial cost.

Equipment - Cooking

Vegetables

- Tank Blancher
- Screw Conveyor Blancher
- (BC)-Hydrostatic Water Seals
- Tubular Blancher
- Belt Conveyor/ Water Curtain
- (BC)-No End Seals

Canned Products

- Crateless Retort
- Continuous Rotary
- Autoclave
- Hydrostatic Sterilizer

Chicken Pieces & Fish

- Bottom-Fired Fryer
- Heat Exchanger Fryer
- Immersion-Tube Fryer

Processed Beef & Pork

- Flame Impingement Oven
- Hot Air Oven

Cooking - Details

Cooking- is usually the last things done before foo is packaged or consumed. It includes frying, sterilizing canned products and blanching, the rapid heating of fruits/vegetables to stop the enzyme action that causes deterioration.

Vegetables:

Tank Blancher : Energy Intensity: 400-500 Btu/lb of product. Stainless steel tank with steam-heated water and sieve for draining product. Used to stop enzyme action that deteriorates flavor, texture and nutrients in fruits/vegetables. Not suited to automatic operation and rarely used in modern food processing facilities. Less efficient due to significant steam venting

Tubular Blancher : Energy Intensity: 300-400 Btu/lb of product. Holding tank, stainless steel pipes (several inches in diameter and. hundreds of feet long) and sieve in which product is preheated, scalded or briefly boiled, and strained. Used to stop enzyme action that deteriorates flavor, texture and nutrients in fruits/vegetables. Efficiencies gained through capture of excess steam and water recirculation. Water-based blanchers generally more efficient than steam-based

Screw Conveyor Blancher: Energy Intensity: 300-400 Btu/lb of product. Round-bottom, stainless steel vessel with an electrically powered, rotating screw that moves product from entry to exit as steam is injected into vessel under screw conveyor. Used to stop enzyme action that deteriorates flavor, texture and nutrients in fruits/vegetables. Less efficient than tubular blanchers due to less steam condensation and venting of excess steam. Water-based blanchers generally more efficient than steam-based

Belt Conveyor/Water Curtains : Energy Intensity: About 600 Btu/lb of product. A belt conveyor blancher with water sprays at the exit point to capture escaping steam and cool product. Used to stop enzyme action that deteriorates flavor, texture and nutrients in fruits/vegetables. Slightly more efficient than basic belt conveyor. Captures excess steam, reducing risk of unsanitary conditions. Provides needed product cooling. Water sprays reduce available blanching area Steam losses still occur through roof vent ducts. Steam-based blanchers generally less efficient than water-based …Continued

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Cooking - Details

Belt Conveyor/Hydrostatic Water Seals : Energy Intensity: 450 Btu/lb of product. A belt conveyor blancher in which the conveyor travels underwater as it passes water seals at the entry and exit points. Used to stop enzyme action that deteriorates flavor, texture and nutrients in fruits/vegetables. Improved efficiency due to condensation of process steam by water seals. Requires longer system than one without seals. Efficiency losses result from overflow of hot water from condensed process steam. Steam-based blanchers generally less efficient than water-based

Belt Conveyor/Hydrostatic Water Seals: Energy Intensity: About 400 Btu/lb of product. A belt conveyor with water seals and the addition of Venturi nozzles to the steam injection system; Venturi design increases flow velocity and recycles steam from top of blancher into a tube and the nozzles. Used to stop enzyme action that deteriorates flavor, texture and nutrients in fruits/vegetables. Significantly improved efficiency – comparable to water-based blanchers

Canned Products:

Crateless Retort: Energy Intensity: 100-300 Btu/lb. Sealed cans loaded into water-filled oven, subjected to 250°F steam, then cooled. Used to sterilize canned products. Simple and flexible. Adaptable to automation and virtually any can size. Efficient – steam and water recycled. Higher energy use than rotary cookers or hydrostatic sterilizers

Autoclave ; Energy Intensity: 100-500 Btu/lb. Steam tube-jacketed batch oven heats meat to be rendered to 280°F for several hours at three atmospheres of pressure; heats canned products to 250°F; may be fitted with fans to facilitate hot air movement in chamber. Used to render meat by-products and sterilizing canned goods
Suitable for a wide range of products. Flexible for small facilities and smaller production runs

Continuous Rotary Cooker: Energy Intensity: 100-300 Btu/lb. Canned products travel a spiral path through two horizontal, cylinder-shaped chambers; first chamber sterilizes, second chamber cools. Rotary pressure sealed transfer valve at entry/exit points maintains steam and pressure needs during continuous process. Used to sterilize canned products. Can rotation on spiral track enhances even heat transfer. Multiple chambers allow for specific heating/cooling patterns. Requires less steam than crateless retort system. Less labor intensive. System can handle smaller cans than crateless system …Continued

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Cooking - Details

Hydrostatic Sterilizer: Energy Intensity: 100-300 Btu/lb. Canned products travel on conveyor down a water column into steam dome, through several passes in the steam zone, and into an exit water column; water column keeps steam in dome and provides pressurization. Used to sterilize canned products. Suited to a large variety of can sizes. Requires significant ceiling height to accommodate water column and may be located outdoors

Chicken Pieces & Fish:

Bottom-Fired Fryer: Energy Intensity: 1,450-5,900 Btu/lb. Small natural gas-fired burners below fryer kettle heat oil in which meat pieces are partially or totally immersed. Least expensive of all conventional industrial fryers. Shallow kettle reduces oil requirements and promotes rapid oil turnover. Accumulation of solid particles reduces heat transfer rate and accelerates oil degradation; can be alleviated by a cold well with an oil-circulation pump. Generally least efficient of all conventional industrial fryers

Immersion Tube Fryer : Energy Intensity: 975-4,550 Btu/lb. Tubes run across width and above bottom of kettle carrying hot combustion gases to heat frying oil. Usually natural gas fuelled, but can use fuel oil or electric coil (in areas with low electric prices). Most common fryer for industrial/commercial use. Cooler zone below immersion tubes eliminates problems of solids accumulation. Requires large amount of oil to achieve proper fill height. More difficult to clean than other types of fryers

