

# A CENTURY OF TRIUMPHS:

## Ten Lasting Chemical Engineering Achievements — and 100 Markers of Chemical Engineers' Progress Toward Them



**T**his month, AIChE's Centennial Celebration Committee brings its year-long retrospective of chemical engineering's first century to a close — with a grand finale devoted to some of the profession's contributions to society's well-being.

Over nine issues of *CEP*, we've taken an impressive journey through chemical engineering and AIChE history — with fascinating and inspiring people and breakthroughs all along the route. We were reminded of our heritage through the achievements of the profession's original innovators and forebears. We traveled on a space odyssey with chemical engineers in Earth's orbit. We ventured outside the profession to meet successful business leaders, artists, and other persons of renown — linked by their early training as chemical engineers. We saluted the people who wrote the textbooks that set the foundation for our education and professional progress. And, we reflected on the evolution of AIChE — from a collective of a few dozen men working mostly in the Middle Atlantic and Great Lakes regions, to a diverse, multi-faceted and interdisciplinary professional home for chemical engineers worldwide.

We covered a lot of ground — yet we were able to only scratch the surface. There are so many more seminal and signature achievements that could have been promoted ... so many more visionary engineers and brilliant researchers who could have been added to our rosters of immortals ... We might very well have continued to publish lists of honorees for years to come, and still never have been able to do justice to all the best of the profession.

The complete legacy of chemical engineers could never be summed up in the samplings printed in our magazine. Indeed, the legacy is still being written — and we can bear witness to its progress day by day —

- ▶ in the development of new ways to bring plentiful clean water, food and medicines to countless people in need
- ▶ in the millions of lives improved and saved through new drug-delivery and health care options
- ▶ in the labs where researchers are exploring a variety of alternative fuel options
- ▶ in new and efficient process designs and the maximizing of raw materials in tight economies
- ▶ in our safer workplaces and cleaner environment
- ▶ in the fresh generation of chemical engineering graduates — well-equipped to enter a new type of chemical engineering practice unimagined by many of their predecessors.

With all this past success and talent to spare, it's easy to feel confident that the next 100 years of the profession are in good hands.

Now, we need look only to tomorrow. Let's turn the page together.



# POWERING EXPANDING ECONOMIES

**C**hemical engineering achievements fuel the world's economies. Witness the dramatic increases in the supplies of higher-quality gasoline and jet fuels that resulted from the discovery and development of continuous catalytic cracking.

The cracking of hydrocarbon molecules — a truly interdisciplinary and international effort — opened the door to advances that energize today's \$63-trillion world economy. Our modern industries and way of life would not exist without the improvements and access to efficient fuels created by chemical engineers. From high-octane gasoline to jet fuel, from chemicals derived from natural gas to the stretching of fossil fuels — chemical engineers power world progress.

► Dr. Robert E. Humphreys with his Burton distillation unit — which now resides in the Smithsonian Institution.

In 1909, William Burton, general manager of manufacturing for Standard Oil of Indiana, instructed chief chemist Robert Humphreys to work on increasing the yield of gasoline from crude oil. Humphreys knew that the application of high temperatures would "crack" molecules, and he theorized that if gas oil could be held under pressure until a cracking temperature was reached, it might improve the yield of gasoline. Humphreys was right and the thermal cracking process was invented.

Photo courtesy of Standard Oil of Indiana archives, Whiting Library, Whiting, IN





## 1912

Thermal cracking at 850° F and 75 psig doubles the yield of gasoline from crude oil, compared with 650° F atmospheric distillation.

*Standard Oil Co. of Indiana*

## 1921

Continuous thermal cracking to convert heavy oil into gasoline is achieved using double coils and tubes.

*Standard Oil Co. of New Jersey*

## 1930

Low-temperature lube oils are produced using an additive to prevent paraffin crystallization.

*Standard Oil Development*

## 1937

High-octane gasoline is achieved by catalytic cracking using rapidly deactivating silica catalyst regenerated in cyclic operations. This development paved the way for fixed-bed catalytic cracking using reactors packed with catalyst pellets.

*Houdry, Socony Vacuum, Sun Oil*

## 1942

Continuous catalytic cracking is achieved by fluidizing fine silica alumina catalyst so that it flows between reactor and regenerator.

*Standard Oil Co. of New Jersey*

## 1944

First jet fuel, called JP-e, is manufactured to fuel early U.S. jet planes.

*Socony Vacuum*

## 1950

First synthetic jet and turbo-prop aircraft engine lubricants are developed, providing superior lubrication and greater thermal stability.

*Standard Oil Development*

## 1952

Multi-grade all-season motor oil is developed; additives are used to reduce viscosity, temperature dependency, and pour point.

*Standard Oil Development*

## 1970

BF<sub>3</sub>-catalyzed 1-decene polymerization leads to energy efficient synthetic motor oil (Mobil1 — first introduced in 1974; improved polymer added in 2000).

*Mobil Oil*

## 1985

First commercial plant built to convert natural gas to methanol and then to a premium unleaded gasoline.

*Mobil Oil*



▲Photos courtesy of ExxonMobil



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# BROADENING ENERGY OPTIONS

Chemical engineers have been at the forefront of many world-changing — and empowering — developments. From the shepherding of nuclear power to the nickel-metal batteries that power hybrid vehicles, chemical engineering is critical to the creation of new energy options. Today's growing diversity in fuel sources and power devices brings along a new set of challenges, tailor-made for modern chemical engineers — who are working to lower emissions and creating the next generation of clean energy technologies.

► The Oak Ridge K-25 gaseous diffusion plant. Built in 1943 as part of the Manhattan Project, the plant was designed to separate U-235 from U-238.



► The Shippingport reactor pressure vessel during construction, 1956. The plant — built on the Ohio River about 25 miles from Pittsburgh, PA — operated from 1957–1982, and had a capacity of 60 MWe.



► High-powered Ni-MH battery of the Toyota NHW20 Prius.



## 1945

Enriched uranium is produced at the Clinton Engineer works — the 2,142-column thermal diffusion plant at Oak Ridge, TN.

