Resources in Technology

7

INTERNATIONAL TECHNOLOGY EDUCATION ASSOCIATION

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INTERNATIONAL TECHNOLOGY EDUCATION ASSOCIATION

Resources in Technology

Processing Technology

PHOTO 1
A mature stand of loblolly pines is ready for harvesting. Timber management is a must for producers of paper and other forest products.

Resources in Technology is written and prepared by Tidewater Technology Associates (T2A), an educational consulting group that specializes in the development of techincal programs, curriculum and instructional materials. Members of the group are Walter F. Deal, III, Fred Hadley, James A. Jacobs, Thomas F. Kildruff, John M. Ritz, and George Skena. Further inquiries can be made by contacting Walt Deal, III, 429 Lindsay Landing, Yorktown, VA 23692; 804/683-4305.

When one thinks of production technology, a vision of industry making products often comes to mind. Further analysis reveals that the making of products is usually viewed as the construction of structures such as homes, office buildings, roadways, etc. or the manufacturing of automobiles, appliances, or similar products.

However, little thought is given to how products such as food, chemicals, standard industrial stocks, or electrical power are produced to use in everyday life. Whereas construction is concerned with building a structure on a site and manufacturing is involved with putting together subassemblies to produce products, processing is a system of production technology that prepares or modifies material resources through mechanical means so that they may become either direct consumer products or serve as standard stocks for additional production operations. Beverages, paint, glass, cosmetics, lumber, and a host of other products are produced using various forms of processing technology.

Contemporary Analysis

Early humans consumed natural resources found in their locales. Fruit was gathered and eaten. Clay was dug from the ground and shaped into utensils. Oil was gathered from open ponds and used as a lubricant or for medicinal purposes. Berries were crushed and used as dyes for fabrics. As civilizations evolved, however, humans found many resources that could be processed in various ways to make them more useful. Food could be dried or salted to extend its shelf life. Copper and iron ores could be mined and processed through heating so that they could be shaped into weapons, utensils and jewelry.

These acts of transforming—so that materials resources could be modified into useful products—were the start of processing operations that continue into modern times. Processing involves an assortment of operations where natural resources are taken and modified through crushing, sorting, mixing, heating, and forming to make improved products that are more useful to consumers and industry.

For example, a farmer may invest his financial resources in the raising of hogs. He purchases these animals as piglets or breeds his own from his present herd of livestock. When the animals grow to maturity, the farmer sells them at auction to meat processing companies. These companies process the animals into various meat products such as hams, pork chops, ribs, and roasts and uses their remains for further processing into sausage, fertilizers, medicine, leather, animal food, etc.

A forest products company would use similar operations in producing lumber and other forest products. In today's society, not too many virgin or unwooded areas exist. Most forest product companies have managed forest areas (Photo 1). When they cut trees, they usually replant them so that they will be available in the future. Some soft wood companies, pine tree processors, replant trees that have been genetically altered so that they grow to maturity in fewer than ten years.

When soft woods are harvested, they are processed into various products. Lumber is one the mainstays in forest products production. However byproducts are also produced such as pine bark mulch, pine bark nuggets, pulp (used to produce paper and other cellulose products, i.e., diaper linings, food products such as fast food milkshakes, etc.), veneer, pressboard, and so on.

Each of these products requires special systems for its processing. Engineers and technicians spend their lives designing and modifying such systems to make them operate as efficiently as possible. The operations of all processing systems usually requires heat and/or pressure for them to operate efficiently.

For example, a copper processing company will eventually sell its product to a firm that may wish to produce copper water pipe, electrical wire, or other products requiring copper materials. However, the company that produces the copper must first obtain the copper ore from a mining company. This company may also produce the copper ingots that may be further processed into the final products such as wire or pipe.

To produce the copper ingots, many processes must be followed. These include crushing the ore and separating the tailings (waste products such as soil and rocks) through flotations cells where copper bearing particles are washed away from the wastes. After the copper is separated mechanically from wastes, it is heated to impurities. This is referred to as smelting. It removes additional impurities through melting and blowing air through the molten mass.

The resulting copper at this stage of purification is known as blister copper. It can be made into ingots, which can then be made into copper pipe or further processed and refined through electrolysis.

Electrolysis uses electrical current and charges to remove further impurities to make the copper 99.9% pure. This is the quality of copper needed for electrical applications. All these processes requires

FOOD	CHEMICAL	STANDARD STOCK	POWER
Beef	Cosmetics	Lumber	Hydro-electric
Fruit	Medicine	Lubricants	Nuclear
Vegetables	Paint	Metals	Steam
Poultry	Petroleum	Plastic	Solar
Seafood	Fertilizers	Fasteners	Hydraulic
Cereals			

TABLE 1
Examples of processing technology products.

REDUCTION IN SIZE	SEPARATION	COMBINING	CONDITIONING	FORMING
Cutting	Trimming	Mixing	Annealing	Rolling
Crushing	Filtering	Blending	Canning	Compressing
Grinding	Sifting		Dipping	Freezing
	Sorting		Spraying	Stamping
	Refining			Casting

TABLE 2
Examples of processing technology operations.

the use of pressure (crushing) and heat (smelting).

Another example of using processing technology is in the preparation of chemicals. Cosmetics, ammonia, petroleum products and synthetics are all chemical products that require processing systems for their production.

Take, for example, synthetic rubber. To produce synthetic rubber, heat and pressure are also required. It is made by combining two chemicals: butadiene and styrene. Butadiene is obtained by processing (cracking) petroleum into a gaseous form. Styrene is a combination of ethyl benzene that comes from combining petroleum and coal by-products.

To make the synthetic rubber, butadiene and styrene are combined in a soapy solution. The two chemicals polymerize or form chain-like molecules of rubber in a water solution. Other chemicals are added to coagulate the rubber. Then the water is removed leaving a synthetic rubber compound that is shredded and shipped to plants where it can be processed like natural rubber with superior qualities. The tires on today's automobiles are manufactured using synthetic rubber.

Another commodity that is produced through processing technology is electrical energy. This can be produced by processing energy resources such as water, uranium or coal. At a hydroelectric power plant, the dam traps water which has potential energy. This water is diverted through piping systems and converted to kinetic energy through turbines that resemble water wheels used in the past. The turbine operates a generator that produces the electricity through electro-mechanical means. The faster the water turns the turbine and generator, the more energy is produced. After the energy is produced, the water is released back into the stream.

As the above examples point out, processing systems are very important to supporting life in a technological world. There are four major types of products that are produced using processing systems:

- Food products
- Chemicals
- Standard stocks
- Power

Table 1 shows examples of each of these products.

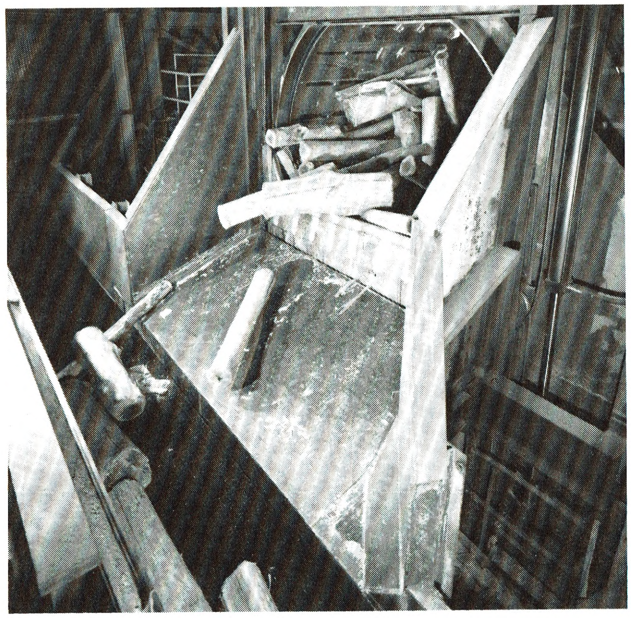

PHOTO 2
Bark is separated from logs so that it can be further processed into paper.

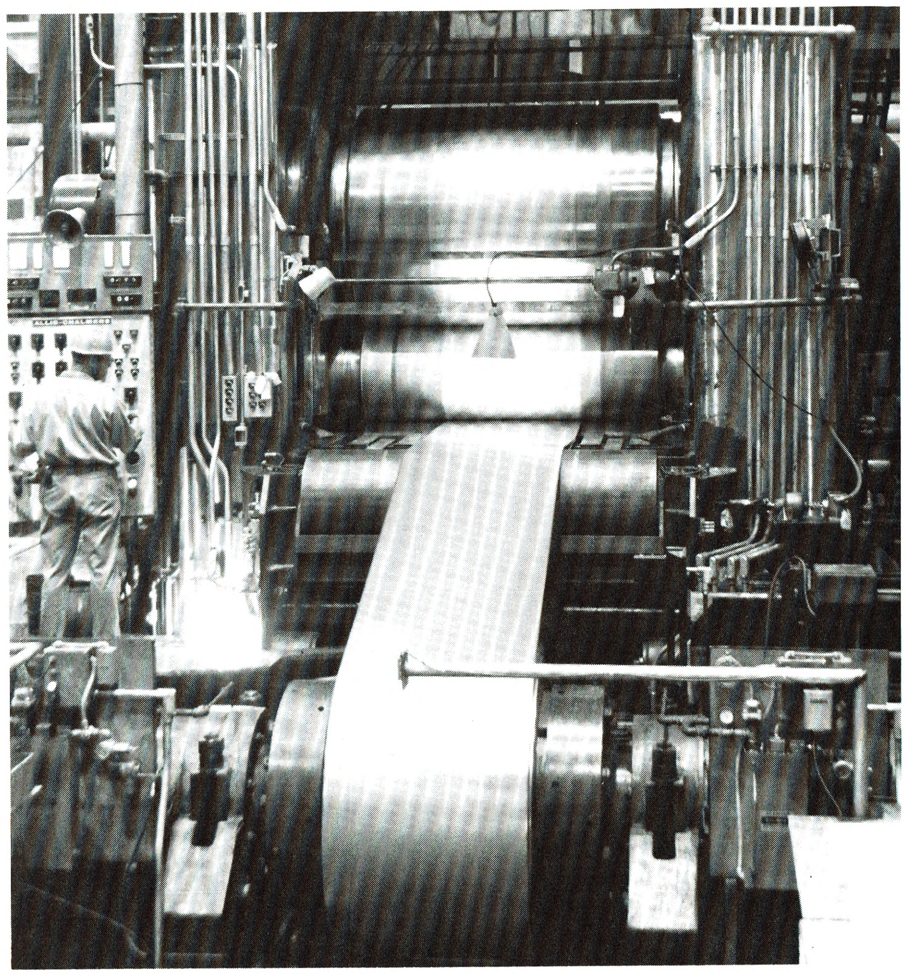

PHOTO 3
Steel sheet enters a temper mill where the metal is rolled through a single stand to restore proper stiffness lost by the metal during the annealing process.

Common Processing Operations

To obtain these products, complex systems must be designed, modeled, tested and built. Researchers and engineers spend their careers perfecting new products and designing the systems to produce them. Within the systems, machinery performs different operations on the raw materials to make them into products or stocks for further processing. Some of the common operations performed by processing systems are shown in Table 2.

Reduction in Size

Reduction in size uses technical operations to break natural resources into smaller sections so that they can be further processed. Processes such as cutting, crushing and grinding are examples of reduction processes. Trees are cut from the forest and cut into logs. Granite is cut to moveable size at the quarry. Iron ore is mined, then crushed to aid in removing impurities. Coffee beans are ground to release their flavor from the bean.

Separation

A second class of processing operations can be grouped under the term separation. Separation includes technical operations used to divide materials into individual components. Bark is trimmed from logs and pork chops are trimmed from the carcass of the hog (Photo 2). Impurities are filtered from copper-bearing particles through flotation. Different grades of coal are separated through sifting operations. Apples and eggs are separated through sorting. Refining is another separation process in which crude oil is broken down into gasoline, lubricants, kerosene, tar and asphalt. These operations are used to assist producers to process many consumer and industrial products.

Combining

The next major group of processing operations are labeled as combining. They use technical operations to combine materials. Cement is made by mixing limestone, silica and alumina. Gasoline is produced by blending hydrocarbons, additives and dyes.

Conditioning

Conditioning operations involve treating materials so that they can be exposed to the environment. Construction lumber is salt treated (impregnated with copper oxides) to prevent insects from boring into it and to make it resistant to moisture. Fabrics have a conditioning agent applied to them so that they will resist staining. Food is canned to preserve its shelf life (Photo 3).

Forming

The final set of processing operations can be labeled as forming. They include technical operations that give size to materials. Luncheon meats are formed in casing to be either round, square, or loaf shaped. Aspirin is formed into either tablets or caplets. Taconite (refined iron ore) is formed into sizes that make them more efficient in steel making.

Research and Development

In the past, many processed products were made in the home. Candles, soap, jelly and canned vegetables are examples. Today industry employes engineers and researchers to research new products and design technical systems for their production. These processes are referred to as research and development. Research is a form of systematic investigation aimed at discovering new facts.

These facts can be used to solve problems. This involves laboratory research to discover such things as new types of paints, cosmetics, treatments for wood,

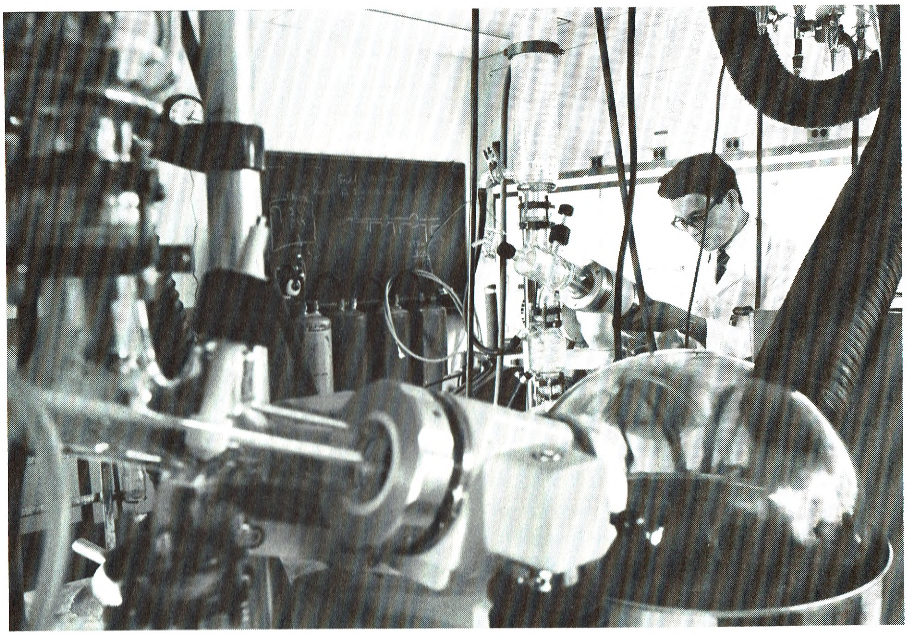

PHOTO 4
A research scientist investigating new ways to process chemical products.

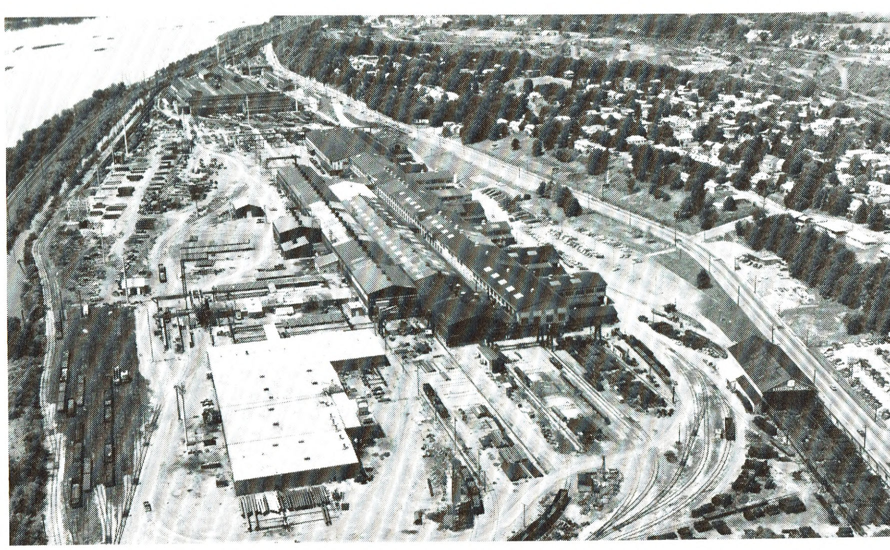

PHOTO 5
This steel mill is located near a waterway and rail line to aid in its transport of raw materials and finished products.

production methods for electricity (superconductivity), lead replacements for gasoline and the like.

Development is the converting of this new information into products. This involves experimenting and prototyping to develop feasible products and economical ways to produce them. Technical systems must be designed to process the products. These range from building an entirely new production facility to modifying existing equipment. In addition, materials must be obtained to process into useful products or services (Photo 4).

Social/Cultural Impacts

The photographs found in this "Resources in Technology" show that processing facilities are usually multi-story complexes and require space for storage of products and methods of transport. Many processing facilities are located on waterways because they use the water to transport raw materials and finished products. Water is also used in many processing operations (Photo 5).

Other plants are located where the natural resources are found or where transportation hubs have been created for ease of transport of the raw materials and the distribution of completed products. One reason Pittsburgh became the steel capital of the world was because it is located on the water (rivers) and because it was a rail transport hub.

To make steel you need iron ore and coal plus other resources such as manganese, limestone, oxygen, etc. The iron ore could be mined in Minnesota and Michigan, shipped over the Great Lakes and then brought to Pittsburgh by rail. The coal was mined in the areas outside Pittsburgh in Western Pennsylvania, West Virginia and Ohio and transported to Pittsburgh by rail.

The completed steel products (I-beams, rolled steel sheet, cast or forged components, etc.) could be transported to the major manufacturing and construction sites easily by rail or to ports using barges on the Ohio River. It should also be noted that when Pittsburgh became the steel capital, most of the U.S. population was located in the east or around the Great Lakes region.

The same was true for the Northeast which became the early manufacturing hub of the United States. Many people settled in the Northeast when they arrived in the United States. The natural streams of the region provided a source of power, water wheels, to operate the belt-driven machinery. Chicago and St. Louis were the meat packing cities of the United States because they were rail centers; where the cattle and hogs could be brought from the Midwest and Great Plains to market and distribution to the population centers.

Today these productions centers have moved throughout the United States and world because of improved and more efficient distribution of natural gas and electricity, improved worldwide communication networks, a less expensive labor force and efficient worldwide transportation systems.

With the processing of resources into standard stocks and consumer products, numerous environmental problems have arisen. In the past, not many cared about what producers were doing to the environment. As long as people had jobs and industry was profitable, government and citizen groups did not intervene. Also control groups did not have the sophisticated testing procedures to analyze the results of industrial production. When people saw

PHOTO 6
Dense white smoke pours from this tall chimney above a processing plant. Governmental regulations are eliminating much of this pollution today.

black smoke billowing from their local plants, they knew there were jobs and the local economy was strong. Yes, the color of water in the streams changed and wildlife died, but these were accepted as signs of economic progress (Photo 6).

Today there is a growing concern for the protection of the environment in developed countries. We hear of acid rain, lack of clean water and poor air quality. No longer can industry upset the ecosystem. Products and production methods must be tested, particularly those produced by processing technology systems, to ensure that they will not harm people or the environment. Too often products are produced, or their wastes from production disposed of, without knowing their long-term effects on individuals or the environment.

Not too many years ago asbestos was the accepted insulator in construction and manufacturing. Today millions of dollars are being spent annually to remove it from buildings and other products. It has been proven that asbestos fibers are a health risk that has been linked to lung disease and cancer.

This is only one reason for testing products in their developmental stage. Cosmetics must be tested to see if they irritate the skin and gasoline additives must be tested to see if they combust efficiently and leave a minimum of toxic elements in their exhaust.

Another reason for testing is to determine if the new processes or products will be profitable to the company. Remember, businesses are established to make a profit for their owners or stockholders. This profit motive is usually the source of most research and development. However, at times, industry seeks new production means and products to protect people and the environment. Sometimes the government passes laws to make industry change. Examples include removing lead from paint and gasoline, disposing of nuclear waste, or removing combustion particles from the air.

No longer is industry allowed to pour wastes and particulates into our lakes and rivers. Campaigns have focused our attentions on cleaning up the oceans, the lakes, rivers and bays. Processing companies must make the water they use in their production clean before they can place it back into our waterways. Solid wastes, such as tailings from mining and crushing operations, must be disposed of properly. Chemical and paper mills are required to prevent their plants from putting unacceptable odors into the air. Mining companies can no longer strip or open pit mine unless they restore the countryside after they complete their operations. These and other problems are forcing processing companies to rethink their practices and develop systems that fit better into the environment.

M/S/T Interface

In the age of technological progress, change is an accepted way of life. One field that has contributed greatly to that change is chemical technology. It has enabled industry to create new and improved processes and products. These include synthetic fibers, plastics, drugs, fertilizers and foods.

Although the study of chemistry is an old science, today it is interwoven into industrial research and development. Chemistry is the study of manipulating matter to produce chemicals and products. It takes raw materials that come from the earth, air, and oceans and transforms them into paper, synthetic rubber, paint, ink, metals and numerous other materials.

The chemicals produced in the greatest numbers are referred to as "heavy chemicals" by industry. These include ammonia, sulfuric acid, nitric acid, chlorine and caustic soda. With more of the world becoming developed, the demand for these chemicals will increase. Fortunately, the raw materials needed to produce the heavy chemicals are abundant in nature and cheap and easy to obtain.

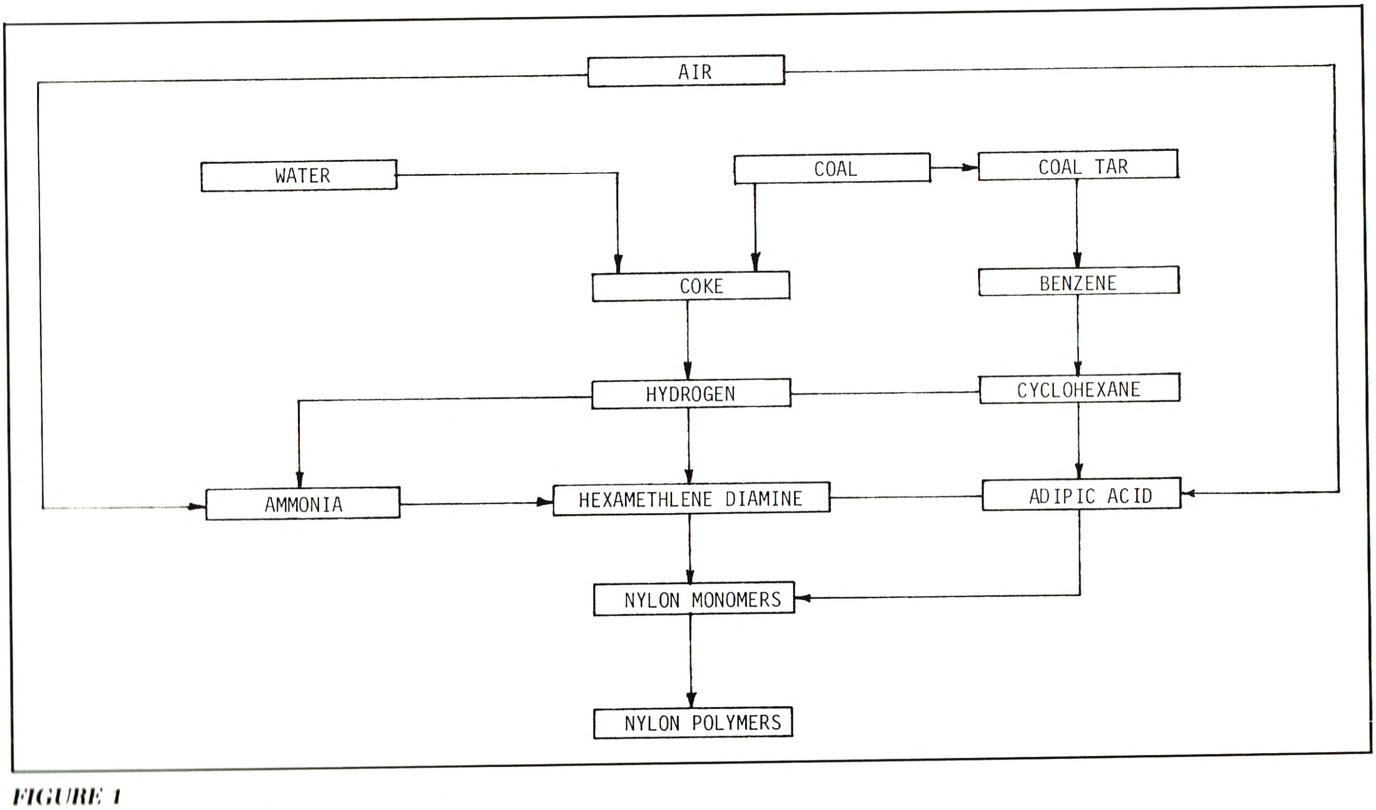

FIGURE 1
The chemical process for forming nylon.

Oxygen and nitrogen from the air and hydrogen from water and natural gas are common materials needed to process nitric acid and ammonia. Chlorine comes from the common salt found in salt water or from underground salt mines. Sulfur for sulfuric acid can be obtained from underground deposits in Texas and Louisiana or from volcanic beds throughout the world.

Although the techniques used in processing these chemicals are complex, the theory behind the processing is not. By uniting nitrogen from the air and hydrogen from natural gas, ammonia can be produced. Chlorine is made by separating the sodium from table salt (sodium chloride).

Sulfuric acid is processed from sulphur that occurs naturally in the environment. It is roasted and its gases are mixed with water to produce the sulfuric acid. It is the most widely used chemical by industry in processing products such as fertilizers, paper, rayon, iron and steel, paint, rubber, dyes, explosives and petroleum products. It has been noted that the amount of sulfuric acid used by a country is a good barometer of industrial activity taking place in the country.

Since chemistry is so important to industrial production, it should be further analyzed to determine how actual products are processed using chemicals. Figure 1 shows how nylon is processed from air, water and coal. As an activity for further study, select a chemical product (paint, steel, rubber, dyes, ammonia, synthetic drugs, etc.) and draw a diagram of the chemicals that go into its production. If possible, use a CAD system to draw the diagram.

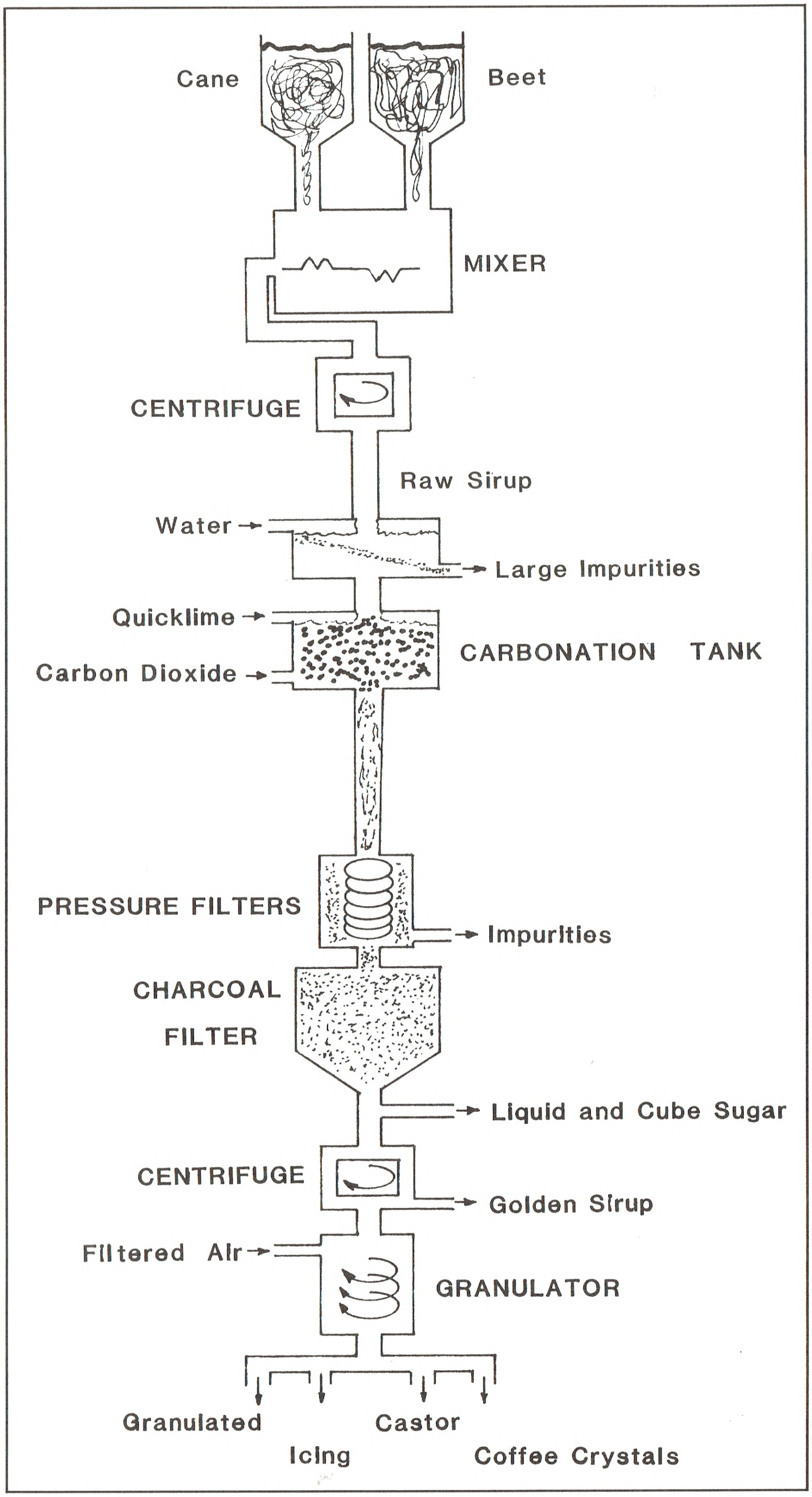

FIGURE 2
This flow chart shows how sugar cane and sugar beets are processed into sugar products.

Construction Activity

Little time is usually spent in schools studying how processed products are produced. However, this is an area of technology that affects us daily, from the foods we eat, chemicals we and use, energy we consume to the standard stocks used by industry to manufacture and construct products. Donald Maley's Maryland Plan proposed that the process industries should be studied through technology education. However little evidence is available that many of our nation's youth get to study these exciting industries and their processes.

As a construction activity, divide the class into groups of three and have them research various products that are produced through process technology. Have the groups report to the class through a seminar on the products they have found through their research. Encyclopedias, particularly *The World Book Encyclopedia*, provide many diagrams that show the flow of how processed products are produced. Figure 2 is an example.

After the presentations, have each group select one processed product to study in depth. They should prepare a 3-D display with models that illustrate the processing of their selected product. The display should include illustrations for impact and should be realistically constructed. The students should also put together a research report on the product they have studied including its history, scientific principles, social/cultural impacts, recent developments, and economic forecasts.

During the research and construction phases, hold weekly seminars to share information on the students' research. This sharing of information teaches each class member about technology, its processes, operations and impacts. At the completion of the unit of study, have each group present their processing operation to the class.

This is also a good time to invite outside guests and build the image of your Technology Education program. In addition this is an exceptional way to study Technology Education.

Another processing activity that can build high interest is to have the class process a food product or beverage. With modern ice cream makers, this can be a relatively easy food product to make. Class members could bring ice cream makers from home and class groups could process various flavors of ice cream. Jelly and root beer are other products the class could make. Regional specialties could also be processed and sold by the local club of the Technology Student Association as a fund-raising project.

A final processing activity that may be used to illustrate processing technology is the production of paper. In the past, many graphic arts classes did this. Ingredients and procedures can be found in older copies of graphic arts books.

Summary

Processing technology systems are very complex systems that provide us with both raw materials for industry and consumer products. These include food, chemicals, power, and standard stocks. The technical operations used by processing systems include reduction in size, separation, combining, conditioning, and forming. Chemistry is very important to the processing of products. It assists with the separation, combining and forming of various materials. Although often referred by some as primary manufacturing, processing technology is a separate area of production that can stand on its own.

Student Quiz

1. The system of production technology that prepares or modifies material resources through mechanical means so that they may become either direct consumer products or serve as standard stocks for additional production operations is:
A. Construction
B. Manufacturing
<u>C. Processing</u>
D. Mechanical Engineering
2. List the four categories of products that many be produced using processing systems.
Food, Chemicals, Standard Stocks, and Power
3. Technical operations for treating materials so that they can be exposed to the environment are?
A. Combining
<u>B. Conditioning</u>
C. Reducing
D. Separation
4. Technical operations used to break resources into smaller sections so that they can be processed are?
A. Combining
B. Conditioning
<u>C. Reducing</u>
D. Separation
5. Define research.
Systematic investigation into a subject.
6. Define development.
The conversion of research information into products.
7. Why is testing so important to processing companies?
To determine if products will be dangerous to individuals and the environment.
8. Why did some cities become industrial centers?
They had access to raw materials and distribution networks to the population because of their transportation systems.
9. Sulfuric acid, ammonia, nitric acid, chlorine and caustic soda are known as what chemicals?
A. Heavy metals
B. Industrial barometers
<u>C. Heavy chemicals</u>
D. Catalysts
10. Which chemical is a good indicator of the industrial productivity of a country?
<u>a. Sulfuric acid</u>
b. Ammonia
c. Nitric acid
d. Chlorine

Possible Student Outcomes

1. Explain processing technology.
2. Describe the classification of processing technology products.
3. Describe the processes needed to process products.
4. Relate the importance of chemistry to processing technology.
5. Produce products using processing technology systems.

Reference

Ritz, J., Hadley, F. & Bonebrake, J. (1989). *Exploring production systems*. Worcester, MA: Davis.

Resources in Technology

WATER
A Magic Resource

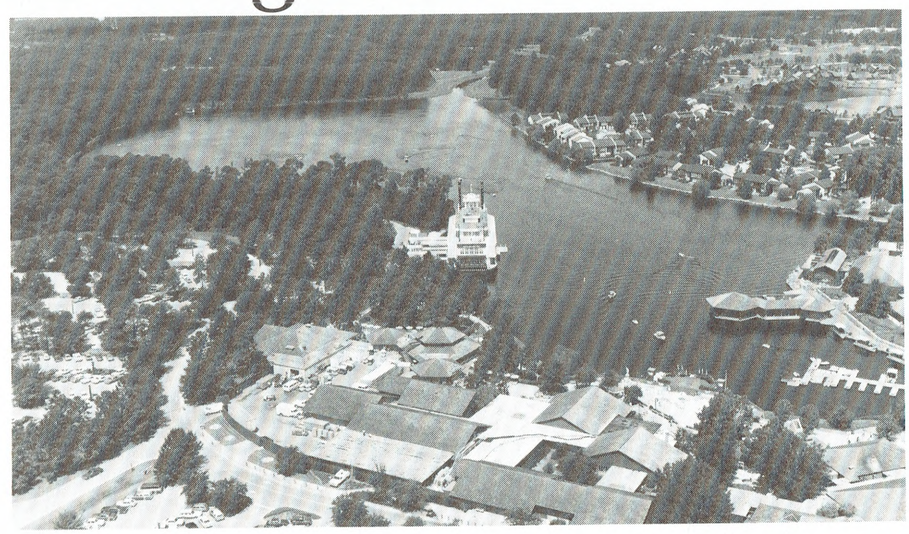

PHOTO 1
Water may be used for recreation, transportation, protection, and for its scenic beauty.

