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# engineer

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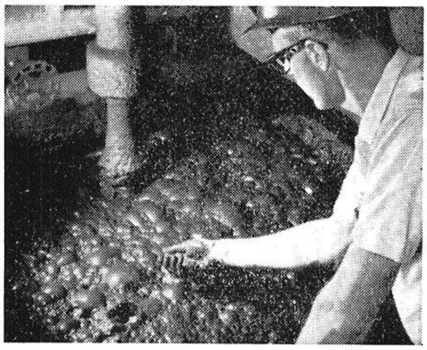
# Opportunities at Anaconda

**in mining and metallurgy here and abroad, at Anaconda American Brass Co., Anaconda Wire & Cable Co., and Anaconda Aluminum Co.**



## Extractive metallurgy is a key to more metal

The metallurgical bubble bath above is a flotation cell in a new Anaconda concentrator. Although it may seem crude and simple to a layman, the process involves complex combinations of colloidal and surface chemistry, crystallography, physics, and special grinding methods adapted to the ores at each individual mine. It represents one way Anaconda's metallurgical research is helping make more metal available for our growing economy.

At Butte, Mont., such research, in raising recovery of metal from low-grade ores, is making today's submarginal material part of tomorrow's ore reserves.

As Anaconda's intensified geological research and exploration turns up new prospective mineral deposits, the need for metallurgical research and development grows. Each deposit must be analyzed to determine the feasibility of recovering its metal. And as research develops more efficient extraction processes, lower grade and more complex deposits can become mines.

To accomplish this, Anaconda is establishing a central extractive metallurgical research center at Tucson, Arizona. It is carefully planned and is being superbly equipped. It is near a large university staff, which can be consulted as needs arise, thus offering a stimulating environment for progressive research and development. In turn, this means attractive new openings for a variety of engineering talents—not only in metallurgy, but also in chemistry, physics, and mechanical engineering.

## Dynamic test yields new data on copper-metal springs

Copper metals are among the most useful spring materials known to man. The role of modulus of elasticity in this application was studied at the Research and Technical Center of Anaconda American Brass for more precise data and to make possible predicting spring performance at various ambient temperatures.

Modulus of elasticity can be determined by physical testing in tension or compression. But Anaconda found the dynamic method (below) easier to perform and just as accurate.

Results are of prime importance to designers of spring devices. The significantly lower modulus of elasticity for copper metals means that at the same level of stress, copper alloy components will deflect or extend almost twice as far as components made of steel—usually with no sacrifice of maximum stress. This can mean more sensitive controls—or "softer" action in the absorption of energy.

This is but one way Anaconda is refining and broadening knowledge of the many useful properties of copper metals. Such research opens vast new opportunities for growth—career opportunities at Anaconda American Brass for college graduates in all fields of engineering, in business administration, and sales.

**The talents and skills of technically qualified men and women will always be needed by Anaconda in important positions in exploration, mining, extractive metallurgy, manufacturing, scientific research, sales, and administration.**

**If you would like more information about Anaconda or wish to apply for employment, write to: Director of Personnel, The Anaconda Company, 25 Broadway, N.Y., N.Y. 10004.**

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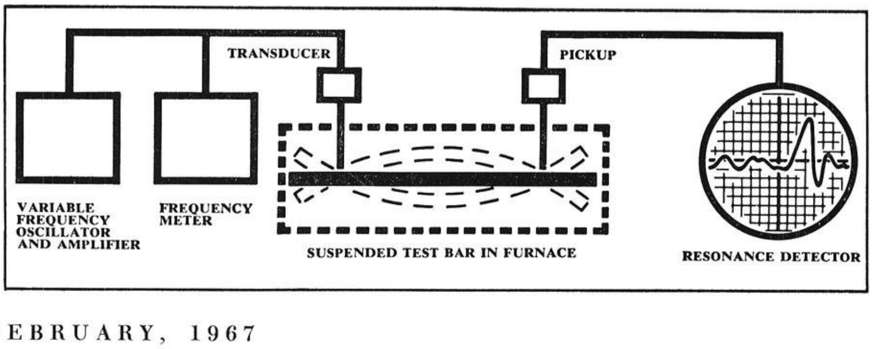
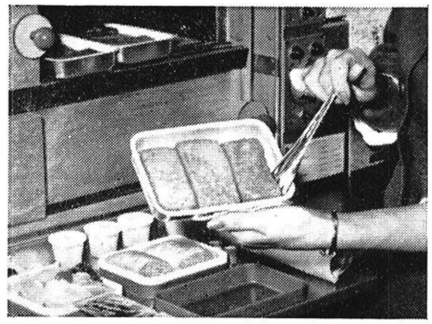



Left: Dynamic test for modulus of elasticity. Oscillator changes frequency until test bar begins to vibrate. From natural frequency shown on oscilloscope, "dynamic modulus" can be computed.



