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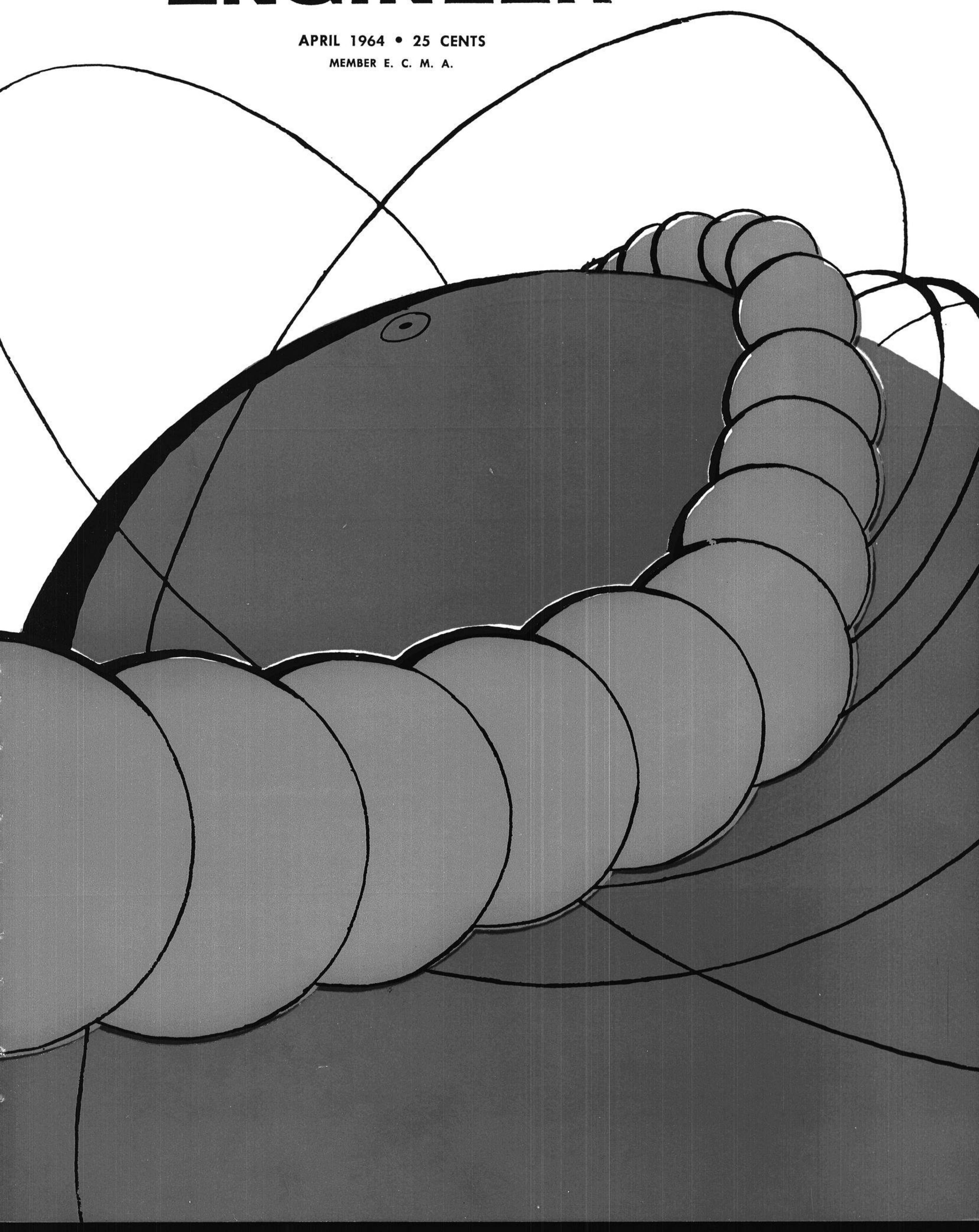
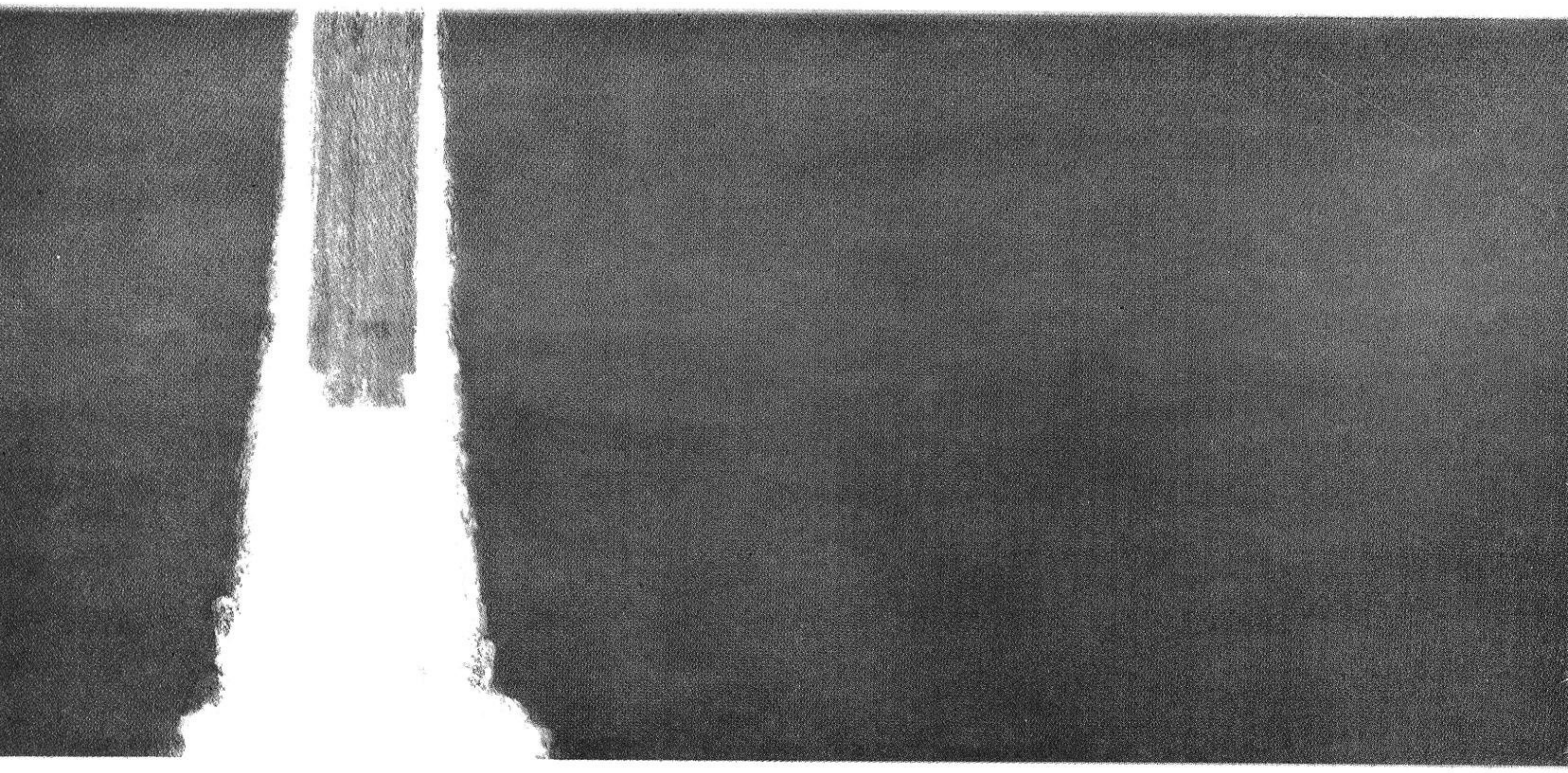
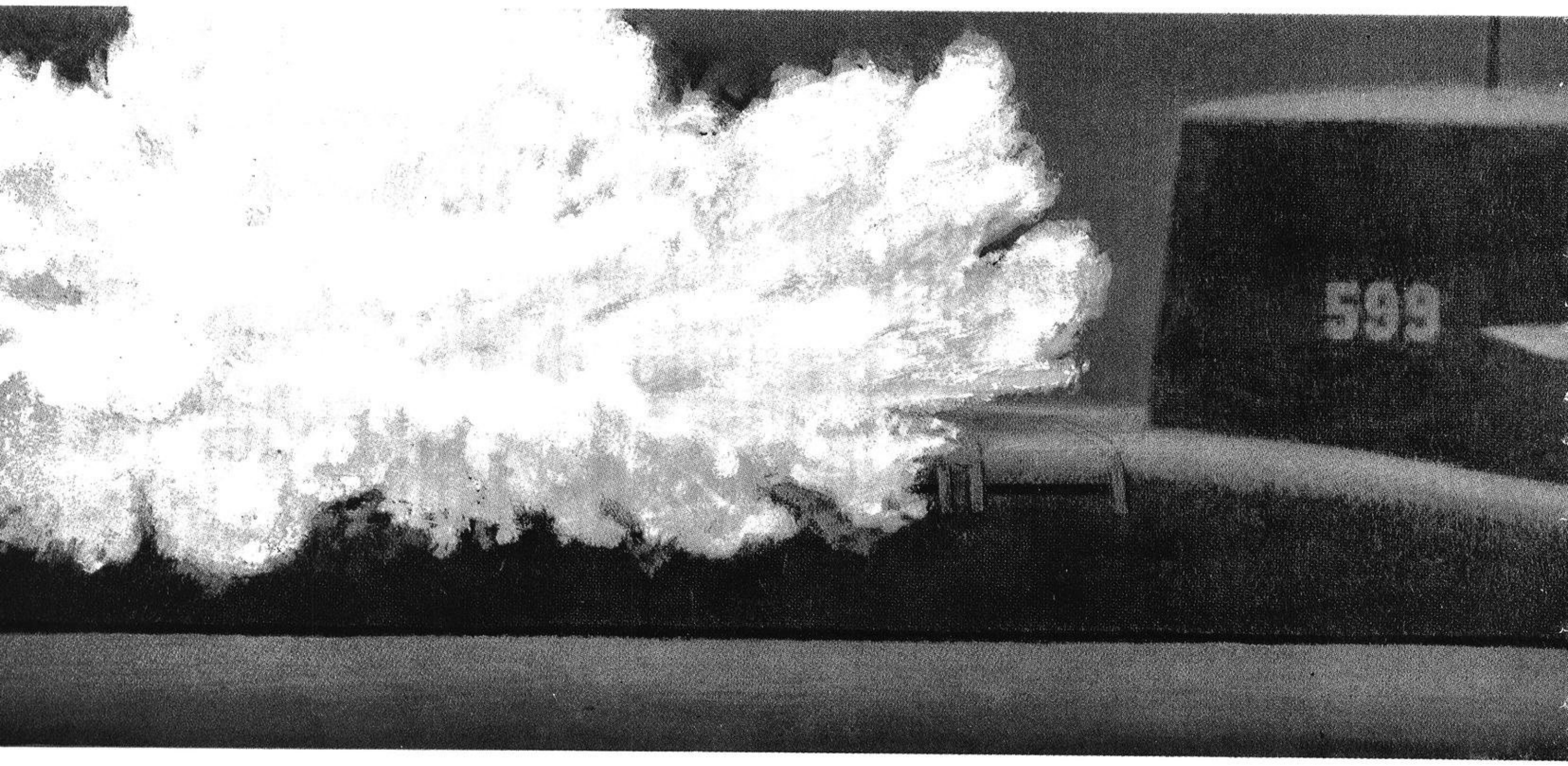
THE WISCONSIN ENGINEER

APRIL 1964 • 25 CENTS
MEMBER E. C. M. A.





Polaris missiles are fired by Westinghouse launching systems



Polaris subs are powered by Westinghouse-designed atomic reactors

Twenty Polaris submarines have gone to sea. Each carries 16 Polaris missiles. They give the U.S. a deterrent force that no enemy can hope to strike out of action.

These subs can travel to any ocean in the world and stay hidden under water for months, because they are nuclear powered.

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APRIL 1964

ARTICLES

THE WISCONSIN ENGINEER

The Student Engineer's Magazine Founded in 1896

FEATURES

THIS MONTH'S COVER

This month's cover draws your attention to the first article in this issue. The artist is Jim Lawton.