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Three-fourths of the planet earth is covered by water. There is no other more abundant resource or one more necessary than water. Water is present as a gas—water vapor or fog; liquid—such as the water that we drink, cook with, bathe in, and that falls as rain; or a solid—ice as cubes in our sodas or frozen desserts, or the icebergs in the Arctic.

In the earliest of times, water served humans in many ways. Water served as gathering points, means of transportation, as a protective barrier, routes for migration, and a seemingly endless source of food and drink. It is a resource because it is essential for survival. Its use underlies agricultural and industrial processes and because it cannot be substituted for technologically. Even though the globe is three-fourths covered by water, however its uneven distribution creates severe problems with too much or too little to satisfy human needs (Figure 1). Even though we are unable to create a substitute for water, technology has enabled humans to alter the flow of rivers, create large lakes, even stop the flow of rivers, and pollute these natural resources on a large scale. These factors emphasize our need for a thorough understanding of the effects of our activities on the availability and purity of water.

History is full of examples of cultural and societal decline caused directly or indirectly by limited amounts of fresh water. The United States faces an acute water resource crisis of major dimensions, which threatens the quality of life, state of individual freedoms, and its position as a world leader.

In our homes, in agriculture, and in industry, we currently consume more water than is being resupplied to usable sources through natural processes. As a society, we retain faith in the false notions that fresh water is a resource without limit and that technological fixes can and will solve all our water resource problems.

As a society we must irrevocably abandon our long-standing frontier ethic, recognizing the real economic value and the preciousness of liquid water. Residential, agricultural, and industrial processes can, with existing technology, be both cost-effective and water-efficient. If we do not act now we are inviting the intervention of natural processes that will work to balance the water supply and demand equation, with catastrophic consequences to our nation and millions throughout the world who depend on us for food. Our future is still in our hands. How will we respond to the challenge?

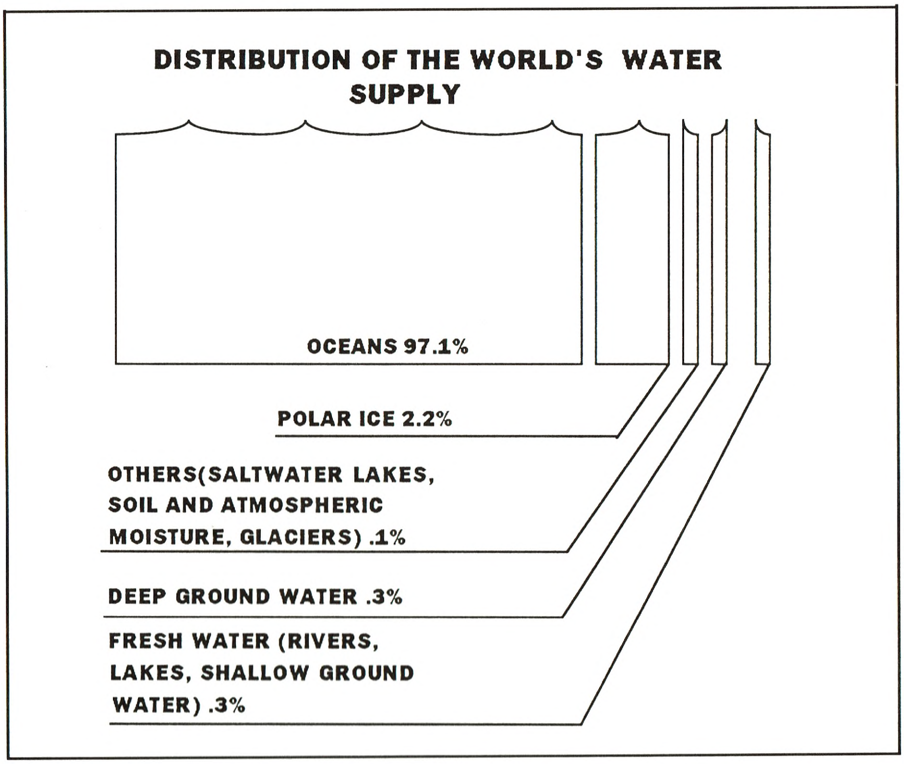

FIGURE 1
Distribution of the world's water supply. While much of the earth is covered with water most of it is saline.

Social/Cultural Impacts

The droplets of water that make the clouds are the purest form of water that occurs naturally. However, as the droplets grow into drops and fall to the earth, the rain picks up some impurities. Near the ocean salt from sea spray is added to it. Over farm areas and deserts, dust is added. Carbon dioxide and other gases in the atmosphere dissolve in rainwater.

As soon as the rain reaches the land, many other substances may dissolve in it. Among them are iron, calcium, magnesium, sodium, potassium, chlorides, sulfates, and nitrates. Most of them remain in the water as it flows into rivers and lakes, or as it seeps into the ground.

Groundwater is used in many parts of the world without any treatment at all. Because it has been filtered as it passes through the soil, groundwater is purer than the water in most lakes and rivers. However, it may still contain impurities that it picked up on its way into the ground from minerals that have dissolved out of rocks.

Hard Water

When water contains dissolved minerals, it is said to be hard. When soap is added to hard water it makes a few suds; the action of the soap is destroyed and a scum or curd forms. Soft water contains few if any minerals—very little soap is needed to make a rich lather.

When the minerals in water are calcium bicarbonate and magnesium bicarbonate, the water is termed "temporarily hard." Boiling will remove all but a trace of the bicarbonates since they have a low boiling point. But the sulfates of calcium and magnesium are very difficult to remove. Usually permanent hard water is treated with a commercial water softener to remove the minerals. Removing minerals from hard water reduces the stone-like scale that forms in pots and also forms on the inside of water and steam pipes. Most groundwater is fairly hard.

The exact hardness of the water is determined by the kinds of rocks that lie under the surface in a particular region. But even very hard groundwater is usually potable—that is, pure enough for people to drink.

Salty Groundwater

Sometimes sodium chloride— ordinary table salt—is found in groundwater. The salt may dissolve out from the surrounding rocks, or it may be from seawater. When the salt content is high the groundwater is definitely not potable. Towns along the seacoast, notably the Netherlands, Japan, California, and the eastern seaboard of the United States often have problems with what is termed "saltwater intrusion."

The phenomenon occurs when excess amounts of water are pumped out of the ground from wells, causing a drop in the water table. If the water table drops below sea level, salt water gets into the groundwater supply. Then old wells cannot be used—they must be abandoned, and new wells drilled further inland. Rainfall alone can usually rebuild a freshwater aquifer, but this may take years, or even decades.

An aquifer is a porous formation below the surface of the earth that can transmit economic quantities of water to wells and springs. In fact, much of the water being pumped from major aquifers in the United States today is ancient water, sev-

PHOTO 2
Agricultural irrigation allows crops to be grown on arid land that otherwise would be unproductive. However, heavy water consumption uses precious groundwater and contributes to salt build-up in the soil.

eral million years old. This water was trapped millions of years ago when the earth's air and water was significantly more pure and untainted. We are using this water at a rate far exceeding the rate of replenishment by natural means—rainfall and surface water seepage.

To speed up this natural process, some regions are using catch basins. They channel small streams through a series of ponds, so runoff is slowed down and some of the water from the streams has a chance to soak into the ground. In parts of California, fresh water that has been collected in reservoirs, streams, ponds, and catch basins is being poured down old wells, directly into the aquifer.

Modern technology has contributed to the process of replenishing. A product manufactured by Phillips Petroleum is used in parts of Australia where water is particularly scarce. A spray that produces a thin film of plastic is used over their ponds and catch basin to slow.down the process of evaporation of water into the air.

Saltwater intrusion has taught humans an important lesson—keep the water table as high as possible! Prudent people will only draw water from the ground equal to the rainfall in the area.

Salt can also get into the groundwater in many unsuspecting ways. In many northeastern states, salt is spread on roads during snowy and icy weather. As the ice and snow melts, salt is carried into the ground. In the New England states, salt already has seeped into many wells near the roads, making the wells unusable.

Salt for use on roads can also pollute groundwater in the area where it is stored. Great piles of salt are held for winter use. When it rains, the salt washes from the piles and into the ground. Large domes are being constructed in some states to cover the salt piles, thus protecting the groundwater in the area.

Contamination by Humans

During the past 30 years society has been putting chemicals into the water that cannot be filtered out or otherwise removed. Currently, some 75,000 chemicals are on the market, and the government has identified nearly one-half of them as being hazardous to health. It is mind boggling to think about the vast amounts of chemicals produced. In 30 years we have gone from producing 1 billion barrels of synthetic chemicals per year to over 50 billion today.

These chemicals are essential for making all sorts of medicines and thousands of different kinds of plastics, for making food additives, fabrics, composites, and many other products that improve our standard of living. But whenever chemicals are produced, there are attendant waste products. A major problem in the world today is what to do with these waste products. Where do we store them?

For decades, chemical wastes were poured into lakes and rivers. Obviously, this polluted those lakes and rivers. In fact, the part of the Cuyahoga River that flows past Cleveland, Ohio, was so polluted with hydrocarbons, fuel oil, and other combustibles that it actually caught fire and burned for several days back in the 1970s.

More recently, wastes have been stored in industrial lagoons. Laws are being passed to eliminate such lagoons, but there are still several thousand of them. As water evaporates from the lagoons, the chemical wastes found in them become more and more concentrated. The lagoons usually have a bottom of porous soil, such as sand, so the chemicals slowly seep down into the ground and find their way into the groundwater.

People also unwittingly pollute water in a number of ways. Phosphates are chemicals that cause a foaming action in laundry detergents. When clothes are washed and rinsed, the phosphates get into the water supply because the sewage treatment process in many areas does not remove them.

Years ago, the phosphate reappeared as foam on lakes, rivers, and ponds in many parts of the country, and people got foaming water when they turned on their faucets. The phosphates from several years ago were still in the water. There was only one thing to do—stop using phosphates in laundry detergents. So, soaps with phosphates were banned in many areas.

Chemicals and bacteria from feedlots where cattle are fattened for market also seep into the ground. A 20-acre feedlot with 2,500 cattle produces as much waste as a town of 15,000 people. Rain carries nitrates and bacteria from these wastes into nearby lakes, streams, and groundwater reserves. The effect of the pollution can continue long after the feedlot has closed. In North Dakota, the water supply of a village was still contaminated some 40 years after a feedlot was closed.

Farmers use chemicals to prevent plant disease and to control insects. However, when it rains, some of the chemicals are carried into streams, or they move deep down into the soil. Eventually they show up in drinking water. This is especially apparent in the runoff from the extensive farming regions surrounding the Chesapeake Bay. The chemicals from the farmers' fields end up in the shellfish beds many miles from the farm.

Most of the chemicals do not affect people, or they can be treated to make them harmless. But many of them affect fragile microscopic plant and animal life

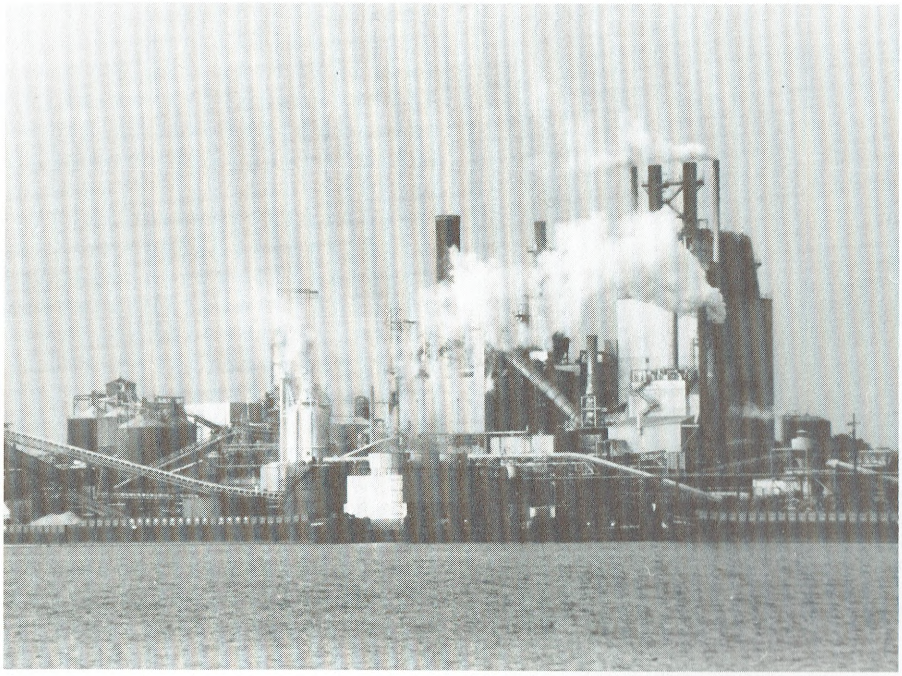

PHOTO 3
While heavy industry and power plants provide economic support for technological societies, smoke stack emissions can contribute to acid rain in many parts of the world.

causing mutations, slowed growth or death. Occasionally a harmful chemical cannot be treated, or it turns into an even more harmful substance once it is combined with water and exposed to other chemicals and sunlight.

Other Wastes and Water Pollution

Chemical wastes from factories and industrial sites are not the only wastes that pollute our water supplies. Ordinary household trash and garbage have water soluble chemicals in them. Some of those chemicals can be poisonous. Every community or village generates tons of garbage. Often this garbage is put in sanitary landfills where layers of soil are bulldozed over the garbage. For a few years this method of disposing of garbage works very well. It may even remain stable for decades.

But, eventually, after 30 to 40 years, a town may be in real trouble. Rain falling on the landfill leaches hundreds of different chemicals out of the trash. Over the decades, the chemicals seep into the ground, and often they reach an aquifer that underlies the region. If the local residents get their drinking water from the aquifer they must find an alternate water supply. In many cases the only way to solve this problem is to pipe water in from a location far enough away to be unaffected by the landfill leachates.

Acid Rain

Acid rain, a kind of water pollution, is a serious problem in the northeastern United States and in eastern Canada. All rainwater contains carbonic acid, so all rain is somewhat acidic. But carbonic acid is a very weak acid. If it is the only acid in rain, the rain is normal, and does no harm. But in some places the rain that falls into lakes and ponds is so acidic that it kills fish and other forms of life (frogs, turtles, salamanders).

When all the life in a lake disappears, including all plant life, we say that the lake has died. There are many dead lakes in New England, New York, and eastern Canada. In West Virginia, too, many fish have been killed in lakes that once produced large amounts of commercial and sport fish.

Rainfall becomes strongly acidic because factories and cars put nitrogen oxides and sulfur into the air. When water combines with sulfur dioxide, sulfuric acid forms. When it combines with nitrogen oxides, nitric acid is created. Both these chemicals are strong acids.

Most of the sulphur that produces acid rainfall seems to come from coal-burning factories and electric generators in the Ohio River Valley. (Some sulfur, but not as much, comes from oil-burning factories and generators in the area). Interestingly enough, the Ohio River Valley has little acid rain; the sulphur goes up the chimneys, is picked up by the wind and travels 1,000 miles or more to produce acid rain in New England and Canada.

M/S/T Interface

H_2O, commonly called water, can be identified as a pale blue liquid that covers 75% of the earth's surface. Chemically, water can be viewed as a covalent hydride, an oxide, or as a hydroxide. It is a good solvent for many kinds of substances such as compounds with polar and ionic bonds. It can be a weak acid or weak base because of its ionization properties.

Water is a polar molecule and shows unique properties because of its hydrogen bonding. As we all know, iron and steel rust when exposed, unprotected, to the weather. The rusting process is caused because water oxidizes reactive metals to form oxides. The reddish brown substance on the surface of iron or steel is actually hydrated iron oxide or $FeO(OH)$.

The volume of free water on the earth's surface is relatively constant and continually in motion. The earth's hydrologic cycle maintains a fairly constant balance of water. It includes precipitation, evaporation, transpiration and percolation. The earth's atmosphere may be thought of as a giant solar engine that draws up water through evaporation and transpiration into the atmosphere as clouds and water vapor.

As atmospheric conditions permit, water vapor is returned to the earth after condensation as rain or snow. The rain and snow will find its way into streams, lakes, rivers and oceans as run-off and begin this hydrologic cycle again. Some of this precipitation, water or snow, will enter the surface of the earth as ground water and recharge aquifers.

Groundwater supplies about 23% of the fresh water used in the United States. Groundwater is the most efficient supply for medium-sized cities and small communities because it does not require costly reservoirs and aqueducts. It is interesting to note that of the 100 largest cities in the U.S., about 34 depend on groundwater. Overall, about 35% of our nation's population depends on ground water. In 1980, the total fresh water used was 290 billion gallons; of this, 88-billion gallons came from ground water sources (Figure 2).

Most community water systems are small and serve 500 or fewer customers. The majority of the public gets its water from medium-sized or large water systems. Water treatment varies widely from one system to another. Some water systems only distribute water and do not treat it, while others provide multi-step or advanced treatment of the water it distributes. In most conventional plants the treatment process includes the following stages:

Coagulation—A chemical such as alum (aluminum sulphate) or ferric chloride is added to create small gelatinous particles called floc that gathers dirt and other solids.

Flocculation—Where there is gentle mixing of the water that causes floc particles to join and form larger particles.

Settling—The floc and sediment fall to

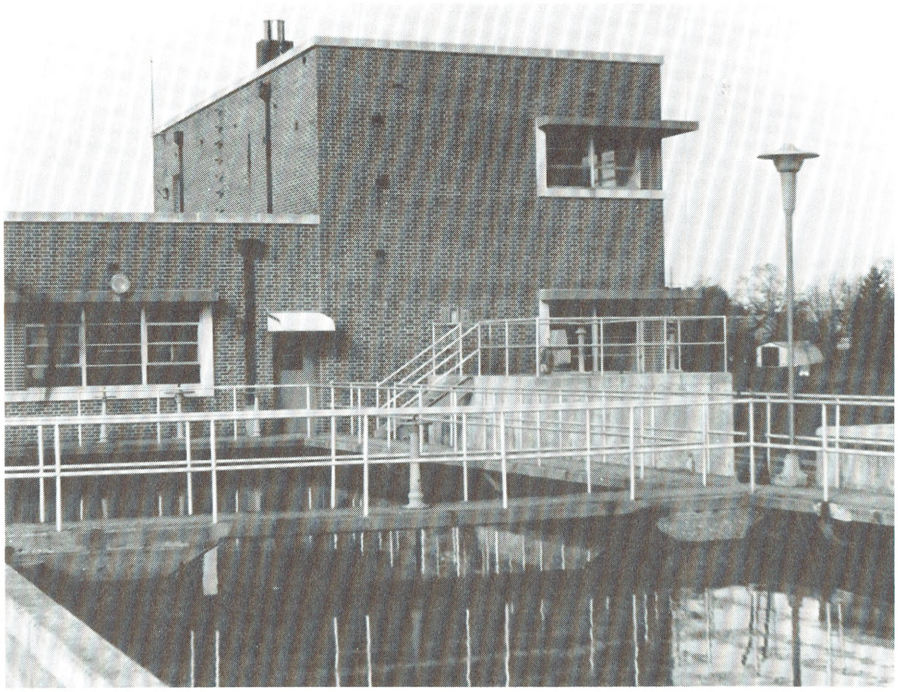

PHOTO 4
A typical water filtration plant for treating drinking water. In front of the building is a sedimentation or settling basin for the removal of suspended solids in the water.

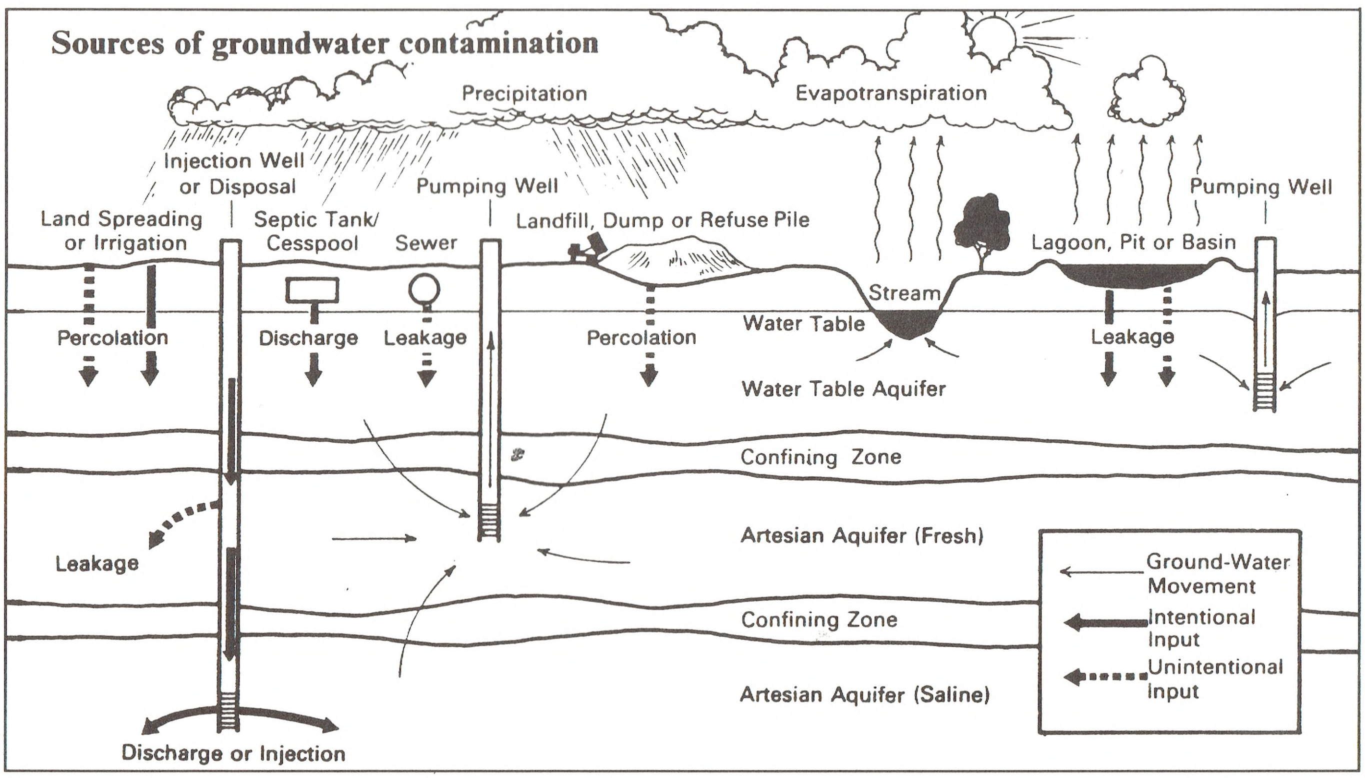

FIGURE 2
Groundwater contamination occurs in many different ways. Business, industry, agriculture, and households contribute to the process of contaminating the earth's groundwater.

the bottom of a settling tank and are removed as sludge.

Filtration—The water is passed through a series of granular filters such as sand or anthracite coal.

Disinfection—Chlorine is added to the water to kill bacteria and other microorganisms.

Corrosion control—Chemicals such as lime, calcium oxide, can be added to reduce the acidity in the water and minimize corrosion in water mains and household plumbing.

Fluoridation—Many municipalities add fluorine to treated water to reduce tooth decay.

A typical water treatment plant is shown in Photograph 4. Each of the water processing stages contribute to the production of high quality, safe drinking water.

Water quality must be monitored throughout the water system to ensure high quality safe water for the system's customers. The frequency of testing varies according to specific contaminants and the size and type of water treatment system. Properly trained personnel are essential for the correct operation and maintenance of a water system.

Waste Water Treatment A Key to Clean Water

Waste water is the flow of used water through a community's sanitary sewer system. The name is very appropriate because waste water is about 99.4% water by weight. The remaining 0.6% is dissolved or suspended material, commonly called suspended solids to differentiate it from dissolved contaminants.

A generally accepted estimate is that each individual, on an average, contributes about 100 gallons of water a day to a community's waste water flow. While most people think of waste water as only sewerage, waste water also comes from many other sources. These sources include businesses, industrial plants, storm sewers, and groundwater. Sanitary sewers carry only household and industrial waste water, while combined sewers carry waste water and storm water runoff.

In the natural process of purifying water, bacteria and other small organisms in a stream or lake are attracted to the waste water as a food source. During this bacteriological process, these organisms produce new bacterial cells, carbon dioxide, and other products. As the water is purified, the bacteria also use oxygen. Natural bodies of water acquire this important oxygen by absorption from the air and aquatic vegetation that converts carbon dioxide into oxygen by photosynthesis.

The quantity of dissolved oxygen in bodies of water affect the aquatic life in rivers and lakes. When there is not enough oxygen in the water, fish and other aquatic life will die. Since oxygen is such an important element in the "life" of a river, stream, or lake, it is important to measure how much oxygen will be used by bacteria to consume the waste in a given volume of waste water.

The measurement of the required oxygen is called the biochemical oxygen demand or BOD. The higher the BOD, the more oxygen will be demanded by

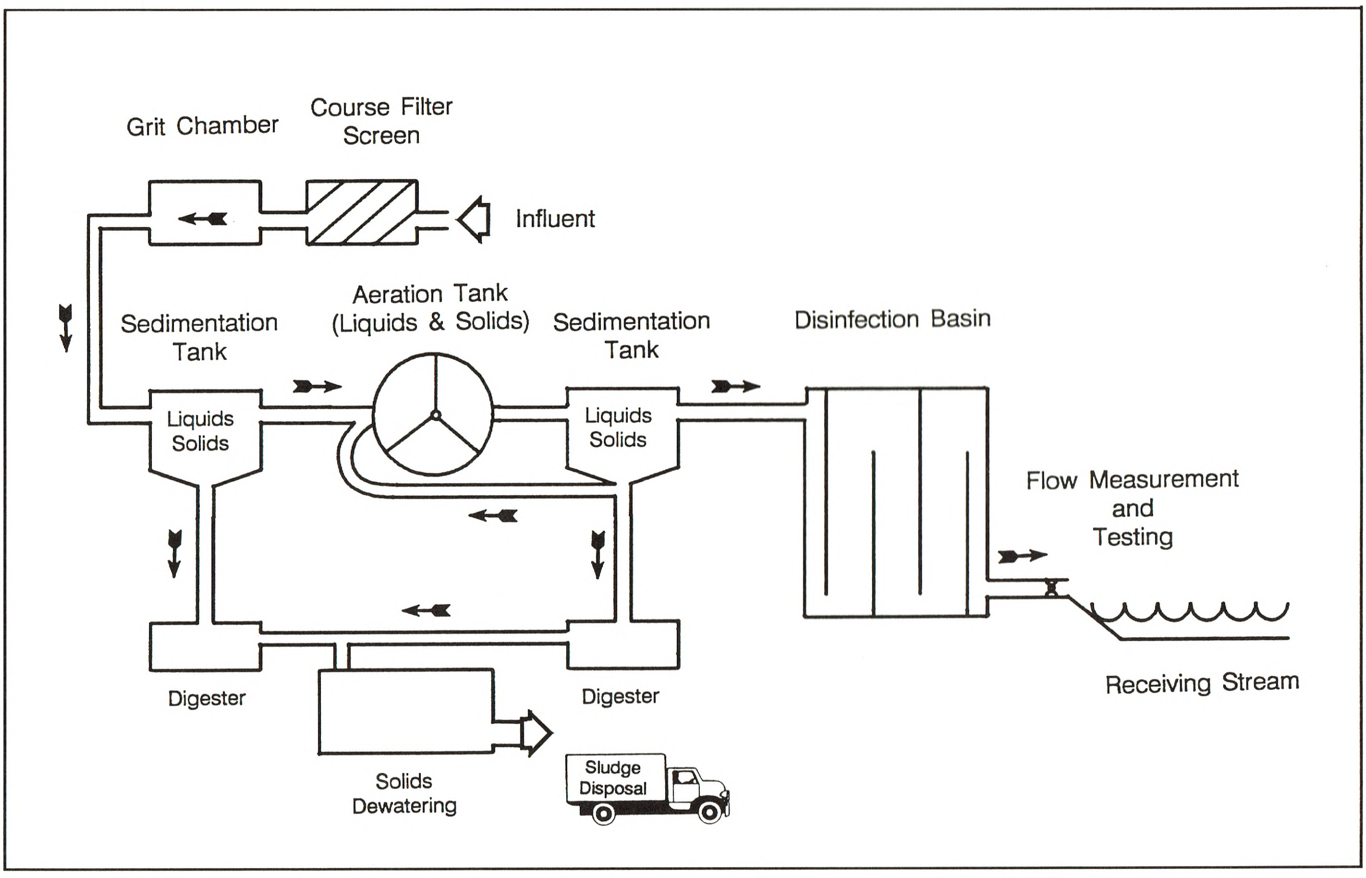

FIGURE 3
Primary and secondary waste water treatment use mechanical filtering or settling and biological processing of waste water.

the bacteria as they consume wastes. The removal of BOD is a major responsibility of waste water treatment systems.

Waste water treatment usually consists of two major steps, primary and secondary, followed by a process to dispose of solids removed during the two steps. Other waste water treatment processes are advanced and tertiary. The objective of primary treatment is to physically removes suspended solids from the waste water by screening or filtering, settling, or floating. Secondary treatment uses biological processes to remove contaminants that are dissolved in the water. Figure 3 shows primary and secondary waste water treatment processes.

Effective waste water treatment depends on the cooperation and participation of all sectors of the public—business, industry, and government—from Congress to individual citizens like you and me. People are the key element in maintaining adequate funding for the construction, operation, and maintenance of water treatment facilities. Understanding the value and importance of clean water will assist in attaining our national clean water goal.

PHOTO 5
Aeration plays major role in adding oxygen during the water treatment process in biologically treating water.

Construction Activity

Most people in the United States obtain their water from small to medium-sized water treatment systems. These water systems generally employ a multi-staged treatment process. The four major stages of water treatment include filtration, flocculation, settling, and disinfection.

This process can be simulated in the laboratory using commonly available materials. Contaminated or untreated water may be prepared from tap water by adding some small gravel, soil, and sand to one liter of tap water and mixing thoroughly. The contaminated water will then closely resemble water that is typically treated by a water treatment plant.

The contaminated water test sample can be treated by processing through four major water treatment stages:

1. *Simulating flocculation*—Using a 250 ml sample of contaminated water, add 0.5 gram of Aluminum Sulphate (alum). Gently stir the test sample for approximately five minutes. Be sure to record the turbidity, particulates, and color of the contaminated water. If possible, measure the density of the water.
2. *Settling*—Allow the test sample to settle for approximately 15 minutes. Observe and record the turbidity, particulates, and color of the contaminated water.
3. *Filtration*—Using a paper coffee filter, pour off the top portion of the test sample of water into a clean container, leaving the sediment in the original container.
4. *Disinfection*—Add approximately one drop of laundry bleach to the filtered water and stir briefly. Record the turbidity, particulates, and color of the contaminated water. If possible, measure the density of the water.

The water treatment process is complete. Compare the observations made in steps 1, 2, and 4. If you were able to measure the density of the samples compare the treated sample with the contaminated water.

Review the test results and discuss the purposes of each of the water treatment stages and make conclusions about each treatment stage and the total water treatment process. Additionally, it is important to discuss what impact heavy metal contamination and chemical contamination may have on the water treatment process.

Warning! It is **not** recommended that the students "taste" the treated water produced in this activity—merely observe the products of the simulated process.

If possible, invite a water treatment resource person to visit your class and discuss how your local water is treated and the sources of water for your community. Determine what student club activities can be identified to help your community to maintain and conserve nature's magic resource—water!

Summary

Water is a vital compound for all living things. Humans and their technology have abused water resources for thousands of years and have come to realize that it is a precious resource that needs protection and conservation. The Federal Safe Drinking Water Act was designed to protect our drinking water resources.

Since the hydrologic cycle maintains a balance of the earth's water through precipitation, evaporation, transpiration and percolation it is important that all sources of water be managed in a thoughtful and prudent manner.

Individuals can do their part to minimize the pollution and contamination of water by not contributing to the pollution cycle. The waste water that is generated as a by-product of agriculture, business, industry, and households eventually is recycled into our environment. Contaminants that are added during its use may present immediate problems or problems for future generations to solve.

Waste and drinking water treatment systems are designed to accelerate nature's process of water purification. Water treatment processes are designed to filter and remove contaminants through primary and secondary treatment processes. Disinfection techniques are used to kill harmful bacteria and pathogens. Some contaminants such as heavy metals and hydrocarbons are difficult to remove and are carefully monitored by municipal water authorities.

As countries continue to use increasing amounts of water, proper use and treatment of water resources becomes more critical. Humans need to be aware of the preciousness of water as a resource for survival of all living things. We must do our part to conserve and protect our water resources.

Possible Student Outcomes

1. Describe the hydrologic process as nature's way of recycling the water resources of the earth.
2. Identify the four major stages of water treatment.
3. Describe or identify sources of groundwater contamination.
4. Describe why industrial wastes must not be discharged into rivers, streams, and the oceans.

Student Quiz

1. What percentage of the earth's surface is covered by water?
75%
2. What are the three states or forms that water is naturally found in?
liquid, solid (ice), and vapor (fog)
3. Why does acid rain frequently occur thousands of miles from the source of the fumes that produce acid rain?
A major cause of acid rain is industrial plant emissions in heavily industrialized regions of the United States and other countries. The emissions are carried by major wind currents to distant locations.
4. Describe the major components of the earth's hydrologic cycle.
Precipitation, transpiration, percolation, and ground water flow
5. Identify four sources of ground water contamination.
Excessive chemical fertilizer use, pesticides, improper sanitary landfills, and septic tanks or cesspools.
6. List the two major classification of water treatment systems.
Primary and secondary.
7. How are harmful bacteria, microorganisms, and pathogens removed from waste and drinking water?
Disinfection

Acknowledgements

■ Figure 1—CONCERN Inc., 1794 Columbia Road NW, Washington, DC, 2000

■ Photograph 1—Walt Disney Company

■ Photographs 2, 3, and 5—Carolyn J. Kroehler, Virginia Water Resources Research Center, Blacksburg, VA 24060

■ Photograph 4—Diana L. Weigmann, Virginia Water Resources Research Center, Blacksburg, VA 24060

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Resources in Technology

Hazardous Waste Disposal

The "NIMBY" Syndrome ("... not in my backyard")

Even a small motorcycle paint shop such as this one produces hazardous wastes in the form of paints, thinners, lacquers, solvents, etc. which must be disposed of properly. Many communities now have collection points where homeowners can take used motor oil, solvents, cleaners, garden chemicals and other potential hazardous wastes.