Heat Exchanger Fryer : Energy Intensity: 950-3,825 Btu/lb. Oil heated directly in shell-and-tube heat exchanger by combustion gases or by inert heat transfer medium, then circulated through frying kettle. Natural gas most common fuel, but oil is an option. Reduced oil degradation and extended oil life. Little-used, alternative design heats inert heat transfer medium in combustion chamber which is pumped through pipes in bottom of fryer; advantage of accurate temperature control offset by high operating costs and problems similar to bottom-fired fryers

…Continued

Cooking - Details

Processed Beef & Pork:

Flame-Impingement Oven: Energy Intensity: 400-1,200 Btu/lb. Radiation and flame used to directly heat product traveling on conveyor through tunnel oven. Used to brown surface of meat. Flexible design allows use with hot air oven

Hot Air Oven: Energy Intensity: 400-1,200 Btu/lb. Products cooked by direct heat while traveling via conveyor through tunnel-design oven. Natural or forced convection circulate air and products of combustion. Automatic temperature controls adjust ribbon burners positioned above and below products. Used for processed beef and pork products. Natural gas most common fuel, but propane, butane, fuel oil and solid fuels can be used Independent temperature adjustment in multiple zones

http://foodtechinfo.com/foodpro/index_gas_technologies/fryer_-_immersion_tube/

Equipment - Refrigeration

Cryogenic
- Cryogenic Refrigeration

Mechanical
- Mechanical Refrigeration

Thermal
- Thermal Refrigeration

Poultry Spray Chilling
- Fluid Chilling

Refrigeration - Details

Refrigeration- maintains food at controlled, low temperatures to keep enzymes inactive and inhibit the growth of microbes. Mechanical refrigeration is the workhorse of the food industry, account for 90% of industry chilling applications

Cryogenic Refrigeration: Energy Source: Electricity. Use of low-temperature refrigerant to either absorb heat from another refrigerant or air in a heat exchanger or to directly chill product by immersion. Commonly used cryogenic refrigerants include liquid nitrogen, solid carbon dioxide and liquid carbon dioxide; approximately twice as much carbon dioxide used by food processors compared to liquid nitrogen. Limited application due to high cost (about four times) compared to mechanical refrigeration. Best used for temperatures far below freezing (-100°F); most appropriate below -150°F

Mechanical Refrigeration: Energy Source: Electricity, but natural gas engines have replaced electric motors on some systems. Refrigerant in closed loop system moves heat from one part of system to another

Loop consists of:

- Compressor – compresses refrigerant (usually ammonia) to hot, high-pressure gas
- Condenser – refrigerant releases heat where it becomes a high-pressure liquid
- Expansion Valve – cools refrigerant, making it a low-pressure liquid downstream of valve
- Evaporator – refrigerant becomes a gas and absorbs a great deal of heat
- Efficiency (coefficient of performance) ranges from less than 1 to more than 3. Accounts for 90% of industry chilling applications

…Continued

Refrigeration - Details

Thermal Refrigeration: Energy Source: Electricity. Uses a thermal source operating in an absorption cycle. Absorption cycle loop consists of:

- Generator – ammonia solution heated, sending high-pressure water vapor to condenser
- Condenser – Water vapor cooled to high-pressure liquid
- Evaporator – Water flows through expansion valve into low-pressure evaporator where it evaporates and absorbs heat
- Absorber – Water vapor absorbed by concentrated ammonia solution and returned to generator
- Fewer moving parts than conventional systems. Can use waste heat from other processes (i.e., cogeneration). Higher efficiencies possible from double and triple-effect absorption cycles. Higher capital, cooling tower and installed costs

Fluid Chilling: Energy Source: Electricity, some natural gas. Energy Intensity: 250-1,700 Btu/lb of product. Chilled liquid sprayed on bagged product in tunnel freezer. Chilled liquid—usually propylene glycol, brine, glycerol, calcium chloride solution or other non-toxic chilling substance. Used to freeze products such as poultry in plastic bags. Sturdy, secure bags needed to prevent contact between chilling liquid and product

http://www.cesgroup.com/en/cryogenic-equipment/food/cryogenic-refrigeration/cryogenic-tumbler
http://www.sconinc.com/products/natural-gas-processing/mechanical-refrigerationdewpoint-control-plant/
http://www.vikingcold.com/blog/2016/4/21/m3ldwu9hr61xmary3iw7r1m870twzn
http://www.spray.com.au/markets_and_applications/carcass-spray-chilling.aspx

Equipment - Freezing

Chilled Air

- Still Air Cooling — Air Blast Cooling
- Spiral Belt Freezer — Fluidized Bed Freezer
- Stationary Tunnel Freezer — Mechanized Tunnel Freezer

Surface Chilling

- Plate Freezer — Scraped Surface Freezers

Fluid Chilling

- Fluidized Bed Freezer — Immersion Freezer

Cryogenic

- Liquid Nitrogen — Carbon Dioxide

Freezing - Details

Freezing- Food preservation by freezing involves the same principles as preservation by drying. Water is unavailable for the growth of harmful bacteria because it has become ice. Air blast chillers/freezers are the most common technology in the food industry.

Still Air Cooling: Energy Intensity: 250-1,700 Btu/lb of product. Air cooled mechanically (electricity) or thermally (natural gas) using fans and natural circulation to assist heat transfer. Used for long-term storage of meat carcasses and ice cream hardening. Limited application due to slow heat transfer rates. Results in ice build-up from water sublimation from stored products.

Air Blast Cooling: Energy Intensity: 250-1,700 Btu/lb of product. Air blast unit blows mechanically or thermally chilled air over product. Used for storage of fruits/vegetables and meats. Higher heat transfer rates than still air chillers – 2 to 5 times greater. Rapid cooling prevents spread of bacterial growth.

Spiral Belt Freezer : Energy Intensity: 250-1,700 Btu/lb of product. Metal mesh belt conveys product through freezer using air blast techniques and mechanical or thermal cold air generation systems. Mesh belt facilitates rapid initial cooling. Upward spiral configuration conserves space. Reduces material handling and product degradation Self-stacking belt design (each tier of spiral rests directly on top of tier below) simplifies transport mechanism and reduces risk of contamination.

Fluidized Belt Freezer: Energy Intensity: 250-1,700 Btu/lb of product. Mechanically or thermally cooled air blown up through perforated tray or conveyor. Quickly freezes fruits and vegetables without clumping. Heat transfer rates five times greater than tunnel or spiral belt freezers. Suitable only for products small enough to be fluidized. Higher operating costs than tunnel or belt freezers.