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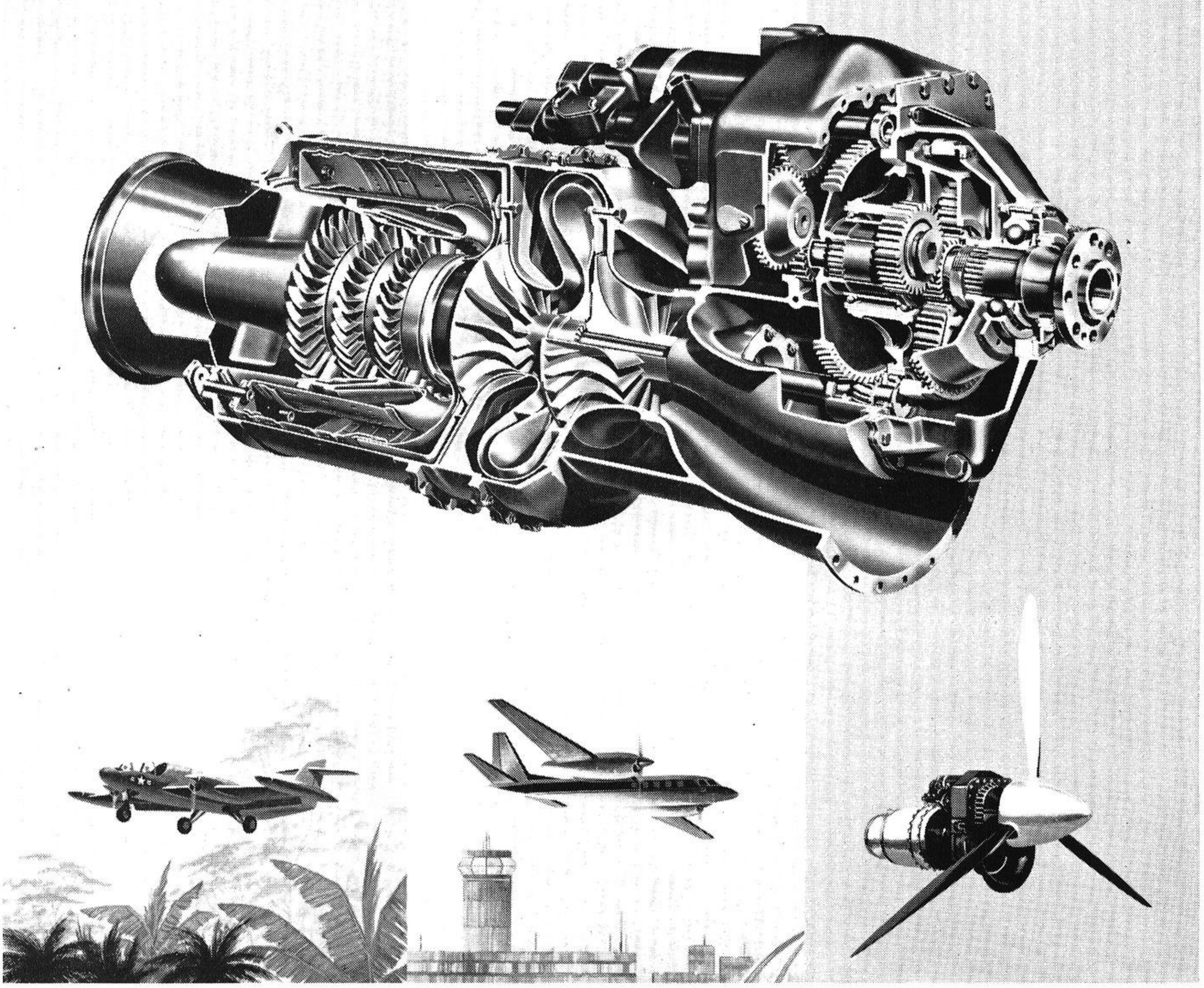
TURBOPROP ENGINE FOR LIGHT AIRCRAFT



This 600 horsepower turboprop engine is designed to power the new generation of light, fixed wing aircraft for both civil and military applications. • The Garrett-AiResearch TPE-331 has a specific fuel consumption of .62 pound per shaft horsepower-hour, and a weight to power ratio of .45 pound per horsepower. The engine has a response rate from flight idle to full power of approximately 1/3 of a second. A military version has been designated the T76 by the U.S. Navy. • Designed specifically as a prime power plant, the model 331 is backed by the company's experience in producing over 10,000 gas turbine engines. • The Model 331 engine is programmed for additional performance growth. The turboshaft version (TSE-331) has been flight tested as a power plant in rotary wing and vertical lift vehicles.

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ENGINE EARS

C.E.'s.

PLAN TO ATTEND THE

20TH ANNUAL A.S.C.E. MID-WESTERN CONFERENCE

Members of the American Society of Civil Engineers from eight midwestern colleges and universities will gather at the University of Wisconsin, Madison on April 23–25 for the 20th Annual Mid-Western Conference. Those student chapters participating are from Iowa State College, Michigan College of Mining and Technology, North Dakota State College, South Dakota State College, University of Iowa, University of Minnesota, University of North Dakota and the University of Wisconsin.

The conference's prime objective is to further the knowledge of the standards and ethics of the engineering profession. It is around this nucleus that the program at Wisconsin has been constructed.

Headlining the conference this year is a panel discussion on "What Is Expected of the Graduate Engineer?" Representatives of various aspects of engineering will present their views on the subject. Representing government will be E. P. Fortson, Jr. Chief of Hydraulics Division, Waterways Experimental Station. Speaking for the contractors will be W. A. Klinger. Thomas M. Niles will represent the consulting engineers. Representing industry will be John Gammel of Allis Chalmers.

Members may participate individually by entering the student paper contest. Each paper submitted is to be written on a technical or professional civil engineering subject. First prize is $20.00 and a one year subscription to A.S.C.E. journals of all technical divisions.

While the conference is sure to provide a technical atmosphere, the calendar of events does include an adequate amount of social events and banquets —a necessity for today's technical man.

Officers and advisors for this conference are: Dwight Zeck, President; Edgar Doss, Vice President; Jerry Bizjak, Secretary; Rod Nilles, Treasurer; and advisors, Professor E. C. Wagner, Richard Dopp and Dennis McMillan.

Coriolis Acceleration
WHAT, WHEN, WHY

By WILLIAM J. SNELLIIG EM'64

Bill Snelling is majoring in engineering mechanics and will graduate next August. He is married and has a baby son. On March 12 he helped the engineers take the St. Pat's Basketball Trophy away from the lawyers.

CORIOLIS acceleration is an acceleration that appears whenever there is motion relative to a rotating frame of reference. It is a function of both the relative motion and the rotation. Mathematically speaking, it is equal to $2\omega v$ where ω is the angular velocity of the frame of reference and v is the relative velocity.

Geophysical Examples

This phenomenon is quite common in nature and has become increasingly important in the space age.

During World War I, gunnery officers had to take Coriolis acceleration into account when shooting over long distances. Germany's giant cannon, Big Bertha, underwent a Coriolis drift of almost a mile when shelling Paris from a distance of 70 miles.

The rockets and missiles of today achieve much greater velocities than did Big Bertha. As a result, their Coriolis terms ($2\omega v$) are much greater and will produce a proportionally larger Cariolis drift. This drift had to be taken into account before the first missile was ever fired down its Atlantic missile range.

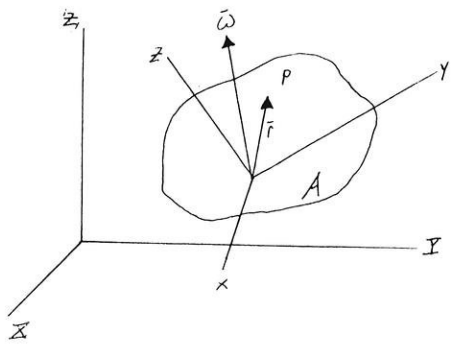
Even rivers are affected by this acceleration. It causes moving water to veer off to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Thus it has been found that the Mississippi River erodes its right bank more than the left.

Winds, like rivers, are effected by Coriolis acceleration. Without the earth's rotation, warm air would rise at the equator, cool and fall at the poles, and return to the equator to become heated again. There would be very little circulating movement, making wind storms almost impossible. Actually, because of the earth's rotation, this warm air is deflected as it travels away from the equator. Thus in the Northern Hemisphere the Coriolis acceleration gives rise to the "prevailing westerlies" which sweep in an easterly direction.

Each of the above examples employ the earth as a rotating frame of reference. Since the angular velocity of the earth is comparatively small (7.27×10^{-5} rad/sec) the resulting Coriolis effects in most cases are either small or negligible. However, where there are moving mechanical parts such as in machinery the angular velocities may be much larger, making the Coriolis effects appreciable. It is for these reasons that an engineering department should be aware of and know how to cope with this acceleration.

DERIVATION OF VELOCITY AND ACCELERATION FOR GENERAL SPACE MOTION

Point P in the figure is moving with respect to the rigid body A. This body is in turn in motion with respect (relative) to a fixed coordinate system XYZ. It both translates and rotates (W). The absolute motion of P is equal to the motion of P with respect to O plus the motion of O with respect to the stationary axis. It is found as follows: (Coriolis factors in the equations are underlined.)



Velocity in 3-space.

POSITION: (RELATIVE TO THE XYZ AXIS)

$$\bar{r} = X\bar{i} + Y\bar{j} + Z\bar{k}$$

DIFFERENTIATE:

$$\dot{\bar{r}} = \left[\dot{X}\bar{i} + \dot{Y}\bar{j} + \dot{Z}\bar{k}\right] + \left(X\frac{d\bar{i}}{dt} + Y\frac{d\bar{j}}{dt} + Z\frac{d\bar{k}}{dt}\right)$$

WHERE:

$$\frac{d\bar{i}}{dt} = \bar{\omega} \times \bar{i}$$

$$\frac{d\bar{j}}{dt} = \bar{\omega} \times \bar{j}$$

$$\frac{d\bar{k}}{dt} = \bar{\omega} \times \bar{k}$$

$$\therefore \dot{\bar{r}} = [\dot{\bar{r}}] + \omega \times (X\bar{i} + Y\bar{j} + Z\bar{k}) = [\dot{\bar{r}}] + \bar{\omega} \times \bar{r}$$

WHERE $[\dot{r}]$ = VELOCITY OF P RELATIVE TO XYZ

$\omega \times r$ = VELOCITY OF P DUE TO ROTATION OF XYZ.

∴ VELOCITY (RELATIVE TO THE XYZ-AXIS)

$$\dot{\bar{r}} = [\dot{r}] + \bar{\omega} \times \bar{r}$$

FROM $\dot{\bar{r}} = [\dot{X}\bar{i} + \dot{Y}\bar{j} + Z\bar{k}] + \bar{\omega} \times (X\bar{i} + Y\bar{j} + Z\bar{k})$

DIFFERENTIATE:

$$\ddot{r} = [\ddot{X}\bar{i} + \ddot{Y}\bar{j} + \ddot{Z}\bar{k}] + \underline{\left(\dot{X}\frac{d\bar{i}}{dt} + \dot{Y}\frac{d\bar{j}}{dt} + \dot{Z}\frac{d\bar{k}}{dt}\right)} + \dot{\omega} \times (X\bar{i} + Y\bar{j} + Z\bar{k})$$
$$+ \underline{\omega \times (\dot{X}\bar{i} + \dot{Y}\bar{j} + \dot{Z}\bar{k})} + \omega \times \left(X\frac{d\bar{i}}{dt} + Y\frac{d\bar{i}}{dt} + Z\frac{d\bar{k}}{dt}\right)$$

OR

$$\ddot{\bar{r}} = [\ddot{\bar{r}}] + \underline{\omega \times [\dot{\bar{r}}]} + \dot{\bar{\omega}} \times \bar{r} + \underline{\bar{\omega} \times [\dot{\bar{r}}]} + \bar{\omega} \times (\bar{\omega} \times \bar{r})$$

WHERE:

$[\ddot{\bar{r}}]$ = ACCELERATION OF P RELATIVE TO XYZ.

THE RED TERMS ARE THE CORIOLIS TERMS.

ACCELERATION: (RELATIVE TO THE XYZ AXIS)

$$\ddot{\bar{r}} = [\ddot{\bar{r}}] + \bar{\omega} \times (\bar{\omega} \times \bar{r}) + \dot{\bar{\omega}} \times \bar{r} \times \underline{2\omega \times [\dot{r}]}$$

NOW LET:

V_0 = VELOCITY OF THE ORIGIN OF XYZ.

a_0 = ACCELERATION OF THE ORIGIN OF XYZ

$\ddot{r} = a$ = ACCELERATION

$\dot{r} = V$ = VELOCITY

THUS IN ABSOLUTE SPACE:

$$\bar{V} = \bar{V}_0 + [\bar{V}] + \bar{\omega} \times \bar{r}$$

$$\bar{a} = \bar{a}_0 + [\bar{a}] + \bar{\omega} \times (\bar{\omega} \times \bar{r}) + \dot{\bar{\omega}} \times \bar{r} + \underline{2\bar{\omega} \times [\bar{V}]}$$

WHERE $\underline{2\bar{\omega} \times [\bar{V}]}$ IS THE "CORIOLIS ACCELERATION"

As seen from the preceding results, omission of the Coriolis term changes the direction of the j-component of acceleration. Thus the force due to a mass at point ρ would act in the wrong direction if Coriolis acceleration were not considered. Note that the motion within the relative system causes a Coriolis term to appear in the relative acceleration term.