*Oak Ridge National Laboratory*

## 1957

Shippingport, the world's first large-scale nuclear power plant, goes into service 15 years after sustained nuclear reaction was demonstrated by Enrico Fermi.

*Duquesne Light Co.*

## 1959

Mass-scale storage and marine transport of liquefied natural gas is proven feasible using a converted World War II liberty freighter.

*Conch Methane Services, Ltd.*

## circa 1964

High-energy lithium batteries using reactive metals in polar (hydrophilic) aprotic (no O-H or N-H bonds) solvents are developed.

*Lawrence Berkeley National Laboratory*

## late 1970s

Environmentally-friendly, high-energy NiMH battery is developed; later used in the Toyota Prius.

*Philips; Centre National de la Recherche Scientifique Laboratories*



# DEALING WITH AN EVER-MORE-CROWDED ENVIRONMENT

**C**hemical engineering has helped to alleviate many of the stresses associated with living on a crowded planet — from mitigating consumer and industrial wastes to easing some of the discomforts of our fast-paced urban, home and work environments. Chemical engineers are finding ways to purify and deliver the world's water supply, provide safer fertilizers, and raise product standards to protect increasing populations. And, through green manufacturing technologies — such as bioremediation of contaminants, chemical scrubbing, and reducing waste in the production of products like ibuprofen — chemical engineers give us a way to better cope with the headaches of everyday life, without creating headaches for the natural world.

► *Hollow-fiber membrane*

*Photo credit: Hangzhou H-Filtration  
Membrane Technology and  
Engineering Co., Ltd.*



**1969**

Hollow-fiber reverse-osmosis membranes are used to treat brackish water, providing greater capacities than similarly sized spiral-wound membranes.

*E.I. DuPont*

**1983**

Polybenzimidazole (PBI) fibers are introduced as a substitute for asbestos, exposure to which can lead to lung cancer.

*Celanese*



**1989**

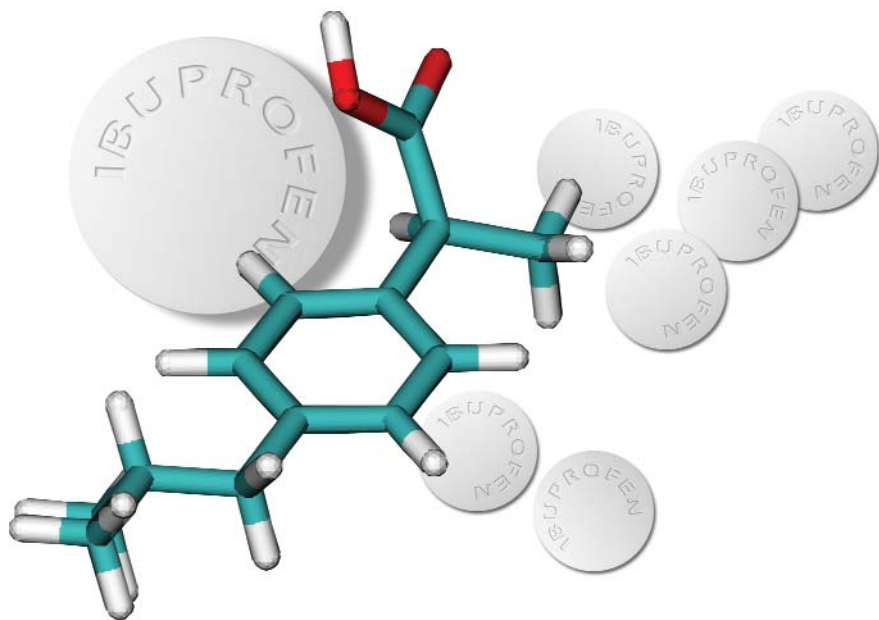
Slow-release fertilizer for bio-remediation of oil-contaminated land and shores is developed.

*Exxon Research and  
Engineering Co.*

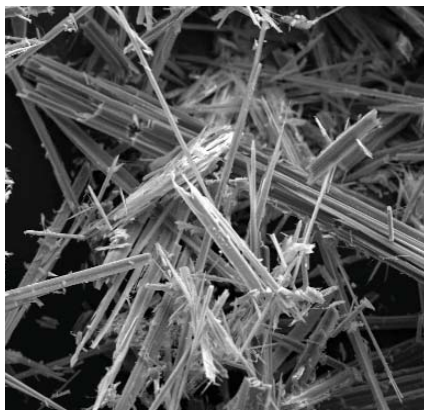
**1918**

FLIT, the first petroleum-based household insecticide, is marketed. Its advertising art was created by Theodor Seuss Geisel (later known as Dr. Seuss).

*Standard Oil of New Jersey*



► Asbestos fibers. Photo courtesy of U.S. Geological Survey



► Individual fibers of Polybenzimidazole (trademarked as Celazole PBI) — a high performance imidized thermoplastic that replaces asbestos.

Photomicrograph by Michael W. Davidson, National High Magnetic Field Laboratory



► New York City Dept. of Environmental Protection Ammonia Recovery Process test system at CASTion's Worcester, MA, facility. Since conducting the demonstration project in 1999 at Staten Island's Oakwood Beach wastewater treatment plant, the process has been improved using proprietary Controlled Air Separation Technology (CAST) followed by ion exchange.

Photo by John Mauer, courtesy of CASTion, A ThermoEnergy Company



## 1991

Anaerobic bioreactors capable of high-rate clean-up of wastewater generated in the making of purified terephthalic acid are developed.

*Amoco Chemical*

## 1993

Ibuprofen is manufactured using anhydrous hydrofluoric acid as both a catalyst and a solvent, resulting in the conversion or complete recovery of starting materials. This eliminated the disposal of large quantities of unrecoverable original aluminum chloride ( $\text{AlCl}_3$ ) catalyst.

*BASF; Celanese*

## 1998

Distillation-based method is developed for recovering unstable tetrahydrofuran (THF) solvent used in paints and paint removers.

*Mitsubishi Chemical*

## 2001

Membrane-based chemisorption process permits ammonia recovery from anaerobic digested wastes; allowed for a 99.9+% recovery of waste stream ammonia at Staten Island, NY, location.