Stationary Tunnel Freezer : Energy Intensity: 250-1,700 Btu/lb of product. Insulated room with either doors (batch system) or air curtain (continuous system) in which mechanically or thermally cooled air is circulated. Acceptable for a wide variety of products. Even cooling if trays consistently and evenly loaded. Heat transfer rates comparable to air blast chillers, 2 to 5 times greater than still air chillers. …Continued

Freezing - Details

Mechanized Tunnel Freezer: Energy Intensity: 250-1,700 Btu/lb of product. Combines air blast and stationary tunnel technology to freeze products loaded onto wheeled pallets or conveyor in a continuous process. Offers automated product handling.

Plate Freezer: Energy Intensity: 250-1,700 Btu/lb of product. Direct contact cooling on vertically or horizontally arranged stainless steel plates. Used for fish, poultry pieces and cartons of vegetables. Compact size. Quickly freezes large products. Higher heat transfer rates than chilled air freezers. Temperature sensors on plates track product surface temperature and aid process controls

Scraped Surface Freezers: Energy Intensity: 250-1,700 Btu/lb of product. Liquid or semi-solid product spread over inside walls of freezer barrel that is mechanically or thermally chilled by jackets containing ammonia, brine or other refrigerant, then scraped off. Primarily used for ice cream production. Rapid freezing with very small ice crystals

Fluidized Bed Freezer: Energy Intensity: 250-1,700 Btu/lb of product. Mechanically or thermally cooled air blown up through perforated tray or conveyor carrying product through chilling fluid; upward air flow entrains product. Chilling fluid—usually propylene glycol, brine, glycerol or calcium chloride solution. Quickly freezes fruits and vegetables without clumping. High rates of cooling

Immersion Freezer: Energy Intensity: 250-1,700 Btu/lb of product. Product immersed in chilling fluid such as propylene glycol, brine, glycerol or calcium chloride solution. Used for products requiring quick cooling after heating, such as canned frozen orange juice, fried fish, blanched vegetables. Very rapid cooling. High heat transfer rates – five time plate chillers and 20 times chilled air systems. Greater tolerance of product shape and orientation variations

Liquid Nitrogen: Energy Intensity: 250-1,700 Btu/lb of product. Combination of straight belt and spiral technologies used to immerse product in liquid nitrogen (-321°F). Used to freeze meats and fruits/vegetables. Heat transfer rate three times greater than fluid immersion chillers. No product contamination from immersion fluid. Smaller, cheaper process lines than chilled air or liquid systems. Rapid cooling improves quality of most products. Proper venting required. No on-site refrigeration equipment …Continued

Freezing - Details

Carbon Dioxide: Energy Intensity: 250-1,700 Btu/lb of product. Combination of straight belt and spiral technologies used to immerse product in liquid carbon dioxide. Used to freeze meats and fruits/vegetables. Very high heat transfer rates. No product contamination from immersion fluid, but proper venting required. Smaller, cheaper process lines than chilled air or liquid systems. Rapid cooling improves quality of most products. No on-site refrigeration equipment. Proper design or adequate freezing time prevents dry-ice snow on product

http://www.samifi.de/en/index.php?option=com_content&task=blogcategory&id=7&Itemid=39
http://www.dsi-as.com/products/dsi-horizontal/
http://www.cesgroup.com/en/products/food/inventory/cryogenic-inventory/immersion-freezer/ces-im-lin-0-5mx0-6m-potl
http://www.cesgroup.com/en/cryogenic-equipment/food

Equipment - Concentration

Evaporation

- Batch Pan — Natural Circulation
- Rising-Falling Film Tubular — Rising Film Tubular
- Falling Film Tubular — Wiped Film
- Rising/Falling Film Plate — Falling Film Plate
- Paravap — Paraflash

Freeze Concentration

- Freeze Concentration

Reverse Osmosis

- Reverse Osmosis

Concentration - Details

Concentration- removes water from food products by **evaporation or reverse osmosis**. Falling film evaporators are dominant in the food industry, but newer technologies have evolved from the falling and rising film concepts.
Batch Pan : Spherical vessel heated by steam jacket or heating element; water collected in separate condenser. Primarily used for whole-fruit products, such as jams and jellies. Oldest type of industrial evaporator. Large capacities (5,000 to 10,000 gallons). Low Heat Transfer Coefficients (HTC). Long cycle times. Vacuum and agitation help speed evaporation
Natural Circulation : Short tube bundle in batch pan or external shell and tube heater; natural circulation causes product to rise in tubes and circulate through main vessel. Used as reboiler at base of distillation column. Improves Heat Transfer Coefficients over batch pan method
Rising-Falling Film Tubular: Combination of rising film and falling film tubular methods; first half of process configured to rising film, second half is falling film process. Used for dairy products and concentrated orange juice. 50% reduction to tube height
Forced Circulation : Natural circulation-type system with pump to force product upward in tubular heater; product continuously circulates between separator (where it flash vaporizes) and heat exchanger; hydrostatic head at top of tube plate prevents boiling. Primarily designed to process liquors. Rapid circulation of product through heat exchanger. Requires large diameter piping and high-capacity pumps. High operating costs
Falling Film Tubular: Vertical tube heated by steam on the outside to create a vacuum that uses gravity to draw condensate and water vapor downward inside tube. Specially designed nozzles or spray distributors improve uniformity. Used for dairy products and concentrated orange juice. Higher cost for process control offset by high throughput rates
Wiped Film : Water removed as product flows down inside of single, large-diameter pipe heated on outside by steam; inside wall of pipe wiped by internal rotor. Used only for viscous, highly concentrated products such as corn or sugar syrup. High-temperature, high-pressure steam needed due to limited surface area of single tube. Expensive to construct and operate …Continued