## Bright future for a bright metal

How do you make containers to hold motor oil or citrus concentrates at lower costs? How can you package airline in-flight meals to enable reconstituting of foods at very high temperatures for fast serving—and retain quality and flavor? These are typical questions asked and answered in the Packaging Development Laboratory of Anaconda Aluminum.

A growing factor in the aluminum industry, Anaconda Aluminum is particularly strong in packaging—with plain foil, laminated foil and rigid foil container products. And it has developed several firsts in the aluminum industry. One is the patented foil-fibre container for motor oil and for citrus concentrates. Another is foil containers (see above) for better airline service in the jet age. Now frozen and refrigerated meals can be heated rapidly and served quickly. Anaconda Aluminum has an outstanding record of developments which have had a tremendous impact on the packaging industry.

Anaconda Aluminum is also a producer of primary aluminum. To meet the growing demand for the metal in packaging, transportation, electrical, and building products, Anaconda Aluminum has been steadily increasing its output—is currently expanding its primary ingot capacity by two-thirds. This expansion involves an investment of $50,000,000.

Anaconda Alumium is growing, and will become an increasingly important factor in the bright future of the bright metal. For this it needs people—not only for its packaging laboratory and foil operations, but also for its other fabricating plants and reduction operations. This means growing opportunities for metallurgists, chemical engineers, industrial engineers, plant engineers, and system engineers. 66125

# FEATURES:



# REAPPEARING NONENTITIES:



# wisconsin engineer

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# EDITORIAL

## THE MAKINGS OF A GOOD PROFESSOR

WHAT makes a good professor? Is it that he knows the material, or that he makes his course interesting, or that he picks a good text? Those are all true, but there must be something more. To me, a good professor feels his subject is so essential that he must teach on a level for everyone's understanding and not for just a smattering of "A" students. If he can do this the other qualities must follow.

You might ask why this is worth mentioning in an editorial—after all, teachers won't revamp their ways because of a few comments. You're perfectly right. The reason we bring it up is something along the lines of "a job well done deserves credit". Several of the staff have been privileged to take a course from Professor Wu, Statistics 110, and we feel that he is one of the few professors to make us feel that his subject was something we *had* to learn.

Professor Wu believes that basic courses *must* be taught for the average students, the "C" students, in short the majority . . . so that this majority has a firm basis on which to become excellent. He seems to have the feeling for the way an engineer thinks. Accordingly, he teaches mainly through examples that you, as an engineer, may someday encounter, and leaves the complicated proofs to the "A" students (on their own time). In short, he isn't concerned that you can derive the Poisson distribution, but that you know which industrial problems can be solved with it . . . a far cry from the many proof-happy engineering basics.

We would venture the thought that because of his theories and method of teaching, Professor Wu has inspired an interest in Statistics in many otherwise-bored students. So, going back to our original question—What makes a good Professor?—my answer is simply: There is no *specific* list of good qualities, but we of the Wisconsin Engineer would point to Professor Wu as *our* answer to the question.

*Mary E. Ingeman*

*(Editor's note: Though not a common editorial subject, the staff and myself felt that Prof. Wu deserved this tribute to an excellent job of teaching.)*

