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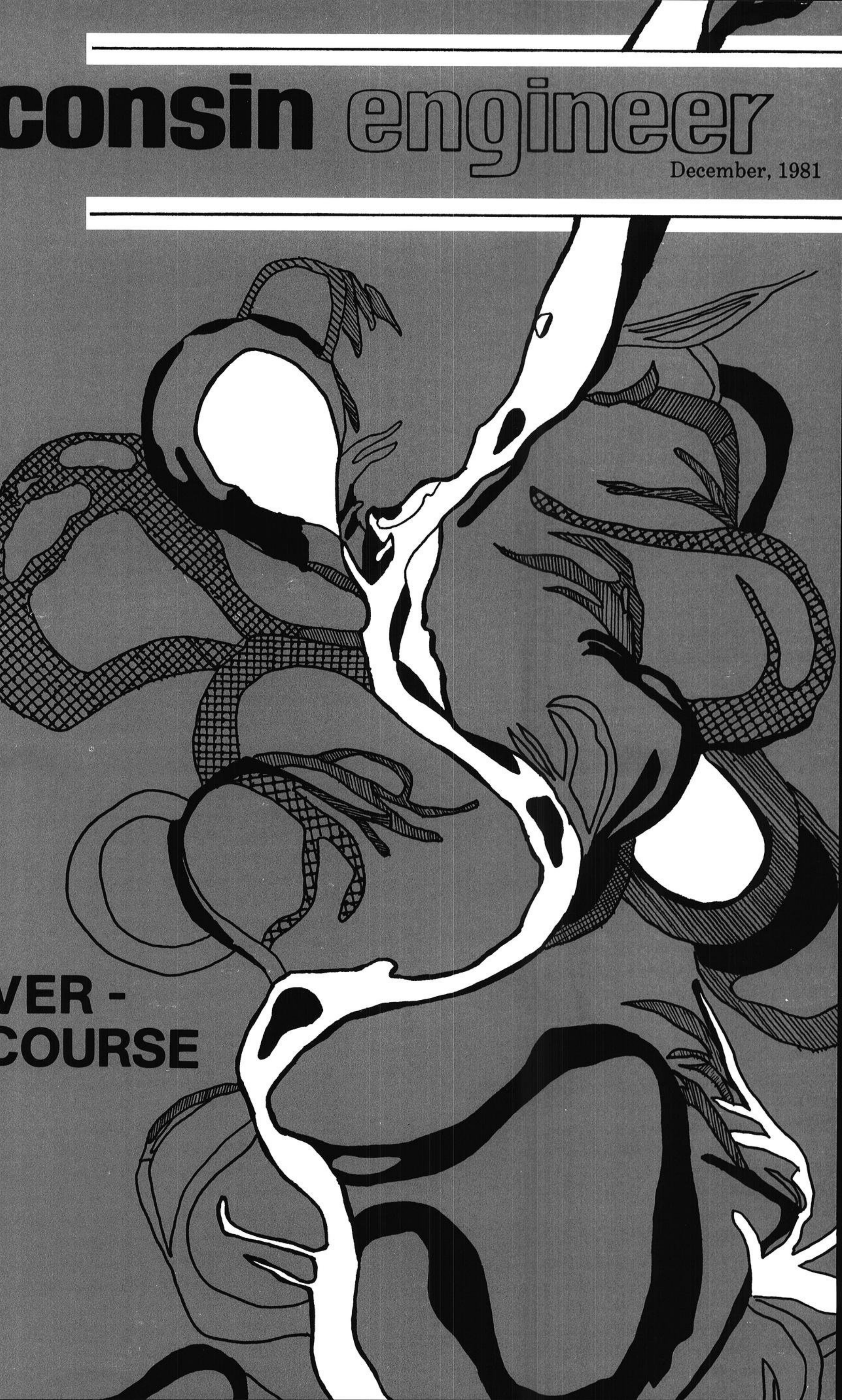

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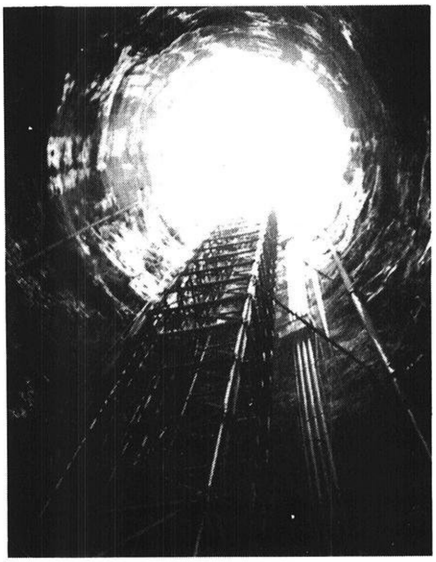
FEATURES



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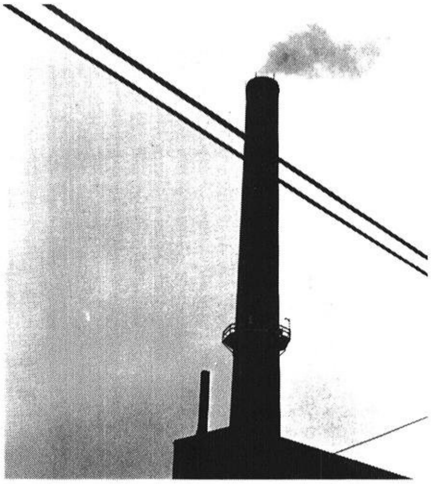

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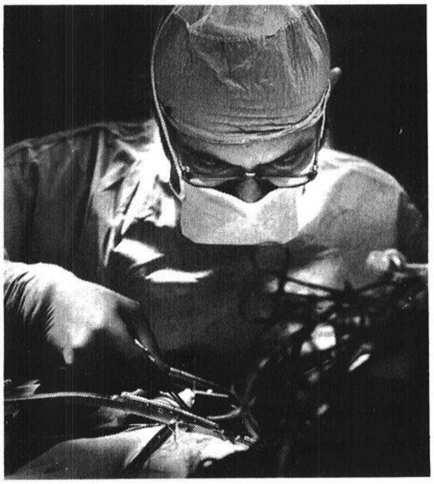

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About the cover: *The cover design was done by Amy Geiger, a senior in the Graphic Arts. The wide loops are former meanders of the Mississippi River that were abandoned when various people dug cutoffs to shorten the trip from St. Louis to New Orleans. The first such cutoff was made in 1717. Today, we are able to assess the full set of consequences of disturbing the river's hydraulic characteristics.*

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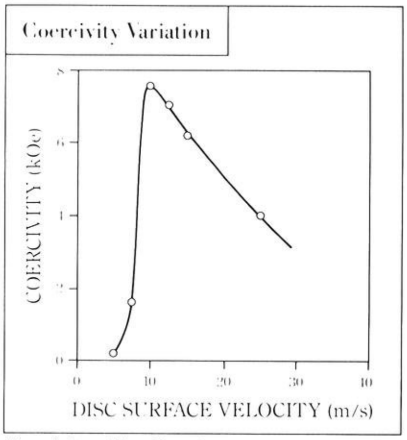
The Critical Interval

There has long been a need in the industrial world for low-cost, high-performance permanent magnets. Recent discoveries at the General Motors Research Laboratories show promise of meeting this challenge by the application of new preparation techniques to new materials.



Coercivity of $Pr_{0.4}Fe_{0.6}$ plotted as a function of disc surface velocity.

Color-enhanced transmission electron micrograph of melt-spun $Nd_{0.4}Fe_{0.6}$ having 7.5 kOe coercivity.

TWO properties characterize desirable permanent magnets: large coercivity (magnetic hardness or resistance to demagnetization) and high remanence (magnetic strength). Higher-performance magnets are required to reduce further the size and weight of a wide variety of electrical devices, including d.c. motors. Such magnets are available, but the cost of the materials necessary to produce them severely limits their use. The research challenge is to select, synthesize, and magnetically harden economically attractive materials of comparable quality.

Prominent among alternative materials candidates are alloys composed of iron and the abundant light rare earths (lanthanum, cerium, praseodymium, neodymium). Investigations conducted by Drs. John Croat and Jan Herbst at the General Motors Research Laboratories have led to the discovery of a method for magnetically hardening these alloys. By means of a rapid-quench technique, the researchers have achieved coercivities in Pr-Fe and Nd-Fe that are the largest ever reported for any rare earth-iron material.

Drs. Croat and Herbst selected praseodymium-iron and neodymium-iron based upon fundamental considerations which indicate that these alloys would exhibit properties conducive to permanent magnet development. These properties include ferromagnetic alignment of the rare earth and iron magnetic moments, which would foster high remanence, and significant magnetic anisotropy, a crucial prerequisite for large coercivity.

That these materials do not form suitable crystalline compounds, an essential requirement for magnetic hardening by traditional methods, presents a major obstacle. Drs. Croat and Herbst hypothesized that a metastable phase having the necessary properties could be formed by cooling a molten alloy at a sufficiently rapid rate. They tested this idea by means of the melt-spinning technique, in which a molten alloy is directed onto a cold, rotating disc. The cooling rate, which can be varied by changing the surface velocity of the disc, can easily approach 100,000°C per second. The alloy emerges in the form of a ribbon.

THE researchers found that variations of the cooling rate can dramatically affect the magnetic properties of the solidified alloys. In particular, appreciable coercivity is achieved within a narrow interval of quench rate.

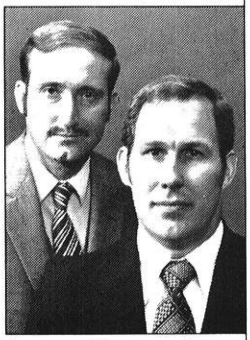
Equally remarkable, synthesis and magnetic hardening, two steps in conventional processing, can be achieved simultaneously.

"X-ray analysis and electron microscopy of the high coercivity alloys reveal an unexpected mixed microstructure," states Dr. Croat. "We observe elongated amorphous regions interspersed with a crystalline rare earth-iron compound."

Understanding the relationship between the coercivity and the microstructure is essential. The two scientists are now studying the extent to which the coercivity is controlled by the shape and composition of the amorphous and crystalline structures.

"The development of significant coercivity is an important and encouraging step," says Dr. Herbst, "but practical application of these materials requires improvement of the remanence. Greater knowledge of the physics governing both properties is the key to meeting the commercial need for permanent magnets."

THE MEN BEHIND THE WORK



Drs. Croat and Herbst are Staff Research Scientists in the Physics Department at the General Motors Research Laboratories.

Dr. Croat (right) received his Ph.D. in metallurgy from Iowa State University. His research interests include the magnetic, magneto-elastic and catalytic properties of pure rare earth metals and their alloys and compounds.

Dr. Herbst (left) received his Ph.D. in physics from Cornell University. In addition to the magnetism of rare earth materials, his research interests include the theory of photo-emission and the physics of fluctuating valence compounds.

Dr. Croat joined General Motors in 1972; Dr. Herbst, in 1977.

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When the River Shifts . . .

by Eric Loucks

Eric Loucks is a Civil Engineering graduate student from Madison, Wisconsin. In his study of water resources planning, he often encounters problems where the planning decisions seem to be leading to disaster rather than a solution to the problem.

When the river shifts, 250 miles of the mighty Mississippi will become a quiet tidal estuary. A new source of fresh water will be needed to serve over a million people. As the water rages down its new channel for the first time, eight highway bridges and a series of natural gas pipelines will be destroyed. The bridges will cost more than $1 billion to replace. The pipelines serve 28 states from Wisconsin to Connecticut; New York and Pennsylvania will be hardest hit. Three hundred eighty million dollars worth of land will disappear beneath the muddy flow of the new Mississippi.

When will the river change its course?

It might happen this spring; it might be twenty years. Congress has authorized $216 million to delay the course change, but it will definitely occur, according to a number of civil engineers at Louisiana State University. They can't say when it will happen, but they can explain why it will happen.

It is awesome to try to count the number of times the Mississippi River has been altered by engineering projects intending to control the river for the benefit of society. It is likewise difficult to comprehend the river's ability to resist containment. Early in this century, engineers generally agreed that the system of levees, constructed over the previous 200 years, offered adequate flood protection to inhabitants of the Lower Mississippi Floodplain. Sure, there would be occasional overtoppings and other failures, but these were considered indicators of where to build the levees taller and stronger. Then, in May of 1927, this approach to flood control was washed out, so to speak. At Vicksburg, Mississippi the river rose fifty feet above its normal stage, often swelling to a width of five miles. Hundreds of miles of levee were breached and thousands lost their homes.

The government reacted with the Flood Control Act of 1928, a bill that presumably would allow the problem to be attacked in a scientific manner. It also allocated the financial resources for the most ambitious civil works project undertaken by any nation: Flood Mitigation on the Mississippi River.

The engineers were so naive prior to 1927 because the potential flooding problem had been escalating through the years as a result of human intervention. The extensive levee system and countless cutoffs (of meander loops) north of Louisiana enabled flood flows to pass upstream areas rapidly, but they robbed the river of natural storage areas. The narrower floodplain and straighter channel had less ability to attenuate flood peaks. As a result, floods occured near the mouth of the river with a ferocity entirely contrary to the historical record.

The logical solution was to create a diversion at the head of the Atchafalaya Basin. The Atchafalaya River is the northernmost distributary of the Mississippi. During floods, it would be possible to divert huge quantities of water into the Atchafalaya Basin, which was mostly undeveloped swamp, and protect heavily settled areas along the last 300 miles of the Mississippi. But some people feared that construction of the floodway would enable the Atchafalaya Basin to capture the major portion of the Mississippi flow. Their fears are now a reality.