*Foster Wheeler; Civil Engineering Research Foundation*

## 2002

Dimethyl terephthalate (DMT) equal in purity to that made from petroleum is made from recycled polyethylene terephthalate (PET) bottles and converted to high-grade terephthalic acid (TPA) for use in making new bottles.

*Teijin Limited*

## 2006

Self-assembled monolayers on mesoporous supports (SAMMS) are used to selectively remove metal contaminants from coal-fired power plant waste streams. This was the first technology to effectively reduce groundwater mercury to meet 2-ppb potable water standards.

*Pacific Northwest National Laboratory*



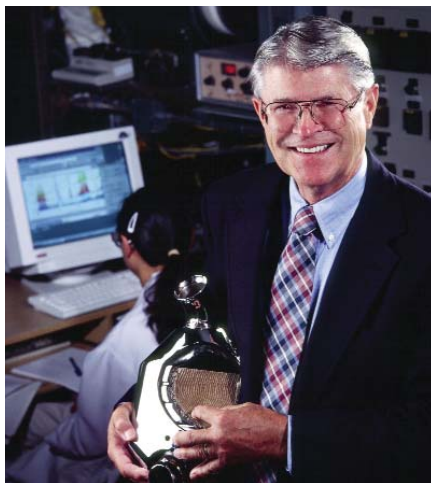


## PROCESSING SULFUR-CONTAINING FUELS

**S**ulfur is one of the noxious components that chemical engineering has helped to remove from burned fossil fuels. The catalytic converter cleaned up automotive exhaust, while other developments dealt with NO<sub>x</sub> and partially oxygenated hydrocarbons. Unleaded gasoline is another chemical engineering innovation that's made life cleaner.

► John J. Mooney co-invented (with Carl D. Keith) the three-way catalytic converter while working at Engelhard Industries (now BASF Corp.) The single catalytic bed in the three-way converter greatly reduced emissions of carbon monoxide, hydrocarbons and nitrogen oxides. First used on 1976 model-year cars, the converter's O<sub>2</sub> sensor feedback system also brought the computer to the automobile, resulting in a 10% to 12% improvement in fuel economy.

*Photo by Nat Clymer*



**1954**

Sulfur in the form of hydrogen sulfide (H<sub>2</sub>S) is removed from heating oil and jet fuel by hydrofining — a catalytic fixed-bed hydrogenation process using hydrogen produced by catalytically reforming *n*-paraffins to high-octane aromatics.

*Standard Oil Development*

**1973**

Automotive catalytic converter is developed to clean up automobile exhaust emissions. Sulfur, a catalyst poison, must first be removed from the gasoline.

*Engelhard; General Motors*

**1978**

First unleaded premium gasoline is introduced. Gasoline would later be reformulated with less benzene and more oxygenated compounds (1989).

*Mobil Oil*

**1983**

Highly efficient selective removal of hydrogen sulfide and other acid gases is achieved using hindered amines (FLEXSORB SE).

*Exxon Research and Engineering Co.*

**1991**

Deep hydrodesulfurization of gasoline is achieved, making possible the simultaneous reductions of nitrogen and aromatic contents.

*Mobil Oil*



# LIVING BETTER THROUGH CHEMISTRY AND PLASTICS

One might wonder whether Buck Henry and Calder Willingham, in their screenplay for “The Graduate,” considered writing an alternative to the mentoring advice delivered to Benjamin Braddock ...

Mr. McGuire: *I have just two words for you.*

Ben: *Yes sir.*

Mr. McGuire: *Are you listening?*

Ben: *Yes. I am.*

Mr. McGuire: *Chemical engineering.*

Ben: *Exactly what do you mean?*

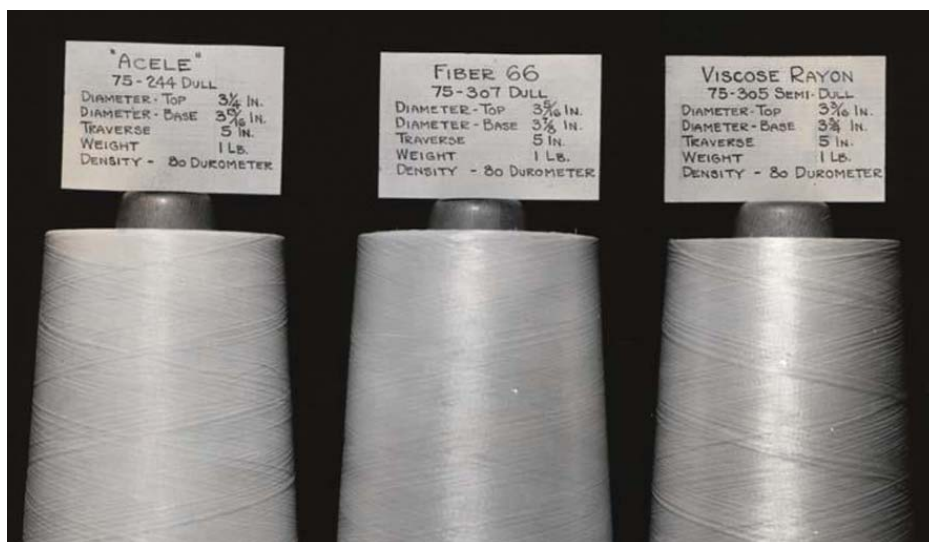
Mr. McGuire: *There's a great future in chemical engineering. Think about it. Will you think about it?*

Ben: *Yes. I will.*

Mr. McGuire: *Enough said.*

Perhaps not. But if Benjamin had followed the actual one-word advice from the movie — “plastics” — he would have certainly rubbed shoulders with chemical engineers, and made a productive career for himself, too.

► In the early 1930s, DuPont's attempts to synthesize commercially viable polyester fibers were stymied by the problems of low melting points and high solubility in water. The research team, led by chemist Walter H. Carothers, turned its attention to polyamides rather than polyesters, and in 1934 pulled a polymer fiber based on an aminoethylester — the first nylon. The team would face two possibilities: polyamide 5,10, made from pentamethylene diamine and sebacic acid; and polyamide 6,6, made from hexamethylenediamine and adipic acid. (DuPont named its molecules for the number of carbons in the starting materials.) DuPont settled on polyamide 6,6, (“Fiber 66”) because the intermediates could be more easily prepared from benzene, a readily available starting material derived from coal tar.