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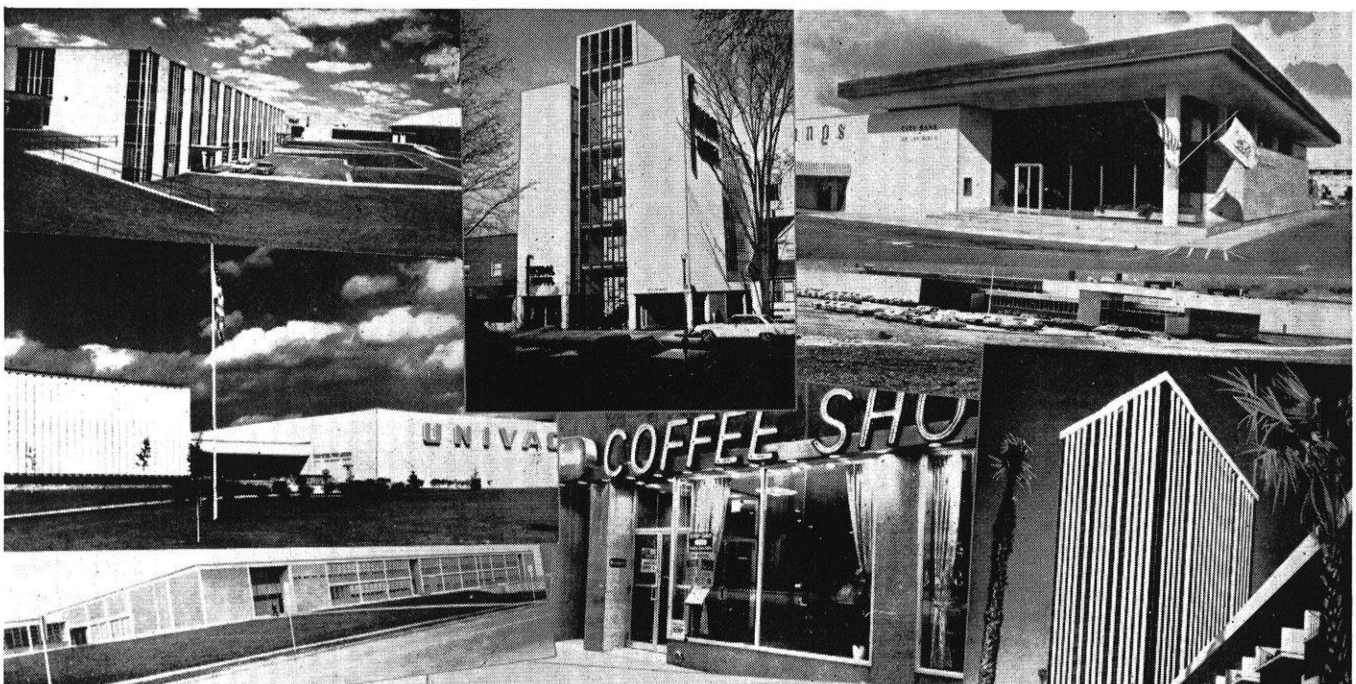

Returns by popular demand . . .

# DEAN'S DESK:

DEAN RATNER

## Responsibilities

An attractive young lady recently came into my office, introduced herself as Mary Ingeman, editor of the *Wisconsin Engineer,* and commented that the *Engineer* has been doing a series on the various aspects of the College of Engineering Administration, and would I please write a short article about the duties and responsibilities of my office. Well, I was doubly flattered and eagerly accepted Miss Ingeman's invitation to write a brief article, although I wasn't sure who would be interested in reading it.

She next asked if I had a picture. Finding one that looked more like a mug shot than a studio photograph I handed it to her and said that this was the best that I could do, and hoped that it would be all right. She murmured, "Well, it doesn't flatter you" (this I took to be a compliment), and then she said, "Why don't Deans ever smile?" To this I had no ready reply. One that did occur to me was, "We do, but then students think that we are showing our fangs." However, this did not seem appropriate and probably not true, so I mumbled something inane. Nevertheless, the question, a perfectly legitimate one, bothered me and made me wonder if no one else had discovered what I had when I became an Assistant Dean in 1964, and that is that Deans are human and much like anyone else. I made a similar discovery about professors when I first started teaching some 17 years ago and I was equally amazed then.

Enough of this introspection, and on to my duties and responsibilities in the College of Engineering. In general, you could say that my primary responsibilities are for the College's operations insofar as they relate to instruction, as differentiated from research. This means fiscal budgetary responsibilities in the areas of salaries, capital expenditures and supplies and expense. It means assisting in budget development for three or four months prior to the new fiscal year beginning July 1 and budget control during the ensuing year. When you consider that we are talking about 300 full and part-time academic personnel and 100 full and part-time classified personnel and an instruction budget that is several millions of dollars, you can see why this activity does consume an appreciable amount of time.

Because of this financial responsibility, I am also assigned to various College of Engineering committees in which there are apt to be fiscal problems considered, among these are the building committees. Probably my contributions to the various committees are not monumental, but the meetings are time-consuming and part of the job. Some "concrete" evidence of the building committees' activities will soon be seen in our parking lot when construction begins in May on the addition to the Minerals and Metals Engineering building and later in the spring on the Engineering Research building.