The cause is rather obvious today and should have been foreseen, though the Mississippi River Commission was acting in desperation at the time. The Atchafalaya River offers a route to the Gulf of Mexico that is only half as long as the Mississippi's course. A small percentage of the Mississippi River discharge followed the Atchafalaya under natural conditions. A small channel cross-section and a series of swamps and log jams created enough hydraulic resistance to keep most of the flow on its present course.

The process leading to the Mississippi shift began in 1831 when the Turnbull Bend Cutoff was completed. Usually when a cutoff is excavated, the ends of the old meander silt up in a few years leaving an oxbow lake in the old channel. In addition to the out flowing Atchafalaya, the Red River joined the channel in the bend, so flow persisted in the old channel. The situation was unstable for a long time. At first the Red River followed the north leg of Turnbull Bend to the Mississippi, while the south leg also reversed direction to supply the Atchafalaya. The Atchafalaya Channel was cleared and improved steadily between 1840 and 1880. During this time the north leg of Turnbull Bend slowly silted shut, forcing the Red River to its present course. The link between the Mississippi and the Red-Atchafalaya Junction was renamed Old River.

Once this configuration was in place, the Atchafalaya Channel began to enlarge. In response to the fear that the Mississippi was in danger of capture, a sill dam was built at the head of the Atchafalaya in 1889. Though the dam controlled the flow, the channel continued to enlarge because downstream levee improvements increased water levels making more energy available for erosion.

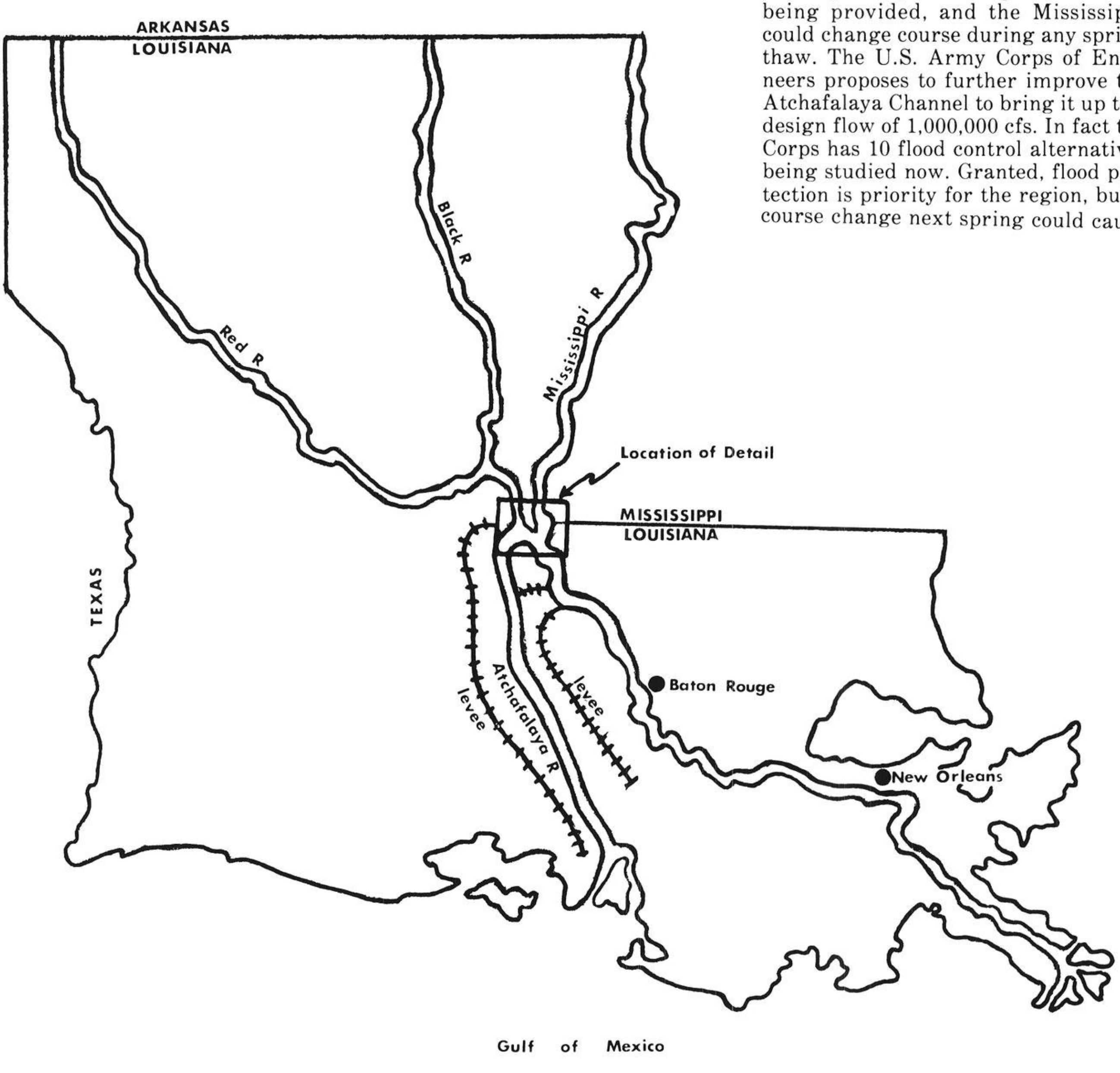
The plan developed after the 1927 flood called for the removal of these dams so the Atchafalaya could be used to the fullest extent possible. Additional improvements included the construction of overbank guide levees that provided a three to five mile wide floodway on the Atchafalaya. The outlet to the Gulf of Mexico was also improved. This improvement actually entailed the construction of two outlet channels since the Atchafalaya had no natural mainstem outlet. All this work was completed in 1941.

From this point on there was no turning back. The uncontrolled diversion through Old River was undependable for two reasons. It required a great deal of maintenance, and it passed an unpredictable amount of flow. The flood of 1955 almost resulted in a course change. In 1962 the Old River was closed off and a new controlled diversion was completed a few miles upstream. This diversion structure was designed to send 30% of the Mississippi flow down the Atchafalaya. This system successfully mitigated the flood of 1965, but it nearly failed in 1973 when the third largest flood of this century occurred.

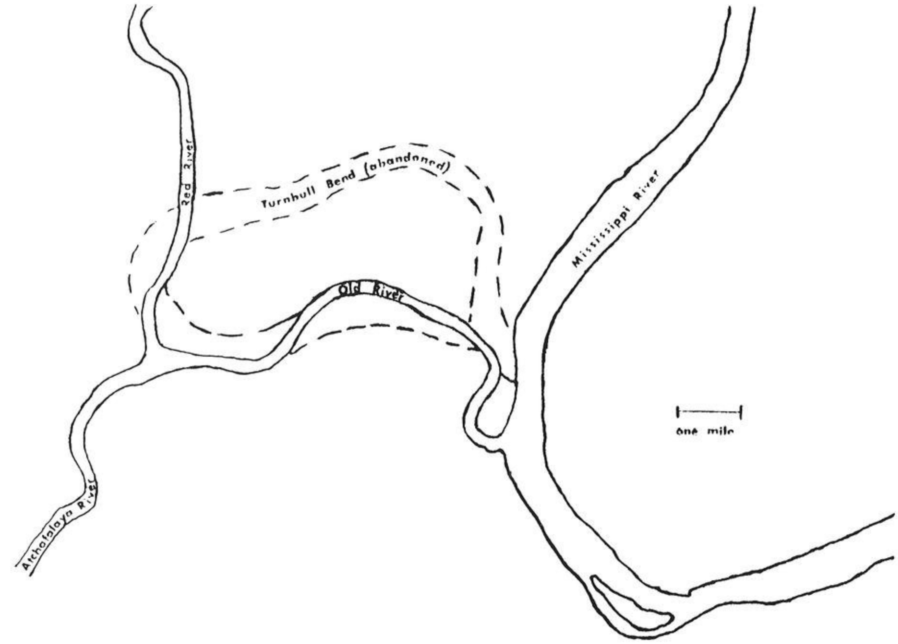
In May, 1973 the peak flow just above the Old River control structures was about 1.6 million cubic feet per second (cfs). According to the 30% design, 480,000 cfs should have been diverted down the Atchafalaya Basin. The actual peak flow was 781,000 cfs. Once again the rivers had taken the situation out of human hands.

There was more disconcerting data. Despite diversions at Old River, Morganza, and Bonnet Carre spill ways, the stage at New Orleans was just 2.5 feet below the all time record (set in 1922). The channel of the Mississippi below Old River had been adjusting to the lower flow through the years. The constantly changing complexion of the channel had always made it difficult to conclude that the channel bed was rising. Making replicate cross-section measurements is practically impossible over a period of years because surveyors would return to a location and find a completely changed channel orientation. Many measurements during the flood of 1973, which persisted a phenomenally long 90 days, provided unmistakable evidence that the Mississippi Channel was losing capacity as well as flow.

Now, a decision must be made concerning the problem which faces, not only Louisiana, but the entire country since any action would need federal funding. Adequate flood protection isn't being provided, and the Mississippi could change course during any spring thaw. The U.S. Army Corps of Engineers proposes to further improve the Atchafalaya Channel to bring it up to a design flow of 1,000,000 cfs. In fact the Corps has 10 flood control alternatives being studied now. Granted, flood protection is priority for the region, but a course change next spring could cause



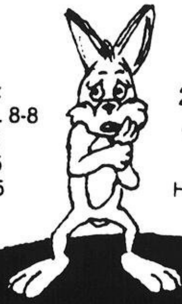
The Mississippi River system in Louisiana. (Detail of Old River is on page 6.)



Detail of the Atchafalaya headwaters region as it existed in 1950. A new diversion was subsequently constructed in the bed of Turnbull Bend and Old River was dammed. Locks were constructed on Old River to permit continued navigation from the end of the Red and Atchafalaya Rivers to the Mississippi.

$4 billion dollars worth of damage. The flood of 1973 wrought $2.2 billion in damage (in 1980 dollars).

The most economical course of action would probably be to prepare southeast Louisiana for a course change. Instead, on the Corps' recommendation, Congress has appropriated $216 million to delay the course change by raising critical levees and improving the diversion works. This might postpone the inevitable by 20 years, but it might buy us nothing. Once the river shifts, anything the Corps has built to control Mississippi floods or prevent the shift will become worthless. □



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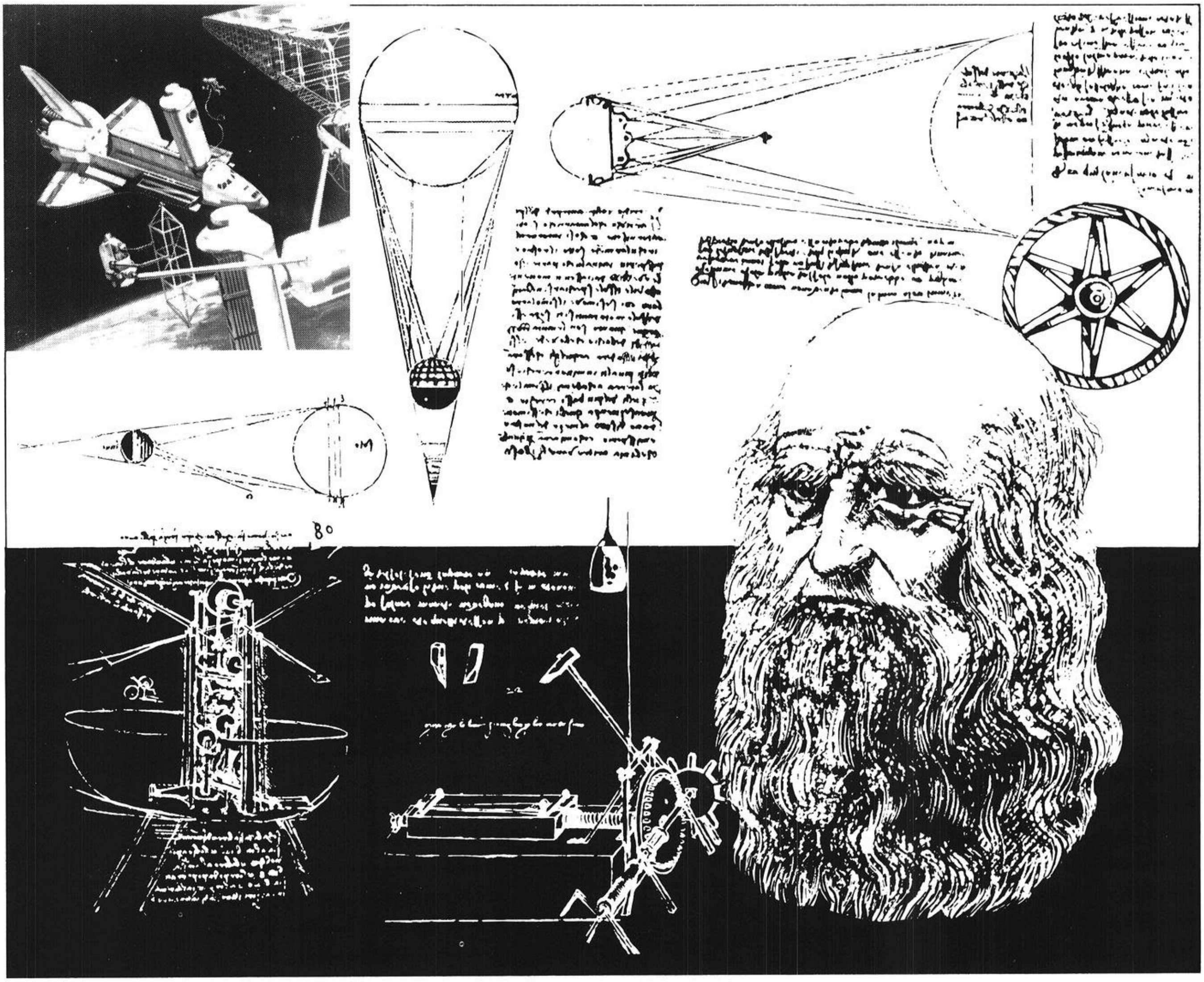
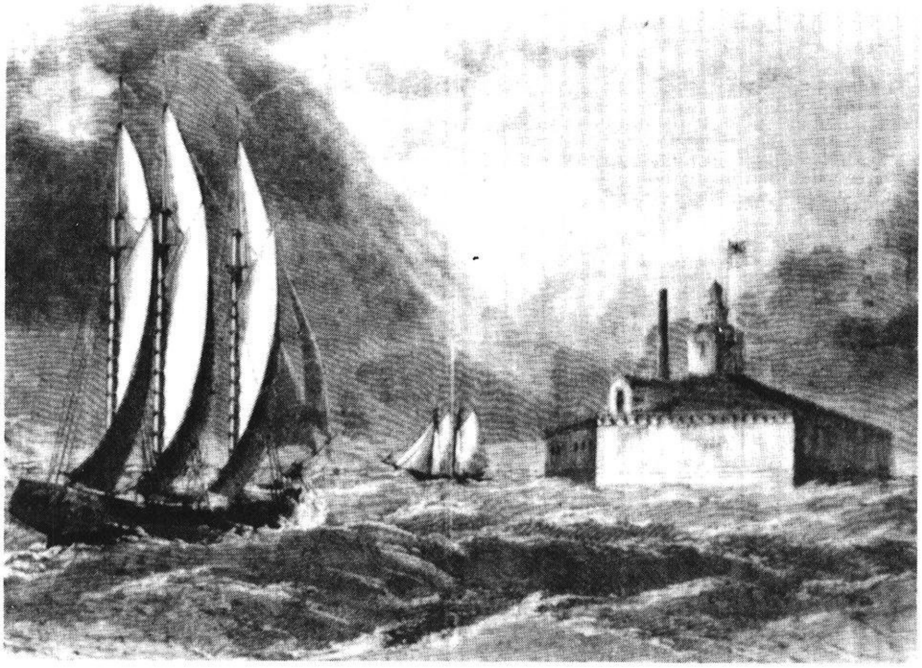