▲ Samples of “Acele,” Fiber 66 (nylon), and Viscose Rayon Fiber (1937). “Acele” was a more-expensive acetate rayon and viscose rayon was a cheaper rayon.

Photo courtesy of Chemical Heritage Foundation Collections

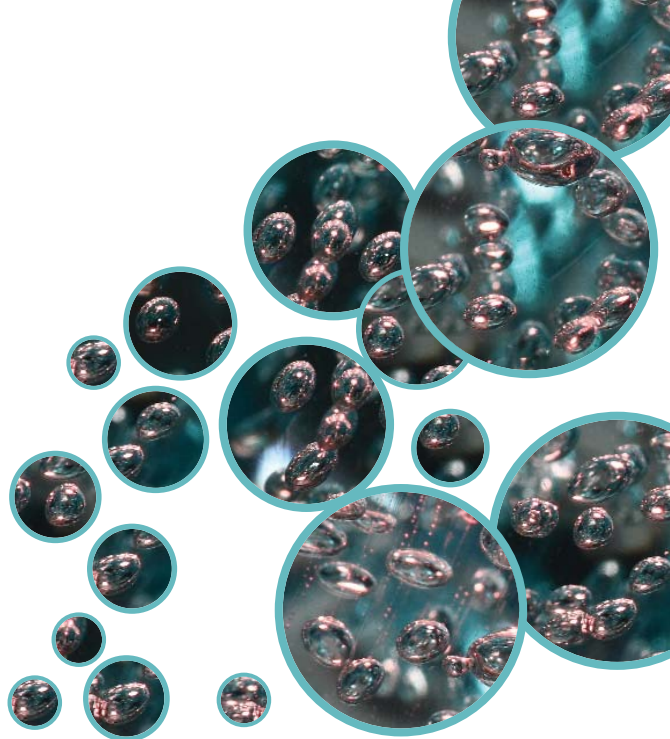
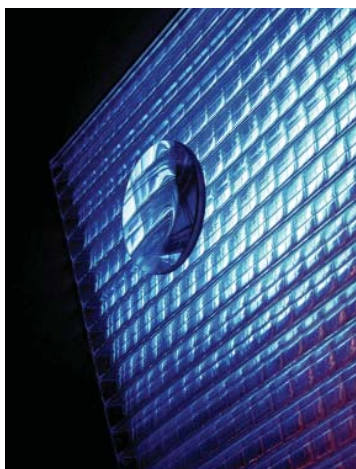


► “Old Faithful” — the first Bakelizer, used in 1909 by Leo Hendrik Baekeland. Made of iron alloys, the steam pressure vessel measures about 36 inches wide and is still in usable condition.

Photo courtesy of Smithsonian Institution



▲ Searching for a synthetic replacement for shellac, Baekeland began experimenting with the reactions of phenol and formaldehyde. By controlling the pressure and temperature applied to an intermediate made from the two reagents, he produced a polymer that, when mixed with fillers, produced a hard moldable plastic. Bakelite, though relatively expensive, soon found many applications — from household products like the telephone to automobile components to the rapidly growing radio industry.



▲ Argon gas bubbles trapped in polystyrene gel.

## 1910

Bakelite, the first entirely synthetic thermosetting plastic, is produced from phenol, formaldehyde and wood flour.

*Bakelite*

## 1928

Polymethyl methacrylate (PMMA) acrylic glass is developed; marketed in 1933 as Plexiglas.

*Rohm & Haas*

## 1937

Polystyrene is produced commercially. It was first made accidentally from a Turkish Sweetgum (*Liquidambar orientalis*) tree in 1839.

*Dow Chemical*

## 1939

Polyamide Nylon 66 is produced commercially for use in women's hosiery.

*E. I. DuPont*

## 1941

Polyethylene terephthalate (PET), the first polyester, and Terylene (a trademark of ICI, known as Dacron in the U.S.), the first polyester fiber, are developed.

*E. I. DuPont*



**1942**

Foamed polystyrene (Styrofoam) is produced and first used to float U.S. Coast Guard six-man life rafts.  
*U.S. Coast Guard; Dow Chemical*

**1946**



Teflon is marketed under its trademark. It was first inadvertently produced in 1938 from compressed/frozen tetrafluoroethylene.  
*E. I. DuPont*

**1952**

Mylar polyester film is introduced; used widely in electrical, electronics, imaging, and graphics applications.  
*E. I. DuPont*

► Mylar polyester film, commercialized in 1952, replaced cellophane as the major product of the DuPont Film Dept.

Photo courtesy of DuPont. From the book "DuPont: From the Banks of the Brandywine to Miracles of Science," by Adrian Kinnane.



**1953**

First-generation alkyl metal catalysts ( $\text{TiCl}_3$  and  $\text{AlEt}_2\text{Cl}$ ) are developed for polymerizing alpha olefins (e.g., ethylene and propylene). Important products include linear low-density polyethylene and crystalline polypropylene.

*Ziegler-Natta*

**1955-59**

High-density polyethylene (1955-56), polypropylene (1957-58) and stereo-specific rubber (1958-59) are commercialized.

*Hoechst; Grace; Hercules; Phillips*

**1959**

First commercial production of thermoplastic polycarbonates — products characterized by outstanding low-temperature ductility, impact resistance and superior optical clarity (Lexan trademark).

*General Electric*

**1977**

Fluid-bed catalytic process is commercialized to produce polyethylene copolymerized with three to six carbon alpha olefins (propylene, *n*-butane, etc.). This development allowed precise control of polymer properties (UNIPOL trademark).

*Union Carbide*

**1982**

Structural composites (e.g., 1984 Corvette bumper) are manufactured using reaction injection molding, the rapid mixing/reaction of isocyanates and polyols.

*NSF; Bayer; Dow; Texaco*

**1993**

Metallocene catalyst is developed to produce ethylene copolymers of exceptional strength, toughness and film clarity. Metallocenes are made of metal atoms held between two carbon rings.