WHY SO IMPORTANT

It should be pointed out that in both the geophysical problems and each of the specific engineering problems the Coriolis term ($2\omega \times V$) was dependent upon the size of the relative velocity (V) and the rate of rotation of the frame of reference (ω). In most geophysical examples the earth's rotation (frame of reference) was small making the Coriolis affects negligible. Only when the relative velocities were great (Big Bertha and rocket launching) were the Coriolis affects noticeable.

Unlike the geophysical examples, engineering problems often have both high relative velocities and high rates of rotation. As seen in the preceding four examples, this tends to make the Coriolis term much more predominate.

Since these rotations and relative velocities are often small or zero, producing negligible Coriolis effects, many engineers tend to neglect and forget—or worse, just are not aware of—Cariolis acceleration. As the daily problems faced by engineers become more complex and working tolerances become smaller, these once negligible Coriolis affects will have to be taken into account. Coriolis acceleration is rapidly becoming an important part of every engineer's life.

SPECIFIC APPLICATIONS

The following four examples show how common this phenomenon is and how significant its results may be.

1. The rocket problem
2. The propeller problem
3. The impeller problem
4. Disk on bar problem

In each example the general terms for velocity and acceleration are those derived above.

The Rocket Problem

For the rocket symbolized on the diagram, the Coriolis deviation can be determined by again referring to the equations for general space motion.

Given:

1. The angular velocity of the earth $= \omega_e$
2. Launch from λ° North.
3. Initial velocity $= \nu_0$ (Vertical)

$$\bar{a} = [\bar{a}]_{REL} + \bar{\omega} \times (\bar{\omega} \times \bar{r}) + \dot{\bar{\omega}} \times \bar{r} + \underline{\underline{2\bar{\omega} \times [\bar{V}]}}_{REL} = -g\bar{K}$$

$$\bar{\omega} \times (\bar{\omega} \times \bar{r}) = \bar{0}$$

$$\dot{\bar{\omega}} \times \bar{r} = 0$$

$$\therefore [\bar{a}]_{REL} = \underline{\underline{-g\bar{K} - 2\omega_e V_z \cos\lambda}}\,\bar{j}$$

DIVIDE $[a]_{REL}$ INTO COMPONENTS.

$$[\ddot{\bar{z}}] = -g\bar{K}$$

$$[\dot{\bar{z}}] = +(-gt + C)\bar{K} = (-gt + V_0)\bar{K} \quad @t=0, \dot{z} = V_0 \therefore C_1 = V_0$$

AT MAXIMUM HEIGHT $\dot{z} = 0 = -gt + V_0$

OR $t = \frac{V_0}{g}$

$$[\ddot{\bar{Y}}] = \underline{\underline{-2\omega_e V_z \cos\lambda}}\,\bar{j} = \underline{\underline{-2\omega_e(-gt + V_0)\cos\lambda}}\,\bar{j}$$

$$[\dot{\bar{Y}}] = \underline{\underline{\left[-2\omega_e \cos\lambda\left(-\frac{gt^2}{2} + V_0 t\right)\right]}}\bar{j} + C_3\bar{j} \quad @t=0, \dot{Y}=0 \Rightarrow C_3 = 0$$

$$[\bar{Y}] = \underline{\underline{\left[-\omega_e \cos\lambda\left(-\frac{gt^3}{3} + V_0 t^2\right)\right]}}\bar{j} + C_4\bar{j} \quad @t=0, Y=0 \Rightarrow C_4 = 0$$

$$\text{OR } [\bar{Y}] = \underline{\underline{-\frac{2}{3}\frac{V_0^3}{g^2}\omega_e \cos\lambda\,\bar{j}}}$$

Conclusions:

From the other page we found $y = -\frac{3}{2}\frac{V_0^3}{9^2}\omega_e \cos\lambda$ to be a result of Coriolis only. For these conditions, γ is a function of λ and V. (g) and ω_e are constants.) Notice that the only time there is no deviation is when $V_0 = 0$ or $\lambda° = 90.°$ This implies that there will be a Coriolis drift for every rocket fired except when a rocket is fired vertically at one of the earth's poles.

The Propeller Problem

For the propeller blade shown, we may determine the acceleration of any point (P) by the general equations for space motion.

Given:

1. The propeller spins with velocity ν.
2. The spinning shaft precesses with velocity N.

$$\bar{\omega}_{cs} = N\bar{j}$$

$$[V]_{REL} = [V']_{REL} + [\bar{\omega} \times \bar{r}]' = -r\cos\theta\, n\bar{i} + r\sin\theta\, n\bar{j}$$

$$\bar{a} = \bar{a}_0 + \bar{\omega} \times (\bar{\omega} \times \bar{r}) + \dot{\bar{\omega}} \times \bar{r} + [\bar{a}]_{REL} + \underline{\underline{2\bar{\omega} \times [\bar{V}]}}$$

$$\bar{a}_0 = \bar{0}$$

$$\bar{\omega} \times (\bar{\omega} \times \bar{r}) = -N^2 r \cos\theta\,\bar{i}$$

$$\dot{\bar{\omega}} \times \bar{r} = \bar{0}$$

$$[\bar{a}]_{REL} = [\bar{a}]'_{REL} + [\bar{\omega} \times (\bar{\omega} \times \bar{r}) + \dot{\bar{\omega}} \times \bar{r}]' + \underline{\underline{[2\omega \times [\bar{V}]]}} = \bar{\omega} \times (\bar{\omega} \times \bar{r})$$

$$= -n^2 r \cos\theta\,\bar{i} - n^2 r \sin\theta\,\bar{j}$$

$$\underline{\underline{2\bar{\omega} \times [\bar{V}]}} = (2N\bar{j}) \times (-r\sin\theta\,\bar{i} + r\cos\theta\,\bar{j})$$

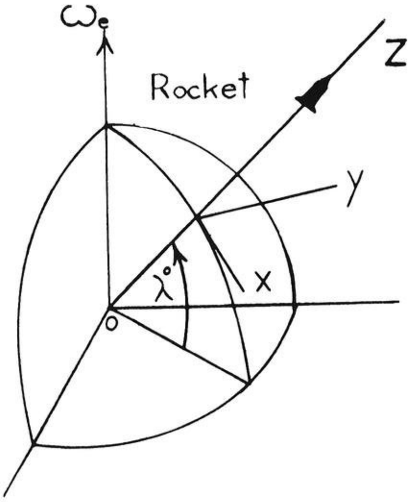
$$= \underline{\underline{2Nnr\sin\theta\,\bar{K}}}$$

$$\therefore \bar{a} = -(N^2 r\cos\theta + n^2 r\cos\theta)\bar{i} - n^2 r\sin\theta\,\bar{j} + \underline{\underline{2nNr\sin\theta}}\,\bar{K}$$

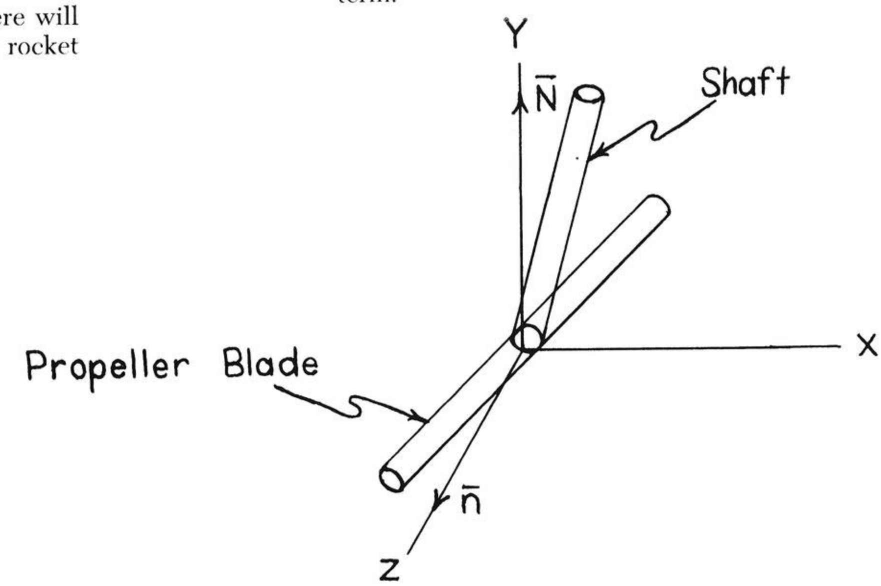
A COMPARISON OF RESULTS

METHOD— —	ACCELERATION COMPONENTS
WITHOUT CORIOLIS	$(N^2 r\cos\theta + n^2 r\cos\theta)i - n^2 r\sin\theta j$
WITH CORIOLIS	$-(N^2 r\cos\theta + n^2 r\cos\theta)\bar{i} - n^2 r\sin\theta j + 2nNr\sin\theta\bar{K}$

As seen from the above table of results, omitting the Coriolis term would omit the κ-component in the result. Omission of the κ-component could cause bearing failures on the shaft and create other physical defects. Note also that motion within the relative system causes a second Coriolis term to appear in the relative acceleration term.



Rocket fired vertically at 2° North.



Propellor Blade on a Precessing Shaft.

The Impeller Problem

Let us determine the acceleration of the fuel as it leaves the impeller (at point P) in the given diagram.

Given:

1. Velocity relative to impeller = 100ft./sec.
2. Acceleration relative to impeller = 120ft./sec.^{2}
3. Angular velocity of wheel = 2400rpm = 251.3rad./sec.

$$\bar{r} = .833\bar{i}$$

$$[\bar{V}]_{REL} = 100(.867)\bar{i} + 100(.5)\bar{j} = 86.7\bar{i} + 50\bar{j}$$

$$\bar{a} = [\bar{a}]_{REL} + \bar{\omega}\times(\bar{\omega}\times\bar{r}) + \dot{\bar{\omega}}\times\bar{r} + 2\bar{\omega}\times[\bar{V}] + \bar{a}_0$$

$$\bar{a}_0 = \bar{0}$$

$$[\bar{a}]_{REL} = 120(.867)\bar{i} + 120(.5)\bar{j} = 100\bar{i} + 60\bar{j}$$

$$\bar{\omega}\times(\bar{\omega}\times\bar{r}) = -(251.3)^2(.833)\bar{i} = -52{,}500\bar{i}$$

$$\dot{\bar{\omega}}\times\bar{r} = \bar{0}$$

$$2\bar{\omega}\times[\bar{V}] = 2(-251.3\bar{k})\times(86.7i + 50\bar{j}) = 25{,}130i - 43{,}500\bar{j}$$

$$\therefore \bar{a} = (-52{,}400 + 25{,}130)\bar{i} + (60 - 43{,}500)\bar{j}$$

CONCLUSIONS:

A COMPARISON OF RESULTS

METHOD	ACCELERATION COMPONENTS
WITHOUT CORIOLIS	$52400\bar{i} + 60j$
WITH CORIOLIS	$-27270\bar{i} - 43{,}440\bar{j}$

As seen from the above table of results, omitting the Coriolic term would greatly change both the magnitude and direction of the results. A blade designed to withstand an acceleration without Coriolis would not apply for the actual (with Coriolis) results.

Disk On Bar Problem

For the disk and bar system drawn, we can find the acceleration of point (P) by the general equations for space motion.