In the past ten years, society's awareness of the hazardous waste disposal problem has grown tremendously. The days of cutting production costs by simply hiring some trucker to dump an industry's hazardous waste into the nearest ditch are definitely gone—and rightly so. As alarming as that unimaginative and life-threatening practice may sound, particularly in this day of heightened environmental awareness, "bury it and forget it" was the generally accepted method for disposing of hazardous waste materials up until fairly recently.

Barbara Blum of the federal Environmental Protection Agency (EPA), has said that less than 10% of all hazardous waste generated by our society is disposed of in an environmentally sound manner. Hazardous wastes, by strict definition, are chemicals and chemical by-products which may endanger human health or pollute the environment if not disposed of properly. The Resource Conservation and Recovery Act (1976) specifies the properties that cause a waste material to be labeled hazardous. The act also covers the disposal of nuclear (radioactive) waste. Although it does not technically fit the accepted definition of hazardous waste, it is included in almost all discussions of the subject.

One or more of the following criteria must be met for a waste material to be considered hazardous:

■ *Ignitability*—Capable of exploding or otherwise presenting a fire hazard during normal waste management.

■ *Corrosivity*—Able to deteriorate standard containers or dissolve toxic components of other materials.

■ *Reactivity*—Has a tendency to become chemically unstable during normal waste management conditions; reacts violently with water; generates toxic gases.

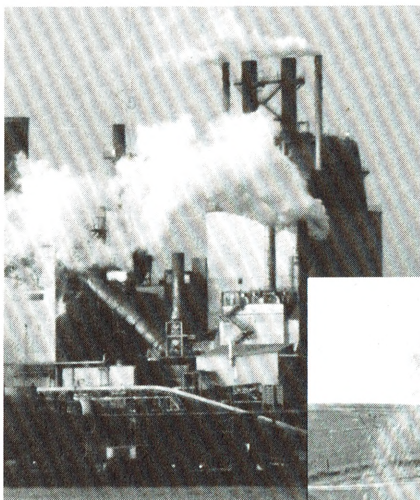
■ *EP Toxicity*—Poisonous.

The adverse effects resulting from the improper disposal of hazardous waste material can be quite devastating, both to humans and our environment. Water, land and air can become polluted. Some wastes may enter various levels of the food chain and eventually poison all the consumers in that chain, including humans.

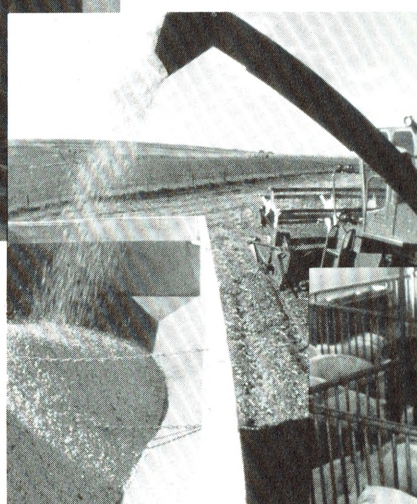
Some industries that produce hazardous wastes include those involved in coking, explosives, ink, inorganic and organic chemicals, petroleum, wood preservation, pesticides, iron and steel, lead, copper, zinc, veterinary pharmaceuticals and certain pigmenting operations.

Practically everyone agrees that the cleanup of old hazardous waste disposal sites is required as soon as possible and the creation of environmentally sound new sites should be a national priority. As far back as 1980, the Surgeon General of the United States called the hazardous waste disposal problem "a ticking time bomb primed to go off."

People also agree that new technology should be developed to deal with the hazardous waste disposal problem. Paradoxically, no one wants the new sites in their community or state. They don't want it in their backyards, thus giving rise to the NIMBY syndrome (" . . . not in my back yard").



Buried hazardous wastes may contaminate the groundwater that is



frequently used to irrigate crops such as this grain which is being harvested

for hog food. When these wastes do contaminate the water supply,

they may eventually wind up on our dinner tables.

Historical Perspective

For about the past 50 years, our society has enjoyed the benefits of the synthetics revolution. We have consumed everything from preserved wood and paneling to cured meat; from nylon fabrics and fertilizer to insulin. All the many benefits gained, however, have not been without their costs, both monetary and environmental.

As a result of "better living through chemistry," we are now faced with thousands of hazardous waste disposal sites. A very few of these have been investigated and cleaned up, while the majority of the others, unfortunately, have not. Some, in fact, are known to exist, but have not been precisely located yet since their original locations were not recorded and have been forgotten.

Many times hazardous waste disposal sites are cleaned up by moving the toxic materials to some other location where they will be less of a threat to humans or the rest of the environment. This often presents only a temporary local solution to the growing problem of hazardous waste disposal.

Let's look briefly at just one example of improper hazardous waste disposal and its consequences. An episode in upper New York State in the late 1970's served more than any other single event to focus our nation's attention of the problem of hazardous waste disposal. The name, Love Canal, has become synonymous with the hazardous waste disposal problems facing our society.

A canal to provide both a navigable channel around Niagara Falls and cheap hydroelectric power was planned by William T. Love in the 1890's. Before Love finally ran out of money and abandoned the scheme, he had created a mile-long ditch, 30′ wide and 10′ to 40′ deep. Over the ensuing years, the canal was used as a dump site for over 21,000 tons of a variety of toxic substances. As time passed, the long abandoned canal was partially filled in and a community grew up around the area.

During the mid-1970's, residents often complained of bad odors in the air and said that swimming in a nearby pond often resulted in skin rashes. After heavy rains and following the melting of the winter snow, chemicals often seeped through basement walls or rose to the surface in outside areas. By 1978 much of the land in the Love Canal area was just a sea of smelly sludge and the softened ground often revealed the crushed tops of rotting barrels containing "unknown substances."

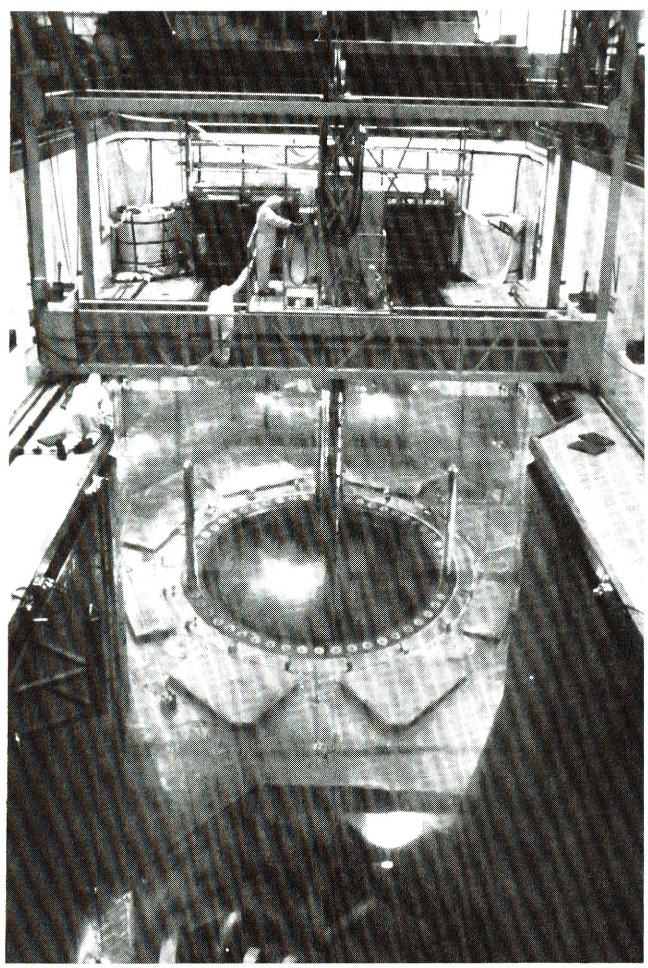
Subsequent initial testing revealed the presence of at least 82 toxic chemicals in the soil and, as of this date, the EPA has positively determined the presence of more than 200 chemicals. Numerous studies have been conducted (and are still going on) which revealed many abnormal health problems for the Love Canal area residents.

Finally, in August of 1978, the area was declared a national disaster and the federal government evacuated 273 families and began a massive, very expensive clean-up effort in the most contaminated areas. Over $250 million has been spent on the still not finished clean-up work. Over 35,000 cubic yards of land were treated with 30 acres fenced off and declared uninhabitable for the forseeable future.

The disposal of nuclear waste has triggered nearly 40 years of disagreement, both political and scientific. Once it was widely believed that these materials could simply be buried and forgotten and that they would become harmless in just a few years. We now know that some nuclear materials will have to be buried at least 25,000 years, if not forever.

We now have over 24 million tons of nuclear waste in underground storage. This, most experts agree, is only a temporary solution to a problem that continues to grow. The present storage facilities are now nearly full and more nuclear waste is being produced all the time. Clearly, something must be done.

In its handling of nuclear waste, the federal government has historically buried both high and low level nuclear waste in shallow trenches. Some of the high level waste is especially dangerous. For example, one microscopic speck of plutonium can cause cancer and even death. The material becomes (almost) no less lethal as time passes. Plutonium loses only one-half its radioactivity in 24,000 years.



The spent nuclear fuel (a hazardous waste) at this power plant is to be stored on the site until a permanent storage facility is available. This is a view of a manipulator crane positioned for removal of the spent fuel.

Social/Cultural Impact

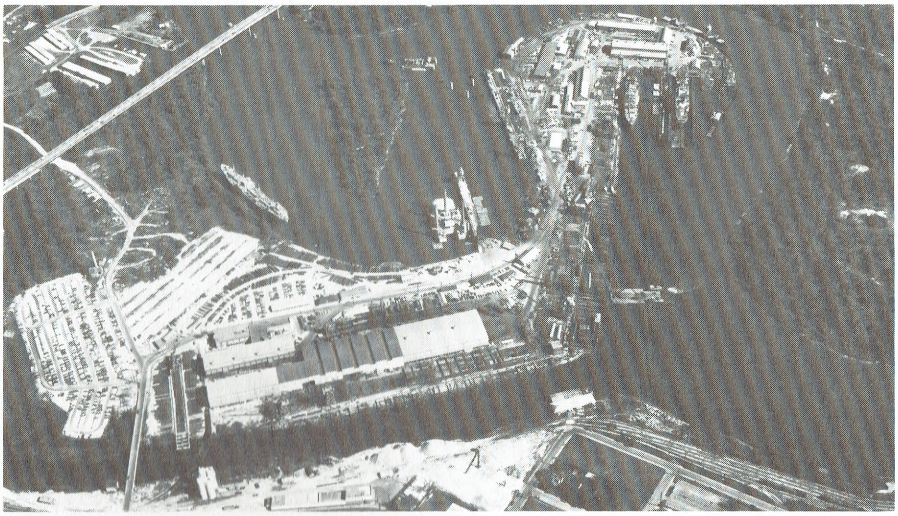
Millions of tons of hazardous wastes are produced annually by our industries. For example, while producing oil and gasoline, oil refineries also generate acids, harmful oils and contaminated sludge. During the production of plastics, harmful organic compounds are also produced. Additionally, other major sources of hazardous waste include hospitals, government agencies, laboratories and others. Over 750,000 various industries contribute annually to our growing hazardous waste problem.

We have all read or watched stories about tons of wastes, both hazardous and otherwise, which have been on ocean cruises while the ships' crews looked for a dump site. Usually the ending of such news items was that the waste had been returned to its point of origin. Many countries are becoming more aware of the potential threat to themselves and will no longer accept imported wastes.

The high costs required for efficient hazardous waste disposal have promoted the birth of a shady industry, called "the midnight dumpers." These clandestine operators get rid of hazardous waste in the most expeditious manner possible by simply dumping it at some remote location or by mixing it in with other, unregulated waste materials. In some documented instances, hazardous waste was mixed with fuel oil which was later sold. It was then shipped all over the country for unsuspecting consumers to burn.

The world community has realized that hazardous waste disposal is a global problem that affects all of us and any solution to that problem must eventually be worldwide in scope. Many nations are already working to solve the problem of hazardous waste disposal. In the United States many laws have been enacted and public anger over the growing problem is increasing.

The Comprehensive Environmental Response, Compensation and Liability Act of 1980, commonly called the Superfund, was designed to cleanup unsafe hazardous waste deposits created in the past. The Superfund provides $1.6 billion for the effort. As written, the Act also encourages the recycling of hazardous waste to recover useful materials in them.



A large shipyard such as this produces a large volume of hazardous waste during its daily operation. Contaminated fuels, oil, solvents, cleaners and many other chemicals must all be disposed of in accordance with current government regulations.

Contemporary Analysis

Americans possess an absolute, almost blind, faith in the ability of technology to extricate them from any problem or difficult situation. To that end, several technological developments have been developed in direct response to the hazardous waste disposal problem. These, however, still do not completely address or solve the entire hazardous waste disposal problem.

The hazardous waste disposal industry has recently been compared to the fledgling computer industry of twenty years ago. It is predicted to grow into a multi-billion dollar industry in the very near future. As the industry grows and a more highly developed technology emerges to deal with hazardous wastes, our society will see the implementation of many new developments. Let's look at a few of the new techniques and methods currently being employed in dealing with hazardous wastes.

Improved landfilling methods, deep underground storage, high temperature incineration and the use of biotechnology are all among the types of hazardous waste disposal that offer the greatest hope for the future.

Landfilling

The practice of ordinary landfilling, a very common "bury it and forget it" technique, has been greatly improved as the need to control the effects of buried wastes has become increasingly evident. During the earliest years of it use, it was believed that simply lining a landfill with a layer of clay, a relatively non-porous material, would be sufficient to contain any buried wastes in the future. We have since learned that even clay will eventually allow materials to leak out and pollute ground and surface water as well as other parts of the environment.

Traditional burial methods have been refined so that now many hazardous wastes can be safely stored in specially designed lined landfills. The bottoms and sides of these new landfills are usually lined with clay, which is then covered with some sort of impermeable material which will be resistant to the types of hazardous wastes that will be placed there. Hazardous wastes going into these secure landfill sites include contaminated soil, construction debris, spent catalysts, contaminated sludge and several others.

A very good example of modern land-

A new process, called soil vacuum extraction, has been developed by Terra Vac, Inc., to clean up some types of existing hazardous waste sites. Clean air is pulled through contaminated soils via a series of wells. The uncontaminated air picks up the hazardous waste's vapors (and some liquids if present) and carries them away.

filling technology at work is operated in Chicago by Waste Management, Inc. The two acre site is 35′ deep with a floor of compacted clay 40′ thick. On top of this is a plastic liner which is covered with a plastic grid that collects and directs any seepage into sump pumps. This is all covered again with more plastic sheets and clay.

Deep Well Injection

This method of hazardous waste disposal has also been proven to be both environmentally and technically sound. The process involves injecting diluted hazardous wastes thousands of feet below the earth's surface into porous geological zones. The wastes are permanently sealed there from both above and below by impermeable rock strata which are hundreds of feet thick.

Incineration

At least two companies, Waste Management, Inc. and At-Sea-Incineration, are preparing to conduct high temperature (1,500°F–1,600°F) hazardous waste burning operations at sea. The costs involved are expected to be considerably less than those encountered in land-based burning methods. Other firms, such as Rollins Environmental Services, Inc., operate land-based high temperature incinerators. These companies are federally licensed to deal with PCB incineration. These companies, however, are able to have only a very small impact on this nation's hazardous waste disposal problem. The EPA estimates that the United States will require at least 82 land-based and 33 sea-going incinerators, all approved for hazardous waste disposal, by the early 1990's.

Biotechnology

This new and exciting field appears to offer some very real solutions to our national hazardous waste disposal problem. In the past few years, scientists have been able to demonstrate that certain organisms can metabolize (break down) some of our worst toxins. The practice of using bacteria in waste disposal is not new, however. They have been utilized for over a century to help break down city waste water.

A microbe called Flavo Bacterium® has now been used to successfully treat soil contaminated with penta, a material used in the preservation of wood. The microbe changes the penta into harmless chlorides and carbon dioxide.

Michigan State University biochemists recently discovered that phanerochaete chrysoporium, a fungus which decomposes dead trees, can also change some of our most deadly hazardous wastes (i.e., DDT, PCBs, dioxin) into harmless carbon dioxide.

Many technical problems remain to be solved before biotechnology can be fully implemented in the treatment of hazardous wastes. For example, in order for the selected organisms to do their work, a proper environment must be provided for them. The oxygen within the disposal site must be closely monitored and controlled. The pH level and temperature inside the site must also be maintained within predetermined limits.

Biotrol is a biotechnical company attempting to use microbiology to dispose of hazardous wastes. Called, "bioreactors," these new devices are designed to allow technicians to control the conditions within them. Although the initial construction and installation costs will be relatively high, the future use of "bioreactors" appears to be very promising.

Genetic Engineering

The company mentioned in the previous paragraph, Biotrol, is also engaged in altering the gene structure of certain microorganisms (or "bugs" as they are called in the industry). These newly created beings will be designed so that they may perform their functions of "eating" hazardous waste materials very effectively. By engineering the appropriate changes in the gene structures of the microorganisms, engineers are able to give them much bigger appetites and to make them more resistant to hazardous waste environments.

Because genetic engineering is still a relatively new field, many problems may be expected. Some of these problems may reasonably be predicted, while others are unforeseeable at this time. For example, new dangers to existing ecosystems through the introduction of new life forms might result in even further environmental damage.

Construction Activity

The thousands of types of chemicals produced in this country annually provide countless benefits for our society. Some of the wastes from those processes, however, can be harmful to the environment or even deadly if not disposed of properly.

At one time, simple dumping was a widely accepted practice in dealing with hazardous wastes. We now know that such practices can cause not only surface pollution and other visible environmental damage, but can also pollute the ground water below the surface. Groundwater provides about half the drinking water in the United States. The burial of hazardous waste materials in barrels, another once common practice, can have similar consequences as the containers rust away.

People have always generally believed that water travelling through soil and rock formations would under go a natural filtration and purification process. At one time, in some locations, that was true, but that is no longer the case. Natural filtration processes do not remove many hazardous waste materials. In order to demonstrate this fact, perform the following construction activity.

Build a Water Filter

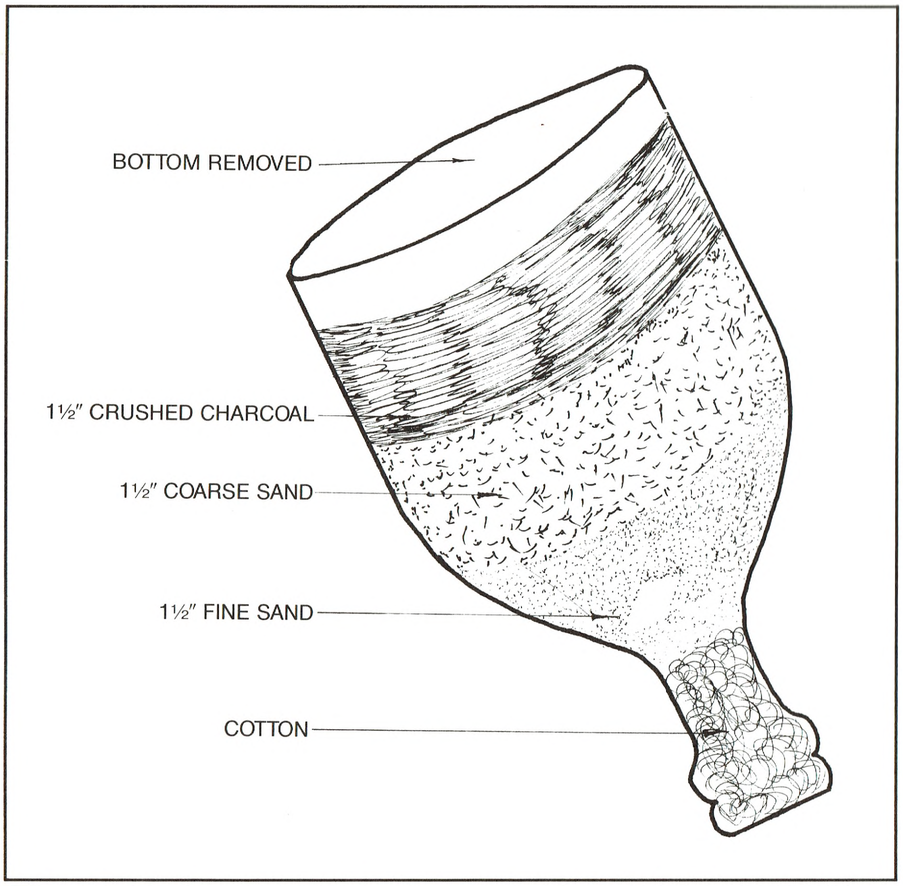
Materials

- Plastic liter-size soda bottle (empty)
- Assorted pollutants (thinner, oil, fuel, mud, etc.)
- Clear quart-size glass containers (2)
- Cotton
- Sand—fine and coarse
- Crushed charcoal
- Bricks
- Technology lab and related equipment

Procedure

1. Cut the bottom off the plastic soda bottle to form a long, deep funnel.
2. Construct a filter: Holding the funnel neck down, stuff the neck with cotton. Pour a 1½" layer of fine sand on top of the cotton and pack into place with a piece of scrap wood stock. Add a 1½" layer of coarse sand above the fine sand and gently pack into place. Finish the filter construction by adding a 1½" layer of the crushed charcoal on top of the coarse sand and packing slightly.
3. Thoroughly mix 4 parts of clean water to 1 part of thinner (or solvent) in one quart container. Add assorted other pollutants (mud, oil, etc.)
4. As slowly as necessary, pour the polluted water sample through your filter into a clean glass container.
5. *Smell* the filtered liquid. Do **not** taste the filtered water no matter how clean it appears or how effective you believe your filter to be.
6. Draw conclusions as your class discusses the following:
   - Does the filtered liquid appear to be pure? Does it smell?
   - Has all the visible pollution (waste) been removed? Do you think it is still polluted? Why?
   - Compare the results of your activity with what you believe might happen to groundwater around buried chemicals.

Note—Be sure to dispose of your materials properly when this activity is completed. Your instructor will show you how.



M/S/T Interface

Sometimes the hazardous waste resulting from processing operations is temporarily stored on-site in large, secure storage containers for later shipment to a permanent disposal location. When engineers design these containers (cylindrical in this example), they must know how much waste storage capacity is needed and for what length of time. These planning decisions are based on the plant's projected production schedule for the future.

If a certain new processing operation will produce 240 gallons of liquid hazardous waste daily and planners anticipate storage for up to 30 days, and after allowing for safety requirements, engineers decide they must design a storage tank with a 7,700 gallon capacity (240 gal/day × 30 days = 7,200 gal). A safety allowance of 500 gallons is allowed for excess amounts. So the total required capacity is 7,700 gallons (7,200 gal + 500 gal = 7,700 gal).

After the capacity requirement is determined, many other questions must also be answered before a tank can actually be constructed. Where will the tank be located? Is there already sufficient space in that location? What will the physical dimensions of the new tank be?

If the engineers in our example find, after making allowances for locating the tank safely, that a diameter of ten feet would be most practical, the height required for a 7,700-gallon capacity tank must then be determined.

To find the required height (h) of a cylindrical storage tank with a 10′ diameter, the gallons of capacity must first be converted into cubic feet of volume. The method for doing this is shown in Figure 1. As Figure 1 illustrates, math and science are integral parts in the designing of facilities for hazardous waste.

The volume in cubic feet equal to a given capacity in gallons is found by dividing the number of gallons by 7.5 (7.5 gal = 1 cu. ft.).

$$\frac{7700}{7.5} = 1026.66 \text{ cu. ft.}$$

Next, the area of a 10′ diameter circle is found.

$$\begin{aligned} A &= \pi r^2 \\ &= 3.1416(25) \\ &= 78.54 \text{ sq. ft.} \end{aligned}$$

The volume of a cylinder is:

$$V = Ah$$

Substituting known values into the formula:

$$1026.66 = (78.54)h$$

To find h (height), divide the volume by the area of the cylinder's diameter:

$$\frac{1026.66}{78.54} = 13.07$$

$$\text{height} = 13.07'$$

FIGURE 1
Calculating the required height of the storage tank.

Conclusion

For nearly half of this century, society has continued to reap the increased benefits provided by technology. During that same time, untold amounts of assorted pollutants such as acids, sludges, fuels, solvents, chemicals, oils and other hazardous wastes have been carelessly disposed of in now-forgotten landfill sites, burned, containerized and buried and, in far too many cases, simply poured down the drain or dumped into some open sewer or ditch.

As our nation and the entire world has come to realize the magnitude and seriousness of the hazardous waste disposal problem, both now and in the future, it has looked toward technology to again provide much needed answers. Today new equipment and methods are being developed to deal more safely, effectively and permanently with hazardous waste disposal.

Student Quiz

1. What is the purpose of the Superfund? Has it done its job? Why or why not? Investigate.
2. Why does simply burying hazardous waste materials not work?
3. What lessons have we learned from places like Love Canal? Be prepared to discuss your answer.
4. Briefly explain the concept of using biotechnology in hazardous waste disposal.
5. What happens to nuclear waste? Is that action satisfactory to everyone? Why or why not? Defend your answer.
6. What is being done in new landfills to keep them from leaking?
7. Since DDT seemed so efficient, why do you think it was banned?
8. What are PCB's?
9. Why do you think hazardous waste materials must be incinerated at such high temperatures?
10. What are the four criteria used in determining whether or not a waste is hazardous?

Possible Student Outcomes

- List ways currently being used to deal with hazardous wastes
- Analyze the use of biotechnical means in hazardous waste disposal.
- Examine global problems associated with hazardous waste disposal.
- Discuss new developments in the field of hazardous waste disposal.
- Apply materials and scientific knowledge to the solution of technological problems.
- Associate math and science as an integral part of the study of hazardous waste disposal.

Glossary

Biotechnology—Using living beings, such as microorganisms, to produce or eliminate products.

DDT—Dichloro-diphenyl-trichloroethane; an insecticide formerly widely used which is now banned.

Dioxins—Any of 75 related chemicals, the deadliest of which is TCDD (2, 3, 7, 8-tetrachlorodibenzene-p-dioxin).

EPA—The Environmental Protection Agency, an independent agency of the federal government created to protect the environment from pollution.

Genetics—A branch of biology relating to heredity and its variations.

Genetic engineering—An artificial process which alters the genetic make-up of an organism or its offspring.

Hazardous wastes—Chemicals and chemical by-products which may endanger humans or damage the environment if disposed of improperly.

Impermeable membrane—A film which does not permit the passage of a liquid through it.

Incineration—The high temperature burning of hazardous waste.

Microorganism—A living being, too small to be seen by the naked eye.

Midnight dumping—The illegal, clandestine dumping of hazardous wastes.

PCB—Polychlorinated biphenoyl; any of a certain group of synthetic organic compounds which do not react with other substances and cannot be readily broken down. They become harmful pollutants when released into the environment.

Penta—Pentachlorophenol, a wood preservative.

Superfund—The Comprehensive Environmental Response, Compensation and Liability Act of 1980 which provided $1.6 billion to clean up hazardous/toxic waste sites and prosecute violators.

Toxic Wastes—Poisonous wastes; may be harmful to humans, animals and plants.

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Resources in Technology is written and prepared by Tidewater Technology Associates (T2A), an educational consulting group that specializes in the development of technical programs, curriculum and instructional materials. Members of the group are Walter F. Deal, III, W. Fred Hadley, James A. Jacobs, Thomas F. Kildruff, John M. Ritz, and George Skena. Further inquiries can be made by contacting Walter F. Deal, III, 429 Lindsay Landing, Yorktown, VA 23692; 804/683-4305.

Resources in Technology

Processing Fibers and Fabrics

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Since the dawn of history, humans have used natural fibers to make clothing and other utilitarian items. The cotton, linen, silk, and wool fibers, although quite desirable then and now, were the only source of fiber available for processing fibers and fabrics. It was not until 1889, when Count Hilaire de Chardonnet introduced his fabric known as "artificial silk" at the Paris Exhibition, that the public got its first look at synthetic fabric.

In 1939, with the introduction of nylon by the DuPont Company, the manmade fiber industry expanded into what was the beginning of production of a long list of fibers synthesized completely from chemicals. The entire production of nylon was allocated by the government for military use during World War II for such items as parachutes, tents, tires, and ropes.

At the end of the war, nylon, which had replaced Japanese silk during the war, was a huge commercial success. The post-war period of the 1950s saw the introduction of acrylic fiber, a wool-like textile first produced by DuPont. It was the production of polyester introduced in 1953 that revolutionized the textile industry from both the apparel and industrial perspectives. Polyester's improved dimensional stability and resistance to chemicals was to set a precedent for the use of fiber technology when solving problems in industrial product design.

NATURAL FIBERS

Cellulosic	Protein	Mineral	Rubber
Cotton	Wool	Asbestos	Rubber
Linen	Specialty Hair		
Jute	Angora		
Hemp	Mohair		
Ramie	Silk		
	Mashmir		

SYNTHETIC FIBERS

Petroleum Base		Cellulosic	Mineral/Metal
Acrylic	Olefin	Acetate	Glass
Aramid	Polyester	Rayon	Metallic
Modacrylic	Saran	Triacetate	
Nylon	Spandex		
Novoloid	Vinyon		

TABLE 1
Major classifications of fibers are natural and synthetic. There is a wide array of fibers that can be grouped in these classifications.

Contemporary Analysis

In order to construct textile materials, four processing stages must be completed. These stages include fiber, yarn, fabric, and finishing. Without these stages we could not produce products such as clothing, protective gear and furnishings, or use them in architectural applications such as stadium roofs, carpeting, wall coverings, etc.

Fiber

Fiber is the basic unit of fabric or textiles. It can be either natural or synthetic (manmade). Our natural fibers come from animals, plants and minerals. Cotton and flax have been used for centuries, along with wool and silk, to produce fiber used in textiles.

More recently, with the invention of rayon and other petroleum-based plastics, industry has been able to engineer fibers to meet specific consumer needs in fabrics. Table 1 shows the array of fibers industry has available to them to produce our textile products.

Natural fibers (plant, animal and mineral) are already in fiber form when they are harvested. However, synthetic material, such as plastics, metals, and glass, must be processed using chemistry and complex machinery to produce a fiber that may be spun into a yarn.

To do this the material must be heated to a high enough temperature to make it melt or treated with chemical solvents so that it will flow. Once the material is made viscous or liquid, it is forced through a forming head, called a spinneret, and formed into a long fiber. This process is a form of extrusion.

There are three different methods used to extrude the fibers. These are called wet spinning, dry spinning, and melt spinning.

Wet spinning involves hardening the fibers by extruding them into chemical baths (Figure 1). Rayon, spandex (synthetic rubber), and acrylic fibers are made in this manner.

Dry spinning uses manmade substances that are dissolved in chemicals and are forced through a spinneret (Figure 2). They are allowed to air harden without being submerged in other chemicals or water. Consequently this process is referred to as dry spinning.

The third method of synthetic fiber forming is called melt spinning (Figure 3). In this process, the substance used to

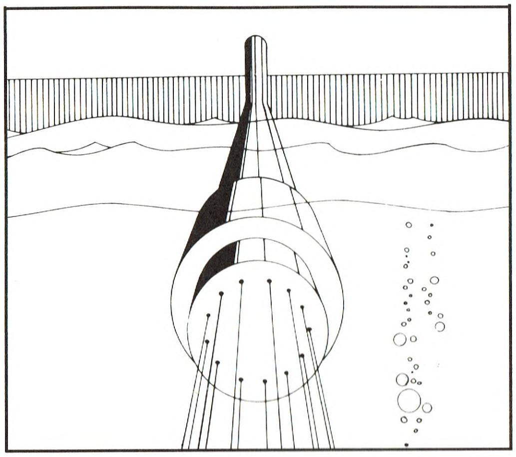

FIGURE 1
Wet Spinning is used to produce rayon, spandex, and acrylic fibers. (Courtesy of American Fiber Manufacturing Association, Inc. Washington, DC).

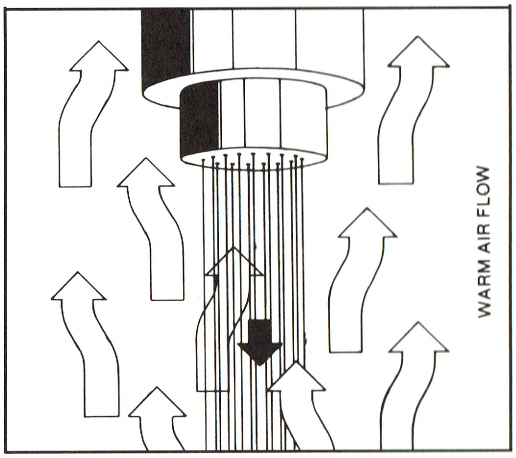

FIGURE 2
Dry spinning produces fibers similar to wet spinning except the fibers are allowed to hardened in a controlled air environment (Courtesy of American Fiber Manufacturing Association, Inc. Washington, DC).

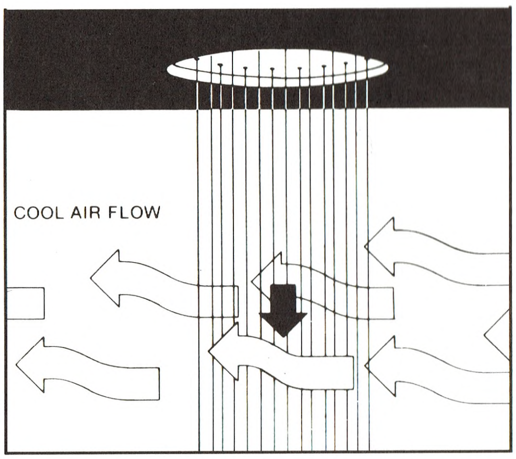

FIGURE 3 Melt spinning produces fibers that are extruded from a molten resin and allowed to air harden. (Courtesy of American Fiber Manufacturing Association, Inc. Washington, DC).

form the fibers is melted, extruded through the spinneret and allowed to air dry to form into fibers.

The fibers formed through both natural and synthetic means possess properties that make them useful in different ways. The most positive attribute of synthetic fibers is that they can be engineered to meet most applications demanded of them by industry and society. Strength, flexibility, spinnability, shape, density, luster and absorbency are some of the properties that can be engineered into synthetic fibers.

Acetate is but one of the many synthetic fibers used today. It has properties that make it very similar to satin. Figure 4 illustrates the chemicals and processes that have been designed for producing acetate fiber. The process starts with wood pulp which is then treated with acetic acid and acetic anhydride. This produces primary acetate or acetate dope. It is then precipitated in water to make secondary acetate. This mixture is then dissolved in acetone, filtered to remove impurities and extruded through spinnerets. The spun fiber is then air-dried and becomes acetate yarn.