*Dow Chemical*

**2003**

Fermented corn sugar is converted to short-chain polylactic acids for use in plastics and fiber manufacture.

*Cargill; Dow LLC*



▲ Polyethylene pipe extruder.

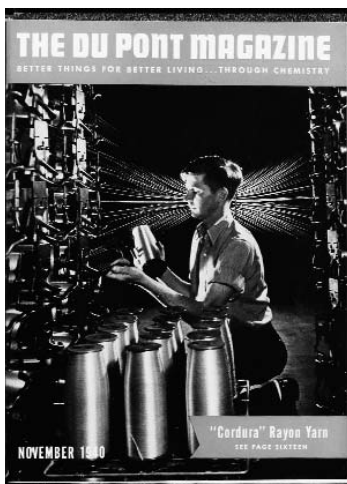


# STRETCHING RESOURCES

**D**evelopments in synthetic rubber are just one exemplar of the evolution of innovative and versatile materials brought about by chemical engineers. From the new rubbers that helped the Allies win World War II ... to the thermoplastics on the soles of athletic shoes ... to the Kevlar vests that protect law enforcement and troops — chemical engineers bring the world new and improved materials, replace scarce ones, and help industry to maximize available resources.

► Cordura rayon yarn was used for tire belting. Here, at the Spruance plant outside Richmond, VA, strands are being drawn from a creel and wound up on a beam. In a textile mill the yarn was then twisted into cord and shipped to a tire manufacturer.

Photo courtesy of DuPont. From the book "DuPont: From the Banks of the Brandywine to Miracles of Science," by Adrian Kinnane.



1933

Rayon tire cord is introduced as Cordura. The trademark may be best recognized for its later use in outdoor nylon products, such as luggage and backpacks.

*E. I. DuPont*

1937

Butyl rubber, particularly known for its impermeability, is produced by polymerizing isobutylene (98%) and isoprene (2%); used as tire inner tubes. *Standard Oil Development*

1943

Silicone elastomers are developed to replace glass fiber containing phenolic resin; used as insulating materials for electric motors and generators.

*General Electric*

1942 - 1947

Superior emulsion-polymerized styrene-butadiene rubber (SBR) produced at 5°C replaces SBR produced at 41°C, resulting in improved tires and retread compounds, and a host of industrial, military and household products.

*U.S. Rubber; Goodyear; Firestone*

1964

Thermoplastics (e.g., shoe soles) are produced by block polymerization of styrene and anionic polyisoprene polymerization in a block sequence. *Shell Chemical*

► At the Shell Amsterdam laboratory, a glass pressure vessel used for polymerization experiments, 1968.

Photo courtesy of Shell International, Ltd.







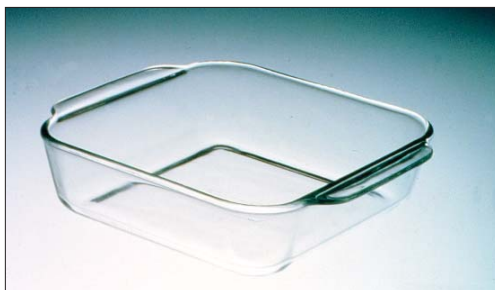
# MANUFACTURING PRODUCTS IN PROFUSION

**C**hemical engineers improve the processes that make mass production possible. They play a pivotal role in the diversity and distinctive properties of consumer products, and the quantities that factories are able to produce — as well as the costs and values of the starting materials and final products.

► Corning Glass Works (now Corning Inc.) used advertising to educate consumers about the benefits of cooking with glass.

Photo courtesy of Corning Inc.

► Pyrex baking dish.  
Photo courtesy of Corning Inc.



## 1915

Highly heat- and corrosion-resistant lead-free borosilicate glass is introduced as Pyrex. The name may have been derived from the Greek "pyra" (hearth).

*Corning Glass*

## 1916

Weitzman acetone-butanol fermentation with *clostridium acetobutylicum* is used to make smokeless gunpowder. Unwanted butanol is later used as automobile lacquer. This development signaled the beginning of large biotechnological processing.

*Strange and Graham, Ltd.*

## 1920

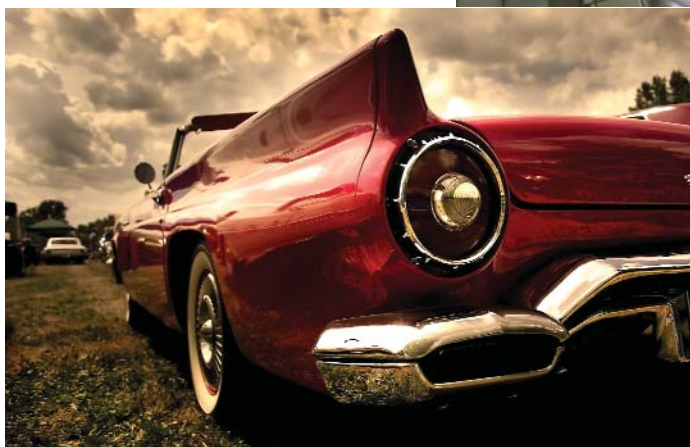
Isopropyl alcohol (rubbing alcohol) is the first commercial petrochemical — made from propylene by indirect hydration in sulfuric acid.

*Standard Oil of New Jersey*

## 1924

Introduction of stainless steel allowed production of nitric acid at high pressure for use in manufacturing agricultural fertilizers, dye-stuffs and explosives.

*E. I. DuPont*



## 1926

Chromium plating is invented to protect iron and steel products, such as automobile bumpers, against rust.

*Columbia Univ. (Colin Fink)*

## 1927

First fractionating bubble tower is introduced, supplanting inexpensive but lower-capacity and less-efficient packed columns (which were introduced in 1889).

*Standard Oil Development*

## 1931

Beginning of tungsten powder metallurgy: ductile tungsten for incandescent lamp filaments is produced by doping tungsten oxide before its reduction.

*Columbia Univ.*

## 1934

First plant capable of extracting 67-ppm bromine from seawater starts up in North Carolina.