The Deep Tunnel of Chicago

by Joan Heitkemper

As editor-in-chief of W.E., and a Civil Engineering senior, Joan feels engineering students should be aware of relevant issues outside the college campus. The Deep Tunnel Project of Chicago has been, and will continue to be a controversial issue for years to come. This article gives the background and major features of the project.



In the 1860's, an attempt to reduce the high death rate caused by water borne diseases resulted in construction of a water intake tunnel and this intake crib two miles out in Lake Michigan. (Courtesy of the Chicago Historical Society and the Harza Engineering Company.)

Major engineering feats do not just appear out of the blue to solve big problems in big ways. There is often a long, complicated history leading to the problem and its ultimate solution. Chicago's Deep Tunnel Plan, also called Tunnel and Reservoir Plan (TARP), is one such vast engineering undertaking. From the time of conception to the completion of the entire system almost four decades will have passed, and at least 1,000 people will have participated in the planning and design of TARP. This story is a description of TARP, its history, design, and future objectives. Using the TARP case as an example, you can see that to find a problem, you must understand the problem's *raison d'etre*, observe the problem from all angles, and remember the human element.

Contrary to popular belief, water pollution has not been a concern limited to recent generations. When Chicago was first settled in the 1830's, the area was a swamp. In fact, the Indian name, shekag-ong (Ojibway Indian, "wild onion place") originated from odors accompanying the swamp. The topography of the area was, and is, extremely flat. Because of the resultant small hydraulic gradient, drainage and control of pollution was a problem even then.

As the settlement grew into a city, it depended on the small and sluggish Chicago River, which fed into Lake Michigan, for drainage. The water supply intake had always been directly from Lake Michigan. In the 1860's the intake was moved two miles out from the shore due to periodic cholera epidemics. The city then felt safe and continued its rapid growth. Tragedy occurred in 1885 when a six inch rainfall flooded the city. Contaminated runoff and sewage was carried as far as the intake and beyond. People were drinking their own pollution, and, as a result, epidemics of cholera, typhoid, and dysentery wiped out 12% of the population (90,000 people died).

In response to this tragedy, the Metropolitan Sanitary District (MSD) was created in 1889. The purposes of MSD were: 1) protect Lake Michigan water supply of the Chicago area from water pollution, 2) collect and dispose of human and industrial wastes, and 3) control storm runoff. Construction of three canals in 1900, 1910, and 1922 led to the reversal of the flow of the Chicago River. Thus, drainage of the Chicago area to its own water supply source (Lake Michigan) was eliminated and area streams were used to help in dilution of wastes.

Early sewer systems were "combined sewers" in that both stormwater runoff and raw wastes flowed in a single sewer. In the 1930's, treatment plants were incorporated to reduce the daily dry-weather loadings of biological oxygen demand and suspended solids to the canal and river system. Wet weather flow was still adequately provided for by the waterways. As the population steadily grew, the sewer system expanded accordingly. Discharges to the canal system also increased in rate and volume until there was little allowance left for wet weather flow. At times of heavy rainfall, water elevation rose and the overflow relief outlets were submerged. This resulted in flooding of basements, streets connected to surcharged sewers, and other low points in the city.

Water quality of the Chicago area streams now fall below present day standards. Three major factors contribute to this condition:

1. The system must handle an enormous population. MSD service area contains 5.5 million people in an 860 sq.

mile area (including Chicago and 117 adjacent communities). Industrial waste load adds an equivalent population of 4.5 million for a grand total of 10 million equivalent population the system must handle.

2. The combined sewers described previously serve a 360 sq. mile area of MSD service area. During dry weather all waste water in the system flows to treatment facilities. Area streams receive discharge of treated water. During wet weather, however, excess combined flows are discharged to these streams directly, without treatment.

3. The great increase in impervious areas like pavements and rooftops increase the rate and amount of runoff during any given storm. Temporary storage areas occurred locally in basements, streets and underpasses. Since this water was polluted, a health hazard was created, as well as causing property damage.

A procedure called backflow allows gates between Lake Michigan and inland waterways to be opened when flooding is imminent. The MSD instituted this procedure in 1957 as a positive short term solution to flooding. As Chicago grew, discharges to Lake Michigan became more frequent. Negative impacts include closing of shoreline beaches (usually in sweltering heat of summer) because of dangerously high bacterial counts and collection of unsightly and disgusting floating matter along the shore.

In 1968, the MSD appointed a Technical Advisory Committee to study alternative solutions to the combined problems of water pollution and flood control. Twenty-three alternatives were matched against regulations of Public Law 92-500 (water quality standards) and cost effectiveness. TARP was the only proposal which could meet the needed qualifications. In 1972 a project similar to the proposed TARP, the Lawrence Avenue Sewer Tunnel, was completed and was an important basis for acceptance of the TARP proposal. The Lawrence Avenue was like a miniature TARP with many of the same major components. More than 10 years of investigation, research and planning were involved before construction of TARP could begin.

The general principle of the system is a combination of Chicago's present underflow concept (recalling the small hydraulic gradient in the Chicago area) and the MSD's underground storage concept. It involves improving outlets for existing and proposed sewers and interceptors; intercepting, conveying, and storing combined sewer overflows that would overflow to waterways otherwise; and releasing stored waters at a reduced rate in order to treat all waters released to the waterways. The project will serve a 375 sq. mile area which presently discharges overflows to area streams. Run-off as little as 0.01 inch per hour has caused spills to occur; this happens approximately 100 times a year.

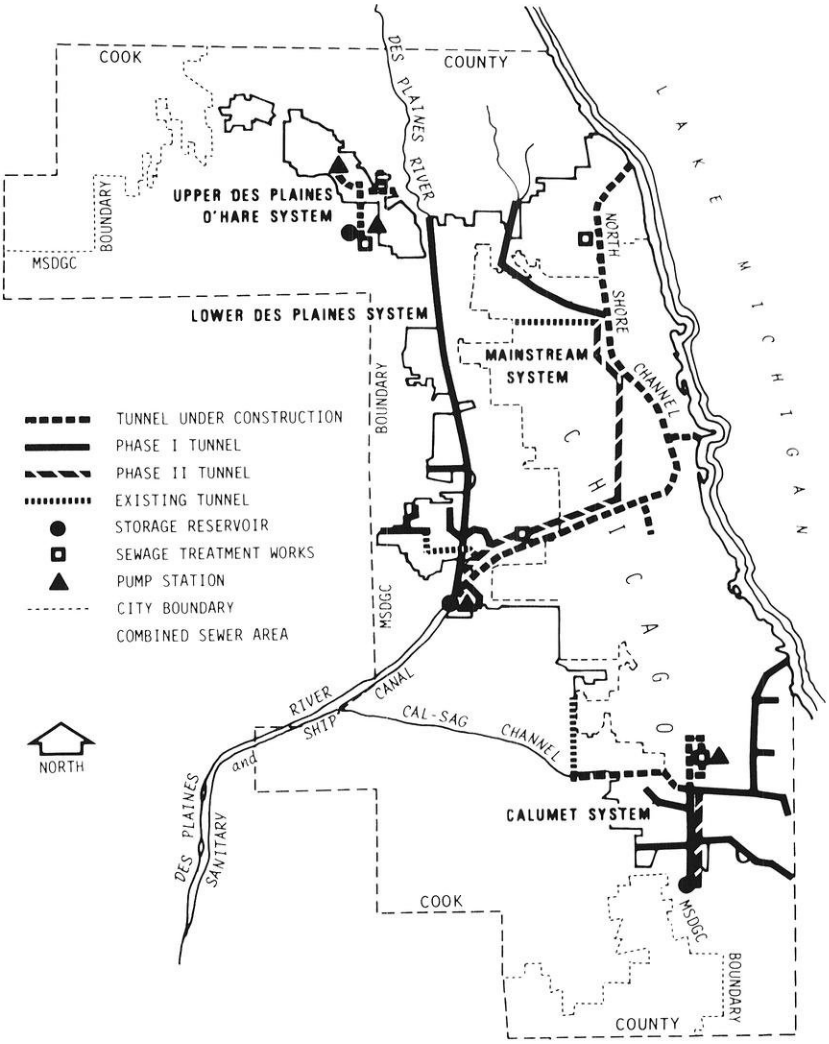
Two phases are involved in the construction of this massive project.

Phase I Components

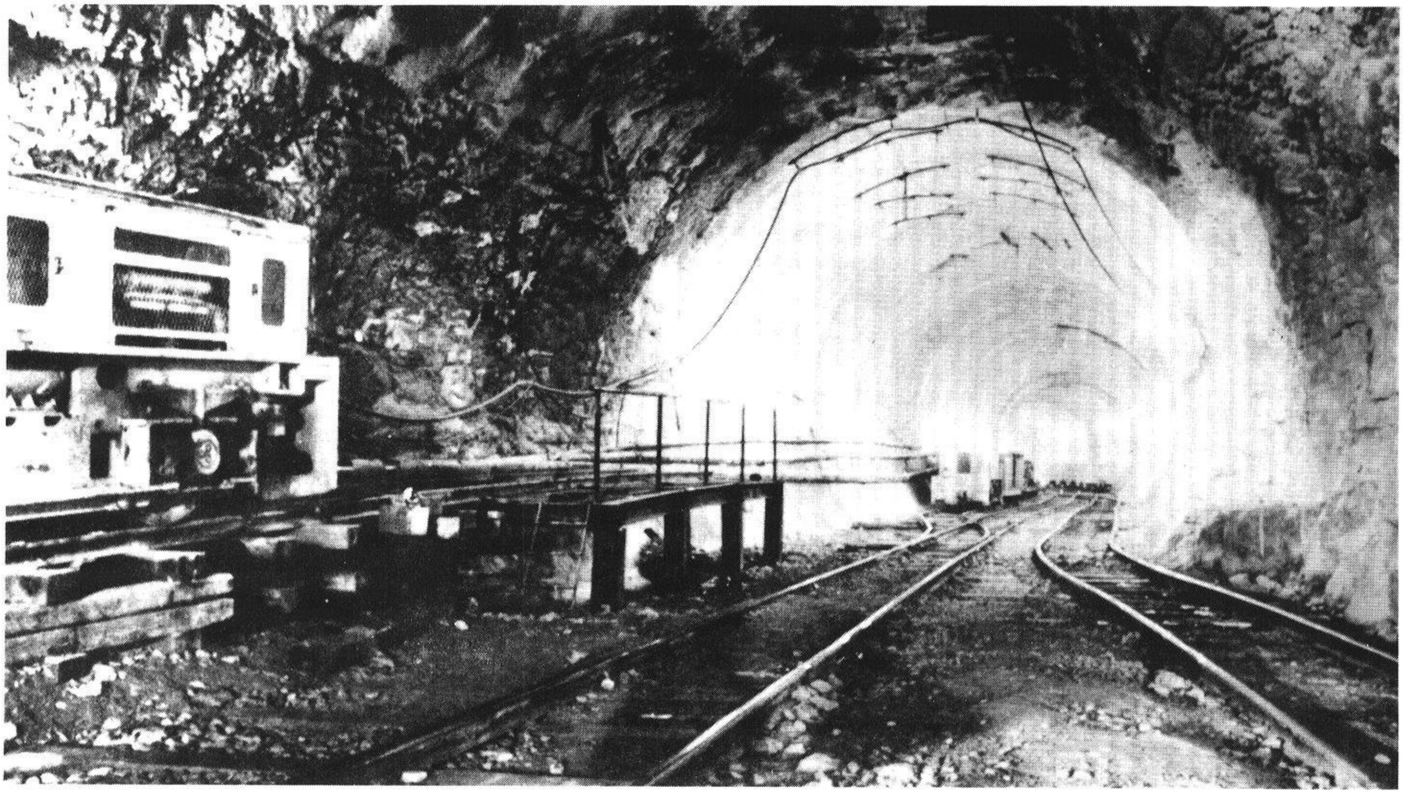
Three separate tunnel-reservoir systems will serve the project area, the largest being the Mainstream System. The depth of the Mainstream Tunnels will range from 180 feet at the north end to 300 feet at the south end. A minimum of 100 feet of bedrock will be maintained over tunnel crowns. Two hundred fifty-two drop shafts, from 4 to 17 feet in diameter, will intercept combined sewers at existing overflow outlets. These will discharge the water into 131 miles of tunnel (total system) which ranges from 13 to 36 feet in diameter. Tunnel boring machines, up to 36 ft. in diameter, will mole the tunnels out of the bedrock and are infinitely more cost-effective than drill-and-blast techniques for a project of this size. An underground pumping station located at the southwest end of the Mainstream system will pump water from the tunnels to be dewatered and purified at the West-Southwest Sewage Treatment Works. Separate pumping stations will perform the same task for the other two systems.