As this production process indicates, the production of synthetic fibers is much more scientific than the harvesting of natural cotton and wool. To be useful, all fibers, natural or synthetic, must next be spun into yarn.

Yarn

The production of yarn is the second step in the processing of fabric. To make yarn, fibers must be spun. This differs from the term spinning used in the production of synthetic fibers as discussed earlier. The object of spinning is to make the fibers (natural or synthetic) adhere to each other to produce a strong, uniform yard. Although there are different methods for spinning fibers into yarn, they all involve the following steps:

1. Individual fibers are aligned to form an untwisted rope called a sliver;
2. A set of slivers are blended and drawn to form a roving (a roving starts the fibers to adhere loosely together to form a chain of fibers);
3. Fibers are drawn and pulled to obtain a desired count and weight of fibers per length (yarn begins to take on desired properties);
4. A twist is added to the drawn yarn to give it strength and aesthetic value (determined by the type of yarn to be spun);
5. The finished yarn is wound onto bobbins for future weaving.

Fabric

To make fabric, yarn must be adhered. Usually this is thought of as knitting or weaving. In knitting, the yarn is looped with mechanized needles and new loops are drawn through the previous ones (Figure 5).

Knitting is used to produce products such as sweaters, hosiery (socks and hose), T-shirts, athletic clothing, lace, and other products. In contrast to knitting is weaving. In weaving, two or more sets of yarns are interlocked at right angles to produce the fabric. Through the weaving process, fabric is produced in rolls or folds that can be later cut and sewn into garments or other textile products. Figure 6 shows rolls of woven fabric that are being made on high-speed water jet weaving machines.

Fabric can also be made by forming fibers directly into cloth. This omits the stage of forming yarn. Ways of producing fabric in this manner include laminating and bonding. In laminating, fibers are adhered to a backing. This is how simulated leather (vinyl), coated rainwear, and flocked velvets are produced. In bonding, the textile fibers are pressed together in uni-directions and adhered by using

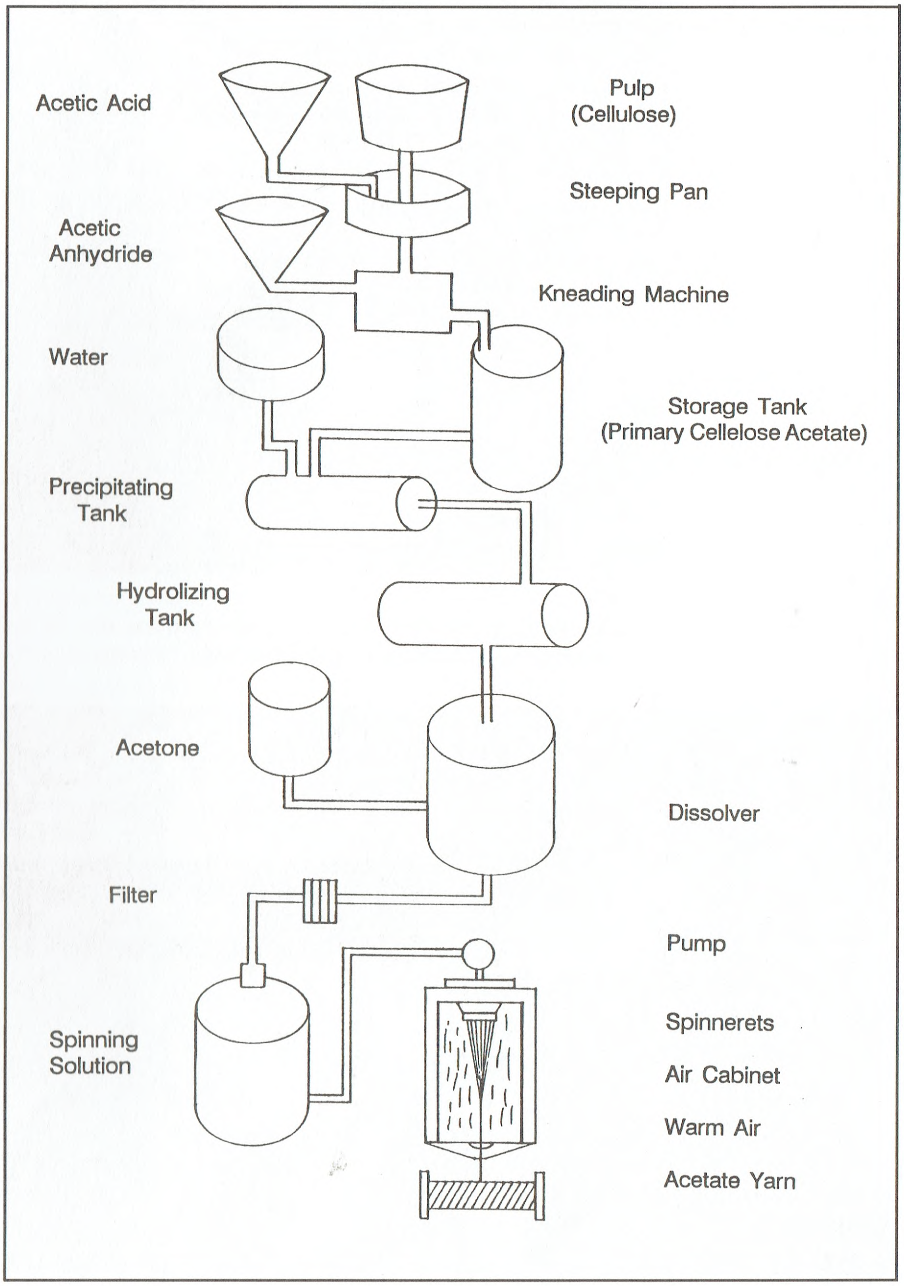

FIGURE 4
A chemical process diagram of the processing sequence for producing acetate yarn. Complex fiber production system also involves precise computer control consistent high quality fibers.

water, heat and pressure. Fabric, such as felt and some synthetics, are produced this way.

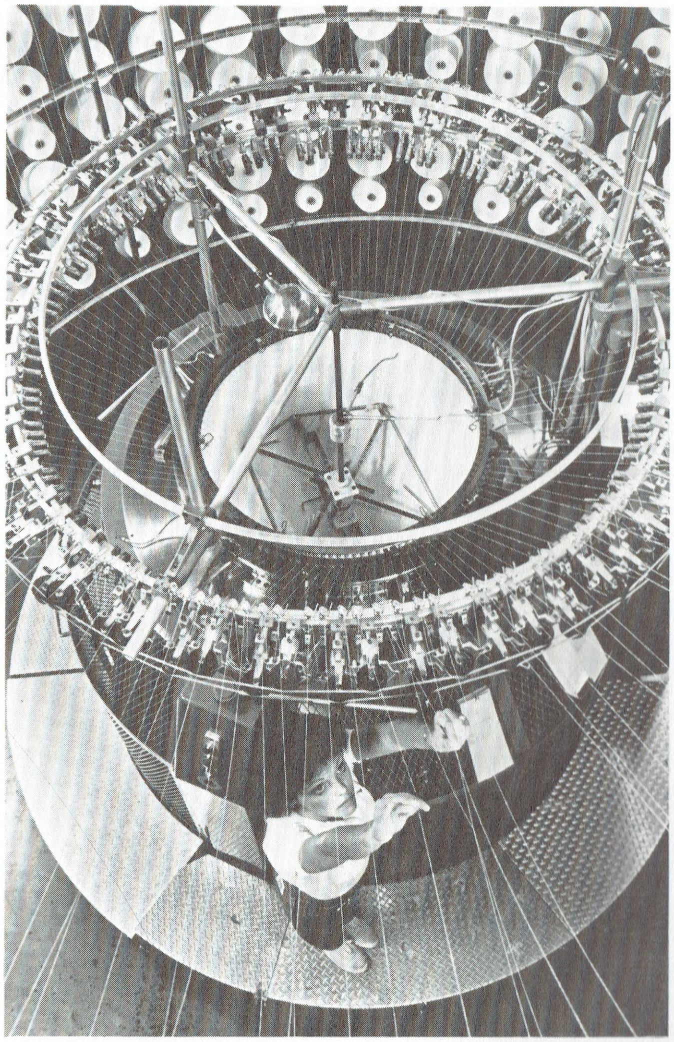

FIGURE 5
A textile worker plucks a strand of yarn entering the circular knitting machine. (Burlington Industries, Inc.)

FIGURE 6
A weaver inspects cloth as it is woven on state-of-the-art water jet weaving machines. The vehicle shown at the left is called a "Prontow" and illustrates the use of materials handling technology. (Burlington Industries, Inc.)

Finish

The final stage in the production of textiles is finishing. A finish enables the fabric to perform certain functions in the most efficient manner. The finish for pajamas would be different from that of textiles used to cover automobile seats. The finish should be directly related to the end use of the fabric. For example, the consumer who purchases a dress shirt would want it to be wrinkle-resistant, anti-snagging, anti-static, durable (washable), shrink resistant and possess a list of other qualities. This would be in contrast to an athletic uniform, which you would want to be durable, flexible, resistant to staining, moth-resistant, and absorbent. Following is a review of some of the major finishes applied to textile materials:

- *Calendering*—The passing of the fabric between heated cylinders. This is similar to ironing. This process provides a smooth luster to the surface of the fabric.
- *Glazing*—The fabric is starched or waxed prior to calendaring. The result is a high glazed or polished effect.
- *Sizing*—Adding compounds to the fabric to cause the individual fibers to keep their size and texture.
- *Napping*—Raising the fibers so that they possess a soft finish.
- Anti-snag—Application of chemicals to make knits resistant to pulls and snags.
- *Absorbent*—Process applied to synthetics to give them the quality of cotton.
- *Water-Repellent*—Chemical finish added to textiles to enable them to repel water.
- *Flame-Retardant*—Chemical treatment to textiles to cause them not to flame up or ignite.
- *Soil Release*—Permits relatively easy removal of soils through laundering.
- *Antiseptic Finish*—Use of bactericides to inhibit bacterial growth.

The list of finishes seems to be endless with the engineering of synthetic fabrics. Some of these potential finishes will be realized as you review the social cultural impact that textiles have had on individuals and industry.

Social/Cultural Impact

An examination of the growth of the textile industry indicates that there is a direct relationship to the social, economic, and even political development of this country's technologically-advanced society. The technology employed by the textile industry to produce fibers and fabrics has proven effective in meeting the demands of society. For example, fibers are used to meet consumer needs in the area of fashion, architecture, sports, leisure, industry, and medicine, just to mention a few.

Fashion

The fashion business, which is a growth industry, contributes $158 billion annually to the national economy. Both the textile and fashion industries developed as a result of the industrial revolution. These industries continue to grow, in part, because of the advancement of technology in the areas of fiber, fabric, and apparel manufacturing. For example, Burlington Industries is using modern technology to speed up the process of creating new designs which normally move slowly from designer to producer, with computer-aided design systems.

Since the beginning of synthetic fiber production in 1910 when rayon was introduced, the fashion industry has depended heavily on the textile industry to bring high quality clothing of lower prices to the public. Liz Claiborne, a famous New York designer, has built a business on bringing affordable fashion to her customers by using high quality polyester. She learned that polyester apparel can be produced and sold at a much lower price than natural fibers and at the same time it is beautiful and serviceable.

Millions of women and men buy products made with polyester fibers. The blending of cotton and wool with this remarkable fiber has made it possible for consumers to travel and wear clothing that is reasonably wrinkle-free. Thus, it provided business women and men opportunities to keep appointments without wasting time with maintenance of clothing.

Social changes that are occurring, such as more women in the work place and the need for easy-care fabrics have become important. Lifestyles now dictate that clothing meet the hectic pace in which most consumers find themselves today. The synthetic fibers industry has been improving the quality of fashion by offering characteristics not found in natural fibers.

For example, triacetate can be used to produce fabrics that are washable, wrinkle-resistant, and with permanently heat-set pleats. Acrylic is an excellent substitute for fleece or wool products and simulated fur. Modacrylics that are flame-resistant provide a safe fiber for children's sleepwear and draperies. The new and improved nylons that have been developed through years of research are so desirable that even the high fashion designers are using this excellent fiber in couture gowns.

Sports and Leisure Wear

High-technology fibers have become more important, particularly when clothing and equipment used when playing sports and/or leisure activities are involved. Fibers that have existed for years are now more visible as more and more manufacturers employ them in activewear and outdoor-wear. For example, nylon has been a major consumer-oriented fiber since 1939 and was never regarded as having moisture-transport properties.

However, as recently as 1987, Allied Fibers introduced its Hydrofil® which is considered the first truly breathable nylon with moisture-transport. It has characteristics that eliminate clamminess and wet cling from the skin, unlike conventional nylon. Susan Butcher, a three-time winner of the Alaskan Iditarod, was dressed from head to toe in Allied's Hydrofil to keep her warmer, drier, and more comfortable.

Another highly successful new "hi tech" fiber is Zefsport® from BASF. It is a tricot knit stretch fabric constructed of nylon combined with Spandex, providing excellent strength and stretch quality. This new fabric is used in swimwear, leotards, tights, and aerobic wear. It takes color well and is very fashionable.

The use of technology to create new fibers is an ongoing process. However, many of the other fibers are being modified to provide characteristics never before imagined. New markets have been created because of second and third-generation manmade fibers that now meet requirements for a wide variety of sports and leisure activities.

Other Uses

Perhaps new developments in fiber research related to the production of new materials for architectural, industrial, and medical use will have the most significant impact. Olefin® fibers are used in many nonwoven fabrics such as Tyvek® by Dupont for wall coverings, packaging, signs, and disposable medical supplies. Vexar®, an Olefin® produced by Dupont, is used for commercial and medical sheeting and packing where ventilation is important. Some other uses of fibers are in cosmetic surgery and products such as tennis balls and awnings. Geofabrics are used in the construction of highways and erosion control projects.

The remarkable growth of the engineered fiber-producers industry during the last 100 years has given rise to innovations that have brought countless improvements to every aspect of modern life. Manufactured fibers will continue to contribute to the ever-changing consumer and industrial needs and demands of our society. Future societies will have a standard of living never dreamed of as the technology of fiber and fabric production continues to develop and affect our everyday lives.

M/S/T Interface

Chemistry has played a major role in the modern textile industry. Chemists in research laboratories have succeeded in synthesizing compounds with qualities necessary to make them useful in textiles. Table 2 shows these properties and briefly describes them. These properties are determined by fiber chemical composition, processing, and treatment.

PROPERTY	*DESCRIPTION*
Physical	Color, Luster, Shape, Surface, Contour, Crimp, Length, Diameter and Fineness
Mechanical	Strength or Tenacity, Specific Gravity, Flexibility, Elongation and Elastic Recovery Dimensional Stability, Resiliency, Abrasion, and Resistance
Chemical	Absorbency, Electrical Conductivity, Effects of Heat, Flammability, Chemical Reactivity and Resistance
Environmental	Sensitivity to microorganisms and insects, and Sensitivity to environmental conditions

TABLE 2
Knowing the physical properties of fibers allows processors and manufacturers to select fibers and fabrics intelligently for specific product designs.

Early synthetic textile fiber production started with materials that had a structure similar to natural fibers. These materials were dissolved with chemical solvents and reconstructed into long filament fibers by a process called regeneration. As chemists came to understand the chemical structure of fiber molecules they realized that it would be possible to create fibers from chemical compounds.

Using a laboratory analytical process known as X-ray diffraction, researchers determined that the fiber-like qualities of a substance depended on the presence of long-chain polymers. With this knowledge, chemists attempted to assemble long-chain polymers using chemical materials in the laboratory. These experiments led to the synthesis of a polypeptide. Polypeptides are polymers containing many linkages that include carbon, oxygen, nitrogen, and hydrogen (CONH) and are commonly called amides. The natural fibers of wool and silk are also polypeptides from a chemical analysis perspective.

Chemical companies played a major role in the development of the manmade fiber industry. W.H. Carothers, a chemist at the E.I. duPont de Nemours Company, is noted for his basic research in the synthesis of long-chain molecules that eventually led to the creation of a number of synthetic compounds and their processing into fibers. Conceptually, Carother's work can be described as assembling large reactive molecules into long chain molecules. The research by Carothers led to the first true synthetic fiber, nylon, that was marketed commercially.

Nylon in its simplest form is made by the condensation of adipic acid and hexamethylene diamine. Nylon, like wool and silk, is a polypeptide. As we have seen earlier, all textile fibers except glass, metal fibers, and asbestos are organic in origin. Organic materials may be defined as substances or compounds that contain the element carbon. Thus, organic chemistry plays a major role in understanding and developing new textile fibers and processes.

The chemical structure of a textile fiber determines its properties and characteristics. When considering our physical world, all matter is made of one or more combinations of elements that can be found on a Periodic Table. An element can be defined as a substance that cannot be broken down into a smaller component without losing it unique identity by chemical means. An element may be thought of as the simple form of matter. Examples of elements include gold, silver, copper, iron, carbon, oxygen, and nitrogen.

When we dress in the morning we rarely think of the clothes we wear as being a "collection of atoms and molecules" that are processed into textile fibers! The atoms of elements are combined into molecules to form specific substances. The ability of atoms to combine with one another is determined, in part, by their valence electrons.

For example, hydrogen has a valence of 1 and can only combine with one other element. Oxygen has a valence of 2 and can combine with two other elements. When looking at a Periodic Table, you will note that each element has a valence number that is expressed as an integer such as 1, 2, 3, 4, . . . etc. Accordingly, two hydrogen atoms can be combined with one oxygen atom and the resulting substance would be water or H_2O. It should be noted that a glass of water contains millions of these water molecules!

Most textile fibers are organic and contain carbon in combination with other elements such as oxygen, hydrogen, nitrogen, fluorine, and chlorine. Carbon has a valence of 4 and can accept bonds at four different points as single, double, or triple bonds. When a carbon atom uses one of its valence points, a single bond is formed. When two valence points are used it is a double bond and three when a triple bond is formed. The second and third bonds are very reactive and it is this property that makes it possible to create many thousands of organic compounds.

The elements that form a compound and the manner in which they are linked together determine the properties of that compound. Textile chemists are concerned with long-chain organic compounds that can be manipulated to improve the properties of existing fibers or develop new fiber formulations. Organic chemists use a type of "shorthand" to show how atoms are connected together. Figure 7 illustrates how a chemist may show how atoms of elements are linked together.

Other forces that hold individual molecules together to form long chains are called attractive forces. These forces are called Van der Waals forces and hydrogen bonding. Van der Waals forces are weak attractive forces caused by the proximity or closeness of one molecule to another. Hydrogen bonding occurs when one atom of hydrogen links together two other atoms. For hydrogen bonding to occur the molecules must be very dense and well-oriented. Additionally, highly reactive elements must be present in the molecules. These elements include oxygen, nitrogen, and fluorine. Hydrogen bonding is found in natural cellulosic and protein fibers such as cotton and wool.

Monomers and Polymers

Monomers may be thought of as basic building blocks or molecules for building complex molecules for fiber compounds and other chemicals. Monomers may be combined to form larger units called polymers.

A polymer is a compound that is formed by the reaction of simple monomer molecules that combine to form larger molecules under certain conditions. These conditions are usually a combination of high temperature and pressure in the presence of a catalyst. Polymers can be formed by polymerization or polycondensation. Polyethylene is an example of a polymer that is made of many monomers.

The type of bonding, molecular structure, and manufacturing processes used to make polymers affects the characteristics of the fibers that are produced. As chemists discover new ways of combining atoms and molecules we will see new fibers with the carefree characteristics that are desired by consumers.

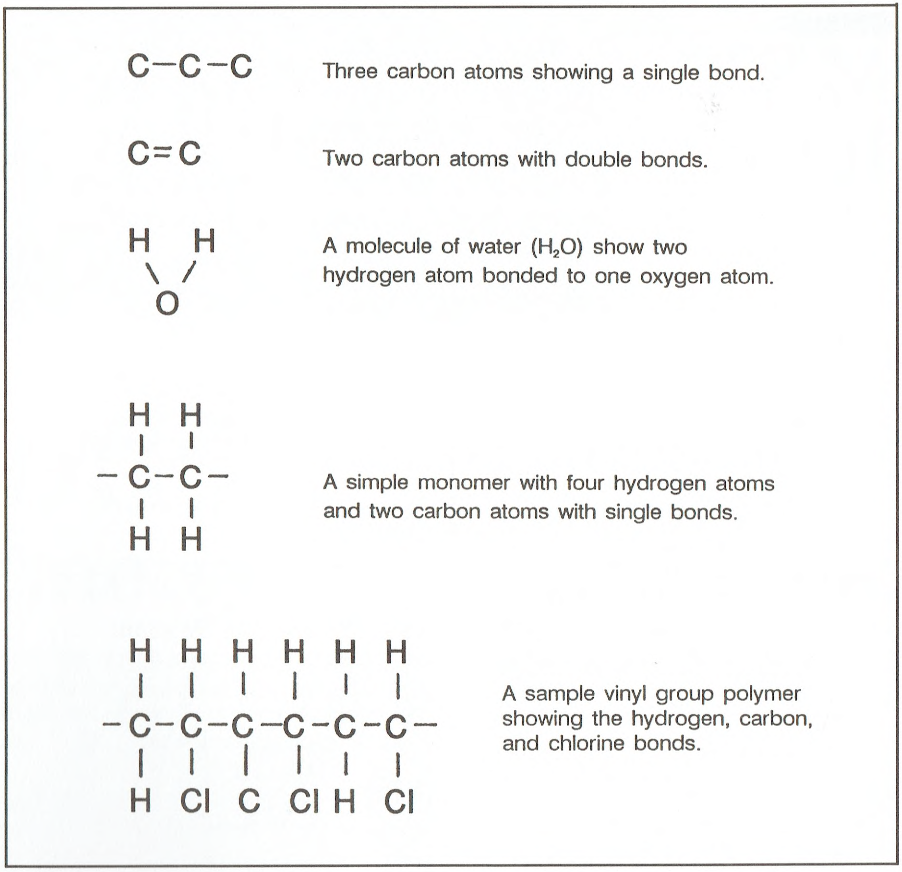

FIGURE 7
Organic chemists use a special "shorthand" to represent the arrangement and bonds of elements in molecules. While these are simple illustrations, most synthetic fiber structures are complex long-chain polymers.

Construction Activity

As we have seen, fiber manufacturers, garment makers, and consumers are concerned with a wide variety of physical and chemical characteristics of fibers, yarns, and fabrics. Fiber manufacturers are concerned with the production of high quality fibers that can be processed into a variety of garment and textile products economically.

Garment makers and other fiber product manufacturers depend on manufacturers to supply them with quality materials on a timely basis and in step with fashion-conscious consumers. The consumer is the end-user of fabrics, garments, and other textile products and is primarily concerned with fashion, durability, stain resistance, color fastness, and dimensional stability.

A laboratory test that can be duplicated in the technology lab is testing fabrics for stain resistance of one or more fabrics. This test can be used to illustrate a concern of fiber manufacturers, garment makers, and consumers.

Many innovations in manufacturing and processing textiles have resulted in excellent stain-resistance of fibers and fabrics. The garments that people wear are exposed to a wide variety of stain-producing materials such as tasty spaghetti sauce and other foods, paints, make-up, inks, and petroleum products. Each of these materials have special requirements for removal.

However, chemists and textile manufacturers have extended great efforts in attempting to minimize the effects of staining agents on fabrics. Manmade fabrics are more stain resistant than natural fibers. A comparison can be made by preparing "stain squares" such as shown in Figure 8.

Fabric samples should be marked into squares and numbered for a stain resistance tests. Use a permanent marking pen to make a 3"×4" matrix. Staining agents, such as those shown below can be used for testing the stain resistance of manmade and natural fabrics.

- Ketchup
- Latex Paint
- Coffee
- Ballpoint Pen Ink
- Mustard
- Oil Stain
- Orange Juice
- India Ink
- Egg White
- Motor Oil
- Lipstick
- Red Ink

Allow the stain squares to "set" for about one week. Launder the stain squares as recommended by their manufacturers. Observe and record your results. The data collected by observing the relative stain resistance of manmade and natural fabrics should be compared and summa-

Stain 1	Stain 2	Stain 3	Stain 4
Stain 5	Stain 6	Stain 7	Stain 8
Stain 9	Stain 10	Stain 11	Stain 12

FIGURE 8
Fabric samples that measure 12″ × 16″ can be used for testing the stain resistance of a variety of fiber materials.

rized. Your observations should lead you to make conclusions about fabric stain-resistance and groups of staining agents that are easily removed and those that are permanent.

Summary

Fibers and fabric are important to all nations and walks of life. With developments in the technology of processing and engineering, fabrics have been developed that make our life more comfortable. In addition to serving as clothing, textiles and fibers are important in the production of manufactured products, the construction of our living, working and leisure environments, and to applications in the field of medicine, industry and research. As we learn more about chemistry and the finishing of textiles, our world should continue to be custom-made to satisfy our needs.

Possible Student Outcomes

- Describe the stages followed in the production of textiles.
- List natural and synthetic fibers.
- Describe the three methods of producing synthetic fibers.
- Describe various finished applied to fabrics.
- Analyze why various fibers have been used in the production of textile products.
- Explain why a knowledge of chemistry is important to those who work in the textile field.
- Participate in activities that involve the testing of textile materials.

Student Quiz

1. List the four major stages employed in the production of textile materials.
Fiber, yarn, fabric, finish
2. List three natural and three synthetic fibers.
Natural cotton, wool, silk, rubber, etc.; synthetic—acrylic, nylon, polyester, spandex, rayon, glass, etc.
3. What are the three methods of producing synthetic fibers?
Wet, dry, and melt spinning
4. List three finishes applied to textile materials.
Calendaring, sizing, anti-snag, absorbent, soil release, etc.
5. List three examples of specially designed fabrics and their applications.
Polyester—action wear, triacetate—wrinkle resistant, rayon—gowns, hydrofil—winter sportswear, spandex—swim wear, etc.
6. Why is chemistry important to the design of textile materials?
The chemical structure of a textile fiber determines its properties and characteristics.

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ROBOTICS An Emerging Technology

FIGURE 1
"Manny" an articulated mannequin with 42 degrees of freedom serves as a research robot.

At 2:30 pm local time on March 6, 2001, what do you think you will be doing? Sound like a strange question? Does that seem like such a long time away? Stop right now and calculate the years. That new millennium (2000 years) will be on us very soon, won't it? What changes will it bring?

No one can tell us for certain what our world will be like on March 6, 2001. Most of us have seen science fiction films that depict human-like robots that look much like Manny in Figure 1. If you have visited Epcot Center at Walt Disney World you have seen the results of considerable research and development of displays to provide us with a glimpse at what our future will be like. In the *Star Wars* movie series, thinking robots served as human slaves doing the bidding of their masters. The science fiction writers and Disney "imagineers" do have information on developing technologies to help make forecasts about the future, as do those involved in the scientific and engineering research in robotics.

Among the vast number of emerging technologies, artificial intelligence, often referred to as AI, is an innovation that is sure to progress. Refer to "Introduction to Artificial Intelligence," *The Technology Teacher*, November, 1987, to gain more insight into AI. Robotics is greatly enhanced by the use of AI.

While it is doubtful that the R2D2 "humanoids" of the *Star Wars* movie is in our near future, we are quite sure that robots will play a significant role in our lives in 2001 and beyond. They are currently used in manufacturing for education, research and service applications. So you may find it interesting to gain a better understanding of the current status of robots and robotics and see what direction robot technology is heading and whether you may wish to be a part of it.

Robots Defined

Robots are being developed and used more in manufacturing than other fields because of the significant advantage they offer in production jobs that are boring and/or hazardous to people. Robots also are used in brain surgery. They venture into mines, into contaminated nuclear powers plants (Three Mile Island and Chernoble) to provide a view and to perform functions in environments hostile to humans. They have even been used to disarm a bomb placed in a briefcase.

Robots serve research in numerous capacities, such as Manny (Figure 1) which was developed to mimic human senses. Service robots deliver mail, vacuum floors, act as security guards and deliver food to patients in hospitals. There are many educational robots from elementary schools all the way through college graduate programs to meet the needs of a wide range of activities.

A "robot" is defined by the Robot Institute of America (RIA) as . . .

> a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

This definition focuses on industrial robots, which represent the largest group. Robots are being developed to serve many purposes in addition to industrial production. Robots in a broader context are reprogrammable, multifunctional devices capable of replicating human senses, motions and activities to meet a broad range of demands to relieve humans of tasks which may be dangerous, monotonous, or require a degree of precision or strength beyond human capabilities.

People sometimes incorrectly label many automated devices as robots, but those electromechanical devices often don't meet the reprogrammable and multifunctional criteria that help to differentiate robots from other machinery. Remote manipulators include cranes and other lifting devices such as the equipment now found on garbage trucks that allow the driver to lift garbage containers from the street to dump in the truck without the driver leaving the cab. This is a remote manipulator, but it is manually guided by a human operator rather

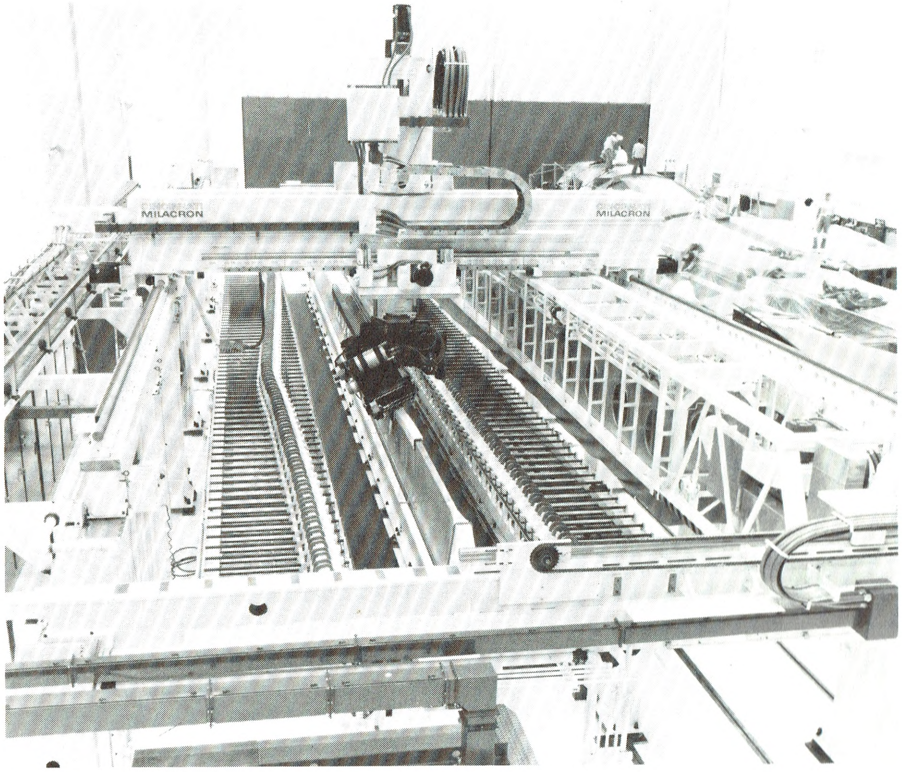

FIGURE 2
Channel Stringer Manufacturing System—NC—controlled lay up of graphite-epoxy channel stiffeners. Tape head dispenses 20" wide fabric onto contoured mandrel. System was developed by Cincinnati Milicron for Boeing Advanced Systems. Note the size of the system by comparing it with the workers on the right.

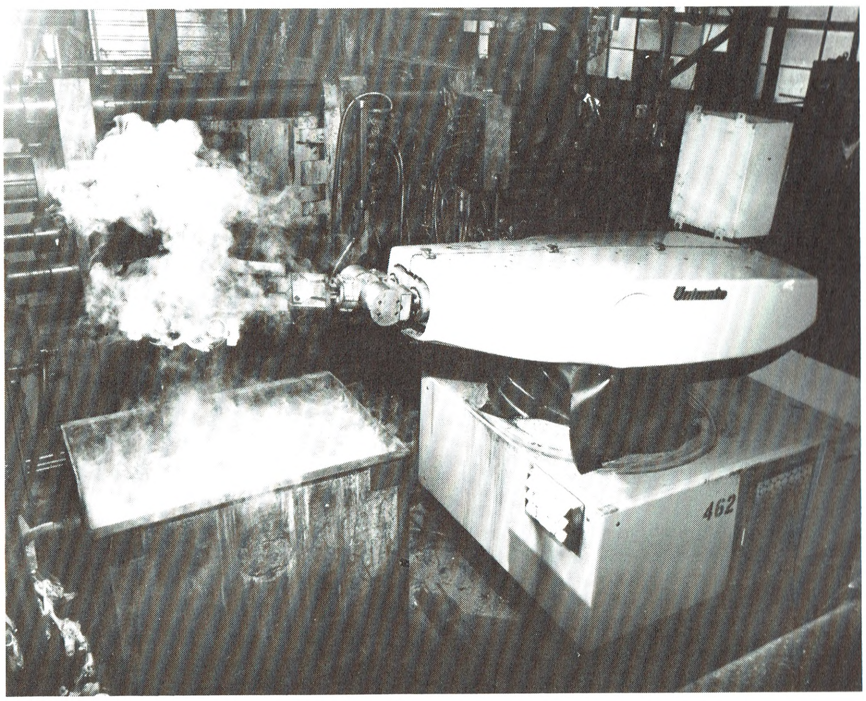

FIGURE 3
Die Casting operation automated with a Unimate 2000 Series industrial robot. The robot removes the cast part, quenches it in a water bath for cooling and places it on output conveyors. Cycle is automatically repeated.

than being programmed to automatically perform its task.

Other automated equipment such as numerically controlled lathes are reprogrammable but they are not multifunctional. The same robot used for welding can be used to paint, load materials, perform assembly operations and a variety of other tasks through changes in the end efforts (end of arm tooling) and reprogramming. Figure 3 is one of the series the early and highly successful Unimate industrial robots. Unimate robots installed for General Motors in 1962 marked the first mass production use of robots.

Robotics is a term that covers the full range of robot technology including industrial robots, research robots, service robots, teaching robots and special purpose robots. Researchers are busy all over the world developing many aspects of robotics from robots to simulate human biological systems, to robots to assist in the exploration of the earth and space, to robots to assist in laboratories in the mixing of chemicals.

Research robots are used for problem-solving by scientists, technicians, engineers and technologists; they make take any forms determined important to study a particular set of problems. Manny, in Figure 1, is a unique research robot developed by a technical team of 12 researchers representing bioengineering, computer graphics and materials science at Battelle's Pacific Northwest Laboratory as a research device for the U.S. Army's Material test facility.

This anthropomorphic (human-like) robot represents what people, often mistakenly, imagine as robots because of the way they are depicted in movies. It is a $2 million wonder of technical problem-solving, but does not begin to approach the capabilities of the simplest of humans.

Manny, a very sophisticated mannequin, was designed to test protective clothing that may be used in chemical warfare, fires or other very hazardous conditions. Because of the dangers of using humans to test clothing, Manny has been designed to incorporate physiological systems controlled by microprocessors and a remote computer that is attached to the robot by flexible cable.