Given:

1. Angular velocity of disk = 5rad/sec
2. Angular velocity of rod = 3 rad/sec
3. Angular acceleration of disk = -8 rad/sec^2
4. Angular acceleration of rod = 4 rad/sec^2
5. Relative velocity of disk = 12ft/sec
6. Relative acceleration of disk = -20 ft/sec^2

$$\bar{\omega}_{CS} = -3\bar{k}$$

$$[\bar{V}]_{REL} = [\bar{V}]'_{REL} + [\bar{\omega}\times\bar{r}]' = 12\bar{i} + 5\bar{i} = 17\bar{i}$$

$$\bar{a}_P = \bar{a}_0 + [\bar{a}]_{REL} + \bar{\omega}\times(\bar{\omega}\times\bar{r}) + \dot{\bar{\omega}}\times\bar{r} + 2\bar{\omega}\times[\bar{V}]$$

$$\bar{a}_0 = \bar{0}$$

$$[\bar{a}]_{REL} = [\bar{a}]' + [\bar{\omega}\times(\bar{\omega}\times\bar{r}) + \dot{\bar{\omega}}\times\bar{r}]' + [2\bar{\omega}\times[\bar{V}]]'$$

$$= -20\bar{i} - 8\bar{i} + 25\bar{j} = -28\bar{i} + 25\bar{j}$$

$$\bar{\omega}\times(\bar{\omega}\times\bar{r}) = -27\bar{i} + 9\bar{j}$$

$$\dot{\bar{\omega}}\times\bar{r} = 4i + 12\bar{j}$$

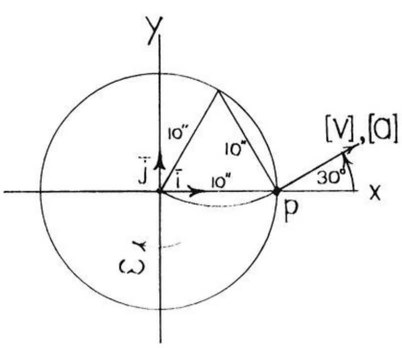
$$2\bar{\omega}\times[\bar{V}] = 2(-3\bar{k})\times(17\bar{i}) = -102\bar{j}$$

$$\therefore \bar{a} = 51\bar{i} + (46 - 102)j$$

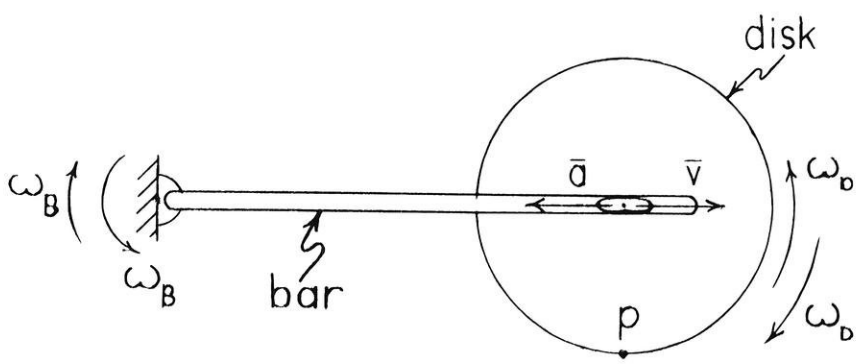
CONCLUSIONS:

A COMPARISON OF RESULTS

METHOD	ACCELERATED COMPONENTS
WITHOUT CORIOLIS	$-51\bar{i} + 46j$
WITH CORIOLIS	$-51\bar{i} - 56\bar{j}$



Impeller Blade of a Turbo-pump.



Disk on Bar System.

Should We Have More T.V.A.'s?

By THOMAS W. HOLZ, CE'63

Tom Holz is from Milwaukee where he attended the University of Wisconsin, Milwaukee. He's one of those rare persons that transferred to engineering after three years in the College of Letters and Science.

THE federally-controlled Tennessee Valley Authority is being presented to the American public as the acme of man's engineering capabilities and the model or "yardstick" of electric power production by which the federal government can measure privately owned power companies' rates. The government is in effect saying T.V.A. is the answer to chronic unemployment and depression in an underdeveloped area. If T.V.A. changed the seven states for which it generates power from a flooded, erosion scalped land into a Utopia, other projects can do the same in other parts of the country. If the federal government is trying to sell the public on socialized power production, it would be wise for us to take a good look at the calibrations on their yardstick before we decide to turn free enterprise out to pasture.

Does T.V.A. really out-produce private industry as it claims? What were T.V.A.'s original goals and has it achieved them? On what authority did the federal government go into the power business? The answers to these questions are vital if Americans must choose between a publicly and privately owned power industry.

REASONS FOR THE CREATION OF T.V.A.

Flood Control, Fertilizer, Navigation

In 1933 the country was in a devastating depression. The people in the states surrounding the Tennessee Valley were particularly stricken by the slump in the nation's economy because they were plagued by periodic floods and the consequent erosion which was destroying their livelihood. In their attempts to revive the valley's economy, the New Dealers put the T.V.A. bill through Congress. The bill was intended to create a series of dams on the Tennessee River primarily to check the ravaging floods and make the river and its tributaries navigable, and, in addition, to create facilities to conduct experiments in fertilizer production. The hydro-electric energy that could be produced as a by-product of the dams was to be sold to the neighboring municipal power companies.

Power, a By-product

A great cry of "socalism" went up when it was suggested that the government sell electric energy, but Congress and the courts were assured that power production was merely a by-product, and that navigation was the important goal in the creation of the project. In fact, Senator George Norris, called the "Father of T.V.A.," had this to say at a congressional hearing about the *T.V.A. Act:*

"I will say to you that I think in view of the decisions by the Supreme Court, I think the constitutionality of this kind of legislation hangs on navigation, so it is important to make navigation important."

Today, 82 per cent of T.V.A.'s investment is in power facilities, and 72 per cent of that investment is in steam plants—not hydroelectric units. It seems obvious that not only is the production of power something other than a by-product of the system of dams, but that it is the main concern of the Authority. No one denies that the system of 28 dams, the steam plants, the reforestration projects, the recreational and other operations, are remarkable achievements, or that all this offers the people of the valley many benefits. But neither can it be denied that T.V.A. has somehow subordinated flood control and navigation to the production of power, and that the government now has a gigantic electric company of questionable constitutional basis.

The defenders of T.V.A. claim that power production is justified because T.V.A. serves as the government's "watchdog". They claim T.V.A. can sell power at half the cost of private companies and still earn a substantial "profit" for the treasury. Considered in this manner, T.V.A. provides healthy competition for private power companies, and the ideal toward which private companies should work.

T.V.A.'S ECONOMICS

T.V.A. as a Yardstick

Before T.V.A. is established in our minds as the model for private power companies, let us take a look at its overall layout. T.V.A. is a wholesale supplier of electricity. It can generate 11.8 million kilowatts of power, or about 6 per cent of the nation's total power supply. It distributes power to less than 200 customers, and one customer, the Atomic Energy Commission (AEC), consumes 27.5 billion kwh annually or about 48 per cent of the power it produces.

The rest of the T.V.A.'s patrons are municipal distributors of power. If T.V.A. is to be properly compared to investor-owned companies it should rightfully be adjusted in two ways: (1) its distributors ought to be included in evaluating its cost; and (2) the AEC should be removed from its books. The reason for these adjustments is fairly obvious. Private companies must put a percentage of their income into bookkeeping; obviously it is much more economical for the Authority to make out one electric bill for the AEC than the several thousand bills a private concern must make out for the large block of homes that would use an equivalent amount of power. Likewise, with the sale of power to municipalities, the cost of accounting would be much greater if all the customers of these municipalities were totaled in T.V.A.'s books. Without these adjustments T.V.A.'s cost of accounting is about .13 mills per kwh, which would mean that it would cost them about $3,500,000 a year to read the AEC's meter. With these adjustments T.V.A.'s are comparable to other large distributors of electricity; yet its power rates are much less than a private company's of about the same size and operating under approximately equal conditions. The reason why T.V.A.'s rates are so low is that T.V.A. has neglected to include all its costs in its books.

Cost of Money

For 26 years, from 1933 to 1959, the T.V.A. paid no interest on some 1.4 billion congressionally appropriated dollars. To appropriate this money, the government had to sell bonds on which it paid $395 million interest. This is an obviously unfair advantage T.V.A. had over private investors who had to pay the going rate for use of money—approximately 5 to 6 per cent.

In 1959, Congress approved a bill which enabled T.V.A. to sell bonds on the open market. It also ordered T.V.A. to begin paying back the $1.4 billion investment in small yearly installments. However, the rate of interest T.V.A. was required to pay by the 1959 law is 3 to 4 per cent on all funds borrowed from the treasury—still below that which private companies pay.

The cost of money to society over-all is going to be equal whether it is supplied by private investors or government. In the case of a private company, the only people expected to pay for the cost of the investment are the consumers of the product. In the case of T.V.A., the cost is subsidized by taxes. In other words, the 80 per cent of the people not buying federal power must pay for a good part of the investment costs for those who do. This discrimination must not be overlooked when we are measuring with the T.V.A. yardstick.

Tax Contribution

Because of the extremely high cost of investment for power equipment on which taxes are based, about one-half of the gross revenue of private power goes toward state and federal taxes. Of course, taxes are a part of the cost of any commodity and must be paid ultimately by the users of that commodity. T.V.A. has paid no federal taxes since its creation in 1933. As of 1959 T.V.A. pays about 0.88 per cent of its gross in municipal and state taxes (approximately ⅔ of what private companies pay), but to this date T.V.A. pays no federal taxes.

Cost and Tax Adjustment

In the light of T.V.A.'s cheap financing and tax exemption, it seems illogical to compare T.V.A.'s prices with those of private companies unless adjustments for these two very important expenses are made. If T.V.A. was to pay 5 per cent of its gross investment for taxes and another 5 per cent for cost of money, it would have to raise its price better than 40 per cent, which would bring its rates up to the level of investor-owned corporation prices.

T.V.A.'s Efficiency

That T.V.A.'s rates would be equivalent to other power companies' rates can be expected, because T.V.A. has never claimed to produce power more efficiently than could a private company. It cannot make steam any cheaper or

MOST EFFICIENT STEAM-ELECTRIC GENERATING STATIONS FOR 1959
BASED ON HEAT RATE—BTU PER KWHR

Rank	Station	System	Heat Rate BTU per Kwhr
1	Dickerson	Potomac Electric Power Co.	9,007
2	Clinch River	Appalachian Power Co.	9,001
3	Kanawha River	Appalachian Power Co.	9,098
4	McMeekin	South Carolina Electric & Gas Co.	9,130
5	Muskingum River	Ohio Power Co.	9,170
	River Rouge	Detroit Edison Co.	9,170
6	Clifty Creek	Indiana–Kentucky Elec. Corp.	9,173
7	G G Allen	Duke Power Co.	9,174
8	Tanners Creek	Indiana & Michigan Electric Co.	9,176
9	Shawville	Pennsylvania Electric Co.	9,179
10	Kammer	Ohio Power Co.	9,203
11	St. Clair	Detroit Edison Co.	9,250
12	Kyger Creek	Ohio Valley Electric Corp.	9,284
13	Portland	Metropolitan Edison Co.	9,322
14	Oak Creek	Wisconsin Electric Power Co.	9,336
15	Bay Shore	Toledo Edison Co.	9,365
16	Milliken	New York State Electric & Gas Corp.	9,374
17	Sporn	Ohio Power & Appalachian Elec. Coop.	9,381
18	**Sevier**	**Tennessee Valley Authority**	**9,390**
19	Manalay	Southern California Edison Co.	9,397
20	Gallatin	Tennessee Valley Authority	9,420
21	Huntington Beach	Southern California Edison Co.	9,436
22	Colbert	Tennessee Valley Authority	9,460
	Will County	Commonwealth Edison Co.	9,460
23	Aqua Fria	Salt River Project AIPD	9,473
24	Salem Harbor	New England Power Co.	9,485
25	Cromby	Philadelphia Electric Co.	9,506

Courtesy Edison Electric.

string lines more economically; government employes are no more efficient than men working for any other business enterprise.

The electrical industry as a whole has tremendously increased its efficiency since the first plants were built in this country. Hardly anyone will argue the fact that electric power is a bargain. Since T.V.A. has relatively new equipment, much of it installed during World War II, we can expect that its efficiency ranks with the best private companies in the country. For 1959 it ranged as 18th most efficient in amount of heat produced per unit of fuel. Coal consumption for a given unit of heat was about 3 per cent more than the most efficient company.

It is easily seen that T.V.A. can't produce energy any more expediently or economically than private concerns. It is therefore reasonable to assume that if all were taken into account, its electric rates would be at the same level as those of private concerns.

IS PUBLIC POWER A NECESSITY?

Private—Public Power Feud

From the above discussion, it can be seen that government cannot produce cheaper power than can private power companies without taxpayers' subsidation. In T.V.A.'s case the cost of financing the project has been thrown on taxpayers not using T.V.A. power, and the customers' electric bills do not reflect their share of taxes. Because of these and other subsidies, private power companies are unable to compete with government power projects. Consequently, a fear has arisen among private concerns that the government is going to build more "flood control" dams and steam generators and force them out of business.

Private Power's Position

Investor-owned producing industries are not standing still while the world around them expands. A prodigious amount of power returns are plowed back into research, and power companies have been expanding rapidly to keep pace with demand for electric energy. Since World War II the demand for energy has been doubling every ten years.

Private power companies consider themselves capable of meeting any demand that may arise. They think that government intrusion in the power business is not only a burdensome expense, but a totally unnecessary one. It is illogical that in a capable, thriving industry and in an economy such as ours, government should see a need to produce power.

Federal Government's Position

The well-known government defense of many of its undertakings is that, for the benefit of the country, it must do what private industry finds uneconomical to do. Government argues that in 1933 the Tennessee Valley was a terribly depressed area, and that private industries would never have undertaken a project of such magnitude with a promise of little or no return. In addition, private companies would be far less inclined to build any more than the minimum in order to produce paper. The T.V.A., it argues, has done extensive work in reforestration, navigation, and in research in farm production. Furthermore, the lift in the economy in the seven states affected by the T.V.A. is beneficial to the entire nation.

How Much Has T.V.A. Helped the Valley?

Nearly everyone agrees that it is the government's right, indeed, duty, to regulate navigation and flood controls because they usually affect more than one state. For these goals the T.V.A. may be lauded. It is not the purpose of this article to analyze how well T.V.A. has fulfilled these goals. But has the federally-owned power company really been the lifeline to the Valley's economy? Certainly the input of approximately $1.4 billion into one area is bound to spur its economy somewhat, but just how has Tennessee grown in comparison with other southern states?