With regard to student-related activities, I teach one course, so I have this contact with students. In addition, as a Dean I have the opportunity to see students who have a variety of problems—personal, academic, and otherwise. These contacts are valued by Deans because at this point one is operating at the interface between the student's present life and his later life and career, and this is the time when the Dean can make a significant contribution to a student's future.

Another service of this Dean's office is the administration of the College of Engineering student loan funds. Usually the funds have been established from contributions in memory of a particular individual. The most recent fund established was the Dan Drescher Loan Fund, an Electrical Engineering student who was fatally injured in a tragic accident last summer. Loans made from these funds have few restrictions. If repaid by their due date, the loans are interest free. For most of them there is no scholastic requirement and no waiting period. Because the total value of the funds is relatively small, loans are for short terms (3–6 months; in exceptional situations one year) and for relatively small amounts ($250 the usual maximum). The fact that we loaned almost twice the total value of the funds for each of the past two years shows the need for this type of fund and the use that is made of it.

Finally, I come to an activity in the College of Engineering which is my responsibility insofar as a faculty adviser can be responsible: the Engineering Exposition, to be held this year April 7–9. As you may know this tremendous undertaking is completely planned and executed by College of Engineering students with selected members of the faculty as advisers. As advisers we more or less sit on the sidelines until our assistance is needed or wanted and then at the end we are privileged to share in the reflected glory of the students who have made the Exposition a success, as it always is. In the process of assisting we share also the opportunity of becoming better acquainted with the many fine students who have made the Exposition a success, the Executive Committee for the Exposition and the many student exhibitors and committeemen.

The idea for the Exposition evolved from the annual feud over St. Pat's occupation—was he an engineer or a lawyer? When the contests between the two claimants of St. Pat began to get out of hand, the engineers decided to use their talents in a more constructive celebration; the result was the 1940 Engineering Exposition. A second Exposition was presented in 1941. Then came World War II and a temporary end to Exposition plans.

Under the sponsorship of the Polygon Board, the Expositions were resumed in 1953 on a triennial basis with the last being held in March of 1965. The principal purpose of the Exposition is to provide the public with a better understanding of the rapidly-developing field of engineering and by so doing to provide encouragement and enlightenment for the development of future engineers. Secondarily the Exposition also serves to inform other students and faculty within the University of what is being done in the College of Engineering. After the last Exposition, the student committee that planned it decided that interest in the Exposition was so great and technology changing so rapidly that the Exposition should be held more often—every other year rather than every third year.

The general chairman for the 1967 Exposition is Dick Schwarte. On his committee are: Jeff Flack, John Strader, Wayne Miller, James Ferrell, John Foltz, Elric Saaski and Dick Friede. If you want to know more about the Exposition or want to help in some way, contact any of the foregoing or contact me. The Exposition deserves the support of every engineering student and faculty member, please stop in and discuss it with me.

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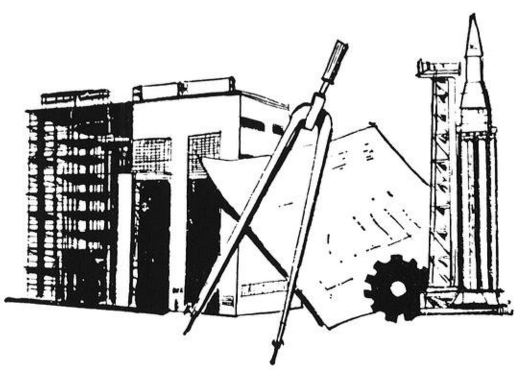

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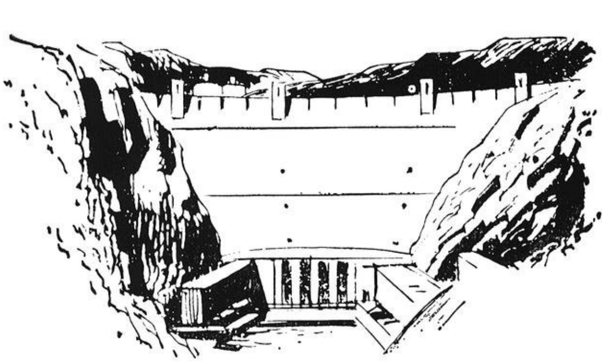

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## COVER STORY:

# THE QUEUEING THEORY

## *theory on the human line*

By **GRANT BELL**

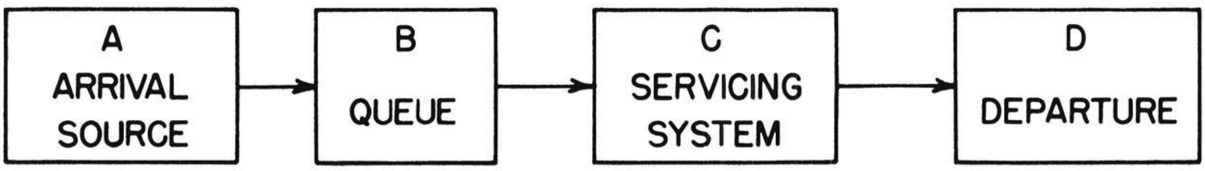



Figure 2 Block Diagram of a Single-channel System.

EVERYONE experiences congestion at one time or another. Whether it is when waiting at a supermarket checkout counter or in making a deposit at a crowded bank, we must queue, or line up, to be served.

This waiting time is wasted time, yet to eliminate it completely would obviously require an infinite number of service facilities. Queueing theory, or the theory of waiting lines, is intended to help maximize the efficiency of a system by showing how well the customers fit the service facility.

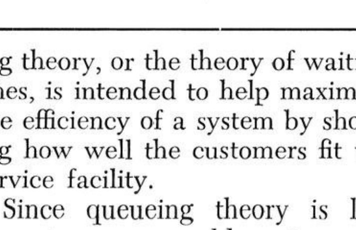



Figure 1 The Gamma Distribution.

Since queueing theory is less than ten years old, not many people outside the field of Operations Research have much knowledge of it. This article is intended to be an introduction to the theory of queueing.

Queueing theory provides a premise for calculating the amount of congestion for many different systems. It is a modelling process wherein each system is set up as a mathematical model to be solved analytically. This model is as close an approximation to the real world as its assumptions will allow.

One recognizes that as the complexity of the system grows, so do the assumptions made in describing its operation. It is evident, then, that a simple, very general, model will apply better to a small system than to a more complicated one. Therefore, we use the general model as a simulation for the simple system and a first approximation for the complex system.

If the model's conclusions are not indicative of the actual operating characteristics of the complex system, then a more specific, more costly model is set up. The more complex models will not be discussed here, though it is sufficient to mention that they sometimes employ a unique form of mathematics called, quite appropriately, the Q-calculus.

Also dependent on the complexity of the model, and the desired accuracy of the solution, is the form of the arrival and servicing distributions used to describe movement into and within the system. While we will be working with the negative exponential, a more advanced distribution such as the Gamma could be used.

The Gamma distribution requires its own development of the effectiveness parameters which are entirely separate from the ones developed here for the negative exponential distribution. They are more involved than the parameters we will develop, but the more involved distribution is available for the higher degrees of accuracy of solution.

### Single-Channel Queues

The simplest form of queueing model is the single-channel queueing system. Here there is a waiting line and service facility which is independent of any others. This is shown in Figure 2. For a specific system, the time period between arrivals (Block A) must be formulated mathematically. The frequency distribution of servicing time (Block C) must also be known. We will see later how in an actual situation a fitting analytical description of interarrival time and service time is the negative exponential distribution:

# QUEUEING THEORY

$F(t) = 1 - e^{-\lambda t}$ for $t \geq 0$.
The associated density function is $f(t) = \lambda e^{-\lambda t}$, which integrates to $F(t)$.

By convention, the probability distribution of interarrival times is called $\lambda e^{-\lambda t}$, and the probability distribution of servicing times is $\mu e^{-\mu t}$; where $\lambda$ is called the interarrival rate and $\mu$ is the servicing rate. Their ratio is called the servicing factor:

$$\frac{\mu}{\lambda} = \rho = \text{servicing factor}$$

where $\rho < 1$.

The stipulation that $\rho$ is less than one is needed because otherwise the waiting line would grow to infinite length.

### Measures of Operational Effectiveness

A first consideration is the level of congestion that the system attains. One parameter to measure this is the average number of individuals in the system T.

$$T = \frac{\rho}{1 - \rho}$$

For a single-channel service system the number of individuals being serviced, S, is either one or zero. Since the system is empty with the probability $P_o = 1 - \rho$, servicing is being done with the probability $1 - (1 - \rho) = \rho$. Therefore, the average number being serviced is $S = \rho$.