Phase II Components

To increase flood storage capacity, aerated storage reservoirs will be added to each of the three tunnel systems. The Mainstream Reservoir will be the largest, 1 mile long by 1/3 mile wide by 300 feet deep (or over 200 football fields in area and one football field in depth). These reservoirs will be made by deepening existing rock quarries and will



The three tunnel-reservoir systems of Chicago's Deep Tunnel Plan. (Courtesy of Harza Engineering Company.)



A 30-foot diameter section of the Mainstream Tunnel shows the drill-and-blast construction access area and the smooth, machine-bored tunnel in the background. (Courtesy of Harza Engineering Company.)

The 30-foot diameter boring machine used in constructing parts of the Mainstream Tunnel.

shift the function of the tunnels from one of storage to one of conveyance. Immediately after a storm, the gates between tunnels and reservoirs will be closed and the water in the tunnel will be pumped to the aerated reservoir. Separate basins will divide the reservoirs so discharges from small storms can be contained for more efficient aeration during storage. The pumping stations used for dewatering tunnels to treatment plants will also direct dewatering discharges to reservoirs. Phase II also includes construction of a second Mainstream tunnel in the central-city portion of the system.

And so, when Phase I is in operation (projected date 1986) overflows to waterways will drop from almost 100 times a year to six or seven times a year. Prevention of approximately 85% of pollutant loads to inland waterways will be attained. If problems with funding are resolved (this is an article in itself), Phase II would be completed and begin operation near the turn of the century. Then, virtually all excess combined sewage would be caught in the tunnel-reservoir system. Flooding would be eliminated, and the existing water quality standards could be attained for Lake Michigan and inland waterways—essentially eliminating both the flood and pollution problems of the city. □

“Pollution” by Clear Water: The Problem with Milwaukee’s Sewer System

by Bonnie Buhrow

Bonnie Buhrow is a senior in Industrial Engineering and has a B.A. degree in English. She is a member of the production staff as well as a writer for the Wisconsin Engineer.

Several years ago, Illinois sued Milwaukee in the United States District Court in Illinois, charging that untreated sewage from Milwaukee’s sewer system was polluting Lake Michigan and endangering the health of Illinois residents. The court ruled in July, 1977, that the Milwaukee Metropolitan Sewerage District (MMSD) had to eliminate sewer overflows and meet wastewater treatment standards six times more stringent than federal standards. The latter ruling was overturned, and the rest of the decision is being appealed to the Supreme Court. But a pollution problem does exist, and the MMSD has been studying solutions to meet the court order and improve water quality.

A major part of Milwaukee’s water pollution problem is caused, ironically, by clear water, water which could normally be discharged into Lake Michigan without treatment. Clear water is produced by rainfall, melting snow, and over-watered lawns. It enters the sewer system by infiltration through leaky sewer pipe joints and faulty lateral and main sewer line connections. It also gets in the sewer systems by inflow through direct connections when the weather is excessively wet. All this additional water overloads the system, which backs up and overflows into waterways such as the Milwaukee River. Untreated wastewater enters Lake Michigan via these waterways, causing pollution and health problems.

In its **Master Facilities Plan** of March, 1980, the MMSD estimates that about half of the excess clear water problem could be remedied by rehabilitation of existing sewers, some of which are as much as 100 years old and have deteriorated considerably. In other parts of Milwaukee, correcting improperly connected roof leaders, downspouts, and sump pumps could go a long way in abating clear water caused pollution.

The other part of the pollution problem involves the design of the sewer system itself. Older sections of Milwaukee (about 27 square miles) are served by combined sewers which carry both wastewater and storm and snow runoff. Although this design was once a big improvement on outhouses in the backyard, it is no longer acceptable because the system can’t handle the volume when the weather is very wet. About 50 times a year, the volume of effluent becomes too large for the Jones treatment plant in Milwaukee to handle; the excess wastewater, suntreated, spills into the Milwaukee River and eventually reaches Lake Michigan. The MMSD has decided to solve this problem by separating the combined sewers. This separation involves installing a new sanitary sewer system to handle wastewater alone, leaving the transport of clear water runoff to the existing sewers.

The areas of Milwaukee not served by combined sewers (about 397 square miles) are served by separated sewers. This part of the sewer system can improve handling of clear water by increasing interceptor sewer service. An interceptor collects flows from smaller sewers and transports them to the treatment plant, easing the burden on the main sewer lines. The MMSD recommends the enlargement of 23 miles of existing interceptor sewers and the construction of new interceptor systems in at least three areas of the city. This increase in conveyance capacity will also necessitate increasing the treatment plant capacities. Presently, the Jones treatment plant handles about 200 million gallons per day at its operational peak; the South Shore treatment plant handles about 80 million gallons per day. It is estimated that this combined capacity will have to be increased to a peak flow of approximately 550 million gallons per day.

The solution to Milwaukee’s clear water pollution problem is not going to be cheap. Clear water related costs account for about $1.2 billion of the Water Pollution Abatement Program’s total estimated cost of $1.65 billion. But the costs of not implementing the plan — limited growth for Milwaukee, pollution — related health problems, the deterioration of Lake Michigan — will inevitably prove to be greater. ☐

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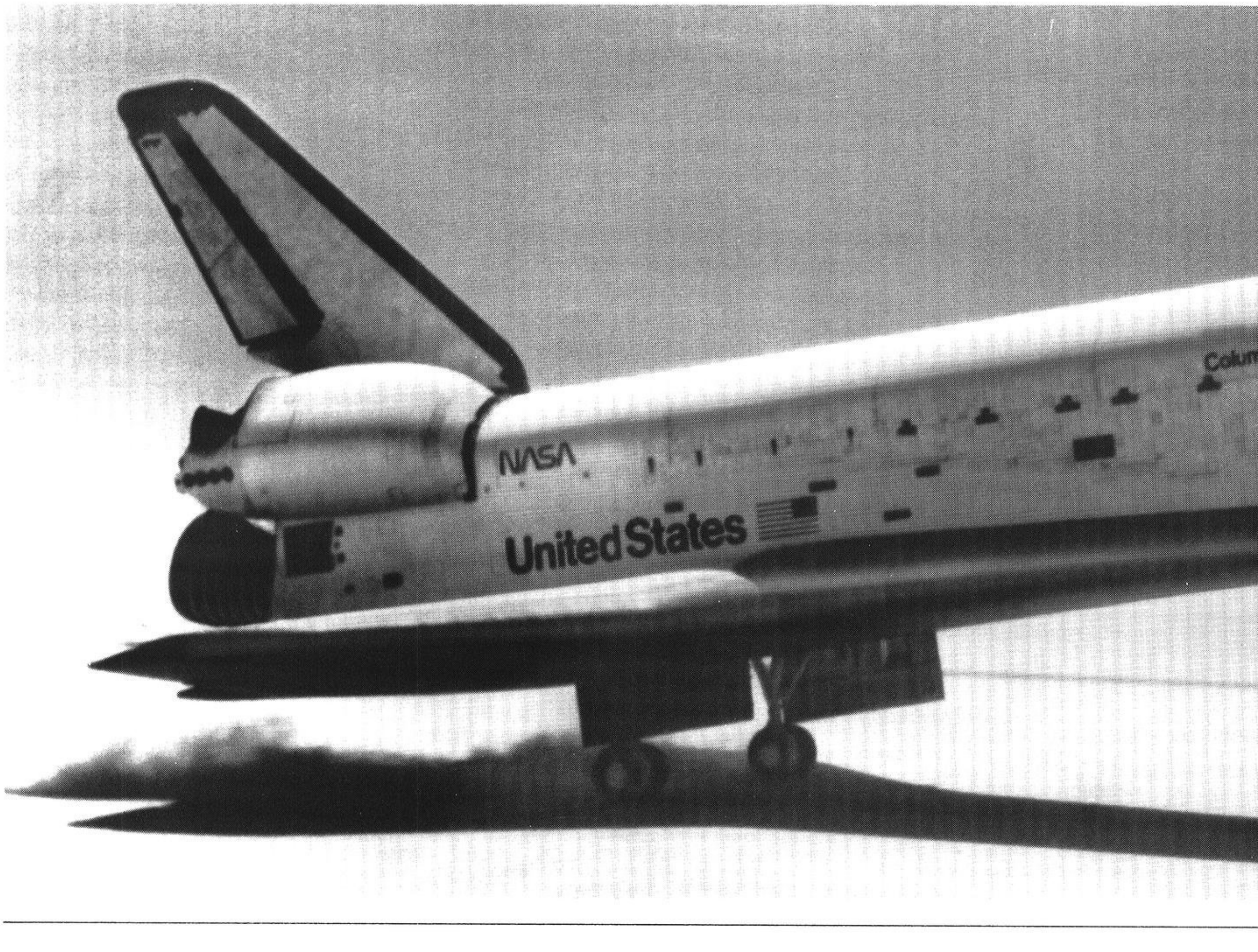

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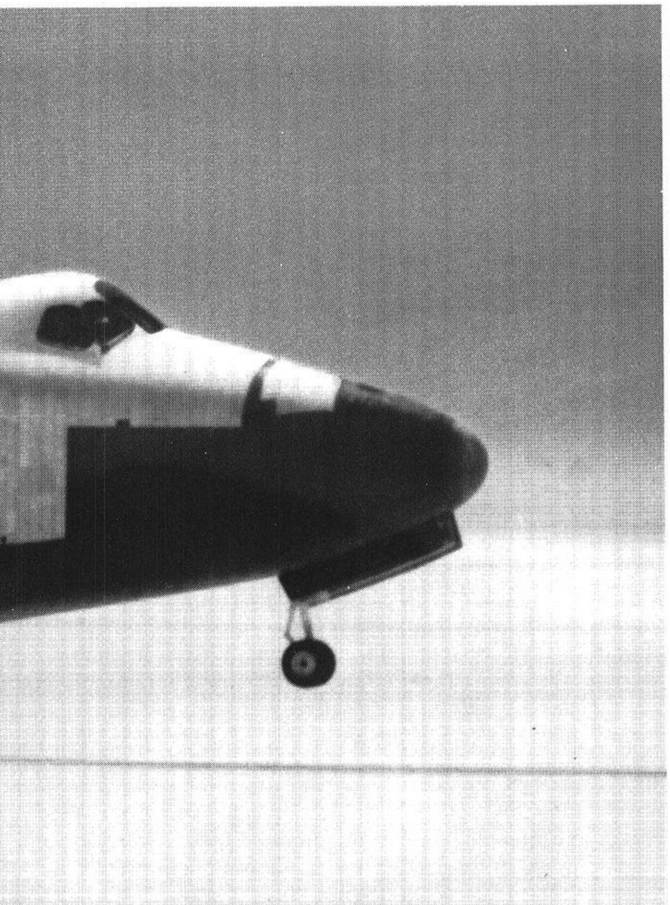

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The Clean Air Act: The Environment vs. The Economy

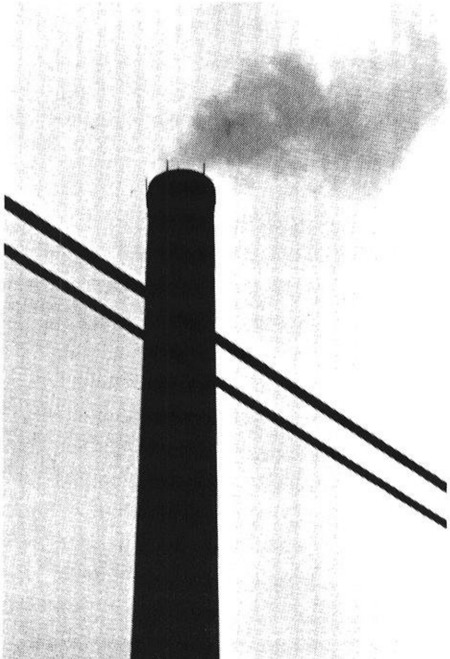
by David Eiche

David Eiche is a freshman in Mechanical Engineering and a recent addition to the staff of the Wisconsin Engineer.