Tennessee's Growth Rate

One indicator of Tennessee's economic health is the gain in bank deposits. In the period from 1940 to 1959, Tennessee's total deposits increased 463 per cent. On the other hand, ten other southeastern states gained 514 per cent. In the same period, Tennessee's population increased 22 per cent, while ten other southeastern states gained 31 per cent. Per capita income gain for Tennessee was about the same as the other southeastern states.

It can hardly be said from these figures that Tennessee's economic growth has exceeded its neighbors.

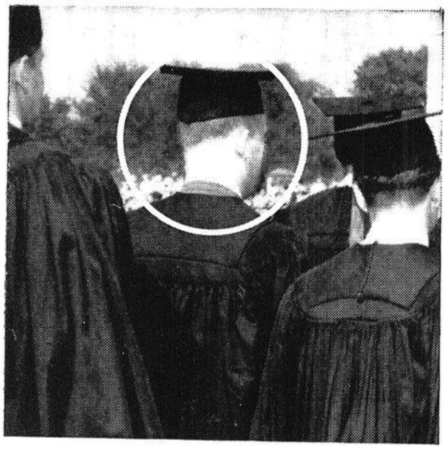
DANGER OF GOVERNMENT ENTERPRISE

Critics of T.V.A. cannot accurately state that T.V.A. is producing power less efficiently than a private company could. Why then, if it could hardly be said that T.V.A. is hurting the economy of the Tennessee Valley, though it is doubtful how much the valley is aided, should it be condemned? It should be condemned because 80 per cent of the people must pay nearly half of the electric bills of the other 20 per cent, and this payment has priority over their own electric bills (taxes by law must be paid—no law says that we must buy electricity). If an adjustment in T.V.A.'s rates were made to remedy this deficiency, T.V.A. would still be a government enterprise, which, if allowed in one area, will surely spread to others.

Other Federal Projects

Since T.V.A. was established, there have been several other fedearl power projects built after the T.V.A. pattern. Among them are the Columbia Valley Authority, the Bonneville Dam project, and others, totaling 20 per cent of the nation's power production; and there are more projects such as the Arkansas Valley Authority, and the Missouri Valley Authority in the planning or construction stage. It must be realized that these projects are being built with "phony" gifts of our own taxes, and in the process, we are accepting a socialized electric power industry without actually voting for it. There are some forces in our government which are striving for just such a goal. A former director

(Continued on page 26)



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Rotational Casting of Plastics

By RICHARD E. SOWLS, ME'64

THE technique of rotational casting itself is not new. It has been used for years by molders of candy to make such things as hollow chocolate Christmas and Easter figures, and by others to manufacture other hollow items. It is, however, only within the past few years that rotational casting has been used to mold plastisols and other plastics.

Evolution

Rotational casting evolved from a process called slush casting. In one method of slush casting, an open female metal mold is filled with a material that gels when heated. The mold is placed in an oven. Oven heat penetrates through the mold and gels the material adjacent to the mold face. When the gelled layer is thick enough, the remainder of the material is poured out of the mold to be used later, and the mold is placed back in the oven until the material is fused. The mold is then cooled, and the molded item is stripped out.

In rotational molding a mold that can consist of two or more pieces is partly filled with a plastic material, and the pieces are assembled to form a completely closed mold. While being heated in an oven the mold is rotated simultaneously in two or more planes. The rotation of the mold allows material to be deposited and gelled on all its inner faces. Gravity, not centrifugal force, is responsible for the coating of the mold wall. When sufficient time has passed to fuse the plastic material, the mold is removed from the oven, is cooled, and the molded article is stripped out. The way in which the layer of plastic material is deposited on the mold wall depends on the nature of the material, and will be described later.

Items made by rotation casting can be completely closed, while those manufactured by slush casting must have an opening through which excess material can be poured out. *The Plastics Engineering Handbook*, 3rd edition says of rotational casting in comparison to slush casting:

> This process has frequently replaced slush casting because it offers the following advantages for the manufacture of hollow items:
>
> 1. The weight of the finished article can be controlled by measuring the quantity of liquid plastisol loaded into the mold.
> 2. Contamination is reduced, since the mold is loaded and closed rather than repeatedly charged.
> 3. With well-designed equipment, the interior of the mold is evenly coated, and the percent of rejects is small.
> 4. Loss in scrap is small and trimming is minimized.
> 5. Less floor space is required than for a slush casting line.
> 6. The operation is cleaner and less wasteful of material, and involves less cost of labor.
> 7. The problem of viscosity stability which arises in slush casting, because of the heating of the working supply of plastisol, is eliminated.

ROTATIONAL CASTING MACHINES

The rotational casting process can be automated to a considerable degree, or much of the process may be carried out using manual labor. The equipment must perform the basic functions of rotating the mold and providing heat for gelation and fusing.

Rotating the Mold

Rotational molding equipment is available for continuous processing as well as for batch processing. The rotation equipment used in batch processing is less complicated than that used in continuous processing. In its simplest form, batch rotation equipment consists of an arm or shaft in an oven that rotates about a horizontal axis and carries with it a spindle that rotates about an axis that is perpendicular to the arm or shaft. A platform which incorporates a means of attaching the molds is mounted on the spindle. In some cases such a platform is mounted on both ends of the spindle to increase the capacity of the machine and to aid in balancing the load on the power source. Figure 1 is a view of the inside of a batch processing oven. Clearly shown are the horizontal shaft and mold mounting fixtures on both ends of the spindle. The spindle and the shaft may be constructed so that each turns in a fixed ratio to the other, or they may be separately driven so that they turn independently. The shaft and the spindle are driven jointly by a single polyphase AC motor or independently by separate motors. The drive is usually through a variable-ratio coupling mechanism to provide flexibility of rotating speed. A locking device is included in the drive train to fix the position of the platform while loading and unloading the molds.

In batch-type equipment, the rotation is started when the operator presses a start button. A pre-set timer sounds an alarm to notify the operator when the cycle is over,

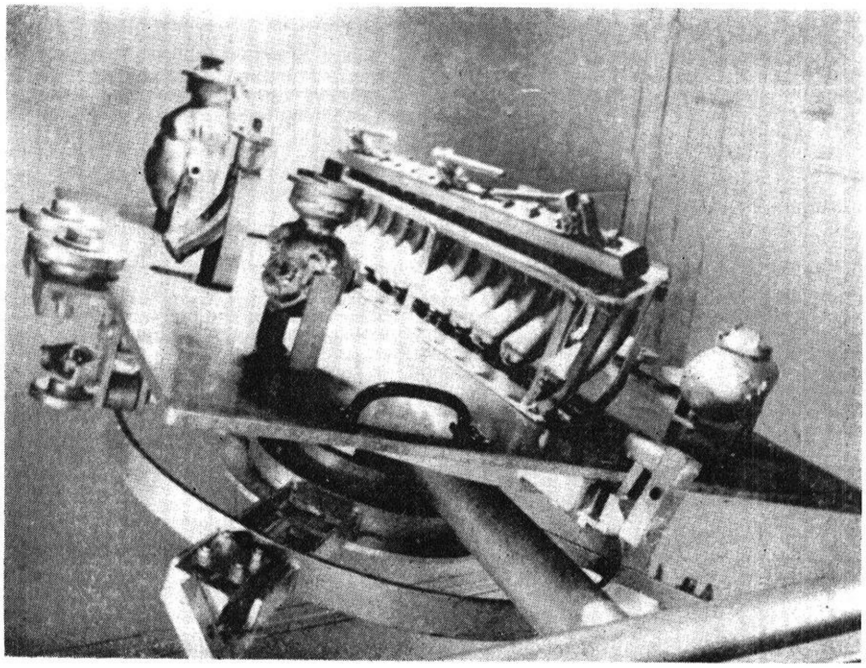


Figure 1. The inside of a batch processing oven showing a method of attaching a group of molds to a spindle. Notice the apparatus for spinning the oven on two axes.

and may also stop the rotation in the correct position for removing the mold.

Figure 1 illustrates one method of attaching a group of molds to a spindle. To install the molds, the spindle is stopped with the plate in a horizontal plane, and the plate is rolled over the roller in the foreground and onto the rollers on the spindle. The plate is locked in place by turning the locking lug in the lower right corner of the picture.

In the continuous type of rotational casting equipment, molds are carried through a molding cycle by a system of individual rotational stations which travel on a conveyor. A molding cycle consists of (1) charging and closing the mold, (2) rotation of the mold in a heated oven to gel and fuse the material, (3) cooling the mold, and (4) opening the mold to remove the cast part. The cycle time is dependent on the speed of the conveyor, which is adjustable. Cam-operated switches start and stop the rotation and control the position of each mold carrier. In contrast with batch-processing equipment, continuous processing equipment usually does not require removing of the molds from the rotating arm for loading and unloading.

Heat Transfer Methods

Rotational casting of plastic materials requires that the mold be heated to gel and fuse the material, and cooled so that the molded article can be removed in a rigid enough condition to retain its shape.

A number of methods are used for heating the molds. Hot air ovens have been used the longest. The hot air oven is usually less messy and quicker to warm up initially than are other types. The air is usually heated in a gas- or oil-fired furnace and circulated through the oven by a blower. The furnace and the blower are thermostatically controlled to obtain the desired oven temperature. A second heat-transfer medium that is commonly used is heat-transfer oil. The oil is heated either in a separate furnace or in the base of the oven, and then pumped through spray heads that are directed at the mold. The spray is turned off when molds are put in or taken out of the oven. The advantages of oil over hot air are, a shorter cycle time because of faster heat transfer, and closer temperature control. Unless the molds seal very tightly, however, oil may find its way into the mold and cause rejects by discoloring, creating blowholes, or otherwise damaging the molded items.

A third heat transfer medium used in rotational casting is fused salts. Some salts which are solid at room temperature, fuse at the temperatures commonly required in rotational casting. Fused salts are used in the same way as the oil described above. In comparison with hot air, fused salts give a shorter molding cycle time because of faster heat transfer, closer temperature control, and a simpler furnace.

Only two mediums, water and air, are used to cool the molds. Water is by far the most common mold-cooling medium. In batch type molding the molds are cooled either by spraying with water or by immersion in a tank of water. Small molds may be immersed manually, but large molds are usually immersed with a power-driven platform. The period of the immersion is controlled by a timer.

In continuous molding equipment, cooling is accomplished by spraying water on the mold from all angles as the conveyor carries it through a spray chamber. The degree of cooling is controlled by adjusting the cooling water spray rate and temperature.

In either batch or continuous processing, the molds are cooled until the casting is rigid enough to be withdrawn from the mold without being deformed, but not so rigid that removal is difficult. Molds that have undercuts, indentations or protuberances that impede withdrawal from a two-piece rigid mold, are usually stripped when warm because the flexibility of plastics is a strong function of temperature.

Cooling water may require softening in order to keep mineral scale from building up on the outside of the molds. When polyvinylchloride plastisols are being used, the cooling water may become acidic because of the presence of HCI. The presence of HCI is a result of decomposition of material that leaks from the mold. This acidic water should be neutralized to prevent it from damaging the molds. Water may seep into a mold during cooling or fall in when the mold is opened to remove the molded part. This water will cause damage to the next cast part if it is not blown out with compressed air or wiped out with a clean dry cloth.

MOLDS FOR ROTATIONAL CASTING

One of the first steps in manufacturing an item using rotational casting is making the molds. Many types of molds have been tried: sheet, fabricatons, castings, and electroformed, among others. Although each have specific advantages, moldmaking techniques need considerable refinement. Because there are enough mold makers in this field for the kind of extensive development required, much current development work is being conducted by molders themselves.

Forming the Mold

Molds are usually made of copper or aluminum to take advantage of high thermal conductivity and ease of fabrication. Iron, steel and some other metals are not used to make molds for plastisols because they tend to cause decompositions of the plastisols.

Copper molds are usually electroformed. They are commonly used where intricate detail is desired, as in molding of doll parts or other toys. Electroformed molds are produced by electrodeposition of copper over a form of wax or elastonomer. When the mold is completed, the wax form is melted out, or if an elastonomer form was used, it is merely pulled out. These molds are inexpensive, easily produced, and provide excellent detail. Because they present a problem in closing, they are not used extensively for parts larger than dolls and small toys.

Aluminum molds that are used in rotational casting are produced by direct machining of aluminum alloy stock, die casting, or high quality sand casting. Direct machining of aluminum stock is the most economical method of making molds where a relatively small number is desired, and the object to be molded is not too complex. Pressure-cast and die-cast aluminum cavities are used when the number of molds required is large enough to justify the die cost. Mold cavities that are made from high pressure die castings usually have very low molding surface porosity and produce high quality castings. Sand cast aluminum molds are often used because of low cost, although they have a disadvantage—sand-cast molds usually have minute surface porosity that may cause rejects due to blistering in the molded article. Blistering occurs when the air or moisture trapped in the pores of the mold expands on heating and pushes the gelled material away from the mold wall.