It is possible to write programs for the device to perform a limited number of human replicating movements. Manny is constructed of wires, tubes switches, motors and joints; it has a base layer of butyl rubber onto which is attached a flexible polymer skin with sensors to detect tem-

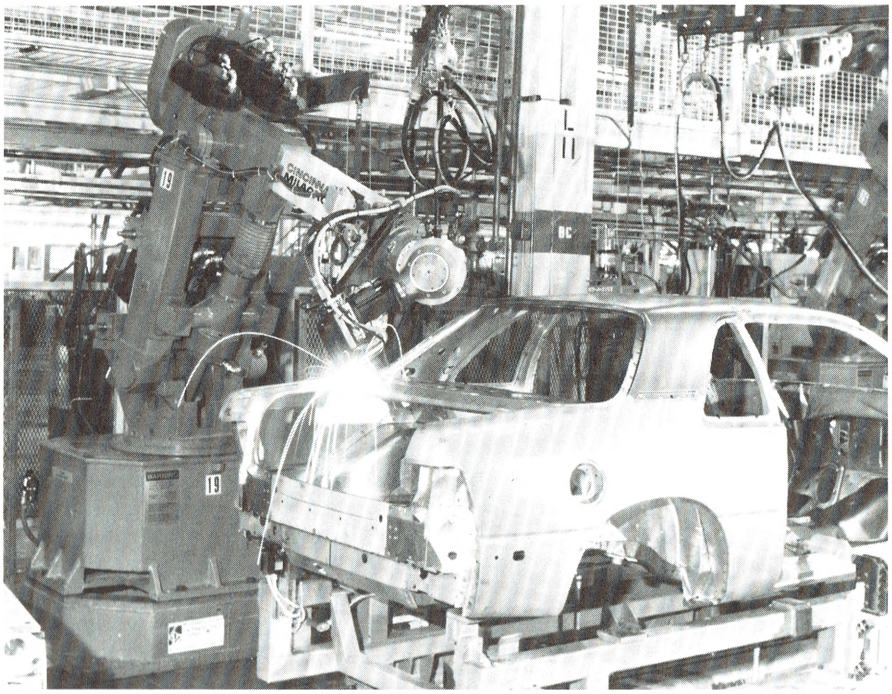

FIGURE 4
The Testing Phases are an important step in the development of knowledge-based systems that control precision robotic spot welding station with a jointed armed spherical robot.

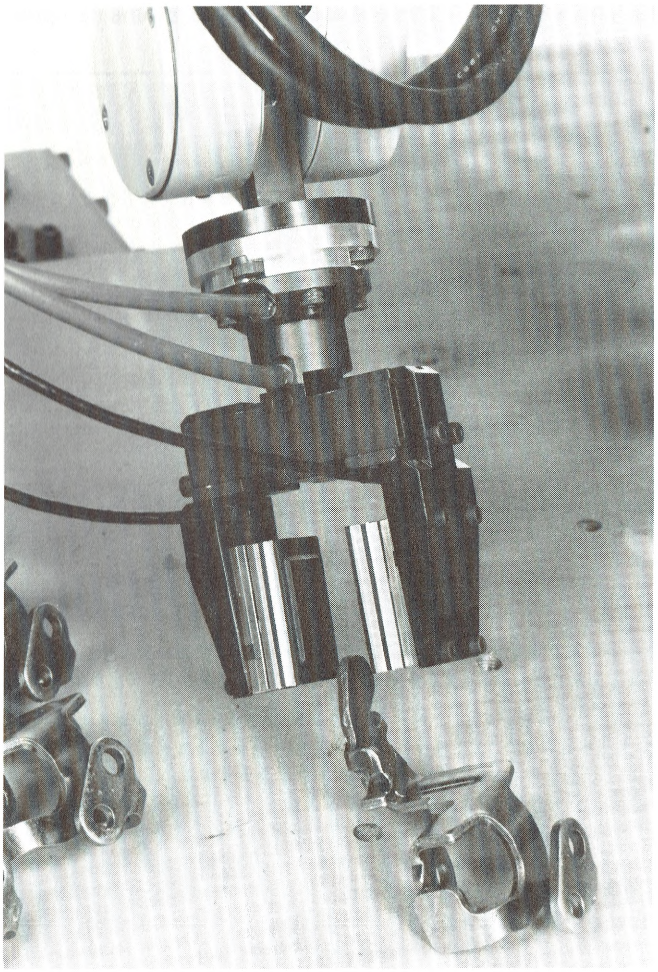

FIGURE 5
End effector: gripper-mounted tactile sensors coupled with machine vision allow controlled pick-up and placement of parts in a workcell.

perature plus an ability to give off heat and moisture to simulate perspiration and temperature.

With industrial robots, 7 degrees of freedom (axis of motion) is consider excellent. This research device has 42 degrees of freedom that allows it to walk (with a support handle attached), crawl, bend, and squat in a simulation of some human movements. Just as with industrial and service robots, the movements are accomplished by motion from hydraulic actuators (which are motors using fluids to transfer energy to cylinders and pistons). Through control of the actuators, researchers can make the robot breath, rotate the shoulders and even salute.

Industrial Robots

The definition given above of industrial robots serves to contrast industrial robots with other automated machinery used in manufacturing. Hard automation is machinery that is limited to specific tasks with no flexibility to be reprogrammed. These are automated devices used for mass production such as conveyors belts, automatic spot welders, drilling machines and material transfer devices such as you might have seen on TV making cars or other products. These automated devices are made to meet the specific needs for a specific product such as an automated assembly line to manufacture 20 cubic-foot refrigerators or Ford Taurus automobiles. They are not multifunctional nor reprogrammable.

The production lines with hard automation require considerable time and expense to design and make; yet if a totally new product is to be made, much of the machinery must be changed to meet the need to place parts in new positions and drill holes and weld parts at different locations.

The hard automated production techniques and machinery developed by Eli Whitney to produce Springfield rifles and further refined by Henry Ford to make low cost cars have served society well for decades. However, the rapid pace of technological development has changed what society is willing to accept. New engineering materials coupled with new discoveries in consumer products such as video recorders and players (VCRs) and compact laser disc players (CDs) plus the ever improving design of these products mean production lines must have the ability to rapidly retool. Because of the need to make fast changes in production lines, hard automated equipment needed to be improved upon.

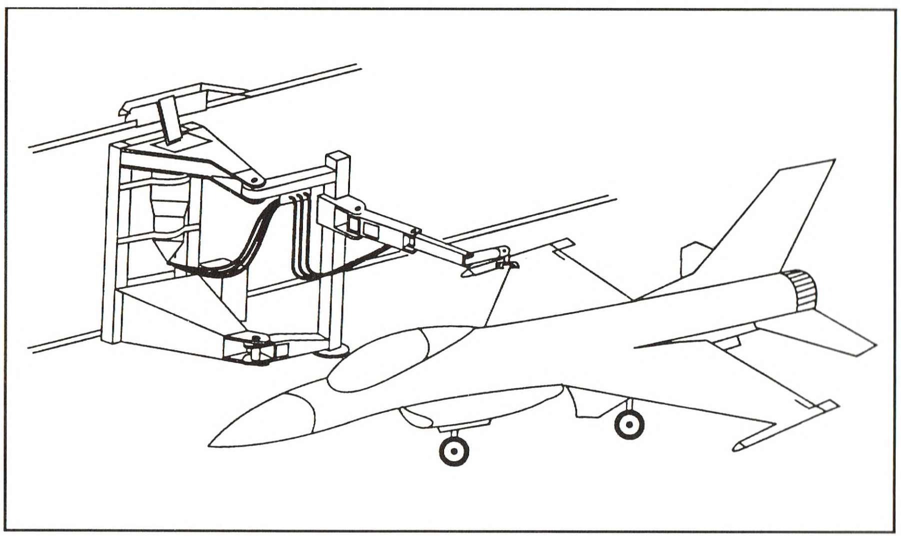

FIGURE 6
A service robot used in paint removal from F-4s and F-16s has an envelope defined by two arms (only one shown) is 30' wide, 100' long and 15' tall.

Flexible automation that allowed more rapid changes in mass production was the answer. The above definition of a robot has the key terms for flexible automation: reprogrammable, multifunctional, variable programmed motions and variety of tasks. These capabilities of a robot that are usually achieved through microprocessors and computers allow one industrial robot to be able to do a full range of jobs from welding to painting to assembly.

In addition to these different tasks that the same robot can do it can be programmed to make changes from one model of product to another. Other improvements in production equipment for use in flexible manufacturing include development of computer numerical controlled (CNC) machine tools (e.g., milling machines, lathes and drills), automated guided vehicles (AGV) to move materials and parts in the factory and automated storage and retrieval systems (ASRS) to make it possible to automatically get the materials and parts from storage shelves for processing and then place them into storage until time to assemble the parts into finished products.

A report in *Business Week*, September 25, 1989, on heavy equipment manufacturer Caterpillar Inc.'s "Plant with a Future" (PWAF) portrays how firms in the United States are investing huge sums of money to modernize their manufacturing plants to meet the competition of Japan and other countries. In earlier decades, equipment manufacturers such as Caterpillar and John Deere could manufacture large $500,000 earth moving equipment along a hard automated production line.

But, there is not the call for so many of these large profitable machines; rather, smaller machines such as farm tractors and backhoe loaders are mixed in with the smaller orders of large equipment. The smaller machines also have smaller profit margins than the big equipment.

In Cat's old plants the "batch" production method was used. For example, steel beams were cut, drilled and heat treated on three separate hard automated production lines. In the new PWAF, steel beams are moved along automated conveyor belts through a tractor-tread "cell" where the cutting, drilling and heat treatment is all done in this flexible cell. Different specifications for making various models of earth moving equipment are met as computers instantly adjust the production equipment for the various materials processing operations.

Under the old hard automated line, it

could take days or weeks to change the production set-up. Cat also uses unmanned "intelligent" cranes to move steel slabs to automated drilling devices where an NC flame cutter burns precise holes. These types of flexible production systems allow Cat to reduce production time from the old methods that required 20 days to 8 days. The article reports that a large investment of dollars is required to make a change from hard automation to flexible automation—a strain that is a difficult adjustment for Caterpillar. (*Newsweek*, 1989)

The case of Cat is being repeated many times in this country as companies scramble to meet changing consumer demands. Not only is automation changing in terms of new production techniques, but new materials are also emerging on the scene that require radically different manufacturing processes.

Composite materials have grown in their importance as engineering materials because of the ability to engineer specific properties into the materials. The surge of the composites into production as a new class of materials has brought about the development of innovative ways to process composite materials into finished products.

Because of their high strength but low weight, composites have long been sought after in aircraft design; however, until now much of the manufacture of composites was highly labor intensive. Boeing automated a time-consuming manual job, thereby making composites a viable aircraft material option. Note in Figure 2 the numerical controlled operated lay up system used to fabricate graphite-epoxy channel stiffeners. The numerical control (NC) system is an example of a flexible manufacturing cell that can be changed with a new NC program.

The Unimate Robot in Figure 3 is seen in a hostile environment of a heat treatment application. This same spherical geometry robot can also be set up to perform other production tasks such as materials handling (loading parts into a lathe, or onto a conveyor belt) or for paint spraying.

Figure 4 shows a jointed-armed spherical robot in a spot welding application. This powerful, complex robot is powered by electric motors and hydraulic actuators. Note the robot has more flexibility than the spherical robot in Figure 3 because of its jointed arm. Additionally, this robot is a part of a knowledge-based system which means the computers and computer software for developing the program for the robot have problem-solving capabilities to aid the programmer.

End effectors are the tooling attached to the end of the robot's arm. Note the different end effectors on the robots in Figure 3 and 4. On the first there is a gripper that is opened and closed by the robot's program commands to pick up the parts in the heat treatment furnace. On the robot in Figure 4 the end effector is a spot welding attachment.

A sophisticated gripper is shown in Figure 5 that has tactile (touch) sensing capabilities, allows it to use varied pressure in gripping parts. This gripper is also attached to a vision system that provides visual sensing (seeing) to guide the robot in selecting and picking up parts. More information on vision systems will be covered in "Machine Vision—Giving Robots Eyes" in next "Resources in Technology."

Because of the reprogrammable, multifunctional nature of robots that are capable of many different tasks, you can expect to see robots in many varied configurations doing a wide variety of jobs in production technology. The applications of robots are only limited by our imagination. The surge of the composites into production as a new class of materials has brought about the development of innovative ways to process composite materials into finished products. The Boeing Company is one aircraft manufacturer that has employed robots in the difficult tasks of laying up composite panels.

Service Robots

As in the production sector of society, the service sector has jobs that are laborious and dull or too difficult for humans to perform, so robots can serve as a substitute. The robot service industry is beginning to grow out of this need. Recent robot exhibitions sponsored by the Society of Manufacturing Engineers (SME) and RIA, have featured multifunctional robots that can vacuum the floor of an office building or be equipped with a TV camera and sound detection devices to act as a security guard. There have been exhibits of robots that serve as mail delivery carts moving about hallways in buildings and stopping at offices to drop off and pick up messages, packages and letters.

We have seen the work of a robot pioneer Joseph Engleberger who moved from the founder of a successful industrial robot firm, Unimation, to service robots designed to work in hospitals and

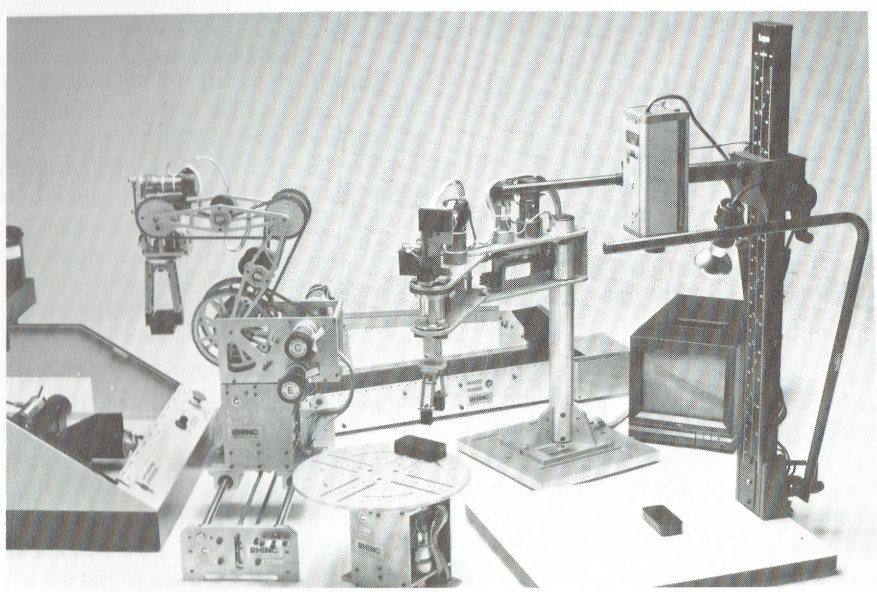

FIGURE 7
Education and Training Robotic systems shown (from left) is a computerized numerical controlled (CNC) lathe that is being loaded by a five axis jointed armed spherical robot. Behind it is a linear conveyor belt and vertical part feeding unit to move parts from one part of the cell to another. In front of the five axis robot is a rotary carousel that has optical sensors and microswitches, as does the conveyor, which precisely determines where parts are located. Moving to the right is a Selective Compliance Articulated Robot Arm (SCARA) often used for assembly. To the far right is a machine vision system used to allow the system to select parts for the robots to pick and place about in the cell.

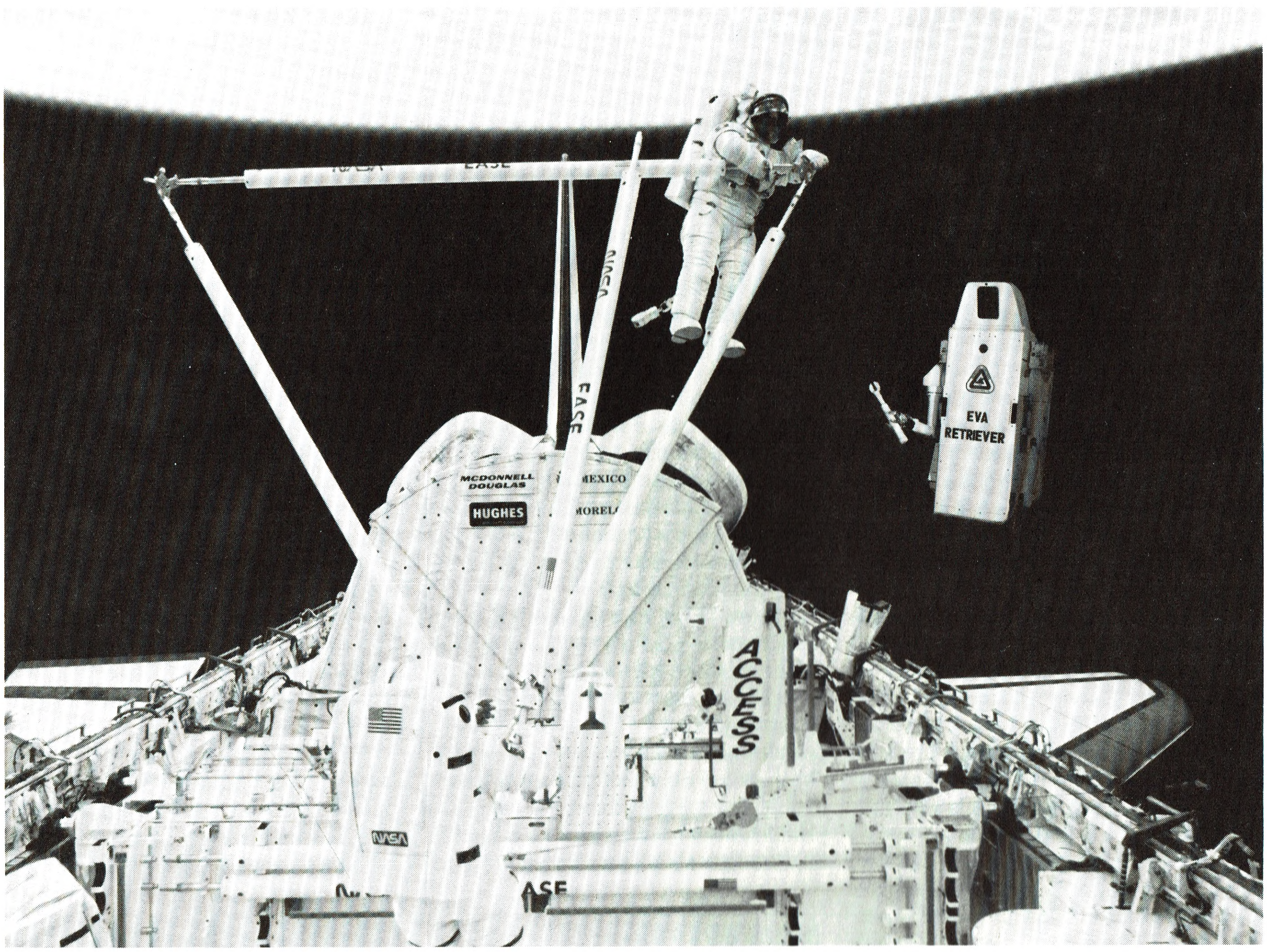

FIGURE 8
Extravehicular Activity Retriever Robot will be a part of the construction crew in building the Space Station Freedom.

nursing homes. His robots carry food and medicine to patients. He and others in the service robot industry are also exploring possibilities of working with appliance manufacturers for innovative devices such as coupling dish washing machines together with robots that would move clean dishes into storage after they are washed. There are even robotic camera operators in development to be used in the film and TV production industry.

Robots have many possible applications in helping the world deal with the problem of hazardous waste. In the United States alone, it is estimated that at least $200 billion will be required to clean up hazardous waste from the nuclear industry. Robots can replace humans in handling these dangerous materials.

Figure 6 depicts another innovation with service robots in which their use can prevent the creation of hazardous waste. Chemical stripping is currently the technique used to remove paint from aircraft. Each aircraft can generate several thousand gallons of toxic chemicals, which must be disposed of properly to protect the environment and humans and animals.

Engineers in the Robotics and Automation Department at Southwest Research Institute (SwRI) have designed a robotic system that uses plastic beads for stripping paint off F-4 and F-16 fighter jets. Their robotic paint stripping cell concept uses two 26,000-pound robots to use air for blasting plastic beads against the surface of the aircraft. The robotic arms have 6 degrees of freedom which allow them to move like a human with shoulder and arm rotation and wrist movements of pitch, yaw and roll capabilities of moving up and down 15′ providing access to all parts of the planes.

Designers at SwRI are also working on service robotics for de-riveting planes. Aircraft require the periodic removal and replacement of rivets in a very time-consuming and precise maintenance procedure. Additional, they have robotic solutions to inspect and repair damaged aircraft canopies. (Southwest Research Industries)

Education and Training Robots

Industrial robots and the components of robotic systems are very costly. They are often large and complex systems of electronic circuitry and may employ hydraulic and pneumatic systems that can be messy and difficult to maintain. Because of this, there is a need for service engineers and technicians to maintain them as well as jobs for designers and programmers of robotic systems. This means expanding career opportunities.

To provide education to students and training to workers in industry, "table top" robotic systems have been devised (Figure 7). The table top systems offer many advantages including lower cost, ease of maintenance and ease of use. They actually are better than industrial robots for providing the basic competencies required to work in robotics.

The system shown in Figure 7 has the same elements found in state-of-the-art flexible manufacturing cells. With the components detailed in the caption under the figure, it is possible to conceive how this set of devices can be arranged in an infinite number of arrangements to simulate industrial robot applications. In addition to learning how to design and program with actual industrial languages, the flexible automated cells can teach operation and maintenance of the computer controls and electromechanical devices in robotic systems.

Special Purpose Robots

NASA will rely on a robot to assist astronauts as they engage in construction of the United States's first Space Station Freedom. The Extravehicular Activity (EVA) Robotic Assistant or Retriever EVAR (Figure 8) was designed as a highly autonomous (self-controlled), free-flying space robot that could assist humans in the difficult job of assembling parts. These tasks include 22 different tasks that have been determined through a thorough analysis of the operations required in Freedom's construction.

From this assessment, four distinct rescue and retrieval task emerged:
1. Locate object
2. Move object
3. Grasp (or capture object)
4. Return object to designated location

Rescuing would involve astronauts; retrieval tools and parts.

A number of sophisticated sensing systems will be needed so that the EVAR can navigate around the Shuttle and Space Station avoiding collision while providing assistance. The sensing systems under study are contact sensors of tactile arrays, optical proximity sensors, machine vision, infrared optical sensor, laser range imager, LIDAR (light detecting and imaging device) and radar. Because of the wide range of distance over which the EVAR must sense, from contact of the end effector to very long range of many meters, more systems are required than would be on industrial and service robots.

Figure 9 depicts a possible end effector that might be used on the EVAR. Note the sensors that include finger tips PVDF (polymer membranes sensitive to forces), LED (light emitting diodes) and optical beams for infrared optical sensing and a small camera (CCD—charged couple device) which would allow the gripping of a torque wrench.

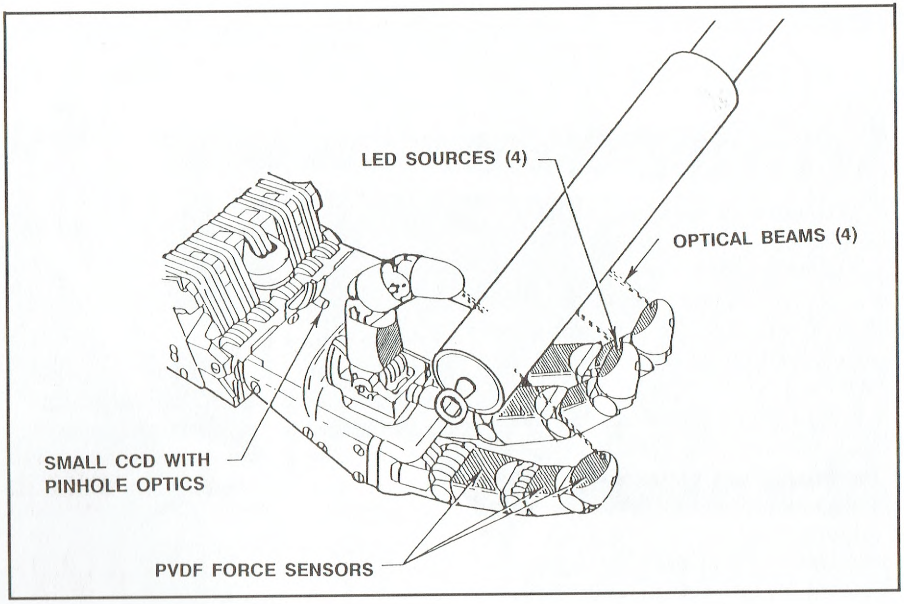

FIGURE 9
Complex end effector instrumented with sensors.

M/S/T Interface

Robotics is a prime example of the mathematics/science/technology interface. As discussed, robotics is a part of artificial intelligence, that is a field aimed at using computers in a better way to do those things which humans do. Development in robotics relies on improved computers, computer languages and computer software. These are developments in computer science as well as mathematics. But computer engineering is also required to take the concepts of computer science and turn them into practical, functional machines that can be manufactured at a saleable price and that will meet the needs of people. Engineers, technicians and technologists are members of the engineering team who turn mathematical and scientific concepts into functional technology.

Technicians, technologists and engineers, just as scientists, must have a good grasp of mathematics and scientific principles if they are to interpret the concepts and transform them into working devices. There are many job opportunities available to those individuals who have an interest and desire to work the M/S/T interface.

Construction Activity

If you wish to gain some hands-on experience with robots, there are several approaches you can take:

■ Build a homemade robot with your own materials from the ideas and plans shown in past issues of *The Technology Teacher*;

■ Purchase a kit to make a scale model robot—some are quite inexpensive, such as those sold by Graymark and Fisher-technic, and at the same time allow computer programming;

■ Enroll in a technology education course that offers instruction in some phases of robotics.

Summary

Changes in manufacturing requirements resulting in a move away from hard automation toward flexible automation have resulted in many advances in industrial robots and industrial robotics. To remain competitive in a world market, manufacturing firms have begun to switch to computer controlled machines that allow them the ability to quickly change from one product model to another.

Robotic research, development and technology, while largely aimed at industrial robotics, has spun off into a varietyof other areas including service robots, research robots and special purpose robots. The developments in robotics are a part of the larger evolution in artificial intelligence that is bringing computers and computer-controlled machines closer to functions performed by humans.

If the United States is to remain world competitive, our educational systems must produce graduates who have technical knowledge for conceiving, designing, building and maintaining new technology. You can participate in this venture and be a part of the new and challenging robotics technology!

Student Quiz

1. Define robots for industrial applications; then give the more general definition.
(See page 16)
2. What is the term for production in which the line of manufacturing equipment is quickly changed over from one product to another?
Flexible automation
3. What is robotics?
Covers the full range of robot technology wherever robots and AI can be utilized.
4. For research, manufacturing, service and special purposes name some tasks where a robot can replace manual labor or hard automation.
Numerous possible answers
5. What preparation is necessary to pursue a career related to robotics?
A well-conceived plan that provides preparation in math, science and technology.

Possible Student Outcomes

■ Define the following terms robots, robotics, artificial intelligence, hard automation, flexible automation.

■ Describe the conditions that caused flexible automation to evolve as a new approach to production technology.

■ Explain how robots may be used in space exploration, research, education, manufacturing and the service industries.

■ Conceive a plan to develop further competencies related to robotics in preparation for a career in the field.

Acknowledgments

■ Figure 1 courtesy of Battelle Pacific Northwest Laboratory.

■ Figure 2 courtesy of Boeing Commercial Airplane.

■ Figure 3 courtesy of Society of Manufacturing Engineers and Unimation.

■ Figure 4 courtesy Cincinnati Milicron

■ Figure 5 courtesy Society of Manufacturing Engineers and Lord Corporation.

■ Figure 6, 8 and 9 courtesy Southwest Research Institute and NASA.

■ Figure 7 courtesy Rhino Company.

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Resources in Technology is written and prepared by Tidewater Technology Associates (T2A), an educational consulting group that specializes in the development of technical programs, curriculum and instructional materials. Members of the group are Walter F. Deal, III, W. Fred Hadley, James A. Jacobs, Thomas F. Kildruff, John M. Ritz and George Skena. Further inquiries can be made by contacting Walter F. Deal, III, 429 Lindsay Landing, Yorktown, VA 23692; 804/683-4305.

Resources in Technology

Machine Vision Giving Eyes to Robots

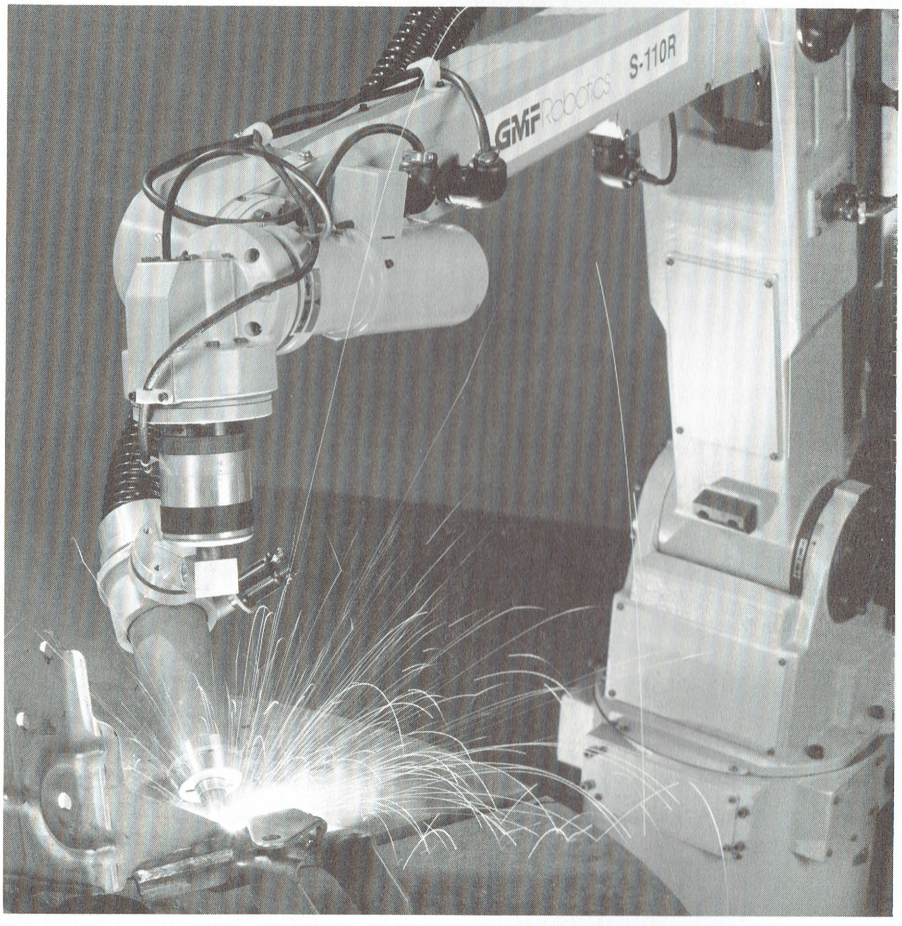


FIGURE 1
Laser-based vision system for real-time arc welding seam tracking.

Do you have the ability to see? If your answer is "yes," then you can count yourself among the vast majority of the population who have the ability of sight. Do you need aid with your sight from eye glasses or contact lenses? Do you have any disorder such as strabismus (cross-eyes) or dyslexia (a problem with reading resulting from the signal sent to the brain from the eye)? Even though you may have difficulty with vision you are still quite fortunate to have this very important sense.

The eye in conjunction with the visual center in the brain is a supreme vision processor. Consider what we can do with our sense of sight. Most obviously, our visual sense allows us to recognize size, shape and color of objects while at the same time see objects in perspective, i.e., determine the relationship of an object's distance and position. Automatically the eye adjusts to lighting conditions and focuses on objects close or far away. Our eyes also help with our other senses: prior to touching an object we might have an idea of its texture, how hard it might be and whether it is hot or cold.

In seeing a rotten orange we know it may smell bad and have an unpleasant taste. Observing a bolt of lightning, we may cover our ears to avoid the noise. These last examples serve to show how the sense of sight is a major part of our life experiences; for most of us the majority of what we learn comes through our eyes.

We humans with our sense of sight, coupled with other senses, plus the gift of intelligence and physical abilities have created technology to improve on the natural conditions of the world. In many, but not all cases, we have made a more comfortable environment for ourselves. Production technology, involving mass production of affordable products, has made numerous labor saving devices available to the majority of the citizens of in developed countries.

Manual labor for processing (cutting, shaping and assembling) and inspecting products was an early part of production technology but has gradually been replaced by automation where machines perform the tasks of humans. Especially in developed nations, the comforts and expectations of society have spawned a population who have little interest in repetitive and perhaps dangerous chores traditionally required of mass production, while at the same time evolving technology has demanded degrees of precision for certain operations beyond the capabilities of most humans in terms of manual dexterity.

A new trend in automation involves a high level of flexibility of the manufacturing equipment plus a desire for human-like capabilities of the computers used in this technology. The fields of robotics and artificial intelligence are entering production technology as major supporting technologies. For more on these technologies see "Robotics: An Emerging Technology," February, 1990, and "Introduction to Artificial Intelligence," November, 1987, issues of *The Technology Teacher*.

Machine vision is technology that has grown out of the conditions described above. It provides an automated means for inspection tasks by identifying and sorting parts and for guiding robots.

Machine Vision—The use of devices for optical noncontact sensing of a real scene, in order to obtain information and/or control machines or processes.

Machine vision as defined above by the Machine Vision Association of the Society of Manufacturing Engineers is one of the elements required for transforming manufacturing into a more fully automated technology; a Computer Integrated Manufacturing (CIM) technology in which humans participate as creators and managers of technology while machines do the low skill, repetitive, dangerous and highly precise tasks.

Figure 1 show how giving vision to robots allows them to do precise, repetitive and somewhat hazardous jobs. The laser-based machine vision system is used to guide the robot, holding a welding torch as it tracks and welds the seam joint which joins two plates of steel together. But how does the vision system provide the eyes for the robot?

Machine Vision System Building Blocks

The machine vision system shown in Figure 1 and in the other photos in this module are designed for specific purposes; no one system can handle all vision needs. However, there are basic building blocks and hardware common to most vision requirements. A description of the elements of a vision system follow and are illustrated in Figures 2 and 3 (White, 1988).

Materials Handling

The object to be captured by the system must be placed in view by a materials handling system which may be a robot, a conveyor belt or a similar device.

Illumination

A source of light is required to illuminate the object in a manner that enhances the features to be recognized by the system. To obtain the information about an object for analysis and comparison with the information stored in the vision system, it is critical to have proper lighting. On a moving conveyor system a strobe light or shutter will freeze the part for the camera to capture the scene.