At a time when regulation in general is becoming increasingly unpopular, Congress is reconsidering the single most important piece of environmental legislation -- the Clean Air Act. Passed in 1970 to alleviate air pollution, the act has had a profound effect upon American industry. Billions of dollars have been spent on pollution control, and the quality of the nation's air has improved. In the meantime, the industries most affected by the Clean Air Act have weakened due to energy crises, changing consumer demands, and government regulations. Congress must now structure the act to protect the environment without further weakening the ailing industrial sector of the economy.

Congress' task can best be appreciated through a brief study of the Clean Air Act itself. The legislation is divided into sections, each dealing with a different air pollution problem. The most important section authorizes the Environmental Protection Agency (EPA) to implement National Ambient Air Quality Standards (NAAQS) in order to protect "public health and welfare" from the effects of major air pollutants. At this time, these pollutants include sulfur dioxide, particulates (microscopic carbon particles), lead, hydrocarbons, carbon monoxide, oxides of nitrogen, and ozone. The NAAQS are subdivided into two categories, "primary" and "secondary." The former protect human health, while the latter concern agriculture and property.

The EPA determines NAAQS by consulting the available data on particular air pollutant effects. The Clean Air Act forbids the EPA from considering the cost or feasibility of compliance in setting pollutant standards. However, the EPA may take into account cost and feasibility in setting compliance schedules. Thus, a company (or an entire industry, for that matter) finding it difficult to meet a pollutant standard may be given more time to find a solution.


While national lobbies await the Clean Air Act vote, UW Madison's heating plants have drawn concern from local environmental groups.

The NAAQS are controversial since they are based upon imprecise scientific data. EPA is required by law to set standards which ensure an "adequate margin of safety." This is difficult since the effects of low concentrations of pollutants are ambiguous. Industry is particularly concerned about EPA's interpretation of data and the resulting standards, which it often sees as unjustifiable and expensive. Enviornmental groups, on the other hand, are concerned that any relaxation of standards could cause significant damage, since science cannot determine the threshold level at which pollution becomes dangerous.

Perhaps the most controversial section of the Clean Air Act is the Prevention of Significant Deterioration (PSD) program. PSD is intended to protect areas of the nation with better air quality than that mandated by federal standards. Under the program, no new pollution sources (e.g., factories) may be created in a PSD area until a one-year air quality test of the region is completed. If the air quality is satisfactory, the factory may be built, and the EPA will order the company to install certain types of pollution controls.

The PSD program is confusing because an area may come under PSD rules for some pollutants but under a totally different set of rules for the others. A case in point is Los Angeles, where PSD rules apply only for sulfur dioxide. Nearly all of the country has low concentrations of at least one pollutant. Thus, the PSD program applies to 90% of the U.S.

Both business and environmentalists agree that the PSD program is overly complicated and should be simplified. Energy companies find PSD rules especially troublesome in the West, where they are hampering energy projects including oil shale development and coal conversion.

A third section of the Clean Air Act concerns nonattainment areas, the regions where NAAQS have not been met. (This applies to nearly all U.S. cities.) The regulations for these areas can be illustrated by an example. Imagine that Smokum Steel Company wishes to build a plant in an area where carbon monoxide standards have not been met. Smokum would be required to make an agreement with an existing company in the area to offset Smokum's new emissions by cutting its own. In this way, the total level of carbon monoxide in the area would be unaffected by the new plant. Smokum would also be required to use the most effective pollution controls possible.

Many major cities are not expected to meet current NAAQS by the deadline date. Normally, nonattainment area rules would call for mandatory federal sanctions in such a case, but Congress may change or abolish the deadlines.

Unlike other industries, the auto industry **has** met pollution standards previously believed unattainable. Nevertheless, automakers are asking for a relaxation of carbon monoxide and oxides of nitrogen rules, which they contend decrease fuel efficiency and increase car prices. Another worry is the 1985 particulate standard, which fuel-efficient diesel models may not meet. The National Academy of Sciences agrees that the carbon monoxide and oxide of nitrogen standards are too stringent. However, the particulate standard may be justified because particulates are suspected carcinogens.

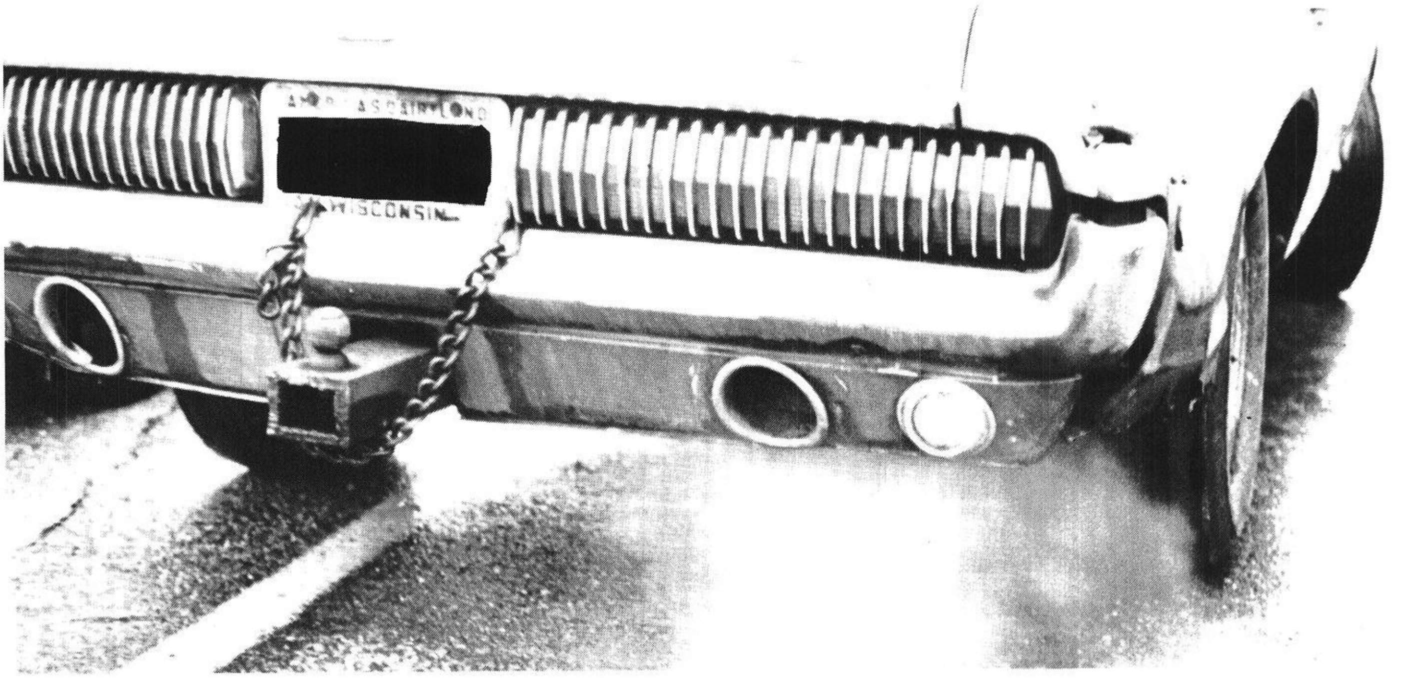
The remaining sections of the Clean Air Act deal with state cooperation with NAAQS and national standards for pollution sources (NSPS). NSPS is intended to set the level of performance for pollution controls at particular facilities. Critics contend that the standards favor older plants, thereby discouraging companies from constructing new and more efficient facilities.

As comprehensive as the Clean Air Act is, it does not deal with one major environmental concern -- acid rain. Acid rain results from sulfur dioxide and oxides of nitrogen emissions, which travel long distances. These chemicals increase the acidity of precipitation and thereby damage lakes. Environmental groups are clamoring for more control of sulfur dioxide and oxides of nitrogen, but industry says more research of the problem is needed. Since some types of coal have a high sulfur content, the issue involves a conflict between the health of northern lakes and domestic energy development.

Environmental issues have received a great deal of publicity over the last decade, and many polls indicate that the public's support for the Clean Air Act is as high as it was when the legislation was passed in 1970. One survey found that over 80% of Americans oppose weakening the Clean Air Act. However, the Council on Environmental Quality found that in 1980 only 27% were willing to sacrifice economic growth for clean air, compared to 58% three years ago. Americans seem to favor the idea of clean air **per se** but become less enthusiastic when the required sacrifices are associated with it.

It is no secret that industry is unhappy with large portions of the Clean Air Act, although no group advocates abolishing it entirely. The Commerce Department reports that industry spent $49.5 billion in 1979 to comply with clean air regulations. This represents 38% of manufacturers after-tax profits. Furthermore, lead times for building new plants have been doubled by pre-construction rules; and with today's inflation and spiraling interest rates, time is indeed money.

Nevertheless, environmental groups justify the Clean Air Act by observing that the quality of air has improved, though not dramatically. For instance, sulfur dioxide concentrations have de-



Although the auto industry has successfully met pollution control standards, Detroit contends that present emission controls decrease fuel efficiency and increase car prices.

creased 20% since 1970. Business expenditures for pollution control have created jobs in the pollution control industry and advanced emission control technology. Finally, environmentalists contend that air pollution is so pernicious that economic sacrifice is necessary -- one study attributes 53,000 deaths per year to fossil fuel combustion.

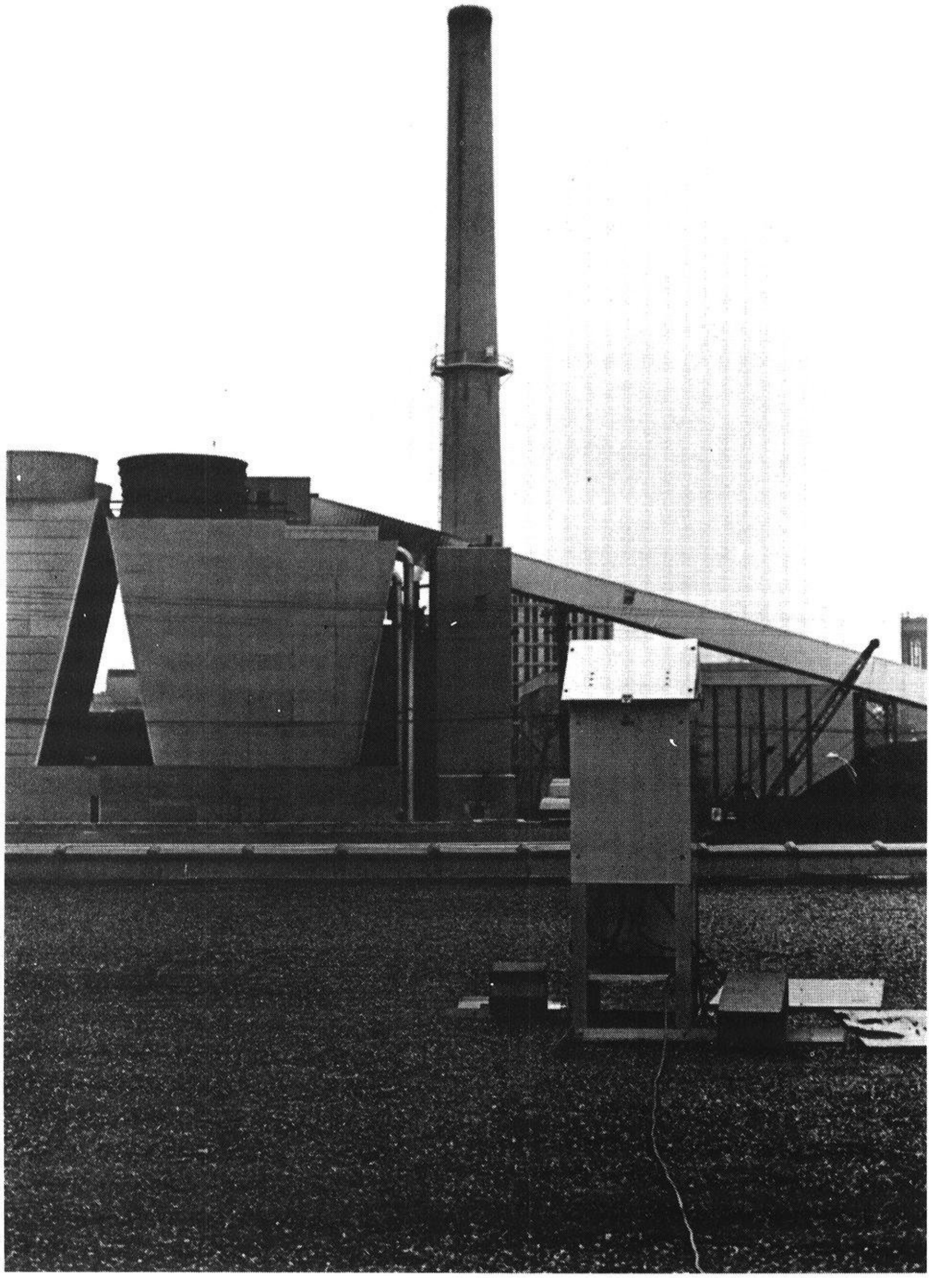
The Reagan administration has apparently sided with industry. At the time of this writing, the clearest indication of Reagan's proposals is contained in a draft of legislation written by a group headed by the new EPA chief, Anne Gorsuch. The major changes presented are:

1. elimination of secondary NAAQS standards
2. elimination of all PSD areas, except near national parks and wilderness areas
3. loss of EPA authority to control acid rain
4. elimination of pollution standard deadlines in nonattainment areas
5. relaxation of oxides of nitrogen and carbon monoxide auto pollution standards
6. elimination of mandatory penalties for polluters who do not meet the standards.