A newer method for manufacturing molds is spray metallizing. In this method, atomized molten metal is sprayed on a form until a layer of the required strength is built up. Because of the porosity of such molds, they have been used only to a limited extent, and where little or no internal pressure can be developed.

Finishing the Mold

The edges of the mold parts that fit together form what is called the parting line of the mold. The parting line should be machined so the mold will close tightly, preventing leakage while the plastic is in liquid form. Leakage is undesirable because it wastes material, causes flash that must be trimmed from the molded part, and may weaken the molded part near the parting line. Further, it involves local material loss, and makes for a messy operation.

The molding surfaces of the molds may be left as they were formed, or they may be polished to any degree. Highly finished molds produce a glossy finish on the product, while unpolished molds leave a dull or mat finish.

Molds for Controlled Wall Thickness

In some cases it is desirable to mold articles in which the wall thickness varies to meet physical requirements or to conserve material. One way that this can be done requires ingenuity in mold design. Because heat is transmitted more slowly through thicker mold walls, and because the thickness of the layer of material that gels to a mold wall depends on the amount of heat that it receives in a given length of time, molded articles of varying wall thicknesses can be rotationally cast in molds of varying wall thicknesses. A similar effect can be obtained by carefully painting the outside of the mold with an insulating coating. The use of such molds makes possible intricately shaped moldings of varying thicknesses.

Summary of Mold Requirements

The third edition of *The Plastics Engineering Handbook* summarizes molds for rotational casting as follows:

> In general, regardless of the material used the mold should meet the following requirements:
>
> 1. The material used should have good thermal conductivity.
> 2. The wall thickness should be the minimum necessary for strength and dimensional stability, and should be uniform.
> 3. Provision must be made for clamping the parts together firmly enough to prevent leakage from internal pressure.
> 4. The mounting must allow free circulation of the heating medium whether air or liquid, so that all surfaces are equally heated in order to achieve uniform distribution of the plastisol within the mold. Uniform deposition regardless of irregularities in configuration of the article is perhaps the most important requirement in rotational molding.

Mounting the Molds

Several individual-mold cavities are usually mounted on frames called spiders. In this way several articles may be molded simultaneously on each spindle. Because of variation in the gel and fusion time and temperature requirements of different molds, it is usually desirable to have only molds of one kind on a spider. However, several different items of similar size and weight may be molded simultaneously on one spindle. Usually the top section of a spider, carrying the upper halves of the mold, is hinged to the lower section, carrying the lower halves of the molds. Thus all the molds on a spider can be opened or closed by opening or closing the spider. Long bolts are often used to clamp the upper and lower halves of the spider together. In operation, these bolts may be installed and removed either by hand or by a compressed air or electric impact wrench. Cam locks and other quick-acting clamping mechanisms are also used. Molds are sometimes difficult to open because of friction or interference between the molds and the molded articles. For this reason, provisions are usually made for prying the spider halves apart.

ROTATIONAL CASTING WITH PLASTISOLS

Materials from a family known as plastisols are the most commonly used in rotational casting. Most of the knowledge of rotational casting of plastisols has been developed in the last ten years.

Plastisols

Plastisols are dispersions of powdered polyvinylchloride resins in suitable liquid plasticizers. In addition, a plastisol may contain fillers, pigments, stabilizers, lubricants, and extenders. Fillers are added for opacity or to make the plastisol less expensive. Pigments are added to obtain the desired color without the need to apply a finish coating. Stabilizers are either to prevent decomposition of the resin while fusing, or to control viscosity buildup of the plastisol during storage. Lubricants are added to aid in removing the molded article from the mold and to help prevent the surface of the finished article from being marred in use. Extenders are used for their effects on viscosity.

Plastisol resins are either of stir-in or grinding types. Stir-in resins are dispersed by simple stirring of the plasticizers, fillers, pigments, stabilizers, and lubricants until a uniform paste is obtained. Grinding types are first dispersed by stirring and then are dispersed further by grinding on a three-roll or a stone mill.

Plasticizer choice is critical when compounding plastisols for rotational casting, because of the viscosity (flow) characteristics which the plasticizer imparts to the dispersion. Low viscosity plasticizers give low initial viscosities in plasticols; however, a high salvating plasticizer (most low viscosity plasticizers are such) will tend to swell the resin particles on aging and cause an increase in viscosity. This is due to a decrease in the available liquid as well as to the increased resin particle size. The stabilizers and other compounding materials also have a pronounced effect on the viscosity and must be chosen carefully. Often nonsolvent type plasticizers, dilutants or extenders, are employed to control viscosity.

Most plastisols that are to be used for rotational casting are deaerated by applying vacuum to the stirred or ground mass. This operation may be accomplished by using a mixer that is airtight and maintaining a high vacuum while the mixing is taking place. Deaeration may also be done in a separate chamber after the mixing is finished. Deaeration is necessary because air bubbles that are entrained in the plastisol expand when the plastisol is heated and cause objectionable surface and subsurface defects (voids) in the finished product.

At room temperature plastisols may vary in consistency from near water-thin to heavy paste. Gelling, fusing, and coating a plastisol results in a solid mass, whose properties depend on the way it was compounded.

During gelation, which is brought about by heating, the solvating plasticizers are absorbed by the resin particles, which swell and soften. If heating is stopped after gelation has occurred, a plastisol is no longer fluid, but consists of a mass of individual resin and plasticizer particles hanging loosely together. The mixture has little or no structural strength.

During fusion this loosely joined structure more or less melts and flows together to become a homogeneous mass. When this mass is cooled it remains homogeneous and may have a tensile strength exceeding 4,000 psi.

Because the properties of plastic materials are strongly temperature-dependent, plastisols should be compounded for the specific conditions of their use. The 1960 edition of *The Modern Plastics Encyclopedia* lists the characteristics that are available in plastisols as follows:

> Plastisols may be formulated to have varied physical and chemical properties. Some of the properties available in almost any combination include:
>
> Tensile strength—as required to 4,000 psi.
> Elongation—as required to 600%.
> Hardness—(Shore A) from 10 to 100
> (Shore D) up to 80.
> Low temperature flexibility-to-65° F.
> Light stability—excellent.
> Chemical resistance—outstanding to most acids, alkalis, detergents, oils, and solvents.
> Heat resistance—available to 225° F for as long as 2,000 hours and to 400° F for as long as 2 hours.
> Dielectric strength-minimum of 400 V/mil when fused in sections 3 mils thick and over.
> Toxicity—may be formulated with FDA accepted materials.
> Color-all colors available including phosphorescent and fluorescent shades.

Casting with Plastisols

Rotational molding of plastisols may be accomplished by either a batch processing or a continuous processing method. Either process can be automated to a considerable extent. In both processes a molded article is produced by the same series of steps, namely:

1. Filling the mold—Usually the plastisol is at room temperature and the mold is warmer but not so hot that it cannot be handled with bare hands.
2. Closing the mold.
3. Rotating the mold *in an oven*—
3. Rotating the mold in an oven—The temperature of the oven varies for different ovens, products, molds and raw materials. For hot oil and fused salt ovens the usual temperature range is from 350° to 500° F. The rotation speeds of the axis and the spindle also vary with mold size and raw material properties.
4. Cooling the mold—The mold is cooled until the molded item is rigid enough to maintain its shape but not so rigid that removal from the mold is difficult.
5. Opening the mold.
6. Removing the molded part—Water that may have entered the mold in the cooling process is blown out with a jet of compressed air.

The mold is still cold when it begins rotating. The rotation speed is set so that plastisol flows around the molding surface and a layer of plastisol clings to it. Rotation that is fast may result in uneven molded wall sections because the plastisol cascades from wall to wall rather than flowing smoothly. Rotation that is too slow may result in uneven molded wall sections because the plastisol gels solid before it has had time to be evenly distributed.

The mold is kept in the oven only long enough to fuse the plastisol. The oven time required to mold an item varies depending on its size, on mold and plastisol characteristics, and on oven temperature. Oven times generally range from 5 to 20 minutes.

The proper combination of oven temperature, rotation speed, and time in the oven for a particular item made from a particular plastisol compound are determined experimentally. The plastisol compound is designed or selected on the basis of the required physical properties and molding characteristics.

ROTATIONAL CASTING WITH POWDERS

Like plastisols, some powdered thermoplastics have properties that permit them to be molded. Rotational casting with powder is much newer than with plastisols; consequently, powders are not as well-developed as plastisols.

Powders

Vinyls, high-density polyethylenes, low-density polyethylenes, propylenes, ethylene copolymers, and butyrates have all been pulverized and tried as powders for rotational casting. Because so much material surface is available to the atmosphere in powder molding, most materials tend to oxidize and be degraded. The only material that has been found capable of withstanding the operating conditions of the powder molding process is low-density polyethylene.

Because the annual tonnage of material consumed for powder molding is still relatively low, the resin manufacturers have not expended much effort to produce resins especially for powder molding. Most of the resins suppliers offer for powder molding are stock resins normally used in film extrusion and in blow and injection molding. Recently several basic resin producers have acquired rotational casting equipment and are evaluating various stabilizer and resin systems. This may mean that materials other than low-density polyethylene will soon be available for powder molding. Two million pounds of resin were consumed in powder-molding applications in 1963. A demand of ten million pounds is predicted for 1965.

Casting with Powdered Polyethylene

Powdered polyethylene is rotationally cast in much the same way that plastisols are. With minor modifications, the same heating, cooling, and rotating equipment can be used to process both materials.

Some molds that are suitable for plastisols are not suitable for polyethylene. Molds for polyethylene should be of split design with the opening coinciding with the largest dimension of the product. This is because polyethylene is not flexible enough to be removed from the narrow-opening molds sometimes used with plastisols.

Except for a few details, the same sequence of events occurs when manufacturing an item using powdered polyethylene as when using plastisol. Charging a mold with polyethylene powder cannot be done with a metering pump as with plastisols. The amount of material required to make the molding may be pre-weighed or premeasured into a container and put into the mold by hand or by machine, or it may be metered into the molds by a device capable of measuring and injecting powdered materials.

Oven temperatures for polyethylene range from 500°F to 750°F, a little higher than for plastisol. When a cold mold containing polyethylene powder is rotated, the powder flows around inside the mold much like a fluid would, except that none of it adheres to the mold wall. When the mold is heated in an oven the plastic particles that are flowing around melt and adhere to the mold wall. After a heating period of from three to ten minutes the polyethylene powder has melted and forms a uniform continuous coating over the interior surface of the mold.

When the molds are removed from the ovens they are cooled either by a water spray or by submerging in a tank of cold water. Rotation during cooling is more desirable when using polyethylene than when using plastisol, because polyethylene creeps much more rapidly at elevated temperatures than does plastisol.

Because polyethylene is less flexible at stripping temperatures than some plastisols, it may be more difficult to strip (remove from the mold) a polyethylene product than to strip an identical plastisol product.

Polyethylene powder has some advantages over plastisols for rotational molding. For one thing, there is no viscosity buildup to limit the storage life, as with plastisols. Also polyethylene's lower density means that a polyethylene part will weigh less than an otherwise identical plastisol part. This and polyethylene's lower cost per pound ($.20–$.25 for polyethylene versus $.30–$.35 for plastisol) makes powdered polyethylene a less expensive material for rotational casting.

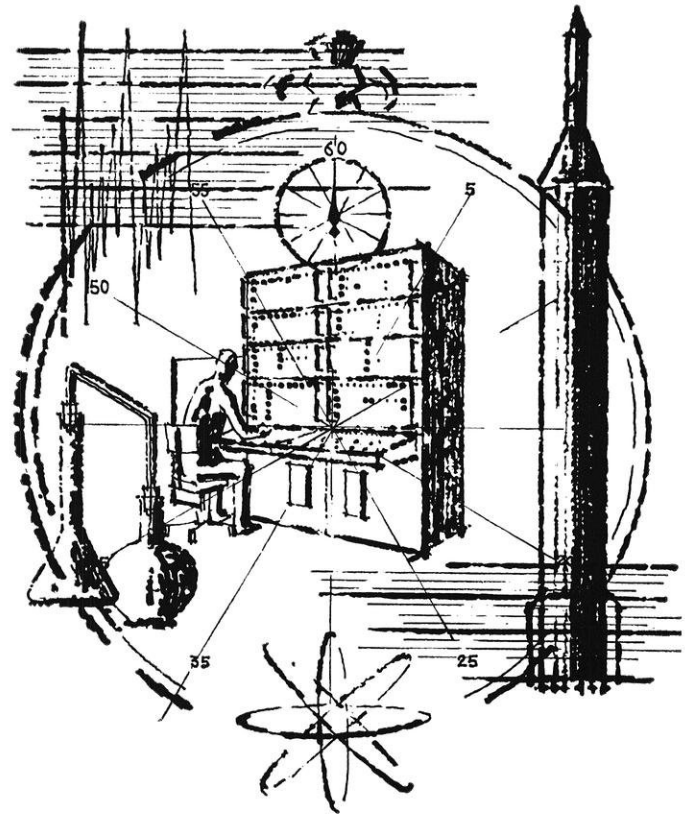
Applications of Rotational Casting

Toys and novelties were the first items to be rotationally cast. More recently the process has been used to form more utilitarian items. Although rigid and resilient *closed* hollow items are its domain, rotational casting can also compete with other forming processes in the manufacture of open hollow items.