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Concentration - Details

Rising/Falling Film Plate: Housing containing one or more sets of rising plate, steam plate, falling plate, steam plate; heat from steam plates promotes evaporation and gravity flows product through a slot from the rising plate to the falling plate where evaporation continues. Used to concentrate juices and dairy products. Energy efficient. Construction less costly and ceiling-height needs lower than with tubular evaporators. Better product quality due to shorter retention times and lower temperatures
Falling Film : Adaptation of rising/falling film plate by removing rising plate. Used to concentrate fruit juices and evaporated milk. Reduces system complexity and process time compared to rising/falling film plate. Reduces product degradation. Improved moisture removal rates, especially with multiple-effect systems. Larger vapor ports required
Paravap: Product pumped under pressure into steam-heated plate heat exchanger, then to a lower pressure vessel where product and water vapor are separated. Used for viscous products such as caramel, hard sugar candies. High heat transfer rates, reduced retention times and product recirculation eliminated. Less high-temperature exposure improves product quality. Can be used as finishing step after other concentrating processes
Paraflash : Paravap system with application of backpressure in heat exchanger to prevent product boiling; moisture removal achieved by flash vaporization as product enters separation vessel. Used for products with high solid content such as cheese, whey, brewer's yeast; also used to concentrate brewery wastes, paint plant wastes, pharmaceutical products. Retains high heat transfer rates offered by paravap systems
Freeze Concentration: Process of chilling product to form and subsequently remove ice crystals using technology such as a scraped surface freezer and spray drying. Used for temperature sensitive products such as dairy products, juices, coffee. More expensive than thermal processes. Primarily used for high-value products
Reverse Osmosis: Product forced through membrane that allows passage of only water. Used for juices, wine, cheese, whey, coffee, sugar solutions. Serial systems allow for high concentration levels. Preserves product quality attributes such as color, flavor, nutrients
http://www.foodbev.com/news/geas-new-freeze-concentration-technology-lowers-costs-by-up-to-40/

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Equipment - Pasteurization

Milk Pasteurization

- Ultra Pasteurization
- Batch or Low-Temp-Long-Time (LTLT) Treatment
- Continuous of High-Temp-Short-Time (HTST) Treatment
- Ultra-High-Temp (UHT) Pasteurization

Meat Pasteurization

- Automatic Cabinet Pasteurization
- Steam Vacuuming
- Hot Water Cleaning

Irradiation Pasteurization

- Irradiation Pasteurization

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Pasteurization - Details

Pasteurization- is a process of heating a product to a specific temperature for a controlled period of time to destroy disease causing microorganisms. Food irradiation is the only new preservation technology developed this century.

Milk:

- **Ultra Pasteurization:** Plate heat exchanger method applies indirect heat or direct heating method where either steam injected into milk or milk passes through steam chamber; milk heated to 138°C for not less than two seconds. Used to destroy disease-causing microorganisms in milk. Reduces pasteurization time compared to LTLT and HTST. Pasteurized product must be refrigerated
- **Batch or Low-Temp-Long-Time (LTLT) Pasteurization** : Product heated and stirred in vat surrounded by circulating water, steam or heating coils of water or steam at 63°C for not less than 30 minutes. Used primarily in ice cream production to destroy disease-causing microorganisms
- **Continuous of High-Temp-Short-Time (HTST) Pasteurization:** Plate heat exchanger, consisting of corrugated stainless steel plates heated by hot water, heats milk to 72°C for at least 15 seconds; cold raw milk is preheated in regenerator section of heat exchanger by flowing preheated milk in a counter current direction; pasteurized milk passes through regenerator section to preheat incoming raw milk. Used to destroy disease-causing microorganisms in milk. Reduces pasteurization time requirement
- **Ultra-High Temp Pasteurization** : Plate heat exchanger method applies indirect heat or direct heating method where either steam injected into milk or milk passes through steam chamber; milk heated to 138°C for not less than two seconds, but packaged in pre-sterilized containers in sterile environment. Used to destroy disease-causing microorganisms in milk. Reduces pasteurization time compared to LTLT and HTST. Homogenizes milk as it pasteurizes

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Pasteurization - Details

Meat

- **Automatic Cabinet Pasteurization** : Energy Intensity: 200-300 Btu/lb. Conveyor runs through 14 to 36 foot long steam cabinet in which nozzles and automatic spray arms deliver solution of saturated steam and antibacterial chemicals to raise carcass surface temperature to 180°F; final cold-water rinse cools carcass. Used to clean carcass, reduce contamination and pasteurize meat. Provides better pasteurization than manual method. Reduces labor cost. Risk of "cooking" meat due to excessive exposure to high-temperature steam
- **Steam Vacuuming** : Energy Intensity: 200-300 Btu/lb. Cabinet steam system configuration, except carcass sprayed with 280°F saturated steam for less than one second, then steam is vacuumed from carcass. Used to clean carcass, reduce contamination and pasteurize meat. More effective killing pathogens on surface of meat. Less risk of cooking meat. Less meat degradation
- **Hot Water Cleaning:** Energy Intensity: 200-300 Btu/lb. High-pressure water sprayer cleans surface of conveyor-suspended, slaughtered carcasses following dehiding and evisceration; water may be treated with acetic or lactic acid. Used to clean carcass, kill microorganisms and reduce contamination. Intensive labor needs limit use of manual systems to smaller operations. Continuous conveyor systems are installed more often

http://foodirradiation.org/Food%20Irradiation%20Updates/June2014.html

Equipment - Scalding

Poultry

- Manual Scalding
- Automated Hard Scalding
- Automated Medium or Sub-scalding
- Automated Soft or Semi-scalding

Pork

- Water Spray
- Steam Spray
- Water Immersion
- Dehiding

Scalding - Details

Poultry

- **Scalding-** involves the immersion of poultry or hogs in hot water to loosed feathers or hairs for removal, although in modern pork processing facilities steam scalding is replacing water immersion
- **Manual Scalding** : Energy Intensity: 100-200 Btu/lb. Open tank of water heated (140° to 150°F) by burner at bottom of tank or supplied by boiler hot water; product immersed in water. Used to loosen poultry feathers for removal. Low capital cost. Labor intensive. Difficult to achieve uniform scalding. Risk of contamination. Limited to smaller operations
- **Hard Scalding:** Energy Intensity: 100-200 Btu/lb. Overhead conveyor carries product through tanks of heated water (140°F for 45-90 seconds for waterfowl and 160°F for as little as 10 seconds for chickens); process may involve counter water flow or multiple tanks to control contamination from product entering tank. Used primarily to loosen feathers on waterfowl; can be used for chickens if skin removal is desired. Faster throughput and improved product consistency due to automation. Degrades skin requiring removal. Risk of bacterial growth
- **Medium or Subscalding:** Energy Intensity: 100-200 Btu/lb. Similar process to hard scalding, but lower temperatures and shorter process time (129° to 136°F at 60-120 second or 140° to 145°F for 15-30 seconds). Used to loosen feathers on mature chickens. Faster processing
- **Soft or Semi-scalding:** Energy Intensity: 100-200 Btu/lb. Similar process to hard and medium scalding with some equipment modification to accommodate high production rates and lower temperatures (124° to 130°F for 45 seconds). Used for broilers and roasters (chickens) and young turkeys. High rate of processing