Bromine, as ethylene dibromide, is used to scavenge lead oxide deposits produced in automobile engines from tetraethyl lead (TEL) added to increase octane number.

*Dow Chemical*

## 1941

Steam cracking is commercialized, and allowed for production of a wide range of chemical feedstocks from ethane, propane and other petroleum naphthas.

*Standard Oil Development*





► General Electric's synthetic diamond press, 1955.

Photo courtesy of Schenectady Museum and Suits-Bueche Planetarium



## 1946

First low-sudsing washing machine detergent, ALL, is produced; a key ingredient was ethylene oxide adduct.

*Monsanto*

## 1955

Industrial synthetic diamonds are produced at 6 to 18 GPa and 5,000°C, from graphite dissolved in a molten nickel, cobalt or iron catalyst.

*General Electric*

## 1959

First synthetic molecular sieve zeolite (Zeolite A) is commercialized to absorb oxygen.

*Union Carbide*

## late 1960s

Kevlar ballistic fabric is developed for use as body armor; it was originally intended to be steel belting in tires. Nylon had been used in WWII flak jackets.

*E. I. DuPont*

## 1961

First disposable paper diaper (creped tissue in rayon/plastic liners) is developed; hydrogel-forming polymers would later provide magnitudes greater absorption (1972).

*Procter & Gamble; Kimberly-Clark*

## 2004

Enhanced morpholine extractive distillation is used to recover high-purity benzene from close-boiling nonaromatics; distillation alone requires too many separate stages and excessive liquid recycle. Benzene is used to make ethylbenzene — a styrene precursor.

*Maxygen; DSM*



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## MAKING FOOD MORE AVAILABLE & CONVENIENT

From the farmer's field to the dinner table, chemical engineers contribute to the abundance of food choices available to modern consumers. Chemical engineers are responsible for putting packaged foods — cake mixes, low-fat snacks, beverages — into their most familiar and convenient forms, and they bring modern consumers increased variety, accessibility, and safety in foods.



### 1922

Peanut butter is commercialized after methods are developed to prevent oil separation. John Kellogg first created peanut butter for toothless patients (1890).  
*Procter & Gamble*



### 1942

Dehydrated, but slushy, orange juice concentrate is developed using the same WWII technology used to freeze-dry blood plasma and then penicillin for battlefield use. It was successfully marketed after the war as Minute Maid Orange Juice.  
*National Research Council (NRC)*



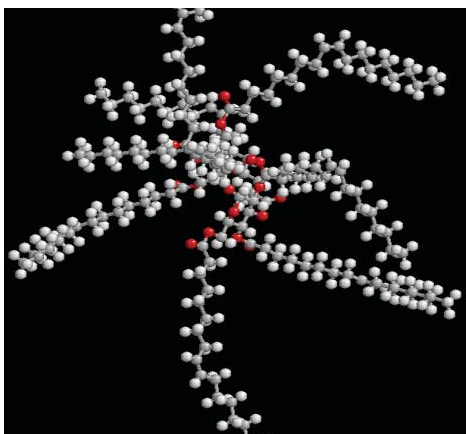
### 1950s

Lumping of cake mix is eliminated by using large milling drums designed to polish aluminum foil; cake mix becomes a best-seller.  
*Procter & Gamble*

### 1959

Asphalt-water emulsion soil barriers are developed to increase crop yields, foster early crop emergence, minimize weed propagation and stabilize arid soil.  
*Esso Research and Engineering Co.*

► *Olestra molecule. While normal fats consist of a glycerol molecule with three fatty acids attached, Olestra is synthesized using a sucrose molecule with up to eight fatty acid chains, making it too large to move through the intestinal wall. Since it does not contain glycerol, and the fatty acids cannot be removed from the sucrose molecule for digestion, it passes through the digestive system without being absorbed.*



## 1966

Fried bacon analog is produced from spun soy protein fiber. This meat flavoring was originally developed as a car fabric (Henry Ford was a soybean-use pioneer, and developed many industrial uses for the crop). Similar spun soy fiber products would be developed for ground beef, as well as beef and poultry chunks.

*Procter & Gamble*

## 1969

Large-scale ham-, beef-, and chicken-flavored protein enters food market, e.g., Beeflike (beef), Prosage (sausage), Stripples (bacon), White Chik (chicken), and other products.

*Worthington Foods*

## 1975

Soda bottles are produced from biaxially oriented terephthalate (polyethylene terephthalate; PET); a major success for the carbonated beverage industry due to PET's toughness, clarity and ability to be oriented.

*E. I. DuPont*

## 1984

First non-toxic oil-based plant and insect spray is developed, initially for apple and pear tree pests (ORCHEX 796).

*ExxonMobil*

## 1996

Food and Drug Administration (FDA) approves use of synthetic cooking oil (Olestra) for production of fat-free snacks. Olestra was later used in french fries and baked goods (1998).

*Procter & Gamble*

## 2004

Self-rehydrating pouches that use reverse-osmosis are developed, allowing 99.9999% bacterial removal from any fresh water source. This permitted a 90% weight reduction in soldiers' daily 3.5-kg food supply.

*U.S. Army Soldier Systems Center*



# DELIVERING NEW MEDICINES & PROSTHETICS

**C**hemical engineering's innovations in medical science run the gamut from antibiotics to new methods of drug delivery; from non-invasive surgery to bioengineered tissue replacement. These advances have brought us an abundant supply of penicillin, nearly painless tests for diabetes, hemodialysis, transdermal patches, and even modern sunscreen ... to name only a few achievements. Chemical engineering saves lives by the millions.

► In 1943, a chemist examines a stack of glass flasks, each containing penicillin mold growing in a wrinkled layer called a "felt." During this process, the mold exuded penicillin into the growing solution, from which it could later be extracted. Each flask contained enough mold to produce a single dose.

*Photo courtesy of Science and Society Picture Library*



**1943**

Large-scale production of penicillin is achieved using submerged fermentation; mold is grown in agitated and aerated tanks, rather than on the medium surface.  
*Abbott; Lederle; Merck; Pfizer; Squibb*

**1949**

The Skeggs Leonards artificial kidney becomes the first practical flat-plate dialyzer, employing negative pressure and hydrostatic ultrafiltration.  
*Development coordinated by the National Institutes of Health*

► The Skeggs Leonards plate dialyzer.