The Structo Toy Company of Freeport, Illinois, has for several years been rotationally casting wheels and tires of rigid plastisol for its line of rolling toys. Similar tires are also used for lawnmowers, coasterwagons, barbecue grills, and for other low-speed and low-load applications. Figure 1 shows a mold for rotational casting of doll arms, legs, heads, and bodies. Other examples of playthings that are rotationally cast are basketballs, beachballs, volleyballs, and hobby horses. Small figures of animals and people, both for play and display, are rotationally cast in polyethylenes and plastisols. Artificial fruit and flowers, and window display mannikins are also beginning to be manufactured in this way.

Open hollow items can be formed by casting the openings with weak edges so that they may be easily punched or cut out. When symmetry permits, two or more parts with openings can be cast in a single mold so that the parts are joined at the opening by a weak section. A weak section is formed by incorporating a narrow little ridge in the mold that will

(Continued on page 26)

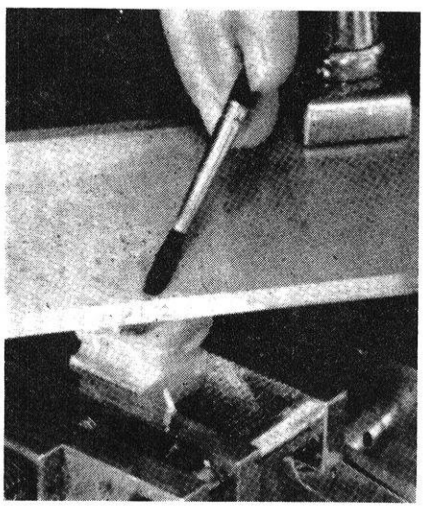


SCIENCE HIGHLIGHTS

By Robert Rosenberg, ME'65

NEW MEDICAL TOOL

In hospitals throughout the nation, a few pounds of tool steel are helping to slice human tissue thinner than tissue paper. This will permit operating surgeons to learn if a tumor is malignant or not, while the patient is still under anesthetic. Other tests, just as dramatic, are being performed daily, thanks to this special tool steel that holds its sharper-than-a-razor edge. Allegheny Ludlum supplies its "Crow" grade steel to the University of Michigan Medical Center for this special use.



Above is a knife made of crow steel.

During an operation, a section of removed tissue is frozen solid or encased in paraffin and put on the specially designed cutter which slices the sample ultra thin. These slices fall into a special sugar solution and are carefully lifted onto glass slides. Pathologists view the slides under a microscope for the fateful answer. All this takes less than five minutes, and the answer is telephoned immediately to the operating room. The surgeon proceeds with the operation knowing the nature of the tumor with which he is working.

Crow steel is a carbon steel with about .50 percent of chromium which provides the high degree of hardness necessary and contributes to the control of depth of hardness for a sharp long lasting edge. The machine with which the Crow steel knife is used is called a sliding microtome; the knives are of various sizes ranging from 4½ to 2½ inches in width with a gauge of ½ to ⅜-inch. The knife is wedge-shaped when finished and the sharpened edge is feathered and honed to ultra sharpness. It takes from two to four hours to put the special edge on the knife.

FUEL CELL

The latest General Electric fuel cell, announced this April, is designed to run on inexpensive hydrocarbon fuels such as propane and natural gas, and it runs to a surprising degree even on gasoline and diesel oil. It operates at atmospheric pressure and in the moderate temperature range of 250–400 degrees Fahrenheit.

Although commercial diesel oil, kerosene and gasoline have worked unexpectedly well in these cells, the performance is improved by the removal from these fuels of certain complex ingredients and additives.

Meanwhile, the simple hydrocarbon fuels—such as propane, methane, and octane—appear to react completely in the new cell, forming harmless carbon dioxide and water, while producing power at efficiencies in the range of 40–50 per cent.

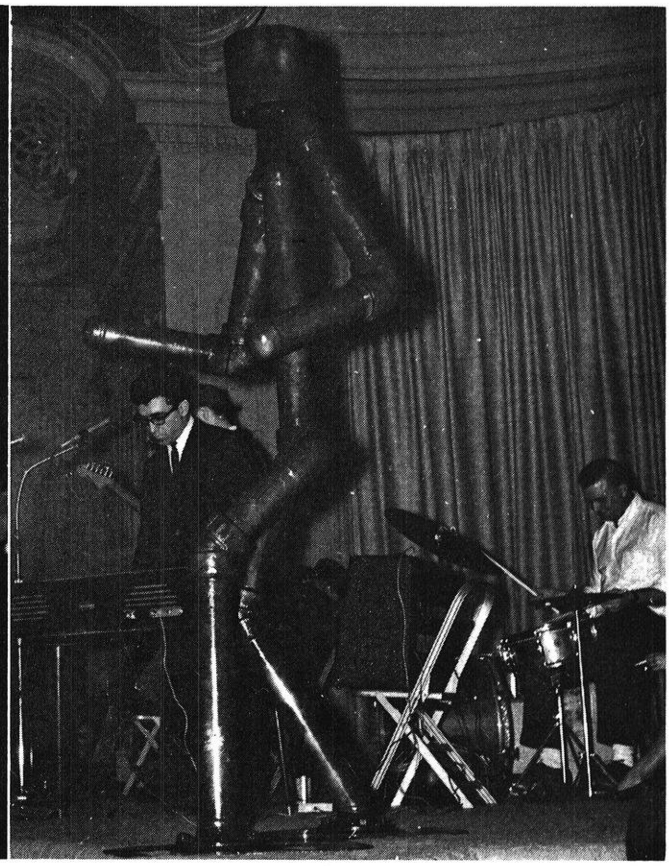
The new fuel cell depends for its operation on a combination of factors, including a novel electrode structure and a liquid electrolyte. While excellent results have been achieved with a phosphoric-acid electrolyte, other electrolytes also show substantial promise.

Current densities up to 25 watts per square foot—50 amps at 0.5 volt—have been achieved with the new cells.

Saint Pat's Dance and Beard Contest

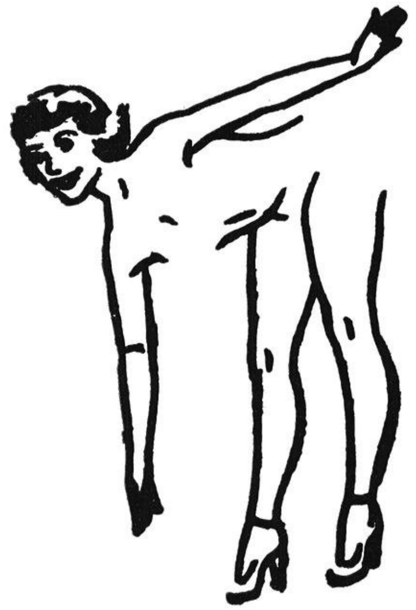
Receiving awards are (left to right): Donald Christopher, Richard Clarkowski, Art Mueller, Chuck Ebert, and Earl Rothweiler. Handing the awards out is Jim Williams.

"I don't care if you won the softest beard category, you stay away from me until you shave."



"Geee . . . . it tickles." "Look Mom, I can twist."

Bushy, High brow, and Satan receiving recognition.



Fill in your Own Lines

Helpful Coed: "Isn't it funny that the length of a man's arm is just equal to the circumference of a girl's waist?"

E.E.: "Let's get a piece of string and find out."

* * *

A lady buying tickets for her nine children explained to the station agent, "These three are all twelve years old and will take full fare; these three are all eight years old and will take half fare," then pointing to the youngest trio, "these three are all four years old and should go free."

The station agent looked at her in amazement and said, "Madam, do you mean that you have three every time you try?"

"Oh no," she replied, "lots of times we don't have any."

* * *

He only drinks to calm himself,
His steadiness to improve.
Last night he got so steady,
He couldn't even move.

* * *

She: "I'm so discouraged. Everything I do seems to be wrong."

He: "What are you doing tonight?"

* * *

Opera is where a man is stabbed in the back and instead of bleeding he sings.

Ginger ale: "A drink that tastes like your foot feels when it's gone to sleep.

Alcoholic rheumatism: Getting stiff in every joint.

* * *

The farmer was "assisting" at the birth of his latest child—he was holding the lamp. When the doctor delivered three fine babies, the farmer suddenly left the room.

"Come back with the lamp!" yelled the doctor.

"Nope," was the reply. "Ain't comin' back, Doc! It's the light that's attractin' them."

* * *

Of all the "Give me a sentence with a word" jokes we've heard, we give the prize to the lad that put effervescent and fiddlestick in one sentence. "Effervescent enough covers on your bed, your fiddlestick out."

* * *

Relative humidity is best demonstrated when you hold your baby in your lap.

* * *

"Won't your wife hit the ceiling when you get home tonight?"

"She probably will; she's a poor shot."

* * *

On the tombstone of an atheist: "All dressed up and no place to go."

Father: "When Abe Lincoln was your age, he was making his own living."

Son: "Yes, and when he was your age, he was President."

* * *

People are like steamboats—they toot loudest when they are in a fog.

* * *

A Long Island Potato married an Idaho Potato and eventually the two became the proud parents of Sweet Potato. Sweet Potato grew up and one day announced her intention of marrying Gabriel Heatter. "But you can't marry him," her shocked parents wailed. "He's only a commentator."

* * *

Girl answering telephone: "Sorry, Betty is not here. This is her 114-pound, five-foot-three, blonde, blue-eyed sister."

* * *

Two guinea pigs stood watching a rocket thunder off the pad carrying their friend guinea pig to certain death.

Guinea pig 1: "Isn't it awful?"

Guinea pig 2: "Don't feel so bad, it beats cancer."

* * *

He who laughs last has found a double meaning.

(Some more on page 27)

T.V.A.

(*Continued from page 14*)

of T.V.A., Mr. David Lilienthall, imagines in his book, *Democracy on the March*, that the vast growth of federal power projects must not go back to private companies or even the municipal and state legislatures elected by the people. Instead they must be administered by directors appointed by the President. From our experience with T.V.A., it can be seen that this situation could be dangerous. T.V.A., originated for the purpose of flood control, is now producing 72 per cent of its power with steam generators. It is unlikely that Congress would have passed the original T.V.A. Act had it imagined that the primary purpose of T.V.A. would be to produce power; it is a little frightening to see how powerful and independent of surveillance the T.V.A. has grown. Other nations are denationalizing their companies and we, the leaders in free enterprise, are socializing ours.

Experience of Other Nations

Germany is perhaps the best example today of what free enterprise can do for an economy. It has one of the largest growth rates in the world and there is a cry going out to other countries to fill the jobs new businesses have created. Volkswagen was just recently denationalized, and it isn't necessary to point out what a smashing success it has been.

Great Britain was socializing all its industry during and shortly after World War II, but it has stopped and is now in the slow process of giving the industries back to the people.

Socialism is Not America's Standard of Progress

Other nations of the free world have learned from us that the free trade incentive system is the best way to make a nation grow strong. It is not government that makes a nation mighty but rather the ability of the nation's peoples to take care of themselves. It sounds very strange indeed to hear that at a recent power convention in Mexico, the United States was explaining the wonders of the publicly owned T.V.A., and Russia was preaching the identical sermon about its government-owned utilities. Other countries must clearly understand that this nation was built by individuals who guarded jealously their right to vote for their leaders and to manage their own affairs. It is almost too late to do anything about T.V.A., but Americans would do well to examine the facts closely before they allow any more T.V.A.'s.

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Rotational Casting

(*Continued from page 20*)

not carry enough heat to form a layer of full thickness on its edge. Plastic boots may be cast joined at the tops in this way and then split apart. Other items that are sometimes rotationally cast with a weak section and then opened, separated, or flexed at the weak section are buckets, wastebaskets, musical instrument cases, and small pieces of luggage. Industrial chemical containers such as acid flasks are rotationally cast in sizes up to 20 gallons. With the advent of more efficient machinery and more economical powdered plastics, molders using rotational casting are expected to compete with other container manufacturers for container sizes from one quart to 55 gallons. Products of rotational casting for industrial use include automotive heating ducts and heater housings, battery-testing unit housings, and liners for supporting containers. The only limitations on the size of industrial parts that can be rotationally cast are imposed by the size of the oven and the capacity of the rotation mechanism. Figure 8 shows a relatively large casting by today's standards.