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Scalding - Details

Pork

- **Water Spray:** Energy Intensity: 200-400 Btu/lb. Conveyor moves product through chamber equipped with hot water sprayers; water drained and disposed. Used to loosen hog hair for removal. Reduces hot water consumption. Cross contamination between carcasses and parts of carcasses eliminated. Replacing immersion scalding at some modern facilities
- **Steam Spray:** Energy Intensity: 200-400 Btu/lb. Conveyor moves product through steam cabinet equipped with multiple spray nozzles; water drained and disposed. Used to loosen hog hair for removal. Replacing immersion scalding at modern facilities; more common than water spray method at larger facilities. Higher throughput. More energy efficient than water immersion. More efficient transfer of thermal energy to skin than water spray. Cross contamination between carcasses and parts of carcasses eliminated
- **Water Immersion:** Energy Intensity: 200-400 Btu/lb. Overhead conveyor deposits product in tank of heated water; performed in batch process; crane may be used to remove product if detached from conveyor. Used to loosen hog hair for removal. Difficult to maintain critical temperatures to ensure product quality. Water spray and, more so steam spray, replacing immersion in modern facilities. Risk of spreading contamination from hog to hog
- **Dehiding:** Alternative to scalding or dehairing to remove hide of hog

Equipment - Rendering

Batch

- Dry Process

Continuous

- Dry-High Temperature
- Dry-Low Temperature

Rendering - Details

Rendering processes- the inedible material from the slaughter of cows, hogs, and poultry into useful products such as meat and bone meal, oils, and a high-protein base for soaps, medicines and candy. Rendering occurs by heating or cooking the material to separate water, oils and solids.

Dry Batch System

Energy Intensity: 442 Btu/lb of material input for all rendering process. Steam-jacketed cooker walls transfer heat (280°F) to render material; no direct contact between steam and material; steam-jacketed agitator may also be used. Used to render meat meal, bone meal and oils from slaughtered beef, pork and poultry. Found in smaller, older facilities. Replaced with larger, more efficient systems

Continuous Dry System

Energy Intensity: 442 Btu/lb of material input for all rendering process. Steam-jacketed horizontal cylinder with a screw or rotating drum to constantly turn and move material through cooker (280°F) zones to facilitate water evaporation and tissue breakdown; steam-jacketed agitator may also be used. Operating system under vacuum enhances water removal. Reduces cycle times compared to batch system. Higher throughput rates.

http://mavitecrendering.com/rendering-equipment/processing-section/supercookor/

Other Industrial Equipment

- Boilers
- Water Heating – Direct Contact
- Power Generation – Combined Heat & Power
- Absorption Chillers
- Engine-Driven Refrigeration
- Air Compressors
- Desiccant Dehumidification

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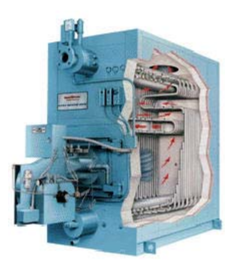
Industrial Equipment - Boilers

- There are many types of Boilers, but only two classifications: Firetube and Watertube
- Firetube: the combustion gases pass inside boiler tubes, and heat is transferred to water on the shell side. Scotch marine boilers are the most common type of industrial firetube boiler
- Watertube: water passes through the tubes while the exhaust gases remain in the shell side, passing over the tube surfaces
- http://cleanboiler.org/



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Boiler - Details

The function of a boiler in the steam cycle is to convert water into steam or hot water. A boiler's operation is the generation of steam, which acts as a medium to convey the energy of the fuel, which is in the form of heat, to a prime mover where that heat energy is converted into energy of motion or work. Boilers vary considerably in detail and design.

Most boilers may be classified and described in terms of a few basic features or characteristics. The most basic classification of boilers is according to the relative location of the fire and water spaces. By this method of classification, boilers are divided into two classes, FIRETUBE BOILERS and WATERTUBE BOILERS. Stationary boilers, such as those found in manufacturing plants, are also rated in terms of boiler horsepower for sizing purposes.

In firetube boilers, the combustion gases pass inside boiler tubes, and heat is transferred to water on the shell side. Scotch marine boilers are the most common type of industrial firetube boiler. The Scotch marine boiler is an industry workhorse due to low initial cost, and advantages in efficiency and durability. Scotch marine boilers are typically cylindrical shells with horizontal tubes configured such that the exhaust gases pass through these tubes, transferring energy to boiler water on the shell side. Scotch marine boilers contain relatively large amounts of water, which enables them to respond to load changes with relatively little change in pressure. However, since the boiler typically holds a large water mass, it requires more time to initiate steaming and more time to accommodate changes in steam pressure. Also, Scotch marine boilers generate steam on the shell side, which has a large surface area, limiting the amount of pressure they can generate. In general, Scotch marine boilers are not used where pressures above 300 psig are required. Today, the biggest firetube boilers are over 1,500 boiler horsepower (about 50,000 lbs/hr). Firetube boilers are often characterized by their number of passes, referring to the number of times the combustion (or flue) gases flow the length of the pressure vessel as they transfer heat to the water. Each pass sends the flue gases through the tubes in the opposite direction. To make another pass, the gases turn 180 degrees and pass back through the shell. The turnaround zones can be either dryback or water-back. In dryback designs, the turnaround area is refractory lined. In water-back designs, this turnaround zone is water-cooled, eliminating the need for the refractory lining.

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Boiler - Details

Water Tube Boilers

In watertube boilers, boiler water passes through the tubes while the exhaust gases remain in the shell side, passing over the tube surfaces. Since tubes can typically withstand higher internal pressure than the large chamber shell in a firetube, watertube boilers are used where high steam pressures (as high as 3,000 psi) are required. Watertube boilers are also capable of high efficiencies and can generate saturated or superheated steam. The ability of watertube boilers to generate superheated steam makes these boilers particularly attractive in applications that require dry, high-pressure, high-energy steam, including steam turbine power generation. The performance characteristics of watertube boilers make them highly favorable in process industries, including chemical manufacturing, pulp and paper manufacturing, and refining. Although firetube boilers account for the majority of boiler sales in terms of units, water-tube boilers account for the majority of boiler capacity.