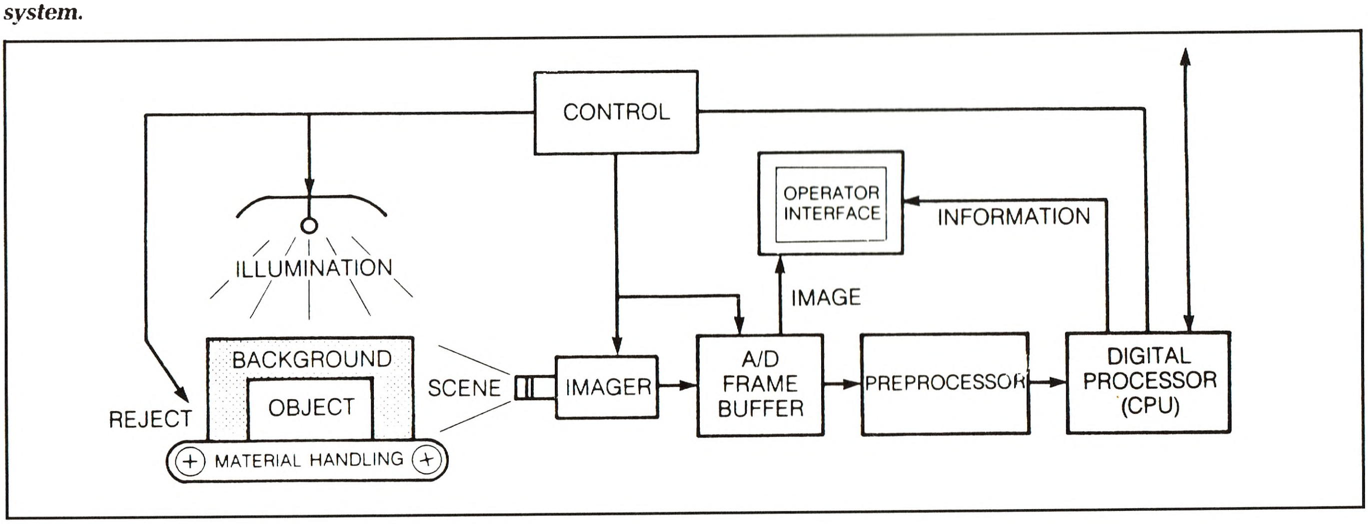
Continuous sources of light include lasers, light emitting diodes, spotlights and fluorescent tubes, which may be a ring, circling the camera lens. Bundles of optical fibers can conduct the light to the object if it is in an obscure location, such as hidden behind the processing equipment or a part of an assembly of parts.

In the description of the capabilities of the human eye, we described the aspects of objects in terms of color, perspective, and texture. These yield "noise" that make it too difficult for a vision system to analyze because the systems are limited in the amount of information that can be processed. The image of the object may be enhanced for analysis through reduction of the amount of information received by the system.

Remember that visible light is but a small part of the radiated wave lengths in the electromagnetic spectrum, which includes cosmic rays, gamma rays, X-rays, ultraviolet, visible, infrared, microwaves, TV and radio waves. Any source of light radiates varying wave lengths as a part of the spectral distribution. The type of light will determine the spectra or spectral distribution. A glass or plastic prism can be used to demonstrate white light which is composed of the various color waves that are also seen in a rainbow when water vapor interacts with sun light as does the prism.

To reduce noise (extra waves) received

FIGURE 2
Building blocks of a machine vision system.



by the imager or camera, it is necessary to determine which waves are to be received and which should be filtered out. With visible light this is done with color filters that provide better contrast or polarized light to reduce glare. Besides the visible light spectrum, other systems for viewing the object in the scene may involve X-rays, ultrasonics, or the ultraviolet and infrared from the electromagnetic wave spectrum.

Background

Another component in "noise" reduction is the background which is a part of the scene viewed by the camera. The proper background will provide improved contrast of the object with its surroundings, allowing easier measurement of the important features of the object in view. Note the backgrounds in the photos in this module.

Imager or Lens

An optical image which fills the image sensors field of view with the part is required. The image is normally focused on the sensor with a lens system. A lens provides a means to control the image and place it on the focal plane of the camera. Lenses are classified by their focal length which is the measurement of the distance from the lens to the focal plane in the camera. The focal plane is where the vision sensor is located.

If you have experience with film cameras you know that a lens with a 35mm lens has a focal length of 35 millimeters. As seen in Figure 4, a lens with a 70mm lens will bring an enlarged image onto the focal plane from the same distance for the 35mm lens. If an image from the 35mm lens provides a field of view which includes an area 30mm high by 40mm wide, a 70mm lens will only focus an area 15mm high by 35mm wide on the focal plane. However the subject focused on the photo sensor mat the focal plane will be shown in greater detail.

The M/S/T Interface section later in this module, provides a method to calculate the area to be represented on a focal plane and photosensor for a given focal length lens. It is necessary to know this information to determine the video image to be transmitted to the computer in the vision system for analysis.

Lens aperture is the opening in the lens that gages how available light will be transmitted. The f-number is a measure relative to the focal length of the lens. The f-stops on a lens allow adjust-

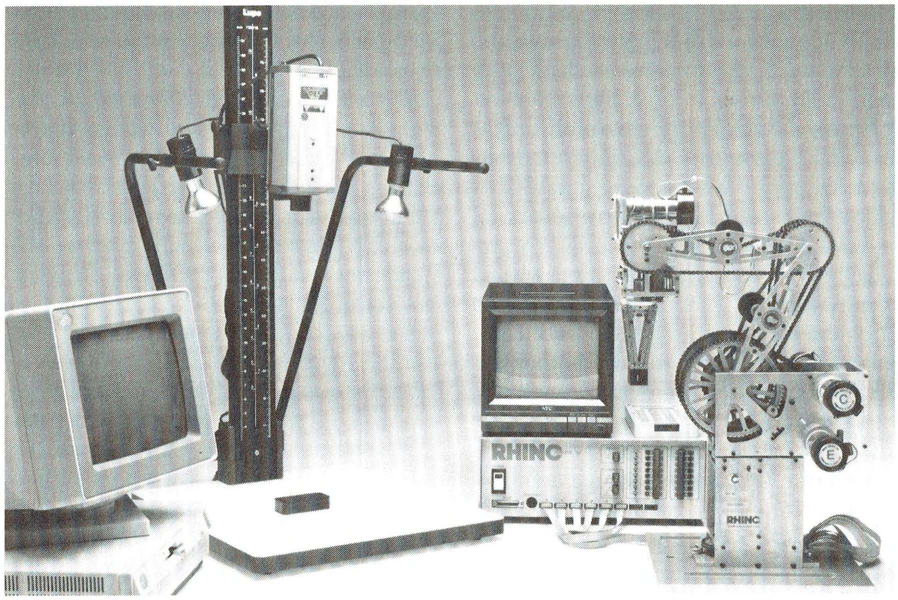


FIGURE 3
A vision system for education and training consists of (left to right) microcomputer with image capture board and software, video camera mounted over background board with spotlights, video monitor sitting on robot controller and 5 axis-robot as a material handler.

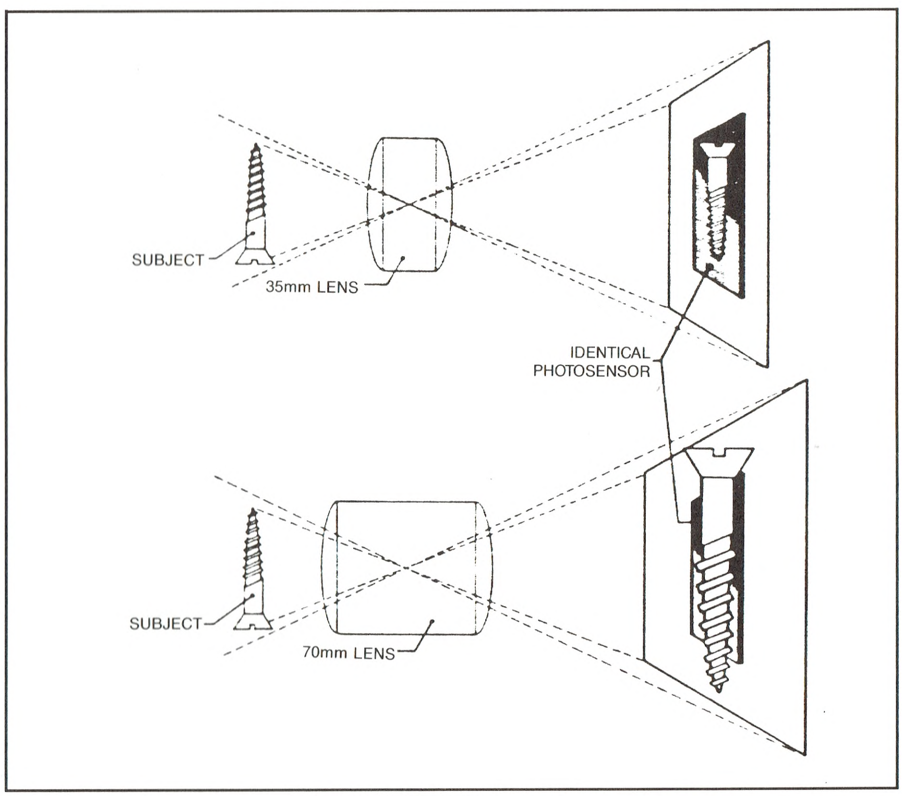


FIGURE 4
Comparison of 35mm lens with a 70mm lens shows that the 70mm lens will make the part appear closer to the camera and fill more of the focal plane.

ment of light. An increase in f-stop reduces the amount of light reaching the focal plane by one half when changing from an f8 to f11.

Depth-of-field is the range of distances from the camera in which objects appear to be focused on the focal plane; it is controlled by the lens aperture and focal length. Decreasing lens aperture increases depth-of-field; as the aperture is closed more reflected light will be available from the subject to maintain the light level going into the photosensor in the camera.

A lens with a shorter focal length provides greater depth-of-field: a 35mm focal length lens provides greater depth-of-field than a 70mm lens. With an increased depth-of-field it is possible to obtain greater detail as the distance varies from part to camera. Using a larger f-stop number, which means a smaller aperture, increases depth-of-field.

Image Sensors or Camera

Light focused by the lens onto the photosensor is processed by silicon. For information on how the silicon is affected by light see the section on opto-electronic devices in such references as *Engineering Materials Technology* (Jacobs & Kilduff, 1985). There are a number of image sensor/camera systems available; usually they employ CCDs (charged coupled devices). The scene may be processed with holography, laser scanning or X-ray imaging among other options.

CCDs are photosensitive, solid state devices (electrons flow through solid materials such as transistors rather than vacuum tubes) which store image information as packets of charges within a semiconductor chip. The circuitry necessary for storing, moving and accessing the packets is on the same chip.

Applying voltage to the chip circuitry controls the charge (Jacobs & Kilduff, 1985, pp. 398, 431). The CCD camera produces a black-and-white TV image with various ranges of gray (gray scale) analyzed by the computer. Color CCD cameras are available. Other solid state imagers are CID (charged injection devices) and MOS (metal-oxide semiconductor) technology.

The solid state photosensors are designed with hundreds to thousands of elements in set patterns. The local sites of the elements are known as pixels. The small photosensor may have 65,000 photosensing pixels, arranged in rows of 256 pixels vertically and 256 rows of pixels horizontally. As seen in Figure 8 this array may be only 8.8 mm wide by 6.6 mm in length.

A photosensor with a 512-by-512 pixel array would provide twice as much vertical and horizontal resolution meaning that the image would have twice as much clarity and be able to distinguish twice as much separate detail of the object being inspected; this array would provide four times as much data.

An entire frame of the scene (image data) is processed every 1/30th of a second in the form of analog (versus digital) voltage. The synchronized signal from the photosensor will provide an image on a TV monitor. As mentioned earlier other image sensors could replace the CCD among them ultrasound, ultraviolet, X-ray and infrared.

The amount of light energy (photons) reaching each pixel determines the charge to be transmitted through the system. The charge is analog voltage which must be converted to digital charges for analysis by the computer.

Analog-to-Digital Frame Buffer

Conversion of the analog voltage to digital voltage is the next stage of image processing. Analog voltage consists of the gradual variation or continuous wave of light that reaches the photosensor which may result from the shades of gray produced by the shape of an object such as the screw depicted in Figure 4.

Viewing the screw, its front portion of the shank and sharp thread edge would reflect more light into the camera than the portion of the shank and threads further from the camera. This provides variation across a gray scale much like your speedometer needle gradually increases as you accelerate or a needle on an analog voltage meter moves with changes in voltage. The computer which analyzes the data of the image must be fed digital voltage (pulses representing the digits 0 and 1). The digital voltage

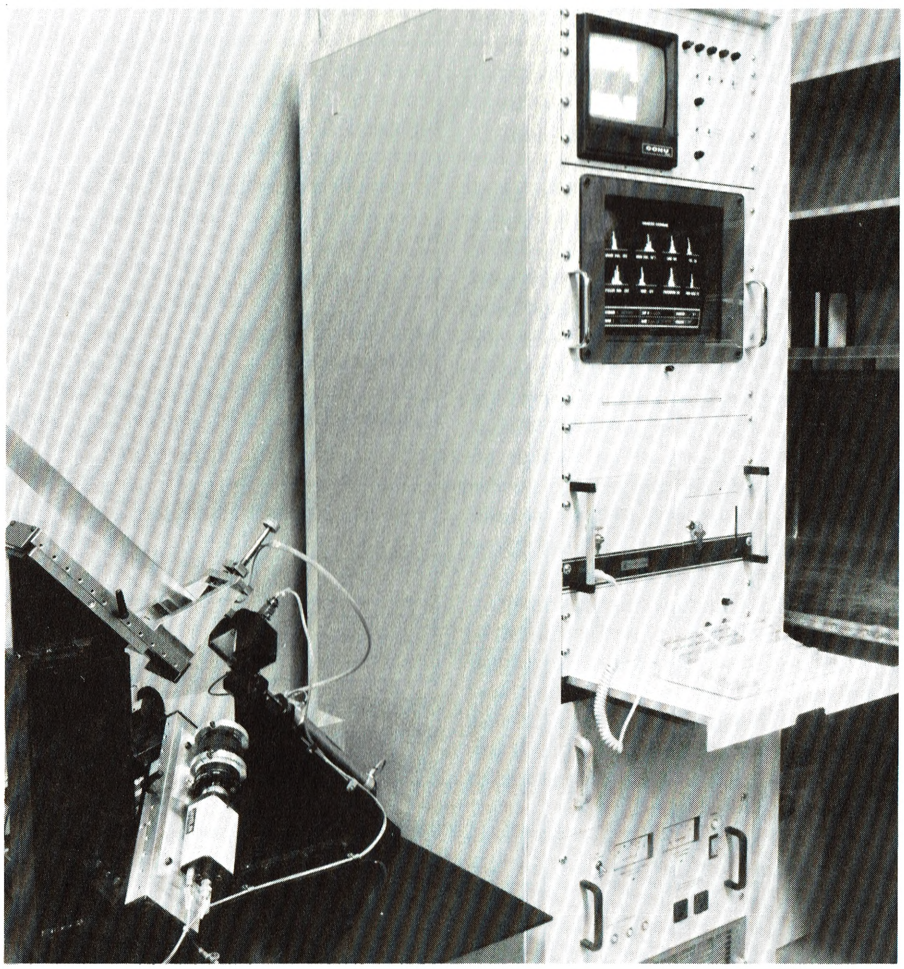


FIGURE 5
Automatic Fastener Inspection System—At left two cameras image a screw bolt that is presented in the scene. At right the console cabinet contains the computer TV monitor and operator interface in form of data display which shows histograms indicating how various features of the screws meet specifications.

provides binary data meaning either a 0 or 1 to correspond to the programming of the computer.

With the simplest machine vision systems, only two-dimensional features and black-and-white data can be processed. The demodulation process separates the gray into either black or white information and is accomplished by the high speed analog-to-digital converter.

More complex systems are capable of distinguishing various shades on the gray scale plus 3D-shape recognition. Next, the system sends the digital data to the frame grabber: computer circuitry in the form of a printed circuit board that has been installed in the computer (CPU). The video frame grabber grabs one frame of data such as 256-by-240 pixels images into the on-board memory; it takes as little as one millisecond to grab a frame.

Preprocessor

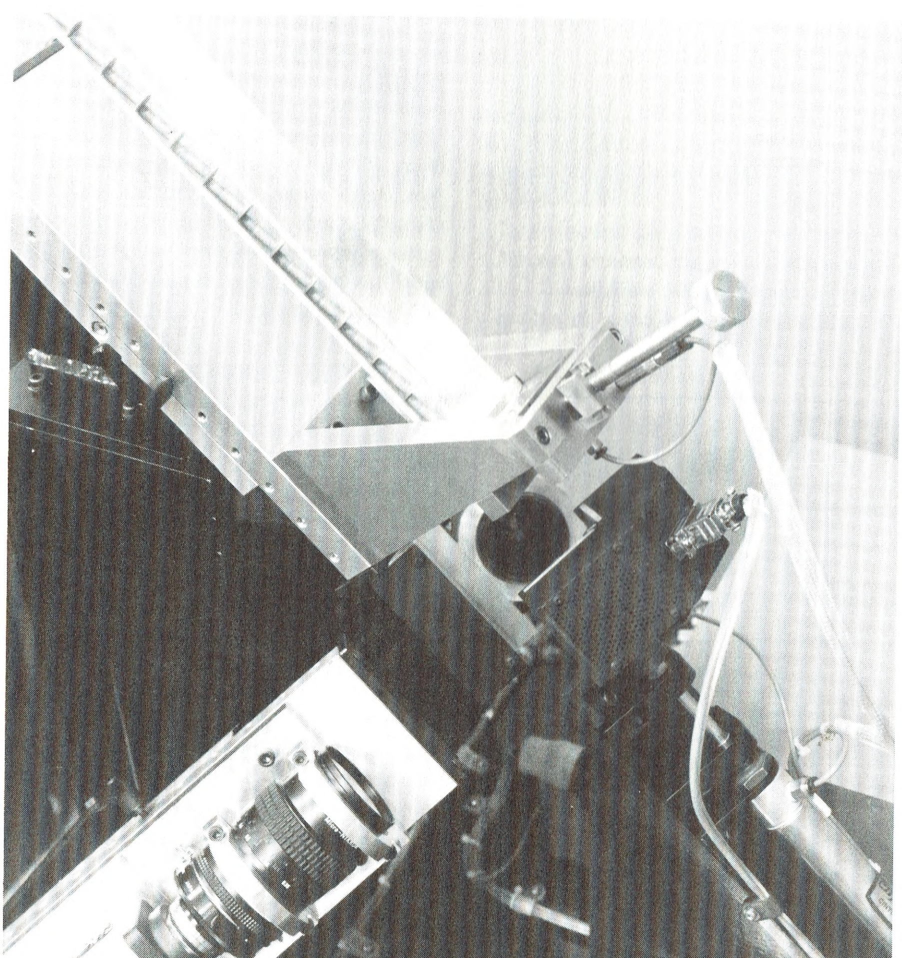
High speed analysis of imaged data is achieved by the preprocessor which enhances the quality of data by extracting selected portions of information. The preprocessor may be looking for only edges of an object, selected measurements or correlations to some other desired condition and feature. Once those key features are selected the system (CPU) analysis is accomplished to determine if the object meets specifications and then make adjustments.

Algorithms, a special method to solve a certain kind of problem, are applied to the particular requirement of the vision system. This involves the hardware (equipment) and software (computer programs). The preprocessor uses an algorithm in order to select only essential data to be analyzed to save the amount of data processing required of the computer.

There are numerous features of an object to be considered; as we said earlier much of it produces unnecessary noise. Color, size, shape, texture, density, edge locations, alignment and so forth. The vision system shown in Figure 3, for example, has demonstration programs as a part of its software that allow random parts to be placed on the platform beneath the camera and the frame grabber quickly stores all information about the geometry of the objects in the scene.

Next, the program prompts the operator to give a name to each object in the scene which has be imaged on the monitor. Now the operator can place the objects in view of the camera and it will display the name of the part on the computer monitor.

Among other demonstration programs available with the Rhino Vision System is one program that allows objects to be placed in view of the camera for the robot to pick up the parts and place them in a box without the operator programming the commands. The vision system controls the materials handling robot without operator interface. It is also possible to use the system to serve as an inspector of parts to determine if parts presented to the view of the camera meet a pattern set into the program of parts.



Operator Interface

This aspect of the vision system involves hardware and software, and is a feature which allows the operator to interact with the system. Through this interaction, the operator can obtain data such as how many parts are being rejected in an inspection process so that she/he can make adjustments to the process.

For example, the fasteners being inspected by the vision system in Figure 5 inspect dimensions of the fastener's heads. It is self-calibrating, and measures eight different parameters of the screw simultaneously including shank diameter, head diameter, fillet radius, head protrusion, head angle, land, eccentricity, and perpendicularity. Fasteners are imaged with back lighting and measurements are calculated from sub-pixel edge scanning data.

Inspection time is ten seconds per fastener and accuracies for some parameters are as tight as plus or minus .0008 mm. A flexible gravity feed system allows flush head rivets and bolts ranging from .25 mm to 1.25 mm diameter to be inspected with minimal setup time. A specification data base allows for automatic defect checking and tabulation as seen by the histograms displayed. The output can be acceptance or rejection of the parts or a statistical analysis. This prototype system is being tested and scheduled to join the Boeing Airplane manufacturing system in early 1990.

Digital Processor

Data imaged and preprocessed is now

FIGURE 6
A close-up of the cameras in the automatic fastener inspection system shown in FIgure 5.

sent to the central processing unit (CPU) which could be a microprocessor, or a mini or micro computer. Here the digital data is analyzed to determine the match with specifications and commands are sent to control some the front end of the vision system. With our vision system in Figure 3, data from the microcomputer is sent to the robot controller.

Control

The control is the automated feature which acts on the analysis data from the CPU. This may involve providing a blast of air to blow away a part that did not meet specifications, it might send information to a robot controller (Figure 3) which would stop the conveyor belt while a part is picked off and placed into a loading pallet, or perhaps a robot would guide a water jet cutting device to cut out a fillet of fish.

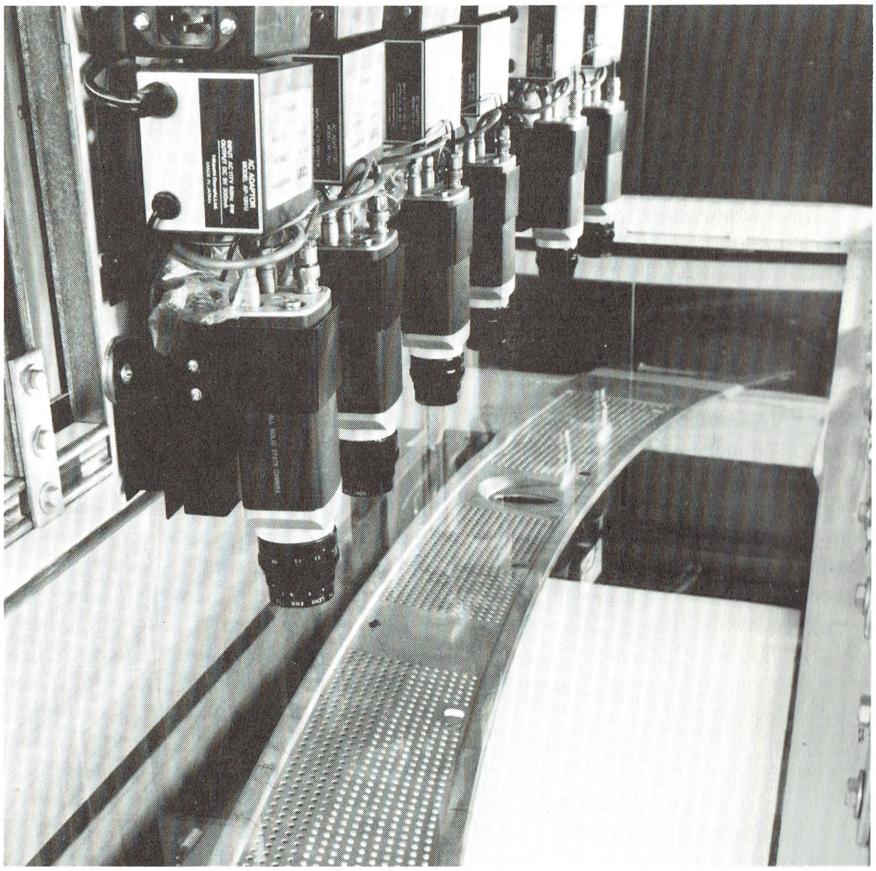


FIGURE 7
This highly portable, camera machine vision system uses a six camera format, fluorescent back-lighting allowing it to inspect a complex scene within 4.5-second cycletime. The system is fault tolerant, allowing engineers to adjust for dirt and part misalignment.

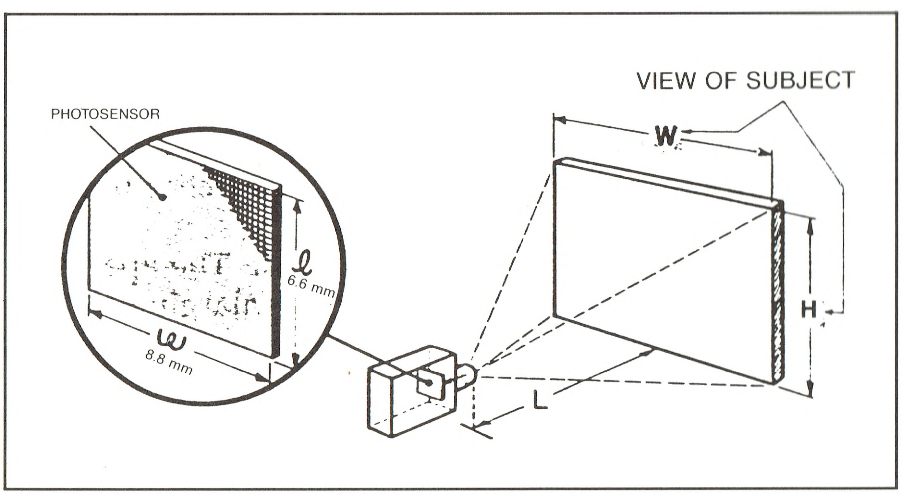


FIGURE 8
A lens is selected to fit the object to be captured on the focal plane where the sensor is located.

Vision System Applications

Machine vision, much like applications of robotics, gets its greatest support from manufacturing because of the unending number of tasks that machines can perform that humans should not do or do not wish to do. Inspection is a case in point. It is a very boring task for a person to sit at a station on a production line and observe threaded fasteners coming by the thousands on the line, and one where errors are likely to occur.

The fasteners inspection vision system illustrated in Figures 5 and 6 shows the potential of automating this type of monotonous task. The vision activity thats follows illustrates why inspection automation is important to manufacturing companies who wish to improve the quality of their products.

As mentioned earlier, machine vision has proven itself as a valuable inspection tool for such purposes as counting multiple holes drilled in a plate (Figure 7), checking to see if a mold of liquid has been filled, evaluating the pattern of a headlight beam, checking for wiring of circuit boards and placement of a computer memory chip, and seeing if frozen food has been placed on packaging even as the packages move by at 100 feet per minute.

Separating the good apples from the bad is another use of machine vision. In one system a vision system inspects each apple as they move down a conveyor belt at the rate of 360 per minute. Apples with bad spots are rejected.

We have seen several examples of vision systems being used to guide robots. Sometimes the task of sorting and orienting parts is done by robotics in conjunction with machine vision as was described for capabilities of Figure 3; these are very valuable uses for manufacturing.

Another common application for vision is found in bar code reading. You are familiar with the optical code recognition systems used in grocery stores that employ laser light to read bar codes on grocery packaging. Similar systems are used in industry to sort parts, keep track of parts on assembled product and keep a record of the products as they go out into the market place. You will find it interesting to do some reading on OCR—optical character recognition—systems.

The description of the robotic/vision system in Figure 3 did not tell you that the robot had to be calibrated in order for the computer and vision system to have a memory of the coordinates of the robot's arms in relation to the workcell in which the robot operates. To overcome the need to recalibrate each time the robot is moved, the INFANT research robot has been designed to learn to reach out adaptively and grasp objects and move them to a programmed location.

The adaptive aspect means that if the robot is moved or the environment changes it adjusts through information from the vision system and no human intervention is required to recalibrate the robot or move objects in the robot's path (Kuperstein, 1989). Adaptive control is another topic of CIM that makes interesting reading.

In other research AT&T Bell Labs has developed a vision system to recognize hand-printed digits using a combination of traditional vision combined with neural-network methods. The U.S. Postal Service served as part of the test of the system. The test involved 10,000 samples with 1000 of each digit; the system demonstrated its feasibility (Denker, 1989).

Machine Vision and the Future

The future of manufacture employing CIM, robotics, AI, ES, and machine vision technology is within the capabilities of current and evolving technology. The "smart factory of the 90's will require a considerable effort in coordination of companies who sell hardware and software to bring all the elements together for effective CIM.

The move is on to standardize the various components of manufacturing systems so they will interconnect and "talk" to each other with their analog and digital data. Machine vision is an important element in the push for better automation. Many opportunities will be opened to those who wish to learn the evolving technology.

Vision Processing Activity

To gain an appreciation for the difficulties of people performing inspection tasks, try this activity. As a class have each member count each letter "e" in the first paragraph of this module; allow two minutes and have the students write down the number they count.

On the chalkboard make a histogram of the number of "e's" counted in order to see the distribution. Discuss why there were different answers. Next, explain how these errors are more likely to increase if a person spent their full shift every working day doing inspection jobs such as looking for missing holes in a part, checking for defective screws coming down an assembly line or examining printed circuit boards for defects.

Now to see the difficulty of automating inspection, locate several parts from old clocks, cars, toys or other products. Describe what you feel would be required of a machine vision system with a robot to inspect the part for defects and determine that each part would meet its design specifications 100% of the time.

M/S/T Interface

In order to rely on the ability of a video camera to be a part of a system for parts inspection, it is necessary to use the constant relationship between the area of the photosensor in the video camera and the size of the objects being viewed by the camera. Camera lenses are selected to make the object fit the photosensor at the scale desired as seen in Figure 8 (CSD International, 1989). The relationship between the photosensors and view of the subject is calculated using the formula below.

In order for the computer to make an analysis of the camera image, it must have proper resolution. This requires a minimum of four pixels (light receiving elements on the photosensor), two across and two down, in order to capture the necessary details of the object being inspected.

The Primer: Machine Vision Inspection, which is available from CSD International Inc., RR#1, Box 10B, Mohawk Trail, Shelburne Falls, MA 01370, provides detailed information on the camera principles involved in machine vision.

$$W = (w/f) \times L \text{ and } H = (l/f) \times L$$

Where:
W = width of subject in view in meters
w = width of photosensors in millimeters
f = focal length of lens in millimeters
L = distance to the object from the camera lens in meters
H = height of object in view in meters

Summary

This module has introduced machine vision. Nine building blocks are identified for a vision system. These are building blocks with common elements, but you may find other elements by examining vision systems in a variety of applications. You learned that machine vision can be used for inspection, robot guidance and for part sorting.

The future for machine vision is sure to include new technology will bring vision systems closer to the ultimate vision processor; the human eye. The technology will involve evolution of AI supported by developments of computers with improved capabilities to process data and computers using neural networks and parallel processing plus ES (expert systems) to aid in problem solving. It may be possible to have an intelligent computer recognize key features of a product that has been designed with CAD and automatically program the machine vision system to use those features for material handling, inspection and guidance of robots.

For this future to be realized young people such as you must enter the fields of science, engineering and technology to create, manufacture, operate and maintain the new machine vision technology. Begin today to explore the career opportunities available to you. Seek guidance on how to prepare to enter these exciting and challenging careers.

Student Quiz

1. Define machine vision general definition.
See page 22.
2. Name four of the nine building blocks of a machine vision system.
Materials handling, illumination, background, imager (lens), image sensor (camera), A/D conversion, preprocessor, operator interface, digital processor and control
3. What are three basic functions of machine vision?
Inspection, part sorting, robot guidance
4. Name two specific applications of vision systems.
Numerous examples are given in the module.
5. Why is it desirable to automate many inspection tasks?
Humans become bored or tired, then make errors.
6. What is a barrier to automating inspection and other image processing?
Human vision and other sensors are the ultimate and are very difficult to replicate.
7. Explain why you may enter a career related to machine vision, robotics and CIM technology.
Student's choice of answer but should include M/S/T interface.

Possible Student Outcomes

- Define the following terms: machine vision, CIM, aperture, depth-of-field, pixels, algorithms, interface, frame grabber, analog, digital, adaptive.
- List and describe the basic building blocks of a machine vision system.
- Explain the basic functions and specific applications of machine vision.
- Tell why inspection is difficult for humans but hard to automate.
- Conceive a plan to develop further competencies related to machine vision technology in preparation for a career in the field.

Acknowledgements

- Figure 1—Courtesy of Society of Manufacturing Engineers and GMF Robotics.
- Figure 2—Courtesy of Visual*Sense*Systems.
- Figure 3—Courtesy Rhino Company.
- Figures 4 & 8 Courtesy of CSD International.
- Figures 5 & 6—Courtesy Boeing Commercial Airplane, Renton Division.
- Figure 7—Courtesy Society of Manufacturing Engineers and Martin Systems.

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Resources in Technology

CROSSING OVER . . . . .
Bridge Technology Comes of Age

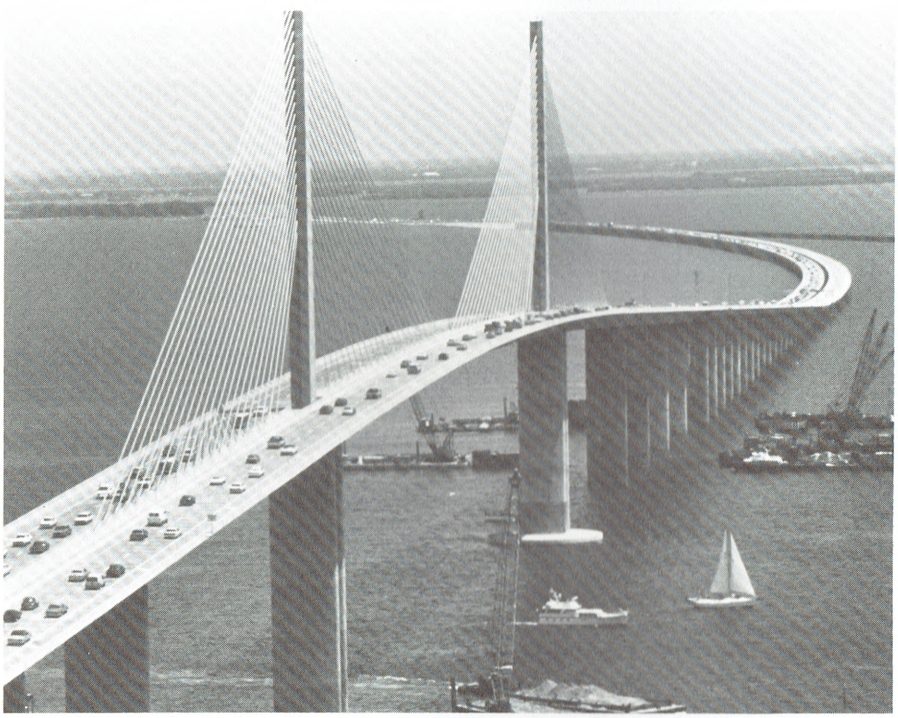


FIGURE 1
The Sunshine Skyway Bridge across Tampa Bay, Florida, with a main span of 1200-feet, is a cable-stayed type of structure. The roadway is supported by individual cables running in a single plane down the centerline of the bridge. (Figg and Muller, Engineers)

Whether it is a picturesque covered wooden bridge in a rural New Hampshire setting or the planned 12,828-foot long suspension bridge across Japan's Akashi Straits, bridges serve the same primary purpose. They are structures which carry people and traffic over areas which are obstacles to travel, such as bays, rivers, canyons or gorges and even other traffic.