Leonard Skeggs, PhD, and Jack Leonards, MD, developed the first parallel-flow artificial kidney at Case Western Reserve Univ. in Cleveland, OH. Two sheets of membrane were sandwiched between two rubber pads in order to reduce the blood volume and to ensure uniform distribution of blood across the membrane. The device had a very low resistance to blood flow and it could be used without a blood pump. The dialyzer used negative pressure — creating a siphon on the effluent of the dialyzing fluid — to remove water from the blood in the artificial kidney.



*Photo courtesy of Dialysis Museum Online*

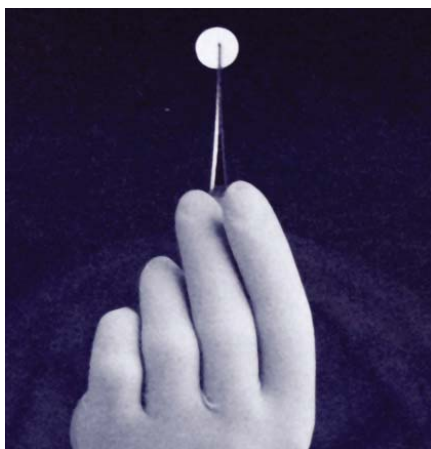
**1964**

First portable patient dialysis machine is developed. The Milton Roy Model A was designed to perform nocturnal home hemodialysis.  
*Univ. of Washington*



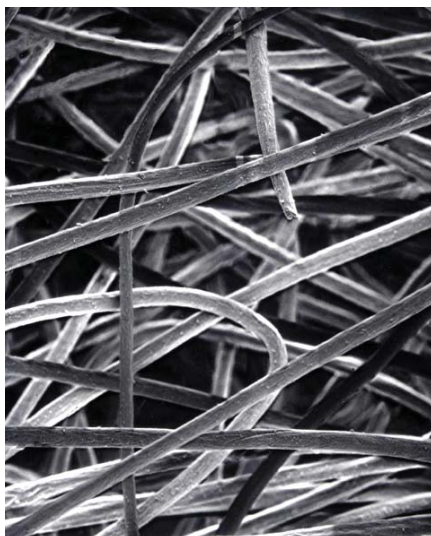
► Implanted at the time of surgery, the biodegradable Gliadel Wafer (polifeprosan 20 with carmustine implant) was the first commercially available brain cancer treatment to deliver chemotherapy directly to the tumor site. The wafer minimizes exposure to other parts of the body, and complements standard therapies, such as surgery, radiation and intravenous injections.

Photo courtesy of Johns Hopkins Medical Institutions



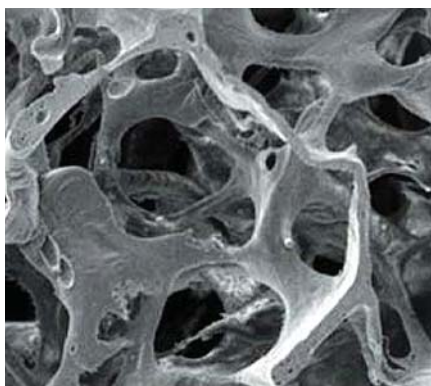
► A scanning electron micrograph of a biodegradable scaffold used to bioengineer skin.

Photo courtesy of FAB —Fidia Advanced Biopolymers



► Biodegradable foam structure for regeneration of bone.

Photo courtesy of M. Shoichet, The Institute of Biomaterials and Biomedicine, Univ. of Toronto



## 1977

Sunscreens containing compounds (such as oxybenzone) that absorb ultraviolet and/or reflect light (titanium dioxide, zinc oxide) are invented.

*U.S. Patent 4,129,645*

## circa 1982

Pressure swing adsorption (PSA) is used to produce enriched oxygen in portable generators that allow patients to receive medical oxygen without sacrificing their mobility. The process was first used in air drying during the 1960s.

*Esso Research and Engineering Co.*

## circa 1985

Dime-sized dissolvable plastic wafers that release chemotherapy drugs to sites of excised brain tumors are developed.

*MIT; Johns Hopkins*

## 1998

Biodegradable plastic scaffolds, capable of regenerating damaged organ tissues, e.g. skin, are produced.

*MIT*

## 1998

Temperature- and flow-controlled microfluidic reactors and subsequent micro-electrophoresis separator carry out various genetic analyses.

*Univ. of Michigan*

## 2000

Painless blood sampling using micro-needle arrays, for closed-loop control of insulin infusion and continuous drug monitoring, are developed.

*Univ. of Texas*

## 2006

Photosensitive silicone lenses that can be precisely and non-invasively adjusted after cataract surgery provide clearer vision in early clinical trials.

*Cal Tech*



# EMPOWERING MOORE'S LAW

**B**ased on the insight of Intel co-founder Gordon E. Moore, Moore's Law describes the exponentially advancing technology of the past half-century,

specifically illustrated by the number of transistors that can be placed on an integrated circuit board — a quantity that doubles approximately every two years. The personal computer, in its various forms, has become the ubiquitous representation of digital technology's penetration into every facet of our existence.

Some believe that Moore's Law is finally approaching its limit, but the law is evident in the capacity of our digital electronic devices, from laptop processing speed to the number of pixels in digital cameras.



## 1950s

Ferrous-oxide-coated magnetic tape (0.5 in. wide by 1,200/2,400 ft. long) becomes the *de facto* standard for computers. In the 1980s, thinner Mylar film would allow for 3,600-ft. long tapes.

IBM

## 1967

The first multi-level computer control system capable of selecting its operating parameters achieves a refinery's targeted fluid catalytic cracking performance.