Industrial Equipment - Water Heating – Direct Contact

- Alternative to a boiler for providing industrial process hot water
- Operate at atmospheric pressure eliminating the need for a full-time boiler engineer
- Delivers significantly higher efficiency and lower emissions compared to conventional heat exchanger technology.
- Heat is transferred from the hot combustion gases to the incoming water indirectly via one or more metal walled heat exchangers.
- Achieves efficiencies approaching 100% due to the direct, rapid transfer of heat from the hot combustion gases to the incoming water

Direct Contact Water Heater - Details

- Initially developed in the 70s through a grant from the DOE's Invention and Innovation Program, the direct contact water heater is promoted primarily as an **alternative to a boiler for providing industrial process hot water and space heating.**
- As a boiler alternative, direct contact water heaters offer several advantages. Unlike pressurized boilers, **direct contact water heaters operate at atmospheric pressure** eliminating the need for a full-time boiler engineer, boiler permits and annual inspections, and the higher insurance rates associated with a pressure system. The water heaters also do not require the chemicals and frequent maintenance of a boiler.
- The **higher efficiencies delivered by direct contact water heaters far surpass average boiler efficiency of 60 to 75%.**
- Direct contact water heaters boast a superior heat transfer system that delivers significantly higher efficiency and lower emissions compared to conventional heat exchanger technology.
- In conventional water heaters, **heat is transferred from the hot combustion gases to the incoming water indirectly** via one or more metal walled heat exchangers.
- **The direct contact water heater achieves efficiencies approaching 100% due to the direct, rapid transfer of heat** from the hot combustion gases to the incoming water.
- Efficiency is further enhanced by capturing heat that would normally be lost into the atmosphere with the exhaust gases. Low NOx burners and special firing chambers reduce carbon dioxide (CO2) and NOx emissions to levels low enough to meet the most stringent environmental requirements.

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Direct Contact Water Heater - Details

How It Works: The direct contact water heater consists of a cylindrical water vessel fitted with a low NOx burner that fires directly into the lower heating chamber and a heat transfer zone made up of stainless steel packing material located in the upper section. As water flows into the unit, it cascades over the packing material and is instantly heated as it comes into contact with the rising hot combustion gas and the burner flame. In models that assure potable hot water, a water-jacketed combustion chamber prevents impingement of the water on the flame and water contamination. The stainless steel packing material increases the contact area and slows the water flow, providing improved heat exchange. The combustion gases cool quickly as they give up their heat to the incoming water and exit the exhaust stack at near ambient temperatures. The heated water collects at the bottom of the tank where it is available for on demand use.
Capacity/Energy Input: Depending on brand and model, direct water heaters can deliver 20 to 7000 gallons per minute with energy inputs of 1.2 to 70 million Btus/hr.
Efficiency: 96% to 99.7%

Industrial Equipment - Power Generation – Combined Heat & Power

- DG is an efficient on–site power system that produces electric power and thermal energy for heat, steam or air conditioning
- CHP is an integrated energy system that can be modified depending upon the needs of the energy end user
- These systems simply capture and utilize excess heat generated during the production of electric power
- CHP systems offer economic, environmental and reliability-related compared to power generation facilities that produce only electricity
- By capturing and using the waste heat, these systems normally consume 50 percent of the fuel burned by a central power station to provide an equivalent amount of energy
- Because greenhouse gas emissions are related to the amount of fuel burned, CO2 production can also cut in half using a distributed generation system

www.understandingchp.com

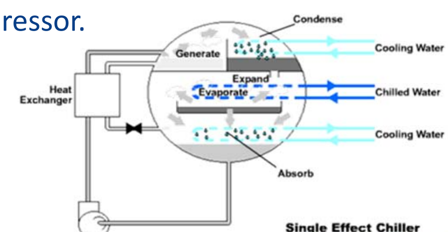
Power Generation - Details

- Distributed Generation is an efficient on–site power system that produces electric power and thermal energy for heat, steam or air conditioning.
- This form of power generation is known today by many names and acronyms. Cogeneration, or combined heat and power (CHP) are two.
- CHP is not a single technology, but an integrated energy system that can be modified depending upon the needs of the energy end user. These systems simply capture and utilize excess heat generated during the production of electric power.
- CHP systems offer economic, environmental and reliability-related compared to power generation facilities that produce only electricity.
- By capturing and using the waste heat, these systems normally consume 50 percent of the fuel burned by a central power station to provide an equivalent amount of energy.
- Because greenhouse gas emissions are related to the amount of fuel burned, $CO2$ production can also cut in half using a distributed generation system.

www.understandingchap.com will provide you information on the various technologies available to produce your own power with recoverable heat. By making continuous use of both electricity and thermal energy, you can save up to 35 percent on overall energy costs.

Industrial Equipment – Absorption Chillers

- Operate in much the same way as vapor compression chillers. Rely on temperature and pressure changes in a refrigerant to absorb and transfer heat from one area to another.
- A significant difference between vapor compression and absorption systems is the use of heat in the absorption chiller's "thermal compressor" rather than a mechanically driven compressor.



Absorption Chillers - Details

Natural gas absorption chillers operate in much the same way as vapor compression chillers. That is, they rely on temperature and pressure changes in a refrigerant to absorb and transfer heat from one area to another.
A significant difference between vapor compression and absorption systems is the use of heat in the absorption chiller's "thermal compressor" rather than a mechanically driven compressor. Heat for the absorption process can be supplied either directly by a gas burner or indirectly from recovered waste heat.

The number of heat exchangers in the system determines whether it is a single-effect or double-effect absorption chiller. Double-effect chillers capture some of the internal heat to provide energy to the generator and are more efficient than single-effect units. Although double-effect absorption chillers are more expensive than electric chillers, developments in controls and operating practices have led to lower maintenance requirements.