Regardless of the type of bridge or the purpose for which it is used, each requires careful planning and extensive design work before construction actually begins. For example, engineers must be sure the bearing surface below the construction will support the loads it will have to carry, for both the proposed bridge's present and future needs. The type of foundation and bridge will be partly determined by this load-carrying capacity. Once the planning is completed, the heavy equipment for actual construction has to be moved to the job site to begin its work. This may entail not only the erection of the bridge structure itself, but also the movement of large volumes of earth, the construction of new roads and other site preparation operations.

Any contemporary discussion of bridges in America almost invariably centers on the serious and growing problem of the repair and/or replacement of our nation's aging structures. In fact, the U. S. congress was told in 1989 that over 40% of this country's bridges were not up to par.

There is, however, a brighter and more promising side to our burgeoning bridge problem. Recently, bridge construction specifications have been modified to incorporate new theories that are based on thorough research as well as experience. These much needed changes have helped to correct deficiencies in existing methods and materials. They have additionally helped to produce more bridge for each dollar spent and have led to more new developments in the technology of bridge building. The new materials, designs and improved construction methods in the field of construction technology have virtually guaranteed that the bridges built today and in the future will last for many generations with only minimal preventative maintenance.

Before looking at this brighter picture, let's briefly examine some recent historical events leading up to the present.

FIGURE 2
Vehicles that will travel on this elevated curved ramp will exert centrifugal forces on the structure. Engineers must calculate those and other forces in order to design structures to withstand them. Note the lack of vertical support under the bridge. (Figg and Muller, Engineers)

Historical Perspective

In the late 1800s, the United States as well as other countries around the globe were plagued by multiple and very often tragic bridge failures. Over forty bridges collapsed or otherwise failed in this country alone during the 1870s. Overseas in Scotland, the infamous Firth of Tay railroad bridge collapsed because of high winds in 1819, spilling and dumping 13 truss spans into the icy water, killing 75 people.

Prior to that time, simple rules of thumb had been applied in nearly all bridge construction situations with no real emphasis on the particular problems that might be presented by individual projects or their locations. These frequent bridge failures outraged the public and brought it, along the engineering and design community of the time, to the realization that the design and construction of a bridge was a job for professionals who were trained in the field of structural engineering.

As various engineering fields became more involved in bridge construction, many forces other than just traffic loads were found to have adverse effects on the structural integrity of a bridge. By the early 1900s, engineers and designers had learned to calculate and make allowances for the forces imposed on their structures, such as winds, ice flow and others. Yield strength and elongation percentages for the steel used in bridge construction were used along with input specifications and stress strain curves. Longitudinal and centrifugal forces and various loading conditions were only a small part of the many calculations that the engineering professionals in bridge construction began to implement.

Social/ Cultural Impact

Bridges enable people and vehicles to cross over rivers, bays and other waterways. They may additionally be used to get over highways, railroads and other geographic barriers to travel. Without them, travel to many areas would be severely restricted, often requiring traveling great distances or transport by boat or aircraft.

There are seven types of bridges that may be constructed. (*See Figure 3*). They are truss, suspension, cable-stayed, arch, girder, cantilever and draw bridges. Descriptions for these may be found in the accompanying glossary. Although suspension and cable- stayed bridges may appear to be very similar, both in appearance and description, they are really quite different.

On a suspension bridge, the deck (i.e., where the roadbed is located) is supported by vertical suspender cables that are attached to large, loosely hung main cables. On a cable-stayed bridge, the deck is attached directly to the supporting towers. When viewed from the side, the cables of this type form a series of overlapping triangles.

A bridge must be able to support not only its own weight and the loads imposed on it by the traffic that uses it, but the structure must also be able to withstand the strain caused by an occasional traffic overload. It may be constructed of steel, concrete, timber or some combination of them. In addition to the forces and loads previously mentioned, a bridge must also be designed to stand up to earthquakes, flowing water and ice and other natural forces.

Bridges can bring formerly isolated areas into the mainstream of contemporary society. The free travel encouraged by the location of a handy bridge has aided greatly in the development of many areas

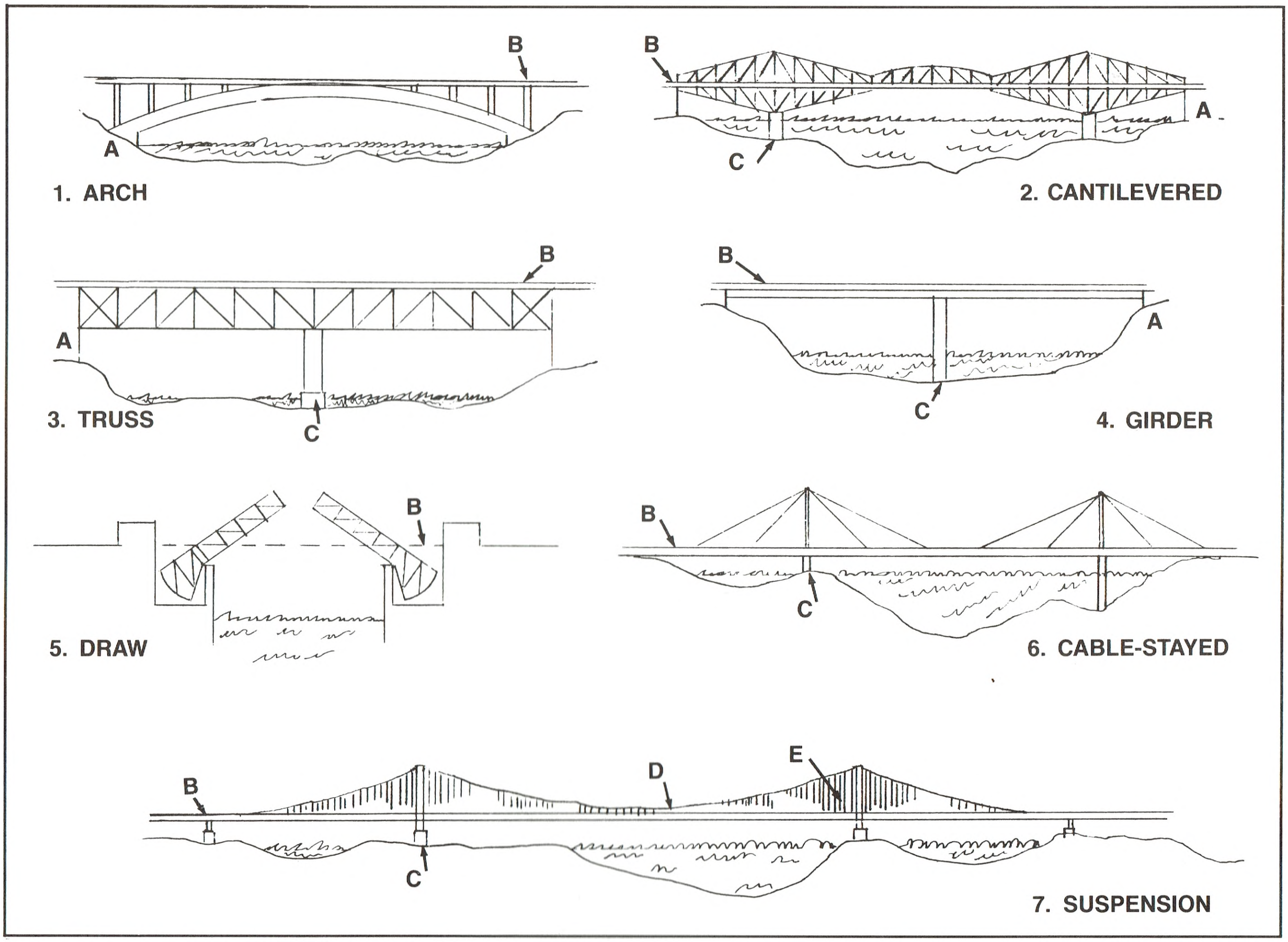


FIGURE 3
The seven types of bridges.
Legend A. Abutment C. Pier E. Vertical Suspender Cables
B. Roadway D. Main Cable

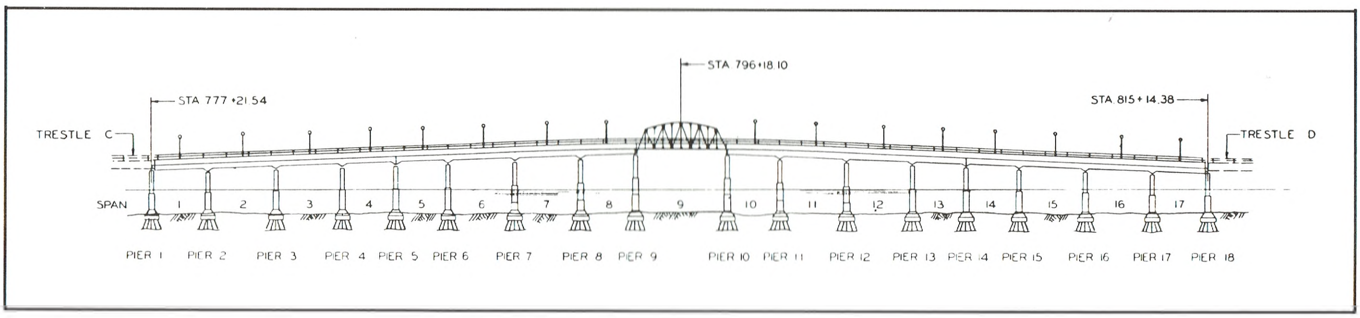


FIGURE 4
This engineer's profile drawing of the North Channel Bridge of the Chesapeake Bay Bridge Tunnel shows the number of supporting piers in that section of the project. (Sverdrup)

of this country. A typical example of such growth can readily be seen by examining the growing development, both commercial and residential, on Virginia's once isolated eastern shore area. Formerly the region was accessible only by a long drive around the Chesapeake Bay or a 17-mile ferry trip across the mouth of the bay. The completion of the Chesapeake Bay Bridge Tunnel, (See *Figure 4*) a combination of trestles, tunnels and bridges, has made the southern end of the eastern shore area a twenty minute drive away from a highly developed urban area. The route across the mouth of the bay has also provided a more direct north-south route for eastern seaboard travelers.

A bridge can be much more than simply a convenient connection from one geographical point to another. Bridges also connect societies, cultures, politics and economics. The proposed Inter-Continental Peace Bridge from Alaska to Siberia exemplifies this, as does the proposed structure which would span the Strait of Gibraltar.

Contemporary Analysis

The use of prestressed concrete in bridge construction has now gained wide acceptance. Engineers using prestressed materials coupled with a segmental design approach to bridge construction have been able to span greater distances with fewer supporting structures below them. They can accomplish this and at the same time construct more efficient bridges. The now-common use of prestressed concrete in bridge construction has enabled us not only to have longer, but also safer spans in our bridges.

Pre-stressed concrete is produced by stretching steel cables in a form using hydraulic jacks and then pouring liquid concrete over them. When the concrete hardens, the jacks are released. The stretched cables embedded within it compress the newly formed concrete. Since both compressed concrete and stretched steel cables are stronger, the best characteristics of both materials are combined to produce and ideal material for building bridges. The same steel cables may also be bent into an arc to help counteract downward pressure. This is especially helpful in bridge construction.

Reinforced concrete must also be used in bridge construction. It is used extensively in foundations, roadbeds, piers and in other applications. This type of concrete is produced by pouring liquid concrete over steel bars and rods embedded in the formwork. When cured, the resulting concrete will be very much stronger than it would have been without the embedded metal or 're-bar.'

Many bridges are also post tensioned. When a bridge is said to be post tensioned, it means that tension was applied to the reinforcing steel after the concrete had cured.

The Sunshine Skyway Bridge across Tampa Bay is a magnificent example of just what can be accomplished using modern bridge construction technology. The cable-stayed bridge has a 1200-foot main span, the longest cable-stayed concrete span in the Western Hemisphere. The bridge was built using segmented box girder construction. The girder segments were cast off-site to exacting specifications, resulting in a rapid 'as-planned' erection time with a minimum of on site adjustments required after delivery.

The bridge's main span is supported by cable stays that run down from two single main pylons in a single plane along 2,280-feet of the span's 4,000-foot center median. The 8,000+ foot section of the Sunshine Skyway Bridge that uses segmental girder construction features 333 trapezoid shaped girders, some weighing over 220-tons. An engineer's description of the structure calls it "a precast, post-tensioned, prestressed concrete cable-stayed bridge erected by a balanced cantilever method."

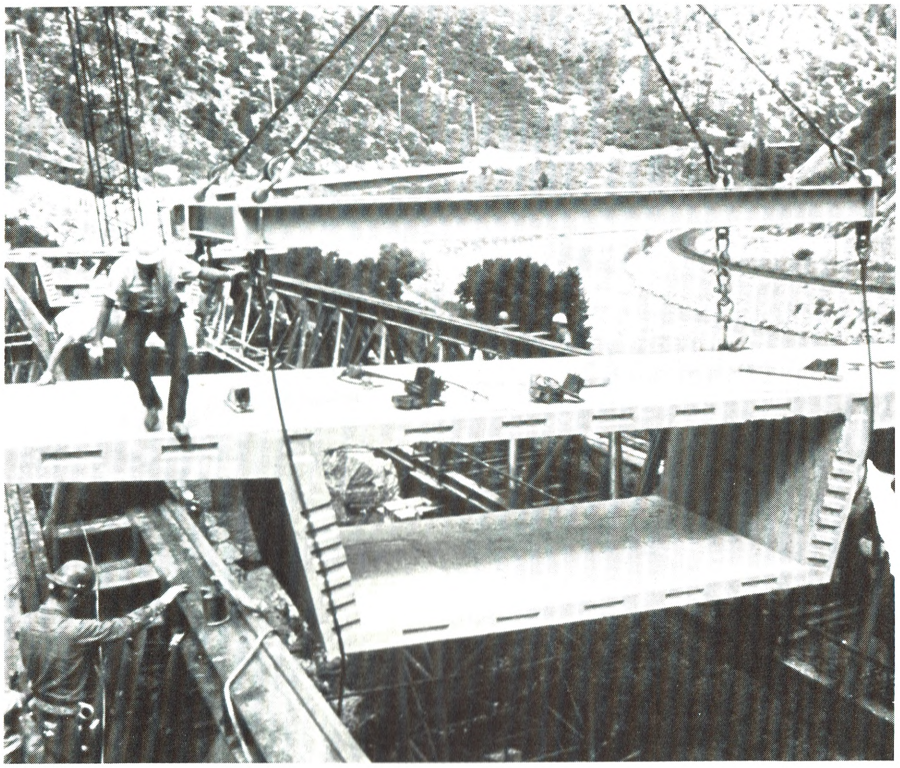


FIGURE 5
Using precast segmental concrete units such as this, bridge builders can now span greater distances than ever before. Using this technology, less material is required for construction, giving more bridge for every dollar spent. (Figg and Muller, Engineers)

During construction, engineers integrated a computer into the bridge's final design. It is connected to hundreds of sensing units to give the designers and engineers immediate feedback and accurate readings on just how the bridge is performing under various loading conditions and against a variety of natural forces. Not exactly your run-of-the-mill truss bridge, is it?

The Wando River Bridge in Charleston, South Carolina, was also constructed using segmental construction techniques. The bridge, actually two separate 7,900-foot spans across the river is typical of bridge construction today. Design engineers have written that the bridge was 'manufactured,' a term not generally used in the heavy construction business. Indeed, all the concrete segments were match cast in a production yard under controlled factory-like conditions. The match casting ensured that each segment would mate perfectly with its adjoining ones. After the concrete segments or box girders were delivered to the construction site, they were erected using assembly line techniques.

Concrete segmental construction of bridges has also been used to help solve the problem of expanding our outdated interstate highway system in urban or residential areas. Engineers wanted to do this without disturbing normal traffic flow patterns and neighborhoods. In one case for example, contractors working on the Biloxi (Mississippi) Interstate 110 built an elevated viaduct with little ground supported falsework and almost zero right-of-way clearance for construction. A casting yard produced about 122 segments per month allowing contractors to erect nearly 1600-feet of bridge in the same time period. All this was accomplished with a minimum of disruption to the surrounding area.

FIGURE 6
The John T. Collinson Bridge was the first railroad bridge in the United States to employ concrete box girder construction. The new structure replaced the obsolete timber one which can be seen just below and behind it. (Figg and Muller, Engineers)

The John T. Collinson Bridge near Pensacola, Florida, is typical of new railroad bridges today. Formerly, trains traveling from New Orleans to Jacksonville had to creep across Escambia Bay on an old timber trestle at 10 mph. The 82-year old bridge was recently replaced with a two mile span of precast concrete segments. Trains can now travel across a new nearly 12,000-foot span at 40 mph.

The Collinson structure was the first railroad bridge of its type in the United States. One very distinct advantage of segmented concrete construction in addition to ease of assembly is that damaged parts or sections (i.e., struck by a barge, storm damage, etc.) may be replaced more readily, resulting in less down time for the structure.

A tension arch design to be used in bridge construction has been patented by a structural engineer in East Logansport, West Virginia. Although it is called a tension arch, it is in actuality a post-tensioned rigid frame. The arch employs a parabolic suspension system whose horizontal tensile forces are resisted by a compressive strut, notched to preserve its parabolic shape. A tension arch bridge structure is basically bars and tubes that are topped with a precast deck and held in place with piers. Using the newly patented design, engineers hope to mass produce entire structures.

FIGURE 7
Girder bridges are commonly used on highway construction projects. Many use prestressed concrete girders or beams. (Figg and Muller, Engineers)

Construction Activity

Bridges must be designed to safely support their own weight (dead load) as well as that of all vehicles that may reasonably be expected to travel over them during the life of the structure. They must additionally be able to withstand the load imposed on them by occasional traffic overloads and to resist other forces, such as winds, earthquakes, stream flow, floating ice and various other pressures. The movement, acceleration and deceleration of vehicles over a bridge causes a dynamic effect as well that must be accounted for. It is called 'impact'.

The material for this activity was drawn from the bridge building contest section of the Technology Student Association (TSA, formerly AIASA) guides. For this construction activity your class will be divided into teams of two or three members. After research, each team is to design and construct a truss bridge. During this activity, you will experience a few of the many complex problems that must be solved each time a designer plans a bridge construction project. Following the construction phase of this activity, your class may elect to stage a contest to determine which design was the most successful.

During this learning activity, you will be permitted to use only those materials designated by your technology instructor. In order to gain additional structural strength, your team may choose to form laminated truss members by gluing two pieces of the ⅛″ × ⅛″ balsa stock together. When making laminated members, you will not be allowed to glue more than two pieces together to form any single member. Be sure the wood grain runs parallel to the wood member.

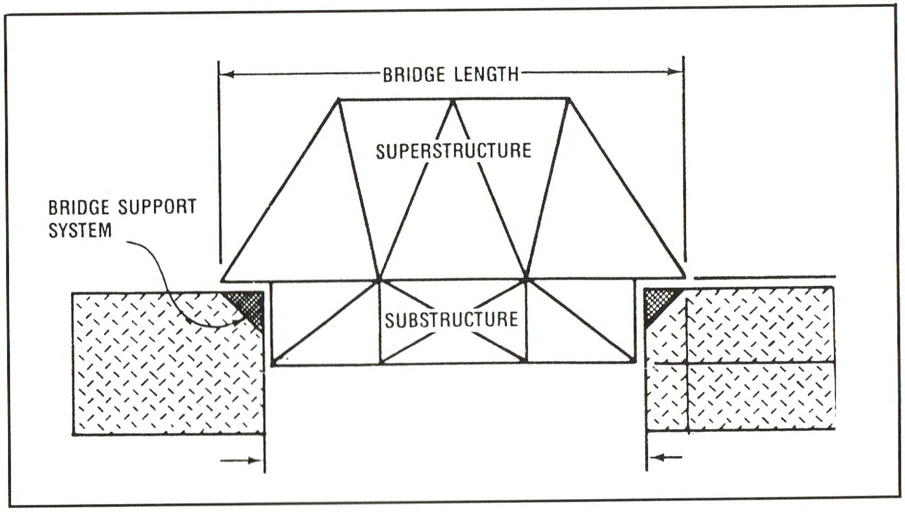


FIGURE 8
Truss bridge diagram (TSA)

Materials and Equipment

- Technology education lab with associated tools and equipment
- 20′/team of ⅛″ × ⅛″ balsa stock
- Elmer's carpenter's glue or similar
- Single edge razor blade or Exacto knife
- Cutting board
- Straight pins
- Grid paper, ¼″ squares
- Scale

NOTE: All bridges will be constructed to the same finished dimensions (span: 16,″ width: 3″), plus or minus ¼″.

Procedure:

1. Discuss various bridge designs with your team. Use textbook and other library resources in researching the subject.
2. Determine a final design for your team's bridge. Present your design in sketch form to your instructor for approval.
3. Make a final scaled drawing of your newly designed bridge.
4. Using the balsa stock and other materials provided, measure, cut, glue and pin your bridge together.
5. Allow the glue to dry overnight.
6. After removing all pins, accurately weigh your finished structure. Record the information.
7. Bridge efficiency may be checked by applying weight to the roadbed until the structure fails. Record the weight.
8. Combine the data recorded during this activity with the information in the MST section that follows to calculate your design's efficiency.

M/S/T Interface

When a body travels in a curvilinear path, such as a moving vehicle does on an elevated curved ramp like those found on many bridge entrance ramps, it produces a centrifugal force. This force is perpendicular to the tangent of the moving vehicle's path (see figure 9).

The moving vehicle's centrifugal force will be transmitted to the roadbed through its wheels. That force is transmitted to the bridge in varying degrees by every vehicle using the curved ramp or roadway simultaneously. It eventually reaches all of the structure's supporting members, with some being more effected than others. Engineers must be able to calculate this force as well as many others in order to design safe, cost-effective bridges.

A formula used to calculate centrifugal force is:

$$F = \frac{W v^2}{g r}$$

where:

W = weight of the vehicle
v = velocity of the vehicle
g = acceleration of gravity
 = 32.2ft./sec^2
r = radius of the path of vehicle

By applying math to the project you and your team just completed in the construction activity portion of this article, you will be able to calculate the effectiveness of your own bridge design. Fortunately, the application of mathematics to your work will be considerably simpler than many of those which must be employed by engineers before, during and after real-world bridge construction projects.

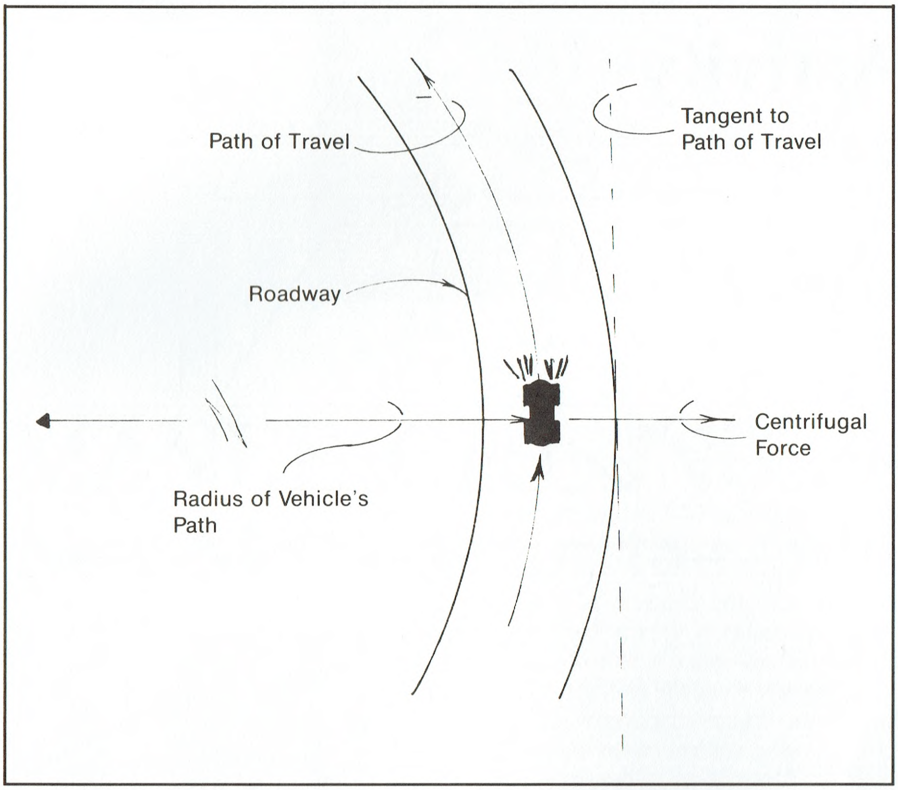


FIGURE 9
Centrifugal force and a curved roadway.

Use the following formula to check the efficiency of your own design:

Procedure:

1. Use the following formula to calculate the efficiency of your bridge:

$$\text{Efficiency (E)} = \frac{\text{failure weight (grams)}}{\text{weight of structure (grams)}}$$

2. Record the results to three decimal places
3. Compare the efficiency rating of your team's bridge design with that obtained by other teams. Discuss the results.

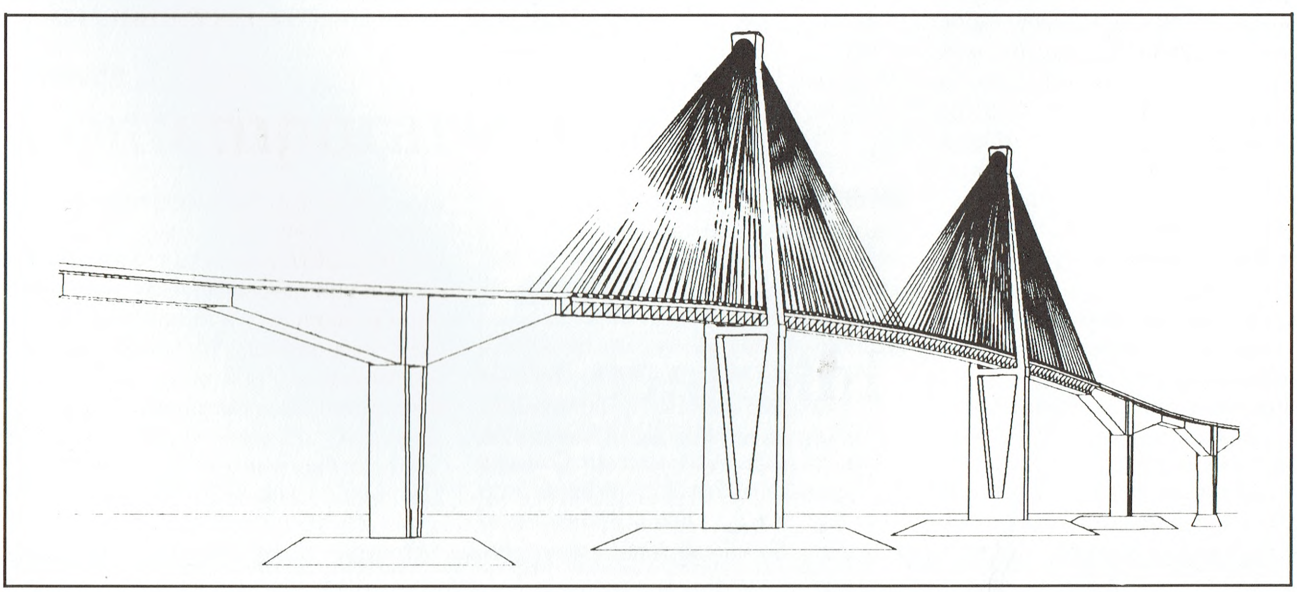
Conclusion

The extensive use of prestressed concrete, post tensioning and concrete box girder designs in our new bridges has greatly enhanced our construction capabilities. As the engineering technology of today continues to offer designers new and better materials to work with, society can expect to see even longer, more safe and efficient bridges.

Student Quiz

1. What is the difference between a suspension bridge and a cable-stayed one?
2. How has the development of segmental concrete box girders helped in the construction of modern bridges?
3. Describe some of the natural forces bridges may experience.
4. What is prestressed concrete and why is it used?
5. What is reinforced concrete?
6. Name the seven types of bridges.
7. List the three kinds of draw bridges.
8. How do you think concrete bridge segments can be cast away from the construction site and still be expected to fit properly?
9. Why was a computer was built into the Sunshine Skyway Bridge?
10. Briefly state how a bridge might effect the economy of an isolated area.

FIGURE 10
An artist's perspective drawing of the proposed Prince Edward Island construction. It will be a cable-stayed bridge with 8.3-miles of prestressed concrete segments. (Figg and Muller, Engineers)



Possible Student Outcomes

- Describe some of the physical forces that are considered when designing bridges
- List the seven types of bridges
- Differentiate between a suspension bridge and a cable-stayed one
- Discuss some of the new developments in bridge design and construction technology
- Associate math and science as an integral part of bridge design and construction technology
- Apply knowledge and materials to the solution of technological problems

Glossary

Abutment—a construction feature which supports the weight at either end of a bridge and resists lateral movement from it

Arch Bridge—structures in which each section or span forms an arch

Bridge Length—the overall length of a bridge, including the span and the required bearing surface area of the roadbed

Cable-Stayed Bridge—similar to a suspension bridge (below), but in this type the supporting cables attach directly to the roadway from the towers. Some bridges of this type have only one single pylon tower

Cantilever Bridge—consists of two independent beams that extend from opposite banks of a river or other area to be crossed. The two beams, called cantilevers, are joined at the center by a beam, truss or girder

Centrifugal force—a force perpendicular to the tangent of the path traveled by a vehicle moving in a curvilinear motion

Dead Load—weight of the structure plus any equipment attached to it

Draw Bridge—has a roadway that may be moved to permit the passage of large ships. There are three types of draw bridges: bascule, lift and swing.

- bascule—some open vertically at only one end, while others may open at the middle
- lift—the roadway extends between two towers and may be raised in a level position between them
- swing—mounted on a center pier and swings or pivots, opening horizontally to allow boat traffic to pass

Dynamic Effect—a physical phenomenon caused by vehicles moving across a bridge as opposed to the force exerted on it when vehicles are stationary. Sometimes called impact'.

Girder Bridge—made of beams whose ends rest on piers or abutments. Commonly used for highway bridges

Live Load—the design load, plus a safety factor, that a bridge can reasonably be expected to experience during its lifetime

Longitudinal Forces—forces that are transmitted lengthwise to the bridge's spans, such as those caused by vehicular braking and acceleration

Post Tensioning—applying tension to reinforcing steel after concrete has cured

Roadbed—the part of the bridge that is meant to be traveled on

Span—the distance between bridge supports

Stream Flow Pressure—the pressure caused by flowing water against a bridge's supporting piers

Sub-Structure—the structure of a bridge that extends below the roadbed

Super-Structure—the structure of a bridge that extends above the roadbed

Suspension Bridge—the roadway hangs from smaller vertical cables suspended by two heavy steel cables which are supported by two high towers

Truss Bridge—a bridge with a superstructure and/or a sub-structure supporting a roadbed across a span

Viaduct—a bridge with supporting towers or piers for carrying a roadway or railroad over something such as a valley, river, neighborhood, etc.

Acknowledgments

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Resources in Technology

MANUFACTURING PROCESSES:
New Methods for the "Materials Age"

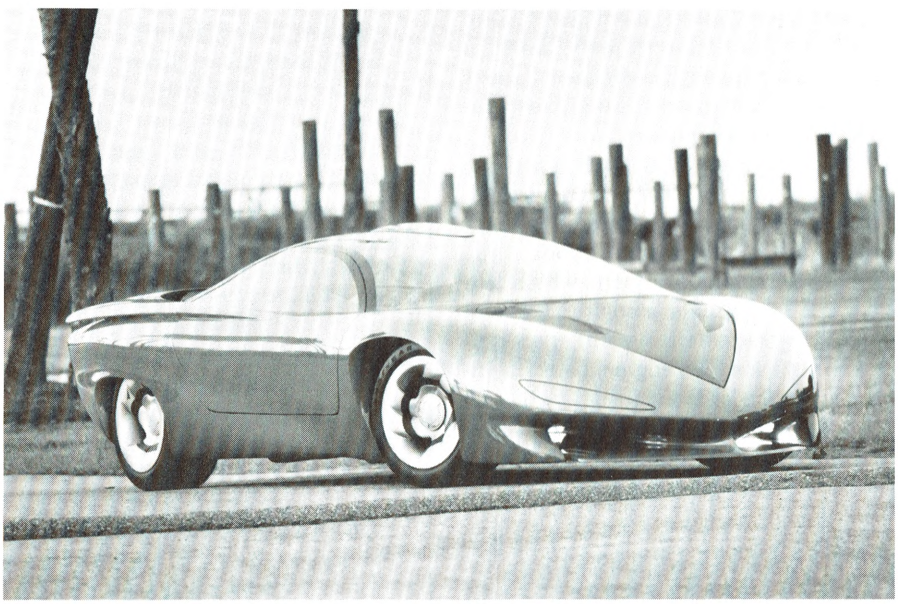

Figure 1
Pontiac Banshee Concept Car—a sleek performance 2+2 coupe that has features that will be used in the "next generation" of cars.

Contemporary Analysis

This instructional module builds on a series that began with "New Materials" (Resources in Technology, Volume 3). You may find it useful to re-read that module as well as "Nature & Properties of Engineering Materials," (Resources in Technology, Volume 4); "Composites Materials" and "Ceramics Materials," (Resources in Technology, Volume 5); "Polymeric Materials," and "Engineering Materials," (Resources in Technology, Volume 6).

Evolution of technology provides society with constant change. As science uncovers the secrets of the nature (matter and energy), engineering uses the new information to develop improved materials and processes to meet the insatiable desire of society for better products and systems. These new materials and processes provide designers with greater flexibility as they go about their creative tasks. The rapid expansion of materials and processes technology has created strong world competition in developed and developing nations.