Reactions to the proposals were mixed. Rep. Harvey Waxman, chairman of the committee holding hearings on the Clean Air Act, called the proposed changes "a blueprint for the destruction of our clean air laws." A manufacturing industry representative expressed a different point of view, finding the proposals "right in line with the things we asked for." Congressional support for the Reagan proposals is unclear at this time, but it is safe to say that Congress is now more sympathetic to industry than it was when the Act was passed in 1970. Final votes on the Clean Air Act may be delayed for a year as debate over the federal budget continues.

There is no doubt that changes to the Act could significantly lessen industry's expenditures for pollution control, much of which is passed on to consumers. Thus, a weakened Clean Air Act could financially benefit the consumer. What the proposed changes could do to the environment is subject to dispute. Our current economic problems have produced one of the most conservative federal environmental concerns. The old philosophy was to side with environmental groups when scientific evidence was ambiguous; today, industrial concerns seem to be favored in such cases.

This does not necessarily mean that air quality will deteriorate to dangerous levels. With sufficient research, it is possible that technical solutions to the pollution problem will be found which will make emissions control more economical and effective. For instance, the development of three-way catalytic converters revolutionized automative exhaust control, reducing emissions to previously "impossible" levels. It will take an effective combination of political and technical efforts to find acceptable solutions to the difficult problem of air pollution control. □



Located on top of University Stores, this particle monitor (foreground) keeps a "nose" on coal dust emissions from the UW Heating Station.

Environment, Fortune, Science News, Time and U.S. News and World Report magazines were consulted in the production of this article.

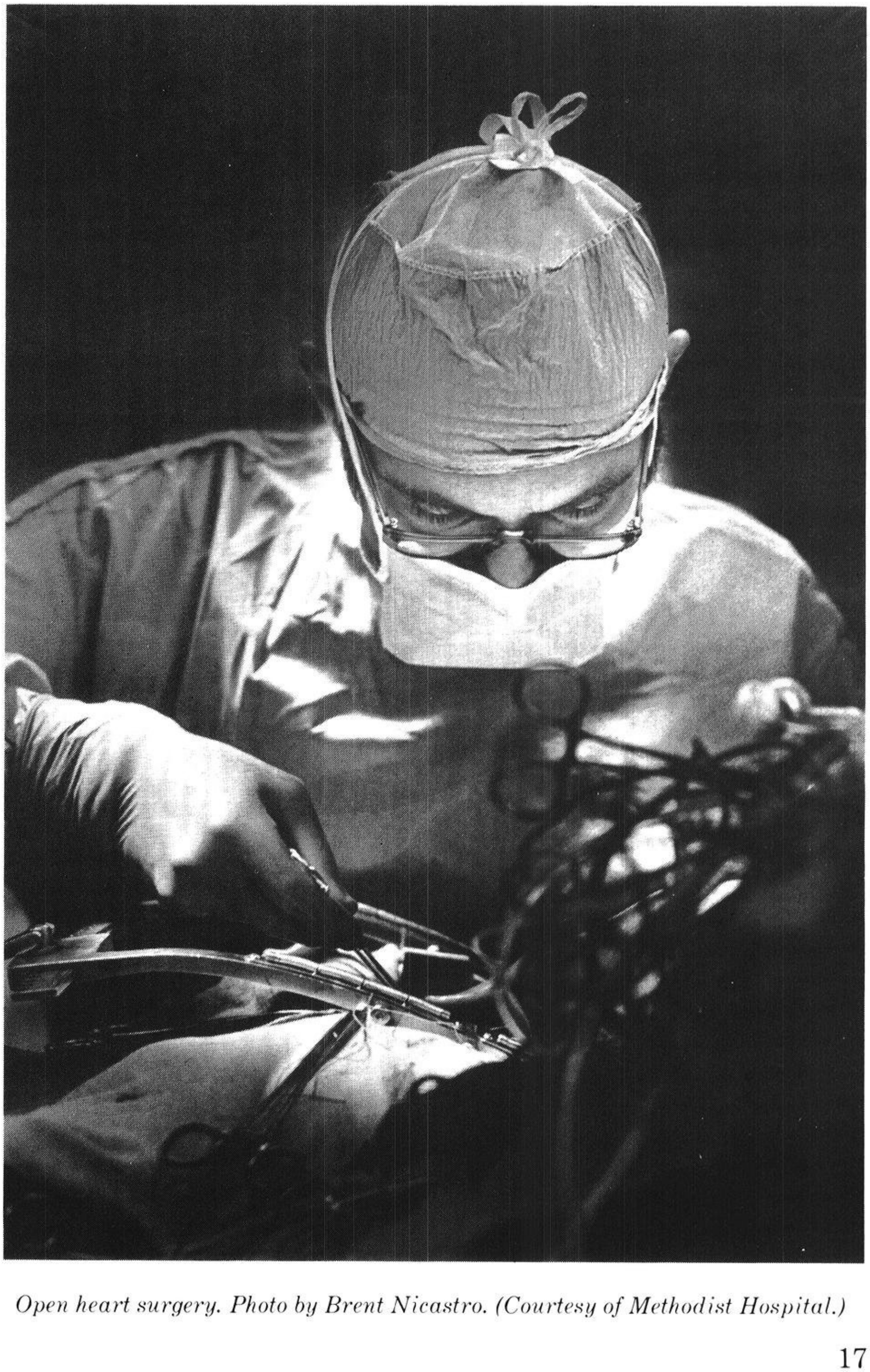
Engineering Design in Biology: The Aortic Valve

by Alan Reed

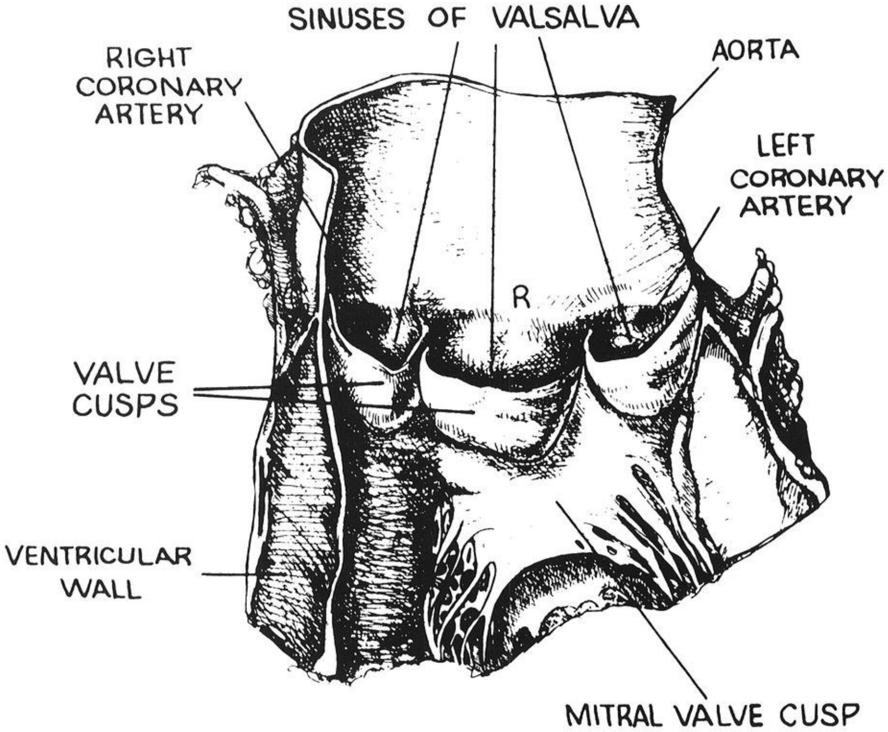
Alan Reed has a deep interest in the design behind biology. In seeking to understand this design at a deep level, he went into chemistry. Now, to understand chemistry and biology at a fundamental level, he is studying the relevant physics behind it. Presently he is a second year graduate student in the Theoretical Chemistry Institute at Madison.

What has the most sophisticated engineering design in the whole world? Your body and mine! The design of the human body is far from being fully understood. Oftentimes, we only realize the complexity of our bodies when we are sick or injured. Our bodies have approximately 100 trillion cells which, in some supremely amazing way, are able to work together for a common purpose and enable us to think, run, talk, play, etc. Each tiny cell is complicated; its instructions are coded onto the six feet of DNA strands in its nucleus. The genetic code on our DNA would occupy one million pages if printed in a book. What a compact library is inside each cell! Each cell has its own power plants, digestive system, factories for making proteins, and a control system for regulating its thousands of chemical activities and directing them according to the needs of the body at each moment. Specifically designed enzymes speed up chemical reactions much more effectively than man-made catalysts. The activity and number of these enzymes is constantly regulated in an intricate way. I do not mean to imply that humans are only complicated pieces of engineering. We are not mere robots and have aspects such as personality and a free will that are beyond what is normally thought of as the physical realm.

The architecture of the human body has many engineering aspects. Later in this article an engineering study of the human aortic valve will be described. Engineers can make unique contributions to medicine and biology by virtue



Open heart surgery. Photo by Brent Nicastro. (Courtesy of Methodist Hospital.)



An Artist's Sketch of the Aortic Opening. The Artery is Cut and Spread Out so as to Show the Three Aortic Valve Cusps and the Sinuses of Valsalva Directly Behind Them.

of their methods, training, and perspective, which are different from those of scientists. And, as engineers look at biology, they not only benefit biology but also their own field. In this modern world, there is a big demand for engineers to keep designing machines and instruments so that they work more efficiently. So, engineers may benefit from and be inspired by studying how various design problems were solved in nature. Such a discipline is called Bionics. For example, Velcro fasteners were developed by an engineer who noticed the design of certain plant seeds that stuck to him as he hiked in the Alps.

One system of the body that has been studied by engineers is the fluid mechanics of the circulatory system. Studies of six aspects of this system are discussed in a monograph by Professor M. E. Clark of the University of Illinois at Urbana-Champaign. It is entitled, "Our Amazing Circulatory System . . . By Chance or Creation?" He argues that, "when the designs are infinitely complex, marvelous in their capabilities, and optimized in all knowable ways, there is a further necessity to say, 'such design requires a divine designer.'" Of course, each person may draw their own conclusion, but there is no question that the design is amazingly complex.

The most astounding example Clark presents is the process by which the right and left pumps of the heart are automatically converted from a parallel to a series pumping arrangement at birth. This feat is accomplished by the change in the blood flow pattern and oxygen content as the umbilical cord is severed and the baby starts breathing. These events at birth automatically set off the closure of two passageways that close only once during one's life; a valve flap over the foramen ovale in the heart and the ductus arteriosus. In this article I shall discuss one of Clark's simpler topics: the role of the sinuses of valsalva in the efficient closure of the aortic valve.

The aortic valve is located at the outlet of the left ventricle. The oxygenated blood leaves the heart to go through the aorta and then to the whole body. The aortic valve serves to prevent reverse flow back into the heart from the aorta. Reverse flow would decrease the output and increase the work load on the heart. All the valves in the circulatory system act as passive controls. They are not controlled by muscles but by the forces that exist in the flowing blood itself. Heart valves have various designs, and my remarks will apply only to the aortic valve.

How would you design the valve? The simplest design would be to put flaps inside the vessel that are pushed open by flow in one direction, and pushed shut by flow in the other direction. Since the valve would not close until a certain amount of blood had flowed back into the heart, this would not be a very efficient valve. The ideal valve would close without letting any blood flow in the reverse direction. This could be done by having an active control device such as a group of muscles closing at the proper time during the heart's cycle. However, if these muscles were not in perfect synchrony with the heart beat, eventually they would start closing at the wrong time and work against the heart by adding a drag to the heart flow. The danger of this happening would be greatest when the valve is needed the most: when the heart output needs to be suddenly increased.

Thus, in many ways, it would be better to have a passive control system, directly controlled by the blood flow. The valves must start closing as the blood flow slows down and before the flow reverses. How can this be done?

In this modern world, there is a big demand for engineers to keep designing machines and instruments so that they work more efficiently.

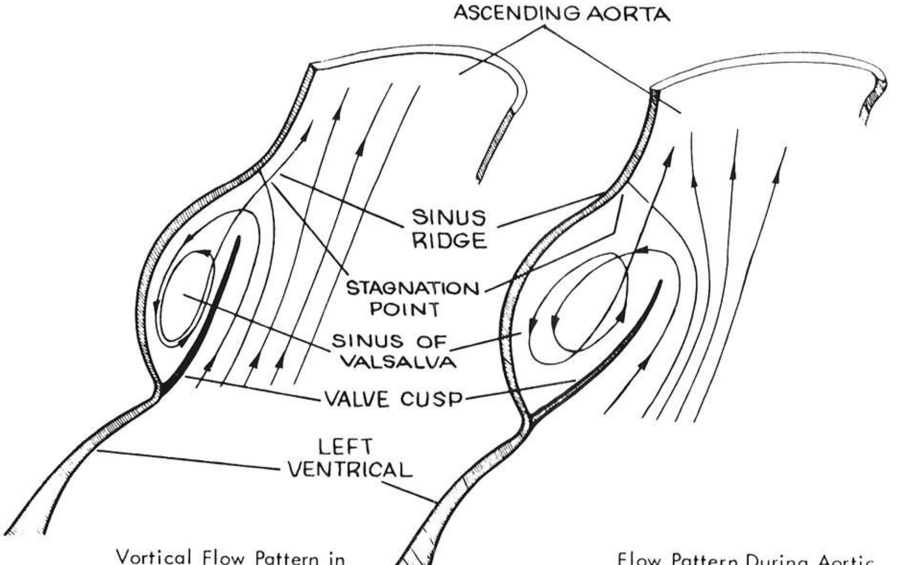
One way is to have out-pouchings behind the flaps of the valve that allow a vortex flow to be set up that will push the flaps shut as the flow decelerates. This is, in general terms, how the aortic valve works. A more detailed description follows.