Another important difference between absorption and vapor compression chillers is the solution used in the vapor compression cycle. Water-cooled absorption systems use water as the refrigerant and a lithium bromide solution as the absorbent material. Air-cooled systems use ammonia as the refrigerant and water as the absorbent. Both options are environmentally benign and eliminate the harmful chlorofluorocarbons (CFCs) common to mechanical systems. The absorption process relies on the affinity of the two liquids for each other to achieve the temperatures and pressures required.

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Absorption Chillers - Details

How It Works
The process begins in the absorption system's thermal compressor—a generator, absorber, pump and heat exchanger. Heat from a burner separates the absorbent from the refrigerant and turns the refrigerant into a high-pressure vapor. In the condenser, the refrigerant gives up its heat to the outdoor atmosphere and returns to a liquid state. As the liquid moves through the throttling valve—similar to the expansion valve in a vapor compression system—into the evaporator, its temperature and pressure are reduced, enabling it to extract heat from the chilled water stream which circulates through indoor cooling coils. The refrigerant passes into the absorber where it is pulled into the absorbent solution (the absorption process) and pumped back to the generator where the process repeats.

Advantages of Absorption Chillers
Absorption chillers offer several noteworthy advantages. Like gas engine-drive chillers, absorption units can prove highly beneficial for peak shaving in areas with high demand charges, especially when teamed with electric chillers in a hybrid system. The ability for absorption chillers to use waste heat from incinerators, industrial furnaces or manufacturing equipment also greatly improves their cost effectiveness. Indirect fired chillers can operate using steam or hot water or integrate with on-site power generation. Single-effect absorption chillers require 167° to 270°F hot water or steam; double-effect units operate on 370°F, 115psig steam.

www.gasairconditioning.com

Industrial Equipment - Engine-Driven Chillers

- Used to cool a stream of chilled water, which in turn, is used in manufacturing to cool processes or sent to air coils to cool and dehumidify the air being delivered to the zones of a building
- Engine-driven cooling systems employ a conventional vapor compression cycle as shown in the following diagram
- Preferred technology due to cost advantage over electricity, engine-driven units have variable speed capability, making them more efficient than electric units to operate partial loads
- Engine jacket water and exhaust gas can be recovered and used to heat boiler feedwater, tank heating, regeneration of desiccants and for domestic hot water
- Using waste heat increases engine operating efficiency, which reduces total energy needs.

Engine Driven Chillers - Details

Chillers are used to cool a stream of chilled water, which in turn, is used in manufacturing to cool processes or sent to air coils to cool and dehumidify the air being delivered to the zones of a building. Smaller air-conditioning units, such as split systems and packaged rooftop units, typically do not employ chilled-water streams or cooling water streams, but rather use direct expansion (DX) refrigerant air coils to both directly remove heat from the condenser and to cool and dehumidify the conditioned air stream with the evaporator.

Engine-driven cooling systems employ a conventional vapor compression cycle. The main components of a vapor compression system are the compressor, condenser, expansion valve, and evaporator as shown in the following diagram. The four main steps in this cycle are also shown on the following page.

Vapor compression equipment typically uses one of three different types of compressors: reciprocating, screw or centrifugal. Reciprocating compressors are typically used for smaller applications of 200 tons or less. Screw compressors, such as the single screw or twin screw, are used for applications ranging from 100 to 1,250 tons. Centrifugal compressors, which can be single or multiple stage, are used for applications ranging from 100 to 10,000 tons.

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Engine Driven Chillers - Details

Mechanical chillers can be driven by any type of motor or engine, depending upon the compressor design. Industrial-grade or marine-derivative engines are typically used because of their long life and reduced maintenance intervals.

Engine-driven systems are the preferred technology in many cases, spurred on by a number of benefits. In addition to their cost advantage over electricity, engine-driven units have variable speed capability, making them more efficient than electric units to operate partial loads. This is particularly significant to the air conditioning market, which commonly operates at partial loads.

Further, engine jacket water and exhaust gas can be recovered and used to heat boiler feedwater, tank heating, regeneration of desiccants and for domestic hot water, reheating, swimming pool heating and other HVAC requirements. Using waste heat increases engine operating efficiency, which reduces total energy needs.

Industrial Equipment – Air Compressors

- Used extensively throughout industrial manufacturing facilities for machinery, power tools, controls etc
- The primary difference between an electric and gas air compressor is the prime mover.
- The natural gas engine is a variable speed driver that is ideally suited to power a rotary screw air compressor since it takes advantage of its positive displacement characteristics.
- The natural gas engine-driven air compressor conceptually consists of an engine, a compressor (air end), and a control system integrated together for performance, reliability, and serviceability.

Air Compressors - Details

Air compressors are used extensively throughout industrial manufacturing facilities for machinery, power tools, controls etc. A compressed air installation may consist of one large or multiple smaller compressors of sufficient size to meet the overall air requirement.

In a typical direct-drive rotary screw air compressor, ambient air enters through a filter on what is called the air end of the compressor. The compressor is driven by a prime mover and is filled with oil for smooth operation. The air and oil mixture flows into and is compressed by a rotary screw assembly.

After compression, the air and oil mixture flows through a separator tank to separate the oil from the air. The oil, which collects at the bottom of the separator tank, flows through an oil cooler and back to the air end after being filtered. The compressed air leaves the separator tank and is reduced in temperature by an after-cooler. Finally, water in the air is removed by a moisture separator before the air enters the industrial plant air system.

The primary difference between an electric and gas air compressor is the prime mover. The natural gas engine is a variable speed driver that is ideally suited to power a rotary screw air compressor since it takes advantage of its positive displacement characteristics.

The natural gas engine-driven air compressor conceptually consists of an engine, a compressor (air end), and a control system integrated together for performance, reliability, and serviceability. Although retrofits are possible, engine-driven air compressors should be viewed as a product offered by a manufacturer, not a collection of pieces which can be assembled in the back shop.