Much has been written about the struggle by companies to maintain their profitability and for countries to maintain a favorable balance of trade. In the National Academy of Sciences' report, *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Materials Age*, we learn about the challenges to both materials scientists and engineers as well as politicians and other policy makers to strengthen our ability to synthesize and process materials. *Synthesis* involves transforming gases, liquids and solid elements into solid raw materials. For example, polyethylene plastic is make by putting hydrogen and carbon under heat and pressure. *Processing* of materials can include any number of techniques ranging from extracting aluminum from bauxite ore dug from the earth to melting and casting of refined aluminum into engine blocks. Synthesis is processing at the level of atoms and molecules while processing is at the larger scale involving materials manufacture for product components or finished products.

The US has slipped from its long dominate role as supplier of many of the worlds manufactured goods. Major US based companies such as General Motors, Ford, General Electric and IBM have had to struggle to earn a profit, while foreign owned companies such as Sony, Toyota, and Canon are gaining more of the world market and earning good profits. Much of the US steel industry has died out as Germany, Japan and Russia became major steel suppliers for the world. What has caused this major reversal of roles?

There are many complex reasons, but as pointed out in the National Academy report, a significant cause is the lack of progress in keeping abreast of materials science and engineering by the US.

The US faces the prospect of becoming a service driven nation. That is, instead of manufacturing products for herself and the world, she will purchase most of her products; jobs will be oriented around providing service on those products rather than production work. This senecio could yield grave consequences in terms of standards of living and security for people in the US. To avoid traveling down a path to dependence on other nations for its manufactured products, governmental agencies such as NASA and NIST (National Institute of Standards and Technology), technical societies such as ASM International, SME (Society of Manufacturing Engineers) and SAE (Society of Automotive Engineers) plus many companies are working on developing newer materials and processes for manufacturing in order to keep this nation competitive. The "Materials Science and Engineering for the 1990's" report offered many recommendations aimed at improving materials science and engineering. Among those recommendations: a call to increase application of computers for R&D in materials; collaboration of industry, government and universities to improve materials synthesis and processing techniques; and provide more financial support to MSE education and R&D.

If the US wishes to maintain her high standard of living, she must continue to develop and apply new manufacturing processes and strategies that provide high quality products and competitive prices which satisfy the world of consumers. Additionally, these processes must be safe for people and the environment.

Materials Processing

Tremendous breakthroughs have been accomplished in both materials and processes. These range from the recent discovery of the so-called high temperature superconductors and the challenges of being able to processes these new conductors in the form of *sintered cermets* (heat bonded powders of ceramics and metals) into useful products; also to the development of processing metals through rapid solidification to stop crystals from growing and thereby yielding amorphous metal; on to automated means of fabricating advanced composites.

Figure 1 (on previous page) is a photo of a concept car: a car which was designed to test new designs and technology. Figure 1a depicts application some of the new materials on parts which will be tested in concept car engines that aim to produce more reliable and energy efficient vehicles. The engine materials include ceramic (silicon nitride) metal matrix composites, rapid solidification aluminum and titanium. Design requiring new materials also means new manufacturing processes because often a different material cannot be processed the in the same manner as the old material.

Table 1 provides a listing which reveals how development of a new material technology results in a chain reaction of more developing technologies to support the new material development. The chain reaction involves materials, design considerations, materials processing, materials evaluation, material maintenance and finally the disposal or recycling of the material. For example, as new MMC (Metal Matrix Composites) are selected for use in automotive engines or NASA's NASP (National Aerospace Plane) the

Figure 1a
Prototype Parts of New Materials—clockwise from upper left: silicon nitride piston pin, two titanium valves, rapid solidification (RS) aluminum valve, silicon nitride valve, metal matrix composite (MMC) piston, RS aluminum connecting rod and two titanium valve spring retainers.

Table 1

CHAIN REACTION
EXPLOSION OF
EMERGING ENGINEERING
MATERIALS TECHNOLOGIES
MATERIAL
Composites
Thin FilmsCeramics
MMC (metal matrix composites)
Multi-layer ceramic
Superconductors
FRP (fiber reinforced plastic)
semiconductor devices
Magnets
Reinforced structural foam
Tool coatings
Abrasives
polymer
Diamond Films Protective
Coatings
DESIGN CONSIDERATIONS
Properties Styles/ Group Joining
Materials
Manufacturability
Shapes Technology
Techniques Systems
MATERIAL PROCESSING
(Diamond Films for example)
Diamond film Deposition
CVD (carbon vapor deposition)
PACVD energeticion-
beam deposition
IBED (plasma-assisted CVD)
(ion-beam-enhanced deposition)
MATERIAL
EVALUATION
Characterization
NDE/NDT
Destructive Testing
(Nondestructive Evaluation/
Testing)
MATERIAL MAINTENANCE
MATERIAL DISPOSAL/
RECLAMATION

TABLE 2

+ + SOME EMERGING ENGINEERING MATERIALS TECHNOLOGIES + +
+ NISTS LIST OF CRITICAL TECHNOLOGIES +
ADVANCED MATERIALS:
—POLYMER COMPOSITES (High Strength Fiber-Reinforced Plastic Resin)
—CERAMICS (High-Performance Structural & Electronic)
—METALS (Rapid Solidification & Metal Matrix Composites)
THIN LAYER TECHNOLOGY:
—SURFACE INTERFACES
—MEMBRANES
ELECTRONICS:
—ADVANCED MICROELECTRONICS (Enhanced VLSI & VHSIC Chips)
—OPTOELECTRONICS (Fiberoptic & Wave Length Processing)
AUTOMATION:
—MANUFACTURING (Computer-Integrated & Flexible Systems)

+ OTHER EMERGING TECHNOLOGIES +
—WATER JET CUTTING
—SMC (SHEET MOLDING COMPOUNDS)
—PM (POWER METALS)
—HSLA (HIGH STRENGTH LOW ALLOYS) STEEL
—ROBOTIC MATERIALS HANDLING/FABRICATION
—3D STEREOLITHOGRAPHY
—HIP (HOT ISOSTATIC PRESSING)
—AMORPHOUS METALS
—METAL INJECTION MOLDING
—RRIM (REINFORCED REACTION INJECTION MOLDING)
—MICROWAVE SINTERING OF CERAMICS
—SMT (SCANNING TUNNELING MICROSCOPY)
—SMT (SURFACE MOUNT TECHNOLOGY)
—SMART MATERIALS
—MEMORY METALS
—ION IMPLANTATION SURFACE ENHANCEMENT
—CERAMIC GLASSES
—HTc (HIGH TEMPERATURE) SUPERCONDUCTORS
—X-RAY LITHOGRAPHY CIRCUIT FABRICATION
—LCD (LIQUID CRYSTAL DISPLAYS)
—LASER PROCESSING
—DIAMOND THIN FILM
—PULTRUSION
—MATERIALS TESTING
—AUTOMATION/INTEGRATION
—CERAMIC HEAT ENGINES
—ADHESIVE BONDING
—COMPUTER MODELING FOR MATERIALS SELECTION/DESIGN/ ANALYSIS
—MICRO BUBBLES
—ENVIRONMENTAL DECONTAMINATION/WASTE DISPOSAL
—LOST-FORM CASTING
—BIOMATERIALS
—HIGH TEMPERATURE COMPOSITES
—CMC (CERAMIC MATRIX COMPOSITES)
—MATERIAL RECOVERY

designers must wrestle with the properties of these new materials, how they can be processed (formed and joined together) which affects the styling of the car or plane; then they will be concerned about how they will interact with other materials. They may corrode or not bond together.

The daily news provides us tragic examples of failures ranging from airplane crashes to bridge collapses that resulted from poor materials maintenance. The nature of our delicate life sustaining atmosphere and world environment has become a cause of increased concern. As materials are processed in manufacturing there must be many safeguards to prevent damage to the atmosphere, rivers, streams and the soil.

Trends in Manufacturing Processes

International developments in materials technology are rapid and cover all of the main groups of our family of materials. There are so many emerging engineering materials technologies (Table 2) that it is difficult to keep track of them. At the top of the table are the technologies judged critical for US economic development by a NIST (National Institute of Standards & Technology) survey.

A major goal of manufacturing engineers is to employ processes that yield parts which do not require many secondary operations to turn the part into a finished product. *Near-net shape* processing are methods that produce parts very close to the final dimension required for the part to be used without the need for much machining, welding or similar secondary operations. Traditional materials and processes were much more "labor intensive" because of the many operations required. The newer materials and methods of processing them will cost more per operation, but the near-net shape processing with a reduction in number of operations, coupled with greater design flexibility will be a bonus to manufacturers. The consumer should benefit from higher quality products at more stable prices.

The remainder of this module will provide a glimpse at a few of the new manufacturing processing technologies in order to give you some ideas on how new processes are evolving to meet the demands of the "Materials Age" and the expectations of a consuming public. Future RIT modules will provide more depth into various processes for new materials.

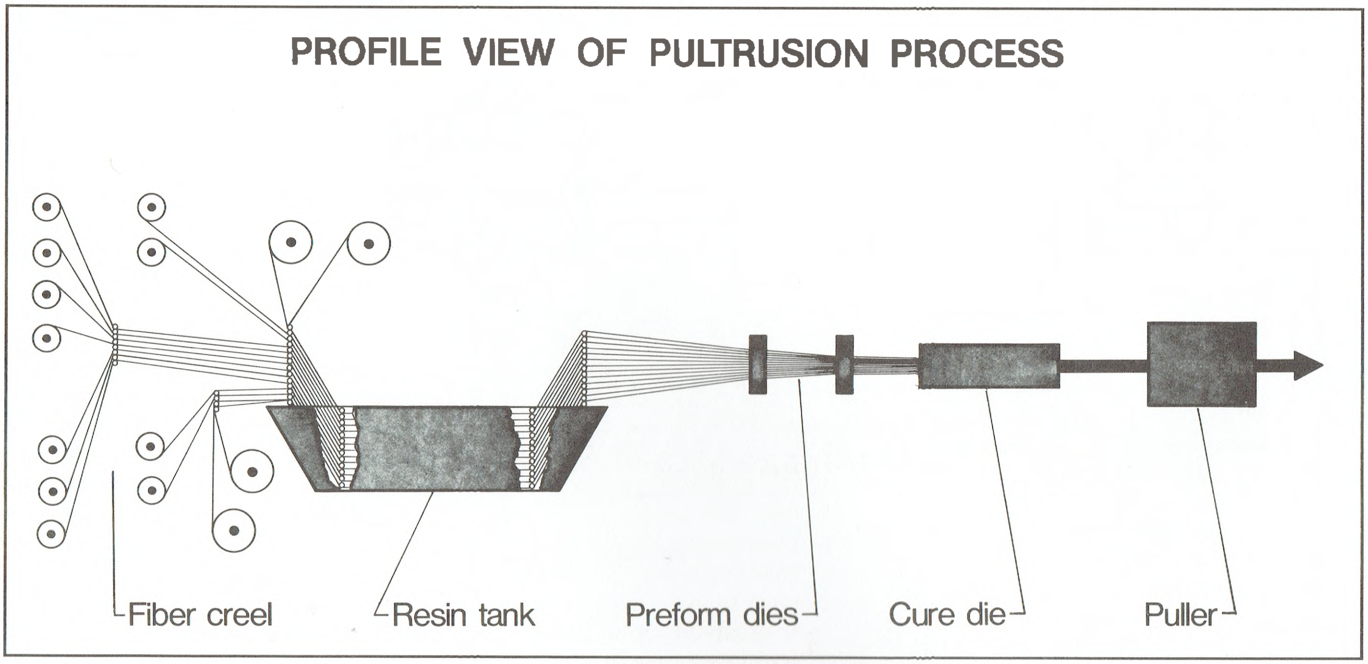

Figure 2
Line drawing of an prototype automated pultrusion line.

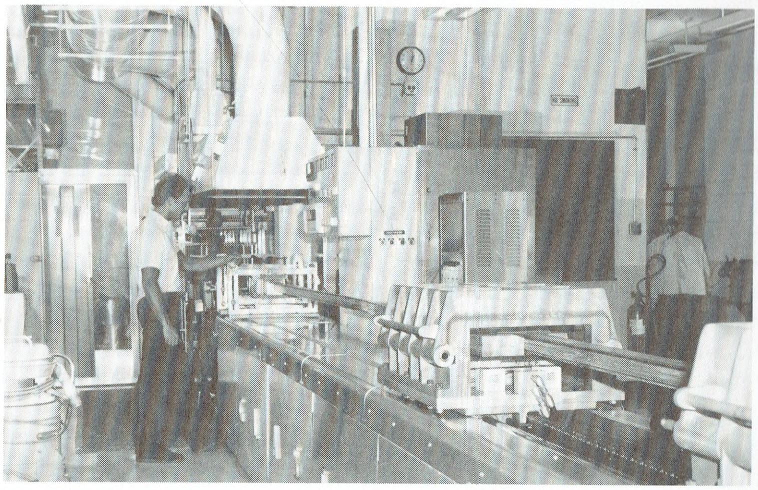

Figure 2a
Photo of the pultrusion line

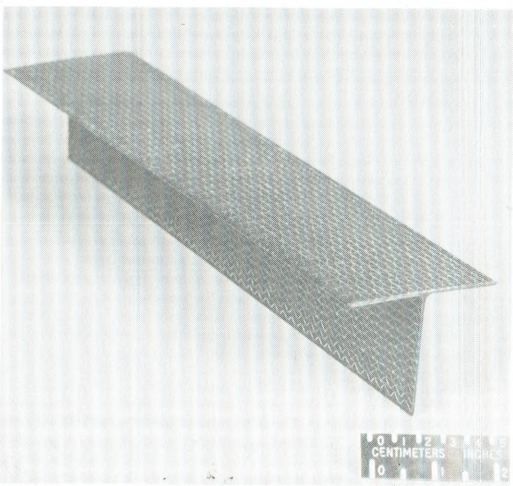

Figure 2b
Structural "T" FRP beam of graphite and epoxy.

Pultrusion

The sleek lines seen on the Banhsee Concept Car in Figure 1 result from a new design freedom made available to designers with plastics and glass reinforced plastic composites (GRP). One of the automated means of producing fiber reinforced plastics (FRP) is pultrusion which is a new process that evolved from two older processes: extrusion and drawing as depicted in Figure 2 & 2a. *Pultrusion* uses a bundle of continuous strands of fiber (glass, graphite or polymer) or mat that are impregnated (soaked) with resin and pulled (drawn) through a die; it results in an extrusion from the die of continuous shapes (rods, tubes, "T" beams) which are pulled to a desired length (Jacobs & Kilduff, 1985. pp.384 & 385). A structural "T" shaped part is seen in Figure 2b; note, the fiber creel may be rolls of individual fibers or woven mat. The "T" shows the multidirectional woven graphite mat fiber that has been impregnated with epoxy resin. It can be rapidly cured in the die using radio frequencies or heat. "T" beams of GRP or FRP can be used for the structural frames of cars, spacecraft, aircraft or buildings.

Injection Molding of Magnesium Alloys

Figure 3 provides a line drawing of a new process developed by Dow Chemicals for producing magnesium parts without melting and casting. Normally, metals must be heat to the liquid state in order to form them into complex shapes.

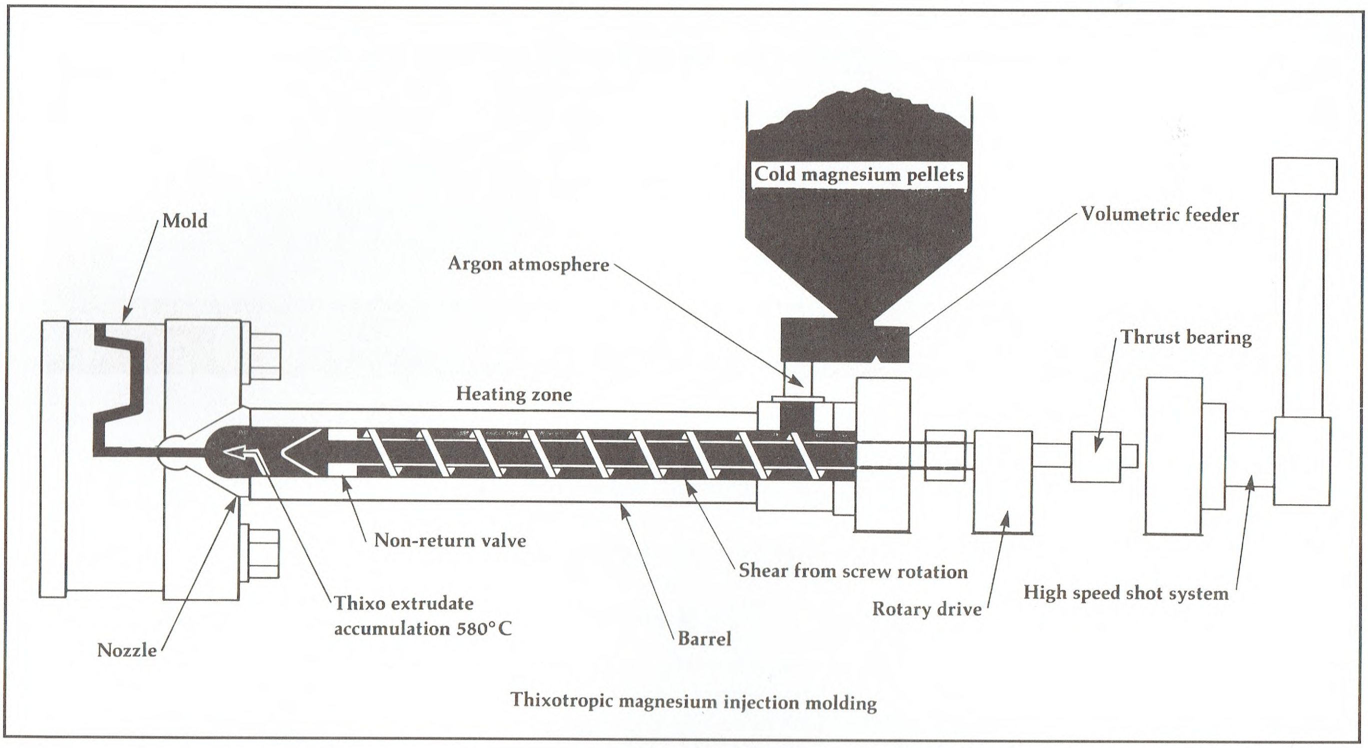

Figure 3
Thixotropic magnesium injection molding

Less complex shapes can be achieved in metals by heating them to a point in which they become plastic or formable. These processes include extrusion, drawing, bending and more. Some softer metals and thinner harder metals can be formed cold (room temperature)

Injection molding, as seen in the drawing, utilizes a screwing action which forces the material through a nozzle into a mold or die made of very hard tool steel or similar die stock. The mold has had a cavity formed into it in the reverse shape (female) of the part to be produced. Injection molding is a process often used for molding plastic and ceramic parts but not metals. The Dow injection molding of magnesium parts is possible because of the thixotropic (thicks-oh-tropic) alloys.

Thixotropic metals are those which exist at a semisolid state; they liquify while under shearing stress and then solidify when let standing. Jello is semisolid but, of course, much softer than a thixotropic metal. It is possible to turn *metal alloys* (mixture of metals and other elements) into the thixotropic state by vigorously stirring metal as it cools from the *liquidus* (liquid state) enroute to the *solidus* (solid state). When metal cools through *equilibrium* (slow, natural change from liquid to solid) as seen in Figure 3a, crystals form: first, by *nucleating* (seed crystals begin), then with further cooling to form *dendrites* (tree shaped structure) and finally into *grains* or *crystals*. If the metal is stirred vigorously while between the liquidus and solidus state (much like the mush of melting snow that is part ice crystals and part water), then the dendrites will form sphere-like shapes (Figure 3b) rather than the normal tree-like dendrites.

In Figure 3 you will notice cold magnesium pellets (in a thixotropic state) are fed through a hopper into a argon atmosphere then into the heated barrel of the injection molding machine. Argon is an *inert gas* and as such protects the magnesium from oxygen in the factory atmo-

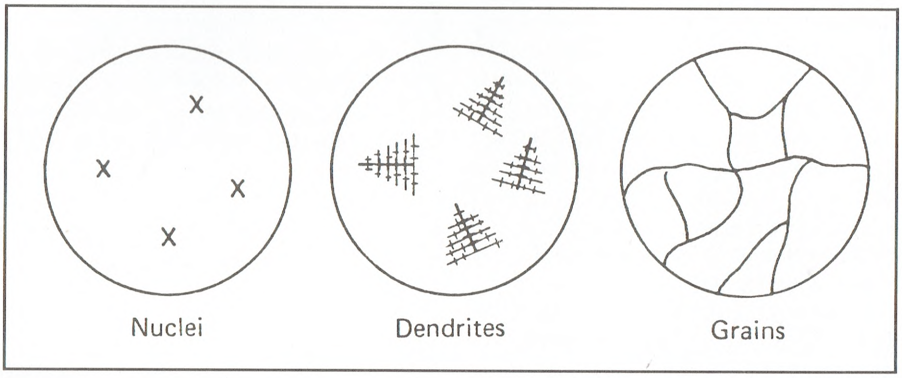

Figure 3a
Metal cooling through equilibrium first nucleates, then forms dendrites and final cools into a crystalline solid.

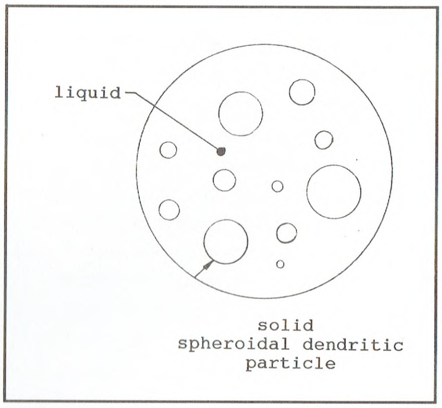

Figure 3b
Semisolid alloys form nearly spheroidal dendrite.

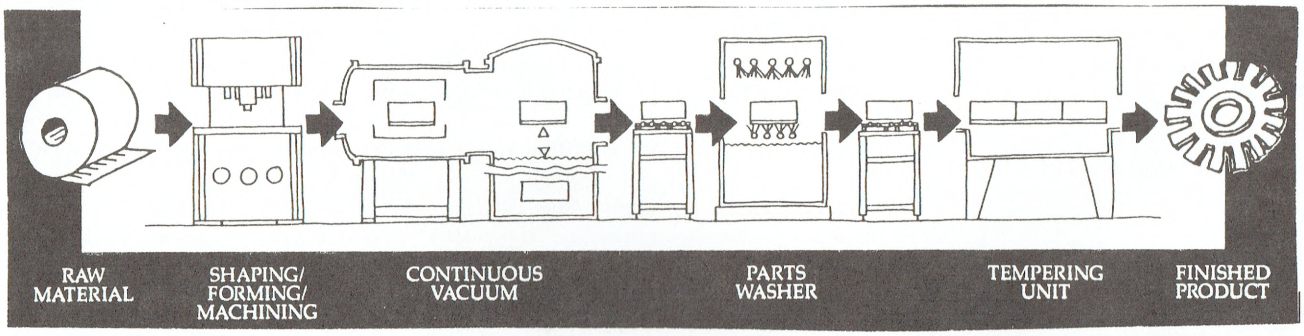

Figure 4
Line Drawing of Continuous Flow Automated Heat Treating System.

sphere. The shearing action of the screw, acting on the magnesium pellets, transforms them into a thixo extrudate at 580 degrees celsius. When enough of the extruded magnesium slurry (solid and liquid) collects in the heating zone chamber, it is injected by the force of the high speed shot systems which pushes against the thrust bearing causing the reciprocating screw to inject slurry through the non-return valve past the nozzle into the mold cavity. The molded part is the same as a part produced through melting and casting in the liquid state. The injection process offers advantages over die casting: improvements in mold cycle time, less down time and improved part quality (Frederick, Bradley & Erickson, 1988).

Heat Treatment in the Automated Manufacturing Cell

Methods of hardening and toughening metals continue to play an important role in manufacturing. Heat treatment includes older processes such as hardening, tempering and annealing. New methods include ion implantation, multilayer coatings and rapid deep freezing. Figure 4 shows a drawing of an automated, continuous flow, design of a heat treating system. This is a dramatic departure from older heat treating facilities which we usually see placed in another part of the factory away from the machining and assembly operations. In those systems "batches" of parts were taken to the heat treatment room, manually loaded into a furnace and heated, removed and cooled at a prescribed rate and sometimes cycled several times through heating and cooling.

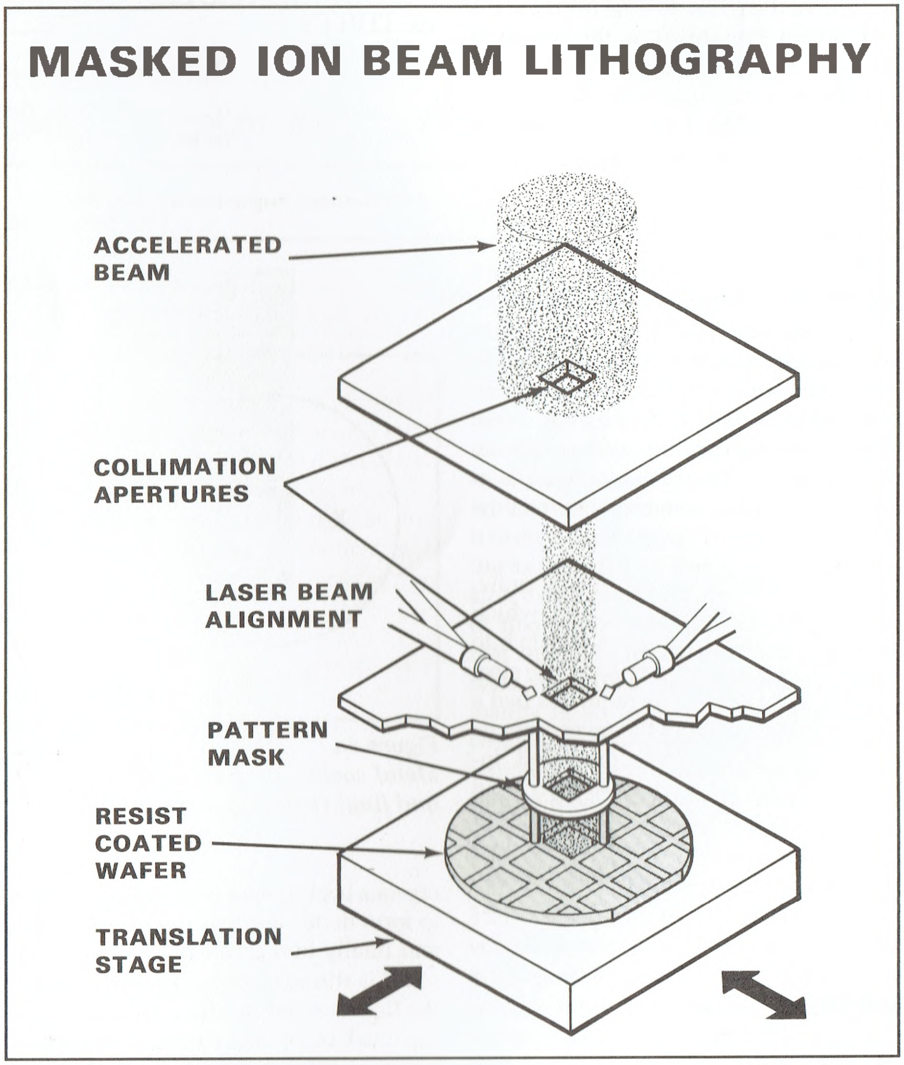

Figure 5
Masked Ion Beam Lithography.

Electronic Circuitry Processing

The availability of low cost digital watches, high power personal computers, computers to monitor car engines and power trains plus the computerized money machine at the bank owe their existence to highly automated electronic circuitry manufacturing processes. Today, many electronic components move through automated lines without a human hand ever touching them. The silicon memory chips are made through techniques of VLSI (very large scaled integration). In this processes the insulating material, silicon glass, is doped with atoms of conducting materials (metals) to make them semiconductors. The chips can store and transmit digital information when electronic impulses are applied. Getting the proper pattern of circuitry is done through a process called lithography.

Lithography involves creating the pattern on the silicon wafer by removing, adding and changing the atomic composition of the silicon. Ion beam lithography is a new technique and has the advantage of greater energy than the older electron beam process thus allowing shorter exposure time that is required to trace the circuit pattern. Seen in Figure 5, the masked ion beam lithography process can yield more dense circuit paths because of the reduced time to create the path which cuts down on the spread of the beam to surrounding silicon.

The silicon wafer has a layer of silicon dioxide formed on the surface. Next the wafer is coated with a photoresist which is sensitive to ultraviolet light.

The wafer is mounted onto a computer controlled translation stage that moves the coated silicon wafer back and forth under the ion beam to line up one chip area at a time. A number of chip circuits are made on each wafer. The ion beam is accelerated through a collimation aperture which keeps it in a straight line and provides the correct opening for the beam to focus on the wafer. Laser beams detect the ion beam to maintain alignment. A mask with circuit pattern openings is held above the wafer to define a pattern for each individual chip as the ion beam is sweeps the chip. The exposed resist materials is removed chemically then the wafer is chemically etched removing silicon that was not covered by the resist. Using the mask again, dopants of conductive materials are implanted onto the silicon where the silicon dioxide was removed. Then individual chips are cut out with a diamond saw. This is a general description of the process although some of the details have been omitted from description of the lithography process.

MST Interface

As describe in the beginning of this module, materials science is a relatively new multidisicilinary field of study. MSE incorporates engineering to make the field even broader. The Manufacturing Process Activity involves use of epoxy resin which is polymerized after introduction of a catalyst. Refer to *Engineering Materials Technology* (Jacobs & Kilduff,1985) and similar references to determine the chemical structure of epoxy and the steps involved in polymerization of a thermosetting resin. Explain why the process gives off heat.

Next look at the engineering data tables for the tensile strength of such plastics as epoxy and polyester then compare them to the same plastics that have been reinforced with fibers of glass and graphite.

MATERIALS PROCESSING ACTIVITY

FRP composite manufacturing is young compared to traditional processing of metals, ceramics and woods. While there are many efforts in place to automated FRP processing, hand lay-up still accounts for many of the products such as boats, aircraft, racecars and spacecraft. This activity provides the basic procedures for hand laminating; it can be modified to meet the needs of a particular product.

Materials and Equipment:
woven fiberglass mat (roven), epoxy resin and catalyst (hardener), paper measuring cups, inexpensive 1" paint brush, clear polyethylene (PE) film (e.g. dry cleaner bag), acetone, wooden tongue depressor or popsicle stick, plastic gloves, shears.

Procedures:
CAUTION: Use a well ventilated room and work with small quantities of resin to limit the fumes and heat generated by the reaction of the epoxy polymerizing. Larger quantities may require a heat resistant surface and high volume ventilation.

1. Cut five to six 4" × 4" fiberglass squares.
2. Measure 2 ounces of epoxy resin into a paper measuring cup and follow directions provided with resin. Use tongue depressor to stir for 3–5 minutes; use a slow motion to keep down air bubbles.
3. Spread out PE film on table.
4. Pour small amount of resin onto the PE film. Spread to a little more than a 4" × 4" square area with brush.
5. Place one fiberglass 4" × 4" mat on onto the resin. Dip the brush into resin and bush onto mat working from center outward to push out air bubbles. The mat will absorb resin first placed on the PE film. Add only enough resin with brush to saturate the mat.
6. Repeat process with each additional fiberglass laminate until desired thickness is achieved.
7. Cover the fiberglass laminate with another PE film. Apply a heavy, flat object to top of the laminated mats to compress the fibers and push off excess resin.
8. Observe the contents of the cup and brush to verify that the resin is curing. The cup will feel warm due to the exothermic reaction that is occurring. An increasing odor will also be noticed as the reaction evolves.
9. The brush can be cleaned with acetone.
10. Allow resin in composite to cure; overnight is best. The PE sheet should separate easily from the composite laminate.

Additional Resources:
—ASM International has a videotape, "Materials: Engineering A Brighter Future for Yourself," that describes careers in MSE. Write to ASM International, Materials Park, OH 44073.
—"A Material World" is a permit exhibit with interactive and live demonstration at the National Museum of American History of the Smithsonian Institution in Washington, DC.
—"Future Materials Exhibit" at the Franklin Institute in Philadelphia provides displays, interactive materials science activities and kits for purchase on the nature, structure and processing of materials.

Society of Manufacturing Engineers has a wide range of videotapes on traditional and new manufacturing processes. Some are available for free loan. Write to SME, One SME Drive, P.O. Box 930, Dearborn, MI. 48121-0930.

Summary

The "Age of Materials" has provided society with new technology ranging from computers to artificial hearts to more fuel efficient cars. To make best use of the new materials, improved materials syntheses and manufacturing processes are required. In order to maintain their economy and balance of trade, nations must strive to keep current with its materials science and engineering technology.

New career opportunities are opening up in materials science and engineering. Do you have a future in MSE? ASM International and the Society of Manufacturing Engineers are two key technical societies with information on these opportunities. See their addresses listed in this module.

Student Quiz

1. Transforming gases, liquids and solid elements into solid raw materials is (*synthesis*).
2. Name the term that describes the transformation of materials by techniques ranging from extracting aluminum from bauxite ore dug from the earth to melting and casting of refined aluminum into engine blocks. (*Processing or manufacturing*)
3. What are some recommendations from the report, "Materials Science and Engineering for the 1990s," competitiveness? (*increase application of computers for R&D in MSE, improve synthesis and processing techniques and strengthen, improve MSE education.*)
4. List five of the emerging engineering materials technologies. (*see Table 2*)
5. A new material causes a chain reaction involving other materials related developments. What are the major categories of technologies involved? (*see Table 1*)
6. Briefly, describe one the new manufacturing processes explained in this module and give one major advantage of it. (*see each process*)
7. Define the following terms: pultrusion, thixotropic, inert gas, VLSI, FRP. (*see terms in text*)
8. Name two technical societies that can provide career information on manufacturing and MSE. (*ASM International and Society of Manufacturing Engineers plus others*)

Possible Student Outcomes

- Describe some of the factors discussed in the report, *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Materials Age*, and what they mean to the future of the USA.
- Differentiate between synthesis and manufacturing processes.
- Define the terms: pultrusion, thixotropic, inert gas, VLSI, FRP, MMC, sintered cermets, near net shape, PCs.
- List some emerging engineering materials technologies and diagram a possible chain reaction effect of a new materials technology.
- Briefly describe the new manufacturing processes pultrusion, injection molding of magnesium and electronic circuitry manufacturing
- Gain a greater appreciation for MSE and discover career opportunities in the field.

Acknowledgements

- Figure 1 Courtesy General Motors. 1a. Courtesy ASM International & Ford Motor Co.
- Figure 2, a & b. Courtesy of NASA Langley Research Center.
- Figure 3 Courtesy ASM International. 3a courtesy Prentice-Hall, Inc. *Engineering Materials Technology.*
- Figure 4 Courtesy of Hayes Inc.
- Figure 5 Courtesy "Navy Manufacturing Technology Report" Manufacturing Processes Activity adapted from the demonstration developed in the Materials Science Technology program by Battelle NPL and Richland High School.

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