Rotationally cast parts are sometimes filled with plastic foam. These foams in unexpanded form are poured or injected into the part through a small opening and allowed to expand to fill the cavity. A number of different materials are used, and will not be discussed here. The foam is usually a soft variety and is used for its cushioning effect. Boat bumpers are a rotationally cast item that may use foam for a cushioning effect. Rigid foam may be used to make thin-shelled products stiffer. For example, the Wonder Products Company of Colliersville, Tennessee, has used a fairly rigid foam to stiffen the rotationally cast body of their hobby horse. Rotationally cast channel marking buoys have also been filled with foam to make them stiffer with a small increase in weight and cost. A foam-filled rotationally cast easy-chair is a future possibility.

Foaming agents may also be included in the plastisol that is used to rotationally cast a part. The purpose in doing this is to change the texture, the conductivity, or some other characteristic of the part. A soft, flexible, cellular product similar in texture and appearance to soft leather can be made in this way. A more rigid cellular material can be made that has heat- and sound-insulating properties that make it suitable for industrial items such as heater ducts and machinery noise shields.

Some conventional formulations of plastisols are employed with blowing agents. The best results are obtained by using blowing agents that are activated at relatively high temperatures—about 450°F. This type blowing agent allows a skin to form next to the mold before the blowing material releases any gas. This prevents gas pockets and porosity on the surface of the molded article and results in a smooth, even finish.

With a good portion of the toy market already captured, industrial castings seem to offer the greatest potential market for rotational casting. The wide range of physical and chemical properties obtained from plastisols and polyethylenes and the wide range of design possibilities that can be formed indicate that rotational casting will probably replace many tedious fabricating and assembly processes using metals, leather, and ceramics.

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Fill In Your Own Lines

(Continued from page 25)

Editors call themselves "we" so the person who doesn't like the article will think there are too many for him to lick.

* * *

Been doing quite a bit of research on the origin of old sayings and phrases, and think I've stumbled upon the beginning of that great old cheer, "Hoorah for our side;" I guess it was first heard on the day Lady Godiva rode side-saddle through the streets of Coventry.

* * *

A patient at a mental hospital who had been certified cured was saying good-by to the head psychiatrist.

"And what are you going to do when you get out in the world?"

"Well I may go back to Wisconsin and finish my CE course. Then, I liked the Army before, so I may enlist again. He paused a moment and thought. "Then again, I may be a teakettle."

* * *

When I grow old and even older,
I'll never forget that manila folder.
Bane of existence, object of hate
And never less than three weeks late.
Title, object, method, theory,
The clock strikes one, my eyes are bleary.
If I could have my preference
I'd never write a reference,
Never compute efficiency
For readings numbering eighty-three,
But many like that I have done,
At least infinity plus one,
Many to tell the dullest dullard
That graphs are labeled and curves are colored.
Engineers arise—storm the fort;
And abolish forever the lab report.

* * *

A farmer and a professor were sharing a seat on a train. It was getting lonesome so the farmer started a conversation and they soon became a friendly pair.

"Let's have a game of riddles to pass the time," said the professor, "if I have a riddle that you can't guess you give me one dollar or vice versa."

Jim: "Honey, did that kiss I just gave you make you long for another?"

Coed: "Sure did, but he goes to Marquette."

* * *

A shovel operator sitting at the bar was surprised to see a kangaroo enter the establishment and approach the bar. Taking his place next to the shovel operator the kangaroo ordered a bourbon.

"How much?" the kangaroo asked the bartender as the drink was set before him.

"Two bucks," answered the bartender.

The kangaroo reached in his pouch, withdrew his wallet and laid two bills on the bar. Then, downing the drink the kangaroo turned to leave.

The shovel operator, watching, bug-eyed, turned and said, "Pardon me, but I'm around here quite a bit and I never saw any kangaroos in here before."

"I'm not surprised," answered the kangaroo, "when they charge two bucks a drink."

* * *

The education system today is based on fear.

The teachers are afraid of the the superintendent. The superintendent is afraid of the parents. The parents are afraid of the kids and the kids, they aren't afraid of anything.

* * *

A student that flunks out of Engineering and goes into Law, raises the overall I. Q. of both departments.

* * *

I think that I shall never see
A girl refuse a meal that's free:
A girl with hungry eyes not fixed
Upon the drink that's being mixed;
A girl who doesn't like to wear
A lot of junk to match her hair;
But girls are loved by guys like me
'Cause I don't like to kiss a tree.

* * *

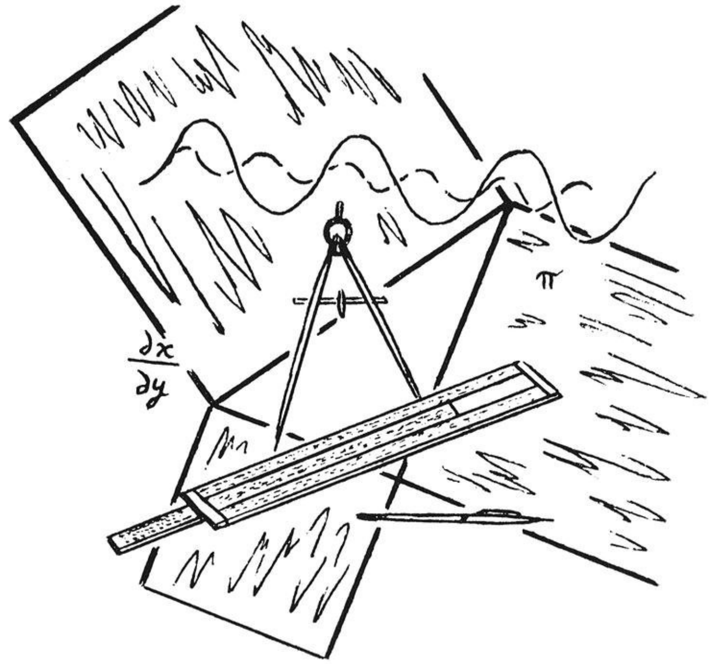
Mother: "Billy, what are you reading?"

Billy: "Playboy, Momma."

Mother: "Oh, that's all right, dear. I was afraid you had got hold of a *Wisconsin Engineer.*"

THE

MENTAL MAZE



By Clifton Fonstad, Jr., EE'65

THIS month there will be no fooling around and we'll get straight to the puzzles—right after one short mathematical poem. It demonstrates in a concise manner the way in which relatively considerations alter the classical answer to an ordinarily simple addition, and it goes like this:

One and one make two,
But if one and one should marry,
In a year or two,
There's two and one to carry.

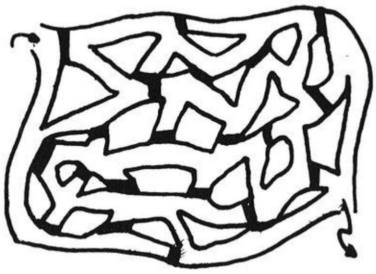
Now, let's get started on the first puzzle—the first turn in this month's mental maze.

1. There's a story going around the Nuclear Engineering Department about a large fish one of the professors caught the other weekend. In true engineering form, the fish is described as follows: Its head was 6 inches long, its body as long as its head and tail, and its tail as long as its head and half its body.

How long was the fish?

2. So much for the animal kingdom for awhile. Here's a puzzle designed to challenge electrical engineers (actually anyone can work it): Your bed and light switch are 12 feet apart. How can you switch off the light and get into bed before the room is dark? You can't move the bed.

3. Two months ago the first "logic" type puzzle appeared in the Mental Maze. Last month, as you all know, the first Maze Master was announced. This month's big thrill is the appearance of a maze. Give yourself 15 seconds and try to make it through the diagram below.



4. Alright, things have been pretty easy until now but this puzzle should make you earn the five dollars. It really isn't that bad so give it a try.

A rope is hanging over a pulley with a weight at one end and a monkey at the other (the monkey and the weight weigh the same). Now suppose the rope weighs 4 ounces per foot and the age of the monkey and the monkey's mother together is four years; and the weight of the monkey is as many pounds as the monkey's mother is years old; and the monkey's mother is twice as old as the monkey was when the monkey was half as old as the monkey will be when the monkey is three times as old as the monkey's mother was when the monkey's mother was three times as old as the monkey; and the weight of the weight and the weight of the rope is half as much again as the difference between the weight of the weight and the weight of the weight and the weight of the monkey.

Oh yes, before we forget—what is the length of the rope?

5. Now, for one, final quicky. There are three urns, each containing two balls. One urn has one black ball, one white; another, two white; and the third, two black. The urns are labeled but, all the labels are incorrect. How many times must you draw from the urns before you know the exact contents of all three urns?

ANSWERS:

The March answers are:

1. 27
2. Baloney
3. $[(2^2)^2 - 2]/2 = 7$ and $2 + 2/2 + 2^2 = 7$
4. Twice
5. 27, 9, 3, 1

Next month we'll have to print the answers with the puzzles so this is your last chance to win five dollars for sending in the correct answers to the Mental Maze. Competition is getting keener so you'd better hurry. The address is still the same: Clifton Fonstad, Jr., % Wisconsin Engineer, 333 Mechanical Engineering Bldg., Madison 6, Wisconsin. February's winner was Ron Rogers, 303 Sullivan Hall, Madison. Ron's winning makes it two ME's in a row.

After McNair designs it, Kelly has to manufacture it

In the broad spectrum of engineers and scientists we constantly seek, we can use more manufacturing engineers like Edward Joseph Kelly (right, six years out of Tufts this June). Mark well the distinction between Kelly's responsibility and that of his opponent in the debate pictured. Out of it upon completion of their differing assignments will come a photographic information storage and retrieval device that will bear our "Recordak" trademark, well known in banking and other businesses.

Dave McNair has determined how the mechanical, optical, and electrical components and subassemblies have to work and fit together for the equipment to do its job. He has come up with a working model. Management likes it.

Enter Kelly. His task: to tell us exactly down to the last detail what we have to do to multiply McNair's working model by *x*, a number chosen by the marketing people. To make the production-run machines work not merely as well as McNair's hand-built one, but better. To decide which parts we should buy and which we should make. To specify the tooling for the parts we make. To specify also the tools for assembly and inspection. To design the fabrication processes. Better than just designing the processes, to see the need for a process which no previous manufacturing engineer had realized was needed and which happens to make the product an irresistible bargain for the ultimate user and a money-maker for us.

We need that kind of manufacturing engineer so that we can teach him how to run a big business.

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Define Your Career Objectives!

■ An interview with W. Scott Hill, Manager—Engineering Recruiting, General Electric Co.

W. Scott Hill

Q. **Mr. Hill, when is the best time to begin making decisions on my career objectives?**

A. When you selected a technical discipline, you made one of your important career decisions. This defined the general area in which you will probably begin your professional work, whether in a job or through further study at the graduate level.

Q. **Can you suggest some factors that might influence my career choice?**

A. By the time you have reached your senior year in college, you know certain things about yourself that are going to be important. If you have a strong technical orientation and like problem solving, there are many good engineering career choices in all functions of industry: design and development; manufacturing and technical marketing. If you enjoy exploring theoretical concepts, perhaps research—on one of the many levels to be found in industry—is a career choice to consider. And don't think any one area offers a great deal more opportunity for your talent than another. They all need top creative engineering skill and the ability to deal successfully with people.

Q. **After I've evaluated my own abilities, how do I judge realistically what I can do with them?**

A. I'm sure you're already getting all the information you can on career fields related to your discipline. Don't overlook your family, friends and acquaintances, especially recent graduates, as sources of information. Have you made full use of your faculty and placement office for advice? Information is available in the technical journals and society publications. Read them to see what firms are contributing to advancement in your field, and how. Review the files in your placement office for company literature. This can tell you a great deal about openings and programs, career areas and company organization.

Q. **Can you suggest what criteria I can apply in relating this information to my own career prospects?**

A. In appraising opportunities, apply criteria important to you. Is location important? What level of income would you like to attain? What is the scope of opportunity of the firm you'll select? Should you trade off starting salary against long-term potential? These are things you must decide for yourself.

Q. **Can companies like General Electric assure me of a correct career choice?**

A. It costs industry a great deal of money to hire a young engineer and start him on a career path. So, very selfishly, we'll be doing everything possible to be sure at the beginning that the choice is right for you. But a bad mistake can cost you even more in lost time and income. General Electric's concept of Personalized Career Planning is to recognize that your decisions will be largely determined by your individual abilities, inclinations, and ambitions. This Company's unusual diversity offers you great flexibility in deciding where you want to start, how you want to start and what you want to accomplish. You will be encouraged to develop to the fullest extent of your capability—to achieve your career objectives, or revise them as your abilities are more fully revealed to you. Make sure you set your goals realistically. But be sure you don't set your sights too low.

FOR MORE INFORMATION on G.E.'s concept of Personalized Career Planning, and for material that will help you define your opportunity at General Electric, write Mr. Hill at this address: General Electric Co., Section 699-10, Schenectady, N. Y. 12305.

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