Industrial Equipment - Desiccant Dehumidification

- Dehumidifiers use specialized materials, called desiccants, to chemically remove moisture from air.
- The desiccant absorbs moisture from incoming air when the air comes in contact with it, then exhausts the moisture outside of the building.
- Gas-fired dehumidification uses either liquid or solid desiccants to remove water vapor from the air

Dehumidification - Details

Desiccant systems remove moisture from the air without cooling it, allowing for the separate control of temperature and humidity and saving costly energy. Gas desiccant systems can remove more than twice as much moisture from the air as a refrigeration system. This is because they generally require less than half the air volume required by conventional electric cooling systems to control humidity. Natural gas desiccant systems also complement conventional gas or electric air conditioning systems because drier air is easier to cool. This allows the cooling equipment to operate more efficiently and the system's air handling equipment to be downsized.
Consistent mold coolant temperature must be maintained for optimum results in the plastic injection molding process. Yet rapid cooling of the mold causes water vapor in the surrounding air to condense on the tool surfaces, which can lead to corrosion in addition to watermarks and cracks on the finished part. If coolant temperatures are raised to avoid condensation, cycle times become slower, production decreases, and resin processing parameters change.
Desiccant dehumidification provides year-round control and increased productivity by preventing condensation, eliminating slippery floors, improving refrigeration efficiency plus reducing the cooling load and defrost cycles. Controlling the environment results in lower operating costs and an improved bottom line for most facilities.
By removing moisture from the air, chilled water can be used instead of room temperature water to significantly decrease machine cycle time. As a result, parts cool faster, molding equipment lasts longer, and maintenance and retooling costs are reduced.
Gas-fired desiccant dryers offer the following benefits: Removes High Moisture. Reduces Corrosion through the Elimination of Condensation. Safer Working Conditions. Lowers Energy and Maintenance Costs. Fewer Molding Equipment Repairs. Produces Faster Cycle Times. Reduces Scrap . Lower Coolant Temperatures Made Possible

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Dehumidification - Details

Processes Desiccant systems can be used in three ways:
1. Spot dehumidifiers deliver dry air directly over the surface of the mold when it opens. This method uses a small dehumidifier and requires ductwork to bring the dehumidified air to the mold cavity.
2. Machine shrouding involves construction of a small chamber to encase the molding machine and limit the infiltration of moist air to the machine.
3. Full-area conditioning eliminates distribution ductwork. However, with a larger space to condition, the unit must be sized to compensate for room openings, people and the presence of other types of equipment.

Common Processes: Any manufacturing or processing function that is sensitive to humidity, temperature or microorganisms is a natural application for a dehumidification system including: Refrigerated warehouses, Plastic injection molding, Food process freezers, Clean rooms, Pharmaceutical encapsulation and packaging, Glass lamination, and Heat sensitive drying applications
How They Work: Gas-fired dehumidification uses either liquid or solid desiccants to remove water vapor from the air.
Liquid Desiccants: Liquid desiccant material is a highly stable, nontoxic solution that attracts moisture. As the air to be dehumidified comes into contact with the liquid desiccant, the moisture is absorbed into the solution. The amount of moisture taken out of the air is directly related to the concentration and temperature of the solution. The solution is then boiled off, and the moisture is removed and released into the atmosphere. This restores the solution's ability to reabsorb moisture and begin the cycle again.

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Dehumidification - Details

Solid Desiccants: Solid desiccants are used in a wheel-type system that resembles a round honeycomb. The holes serve as air channels, each coated with solid desiccant material. Air passes through the holes allowing the desiccant to absorb any moisture in the channels. As the desiccants continue to pick up moisture, their ability to absorb at 100 percent is diminished. This is where natural gas is used. While slowly rotating, 25 percent of the desiccant wheel is dried using a natural gas heat source. The heat evaporates the moisture, releasing it into the atmosphere, while the desiccants regain their maximum absorption ability.

Humidity control is essential to the comfort and health of building occupants, to indoor air quality, and, for industrial enterprises, to the manufacture and storage of products. Excess humidity can cause condensation, encourage the growth of molds, mildew and disease-causing bacteria, infiltrate the manufacturing process, damage stored products, and leave building occupants feeling hot and sticky. Dehumidification is especially important to grocery stores with large refrigeration units, indoor pools and skating rinks, the pharmaceutical, chemical, plastics and electronics industries, and to medical facilities, office buildings and educational institutions. However, any building subject to high humidity can benefit from a dehumidification system.

Dehumidification can be achieved through conventional cooling methods that sacrifice comfort, efficiency and equipment performance by overcooling the conditioned space. A better alternative is desiccant dehumidification which is solely responsible for the humidity component of cooling (latent cooling), leaving the cooling equipment to operate efficiently and effectively on the temperature component (sensible cooling). Working together, conventional air conditioning and desiccant technology can more efficiently handle temperature and humidity control, but desiccant dehumidification can be used as a stand-alone system.

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Case Studies

- Miller Brewing-Engine-Driven Refrigeration
  - http://foodtechinfo.com/files/2016/01/Engine_Chillers_Miller-1.pdf
- Aquamar-Engine-Driven Refrigeration
  - http://foodtechinfo.com/files/2016/01/Engine_Chillers_Aquamar-2.pdf

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Trade Association

- American Association of Meat Processors
  http://www.aamp.com
- American Dairy Products Institute
  http://www.adpi.org
- American Frozen Food Institute
  http://www.affi.com
- American Institute of Baking
  http://www.aibonline.org
- American Meat Institute
  http://www.meatami.com
- American Pet Products Manufacturers Association
  http://www.appma.org

Trade Association

- Association of Food Industries
  http://www.afius.org
- Bakery Equipment Manufacturers Assoc.
  http://www.bema.org
- Bread Bakers Guild of America
  http://www.bbga.org
- Food Institute
  http://www.foodinstitute.com
- Food Marketing Institute
  http://www.fmi.org
- Grocery Manufacturers Association
  http://www.gmabrands.com

Trade Association

- International Association of Food Industry Suppliers
  http://www.iafis.org
- International Dairy-Deli-Bakery Association
  http://www.iddba.org
- International Foodservice Distributors
  http://www.ifdaonline.org
- National Association for the Specialty Food Trade
  http://www.nasft.org

Trade Association

- National Dairy Council
  http://www.nationaldairycouncil.org
- National Food Processors Association
  http://www.nfpa-food.org
- National Frozen & Refrigerated Foods Association
  http://www.nfraweb.org
- National Pasta Association
  http://www.ilovepasta.org
- National Soft Drink Association
  http://www.nsda.org
- Private Label Manufacturers Association
  http://www.plma.com

Trade Association

- RBA, The Retailer's Bakery Association
  http://www.rbanet.com
- Snack Food Association
  http://www.sfa.org
- U.S. Food & Drug Administration
  Center for Food Safety & Applied Nutrition
  http://www.cfsan.fda.gov

Thank you …