The human aortic valve is composed of three valve cusps that are flaps (0.15 mm thick) which close together to stop reverse flow. Behind each of these cusps is a sinus, an out-pouching or bulge in the blood vessel. These are called the sinuses of valsalva. In 1740, Valsalva noticed the uniform presence of these sinuses in a variety of birds and mammals. Until recently, the valve was thought to close by the reverse flow of the blood.

A study of the human aortic valve was made at the Engineering Department of Oxford. The results were published in Bellhouse and Bellhouse, *Nature*, 217, p. 86 (1968) and Bellhouse and Talbot, *J. Fluid Mechanics*, 35, p. 721 (1969). Bellhouse and Talbot constructed a model of the valve with and without the sinuses and measured the efficiencies of both. The efficiency was defined as the net forward flow per pulse multiplied by 100% and divided by the peak forward flow per pulse. The valve with the sinuses was more than 98% efficient and closed smoothly and evenly. An identical valve without the sinuses was only 75% efficient and was closed suddenly and unevenly by reverse flow.

The articles by Bellhouse and Talbot present a mathematical description of the fluid mechanics of the valve and compare it to experimental results. Two essential events must take place for valve closure. First, the pressure must become greater on the sinus side of the cusps as the aortic flow decreases. Second, the blood volume needed for valve closure must be brought to the region between the sinuses and the cusps. An article by Talbot and Berger in *American Scientist*, 62, p. 671 (1974), describes how the vortex in the sinus helps to bring about these events needed for valve closure. The following discussion is based on all four references cited in this article.

When the valve opens, an inflow-outflow vortical motion is established behind the cusps in the space provided by the sinuses of valsalva. The blood that enters the sinus undergoes a few vortical motions and then returns to the main aortic flow, as shown in the figure. A dynamic relationship is set up between the pressures on the opposite sides of the cusp because of the presence of the vortex.



Vortical Flow Pattern in the Sinus of Valsalva at Full Valve Opening.

Flow Pattern During Aortic Valve Closure.

The vorticies derive their energy from the forward flowing stream. After peak systole, which is the instant of maximum flow, the motion of the vorticies in the sinus does not decay as fast as does the main aortic. Thus, there is a phase difference between the main stream and the vorticies. The persisting vorticies provide the pressure to start closing the valve as the flow decelerates. A mathematical analysis shows that when the flow acceleration changes sign (i.e., starts to decelerate), the pressure gradient sign changes also. Thus, there is a large pressure downstream near the flap tip. The vortex motion can pick up this larger pressure and carry it into the region behind the flap, helping to close the valve. This excess pressure is very small, being only 1-2 mm of mercury. In the model aortic valve that was made, high energy vorticies could be seen trapped between the sinuses and the cusps. The peak velocity in the sinuses occurred after peak systole and the vortex persisted through the valve closure period.

It remains to be explained how the blood needed for valve closure is brought to the region behind the valve cusps. If the valve had no sinuses, reverse flow would have to take place in order to supply the needed blood volume. Since the valve does have sinuses, a pattern of blood flow into and out of the sinuses is established as soon as blood starts flowing through the valve. The blood volume behind the cusps can be changed merely by altering the relative amounts of flow into and out of the sinuses, without reversing the main aortic flow. As the model valve shows, the valve can be closed almost all of the way shut by the influence of the flow patterns in the sinus. Only a tiny amount of reverse flow is needed to fully close the valve.

Thus, the sinuses of valsalva are very important and are designed to set up a vortex that will close the valve efficiently with only about two percent flow reversal. The subtle mechanism of the valve should stir one to ask who designed it: Chance or a Divine Designer? This is but one small example of efficient engineering design in biology. Biological designs are not only a source of fascination but also one of potential inspiration. Look around at nature and you will see more splendid examples of design. May you appreciate it and benefit from it. □

Logic, the Army, and Railroad Majors

by Don Leick

Don Leick is a senior in Industrial Engineering. He hopes to make a career of technical writing. This article was motivated by a strong sense of curiosity and a general interest in history.

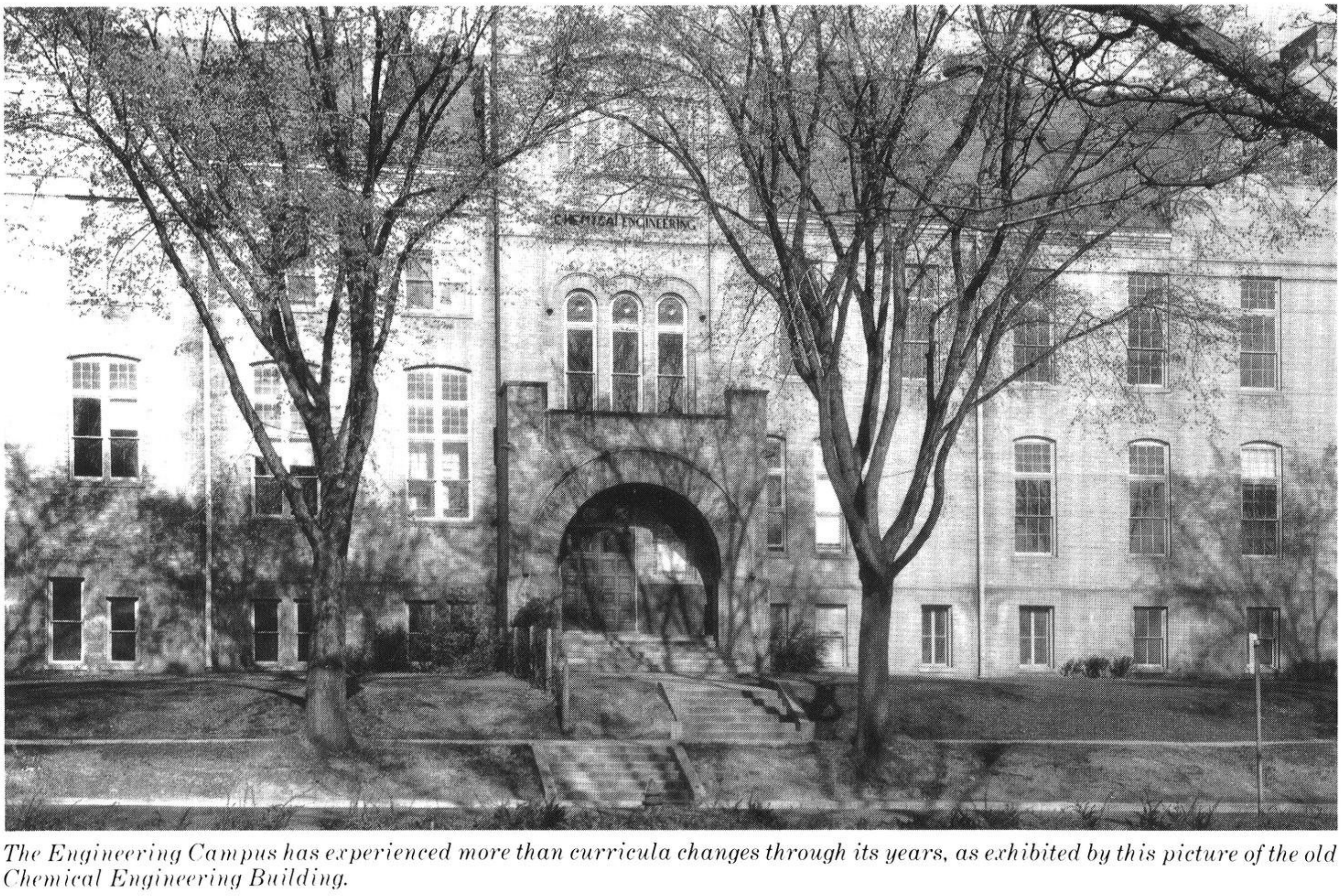
Have you ever met a railroad engineering major? You could have—a hundred years ago. Of course, engineering and engineering education have changed a lot since then. The story of those changes here at the University of Wisconsin is fascinating. I'd like to trace that story by focusing on the changes in the engineering curricula. To start, we need to go back to the time of the founding of the university.

In 1849, Wisconsin, the proud new thirtieth state, declared that it should have its own university. The fledgling University of Wisconsin struggled just to stay alive. There was no instruction in engineering—indeed there was little instruction of any kind. The "university" consisted of one or two rented buildings in which several professors lectured to a handful of Dane County residents.

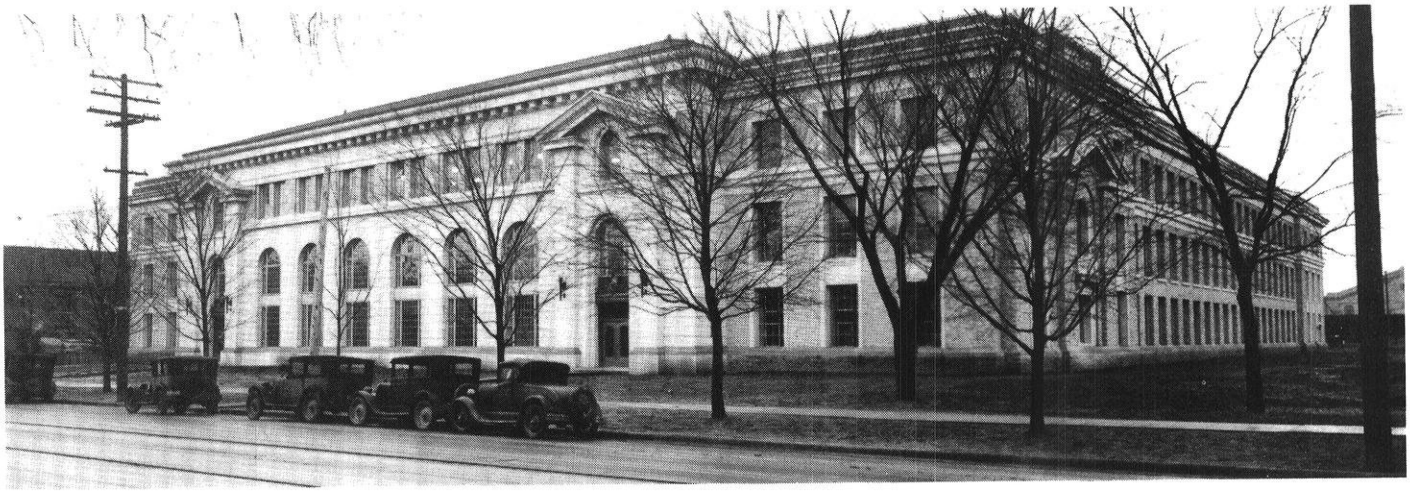
Yet aspirations for the new university were high. The university was to be of practical benefit to all the residents of the state; engineering was to be a prominent part of the University.

In 1858, the Board of Regents ordained that "the subject of study in the School of Civil and Mechanical Engineering shall be: mathematics, practical engineering, architecture, drawing, natural history, general physics, physiology, hygiene, English language and literature, or two of the modern languages."[1] But the Regents' aspirations were ahead of their resources. Because of financial problems no engineering department was formed until 1869.

The engineering department finally formed in 1869 was not the Department of Civil and Mechanical Engineering, but rather the Department of Engineering and Military Tactics. It was an 1860's version of the ROTC. All male students were required to be part of this Army reserve. Each term there was a course in Army regulations, military law and court martial, cavalry and infantry tactics, Ordinance and gunnery, or civil and military engineering. It might not have been a "good way to help



The Engineering Campus has experienced more than curricula changes through its years, as exhibited by this picture of the old Chemical Engineering Building.



The Mechanical Engineering Building before the invention of 'No Parking' signs.

mankind", but it was a good way to get the engineering program started.

Under the direction of U.S. Army Colonel W. R. Pease, the engineering program did grow. Studies in civil engineering were offered in 1872. Programs in mining and metallurgical engineering and mechanical engineering followed several years later.

These budding engineering programs were part of the College of Arts. The University was divided into three colleges during the 1870's and 1880's: the Colleges of Law, Letters, and Arts. The domain of the College of Arts was the sciences and the application of the sciences. All College of Arts students took the same courses in their first two years and then chose between courses in agriculture, commerce, and engineering.

The College of Arts was the practical division of the university. Still, the courses of the 1870's engineering major look much like the courses of today's English major. Literature, history, and languages were given equal time with

A photo of the Girls Mechanics Class from the days when "men were men" and women were engineers.

Groundbreaking ceremonies for the new Engineering Building (1948).

math, science, and engineering. Even some of the engineering courses do not seem much like engineering courses, for example: astronomy, logic, and "mental philosophy". Moreover, some of the important and practical courses of the day now appear archaic—steam engineering and railroad engineering were essentials.

In 1889, the College of Mechanics and Engineering was established. Now engineering had greater autonomy, yet it had something even more important—more money. An electronics lab and a superb machine shop were set up, and new faculty were added.