IBM; Esso Research and Engineering

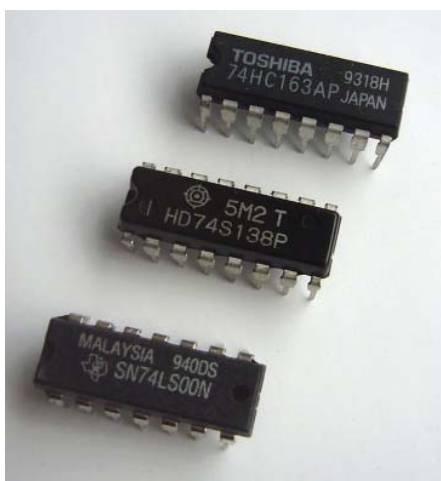
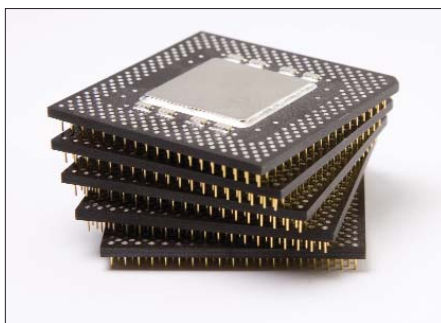
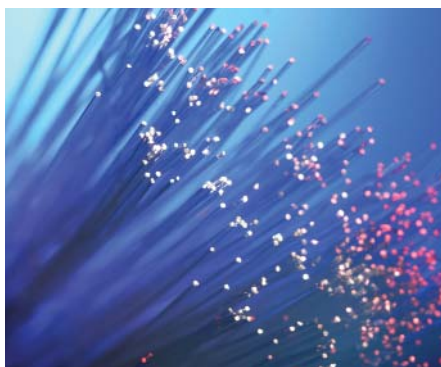
► IBM's tape drive vacuum column paved the way for magnetic tape to become a popular storage medium. Prior to the vacuum column, fragile magnetic tape was plagued by breakages as it was subjected to sudden starts and stops. IBM devised a solution where the tape was held down by a vacuum during these rapid accelerations and decelerations. Its use in the IBM 701 signaled the beginning of the era of magnetic storage, for its buffering technique would become widely adopted throughout the industry.

Photos of IBM 727 and IBM 705 computers (near and far right), courtesy of IBM Corporate Archives



► Dr. John Cressler of Georgia Tech holds a silicon-germanium 200 GHz integrated circuit wafer.

Photo by Gary Meek. Courtesy of Georgia Institute of Technology



## 1968

Solid photoresists and dry polymeric light-resistant films are produced, allowing for precise and convenient reproduction of intricate circuitry.

*E. I. DuPont*

## 1970s

Silicon microchips are mass-produced; devices are nanofabricated using single ultra-pure-silicon crystals cut from 8-in.-diameter by 5-ft.-long wafers (2000s).

*AT&T; Texas Instruments*

## 1972

Urban gaseous and particulate pollutants are successfully modeled. The models would evolve to include photochemical ozone from automobile exhausts.

*Cal Tech*

## 1973

Robust glass optical fibers are developed. By 1986, erbium-doped optical fiber amplifier would significantly reduce the need for optical-electrical-optical repeaters.

*Bell Laboratories*

## 1976

Thin-film liquid crystal displays with picture elements driven by their own individual transistors — a 1970 curiosity — enter the television and other mass markets.

*RCA Corporation*

## 1977

Increased disk storage mandates the use of lithographic techniques to make magnetic heads for reading and recording data.

*U.S. Philips Corp.*

## 1981

Advanced System for Process Engineering (ASPEN) is commercialized. ASPEN-developed software models and analyzes integrated processes from detailed design elements to their costs.

*MIT Energy Lab / U.S. Dept. of Energy (DOE) funding (1976–1981)*



## 1981

First commercial PC-based process simulation software is developed (HYSIM).

*Hyprotech*

## 1989

Silicon germanium (SiGe) chip, with germanium included in the base layer of silicon chips, are commercialized, allowing for faster performance at lower cost.

*IBM*

## 1992

Aluminum oxide and molybdenum or tungsten for interconnecting computer chips is supplanted by fewer, smaller and faster cordierite glass-ceramic and copper layers.

*IBM*

## 1998

Fast, relatively inexpensive microfluidic devices are produced using soft lithography (rapid prototyping and replica molding) in poly(dimethylsiloxane) (PDMS).

*Harvard Univ.*

## 2000

Integrated chips having 20 layers of semiconductor, dielectric, and conducting films, with individual features of 0.5  $\mu\text{m}$ , are developed.

*Taiwan Semiconductor Manufacturing Co.*

## 2003

Full economic potential for process intensification — integrating multiple operations into a single unit — is achieved with model-predictive-controlled divided-wall columns.

*BASF*



## HOW THE MILESTONES AND HONOREES WERE SELECTED

Three years ago, AIChE's Board of Directors launched a 15-person Recognition Committee, composed of a diverse group of well-regarded AIChE members from industry, academia and government. Twelve were male, three were female, and two were minority engineers; five were past AIChE presidents.

This panel turned to many sources to compile lists of candidate engineers and achievements in a variety of areas. Nominations were solicited from corporations, government agencies and academic organizations that employ significant numbers of chemical engineers, plus AIChE's operating councils, local sections and general membership. The panel also considered past awards and recognitions, such as the Hoover, Fritz, CHF Othmer and ACS Perkin Medals, NAE memberships, and major AIChE awards.

All communications regarding candidacy and candidate selection were directed to and through Barry Tarmy and Douglas Raber, the respective chairs of the Recognition Subcommittee and the Selection Working Group.

Special consideration was given to including achievements and engineers from across the 100-year span of the profession. Some of the presentations were devoted exclusively to either the Foundation Era or the Modern Era; the Foundation Era covered chemical engineers who would have nominally attained AIChE Senior Member eligibility during or before 1945.

Nearly 1,000 engineers and more than 400 significant technical achievements were proposed for recognition. The rosters were pared down over the course of many private discussions and multiple secret ballots, resulting in the samplings contained in the centennial celebration lists.

Myriad people assisted with research and fact-checking, and while some errors slipped through, AIChE has been posting corrections in its online versions of the lists — available at [www.aiche.org/100/](http://www.aiche.org/100/). Readers are welcome to send further comments on the centennial lists to [cepedit@aiche.org](mailto:cepedit@aiche.org).