This was an important point in the history of the College of Engineering. Engineering became a four year program. The curriculums were upgraded and a pattern established; engineering fundamentals were emphasized in the early years and application of those fundamentals stressed in the latter years. Lab work was scattered throughout.

The first course in electrical engineering was offered in 1889. The novel fields of electrical and electrochemical engineering developed rapidly in the 1890's. The Department of Chemical Engineering was established in 1905.

By the turn of the century, the course listings in the university catalogue were surprisingly similar to those of today's timetable. Of course, similar titles don't necessarily mean similar content. Understanding has increased greatly, and thus course contents have changed considerably. Still, UW engineers of that era had a particular set of course requirements which trouble few engineers today—it was required, until the 1920's, to have "sufficient foreign languages to enable graduates to read the professional German and French literature."[2]

The first half of the 20th century was a time of steady growth. By 1950, two developments were obvious. First, departments were broadening in scope and increasing their specialization to encompass booming technology. The second development was more subtle—one might even call it a philosophical development. Engineering no longer viewed itself as the art of making things. Rather it had come to view itself as the application of science. The engineering curriculums had shifted their base from engineering practice or fundamentals to science.

The last thirty years have been a time of even more growth and specialization. Engineering Mechanics and Industrial Engineering became separate departments in '59 and '69 respectively. The field of nuclear engineering spawned a new department in 1963. New names also reflected new emphases. The Department of Civil Engineering was changed to Civil and Environmental Engineering, and the Department of Electrical Engineering was renamed Electrical and Computer Engineering.

That's part of the story of the UW College of Engineering as told by its curricula, but the story is not over. The special relationship between the military and engineering ended long ago, railroad and steam engineers are only a memory, and languages in the engineering curriculum are a thing of the past. These features are strange to us. And the future will bring things stranger still. So recognize your place in history—and be glad you don't have to take military law. □

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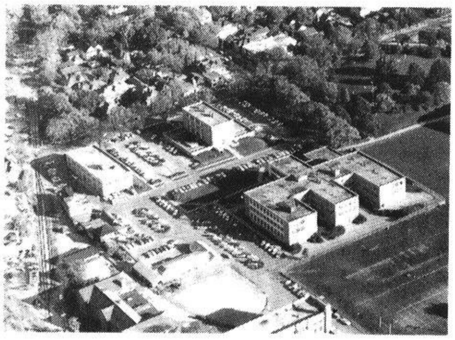
[1] As quoted from Prof. Thomas J. Higgins *A Resourceful College of Engineering*, Madison: UW Press, 1975

[2] *University Catalogue* (any pre-1920's issue)



Two views of the Engineering Building before the renovations existing today.

The Role of Professional Societies

by Noel P. Lindsay and Dirk A. Rodgers

Noel P. Lindsay and Dirk A. Rodgers are seniors in Electrical and Computer Engineering. Noel is the Chairman of the Student Branch of IEEE and Dirk is the Secretary of this organization.

Professor Boyle addressing a recent meeting of the student chapter of the American Society of Civil Engineers.

Picture this scenario: It's your first year at your first job after graduating from the college of engineering. You have recently begun to feel like you understand exactly what your department is doing, and you are beginning to get tired of working on such a limited aspect of that job. You feel as if you are now ready to take on more responsibility. Fortunately your annual performance review is scheduled for next week, and you are hoping for a promotion. Suddenly your supervisor tells you that he has to go out of town unexpectedly and asks you to take his place at the monthly board meeting. Among other things, he tells you that it is vital that more money be allocated to the project that you are presently involved with. Realizing that your performance at this meeting will probably be the decisive factor in your promotion, you now must decide whether or not to gamble your possible advancement on your ability to perform effectively at this meeting.

Your performance in a situation like this would depend not only on your technical competence, but also on your level of professional development. Unfortunately, many engineering students ignore the second of these essential characteristics until it is forced upon them by their first employer. Other students begin their professional growth before they even graduate.

Many people in industry feel that one of the best ways to begin professional development is to become an active member of a professional society as a student, rather than waiting until after you graduate. For example, the student branch of the Institute of Electrical and Electronics Engineers (IEEE) has many programs designed to increase the professional awareness of its members.

As part of one of these programs, industry professionals speak at the student meetings on technical topics. In addition to the valuable technical information, members also have an opportunity to interact with practicing engineers in a relaxed atmosphere. This program also includes a series of plant tours which gives students direct exposure to a variety of industries.

IEEE's summer job placement service was started this year to provide its members with a opportunity to gain invaluable summer engineering experience. Over a thousand electrical engineering positions are now available to IEEE members for next summer. The students participating in this program will receive a computer listing of the positions which correspond to their interests.

Another program consists of soliciting donations of equipment from industry for the student electronic shop and promoting its use. Students using the shop have the opportunity to go beyond designing a mere schematic diagram of a piece of equipment by actually building it and making it work.

To help the students gain a better perspective of their profession, IEEE sponsors a number of design contests. One of these contests is intended to highlight the same economic concerns that industry must consider. The entries will be judged on the basis of marketability, profitability, and the quality of the 'sales' presentation.

IEEE is only one of the many professional engineering societies. Each of these societies has its own methods of accomplishing the same basic goal - to help their members begin their professional development.

While many engineers would have difficulty with the decision in the above scenario, a professional would not hesitate to take the opportunity to show what he can do. Maybe you should begin now to prepare yourself for this kind of situation. Become a professional — join a professional society now. □

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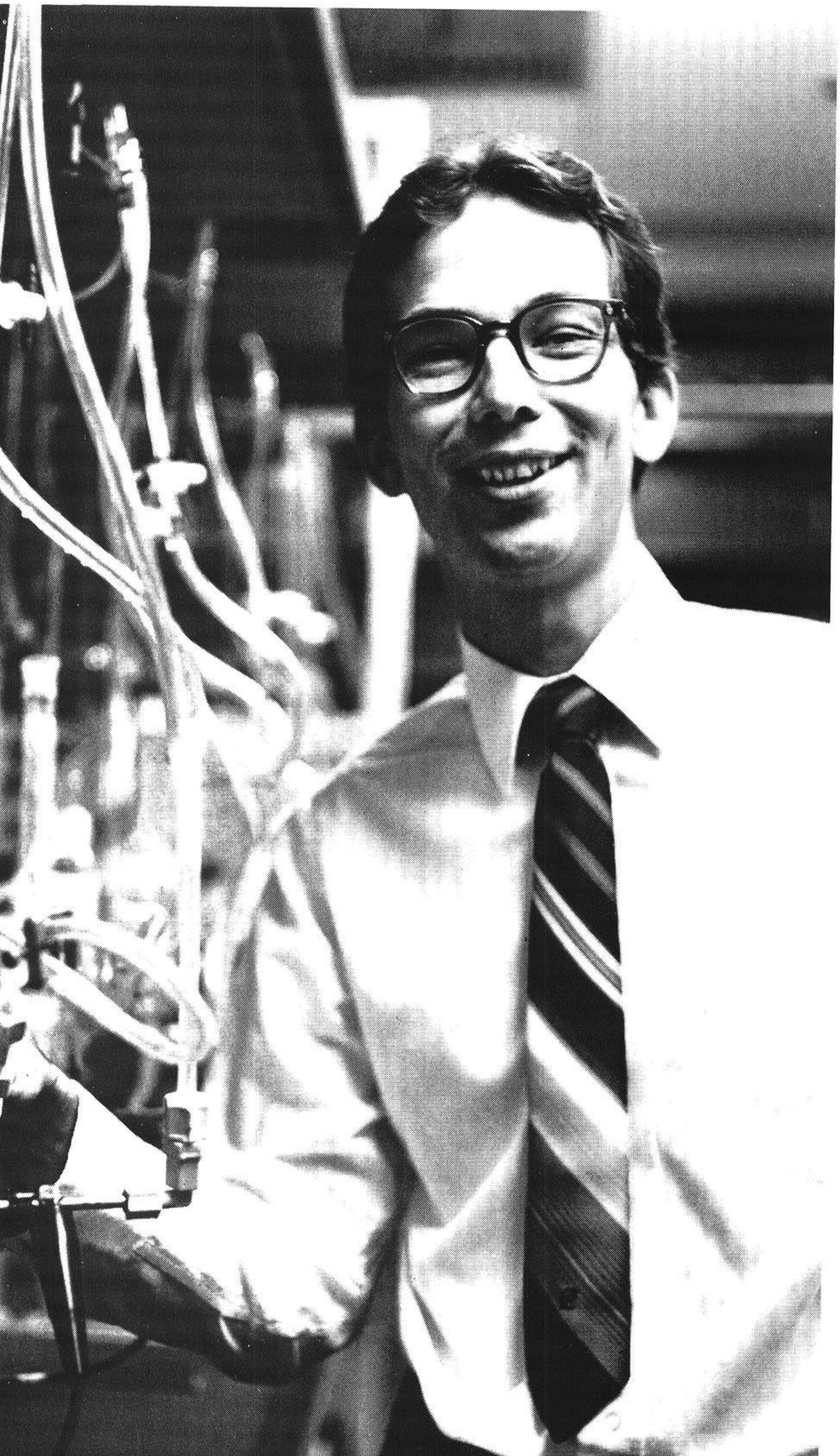

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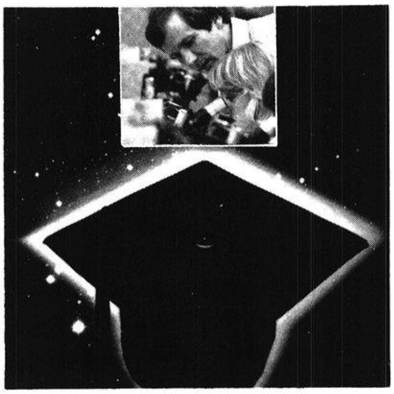

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Campus Interviews

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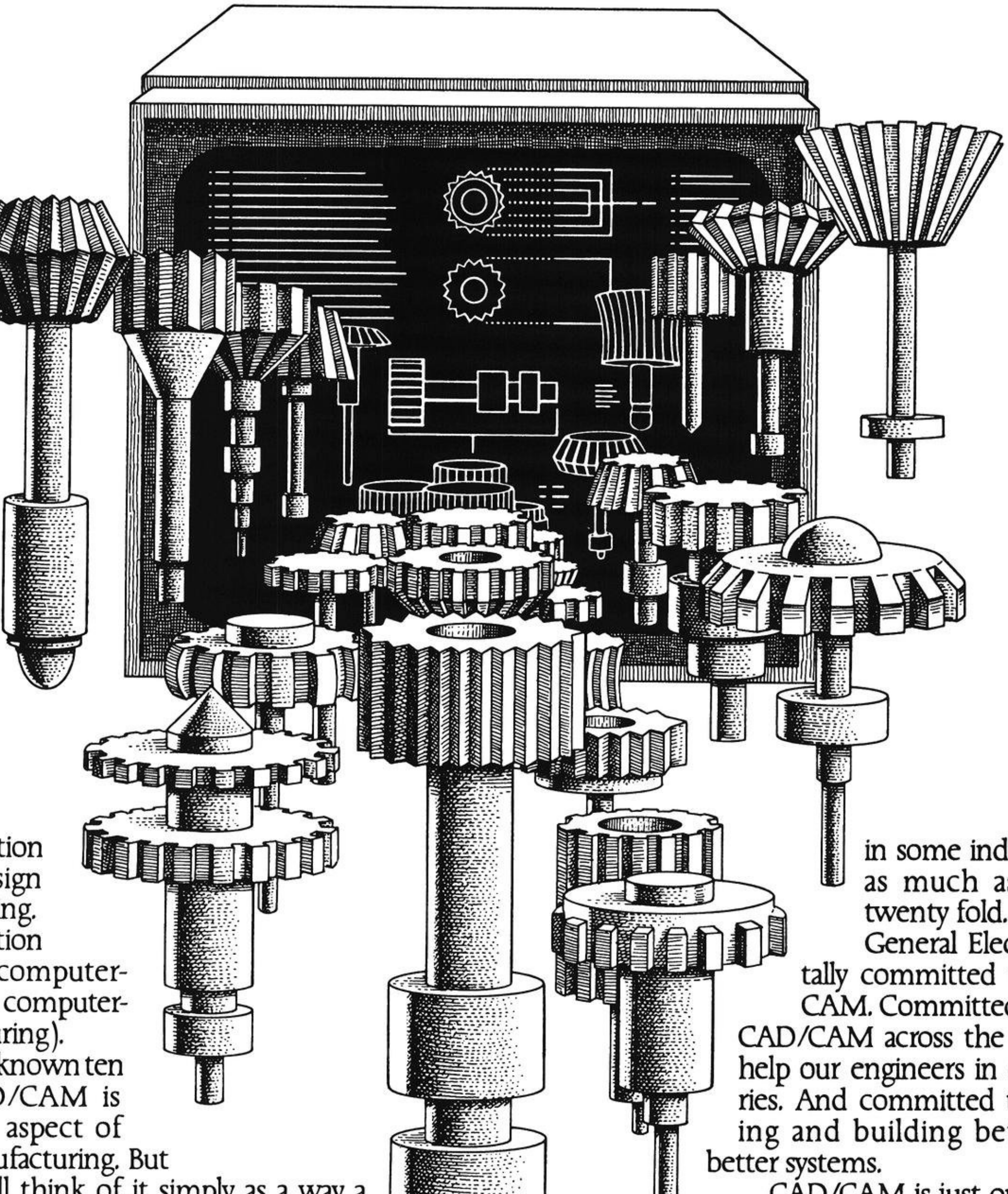

There's a revolution going on in design and manufacturing.

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