Then it follows from

$$T = S + Q$$

that

$$Q = \frac{\rho}{1 - \rho} - \rho = \frac{\rho^2}{1 - \rho}$$

All of these measures of operational effectiveness (T, S, Q) have been concerned with average numbers of individuals. Sometimes one would like to know the time a customer spends in waiting for service. Two measures of this are:

1. Average waiting time, W
2. Average waiting time for a person who must wait, W*

The difference in these is that sometimes upon arrival the customer finds the system empty and he does not have to wait.

When a customer enters the system, he finds a number of individuals already waiting for service. (This includes zero individuals). These must be processed before he is served. Therefore his waiting time is

[number in the system] ×
[service time].

From this we can conclude that the average waiting time is

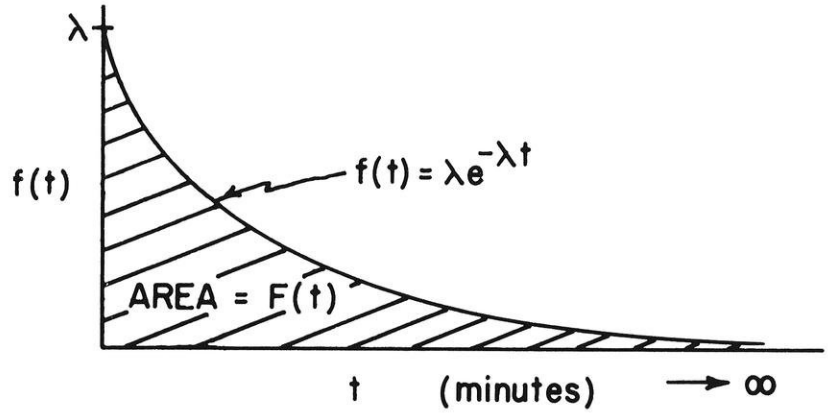



Figure 3 The Negative Exponential Function Characteristic to Queueing Theory.

[average number in the system] ×
[average service time]

**Table 1. Measures of Operational Effectiveness for the Single-channel system.**

| | |
|---|---|
| $\lambda$ | interarrival rate |
| $\mu$ | service rate |
| $\rho = \frac{\lambda}{\mu}$ | servicing factor |
| $T = \frac{\rho}{1-\rho}$ | number in the system |
| $Q = \frac{\rho^2}{1-\rho}$ | number in the queue |
| $S = \rho$ | number being serviced |
| $W = \frac{T}{\mu}$ | waiting time |
| $W^* = \frac{W}{\rho}$ | waiting time for person who must wait |

or

$$W = [T] \times \left\{\frac{1}{\mu}\right\} = \frac{T}{\mu}.$$

$$W = \frac{\text{number of individuals in the system}}{\text{number serviced per minute}}$$

= minutes of waiting time.

The average waiting time per individual includes customers who do not wait at all. To find the average waiting time for those who must wait we see that

$$W = O \cdot \text{Prob}[\text{No one in the system}] + W^* \cdot \text{Prob}\left\{\begin{matrix}\text{Someone} \\ \text{being} \\ \text{served}\end{matrix}\right\}$$

$$= O \cdot P_o + W^* (1 - \rho_o)$$

where $P_o$ probability that there is no one in the system.

$$W^* = \frac{W}{1 - P_o} = \frac{W}{\rho} = \frac{\text{average waiting time}}{\text{servicing factor}}$$

These measures of operational effectiveness can be illustrated by an example:

Arrivals at a phone booth are considered to be Poisson, with an

*(continued on page 27)*

## University students after years of soot covered snows, speak out against • • •

# AIR POLLUTION

PAUL M. KRONBERG

AIR pollution receives the daily attention of the news media, and much of the blame for this increasing nuisance has been placed on coal-burning power plants. Unfortunately, the justification for this blame is not well founded. Automobiles, coal and oil home furnaces, incinerators and other "insignificant" contributors to the problem produce far more contaminating substances than power plants on a basis of pollution per unit of fuel used. Statistics show that less than 6% of all pollution originates from power plant installations.

Air pollution has been shown to be detrimental to human health, harmful to the growth of vegetation, and corrosive and dirtying to the surroundings. Thus, the need for control of pollutants entering our atmosphere is obvious.

Pollutants from power plants burning coal are essentially of two types: gaseous and particulate. Prime components of the gaseous contaminants are sulfur dioxide, nitrogen dioxide, and, to a lesser extent, carbon monoixide. Particulate matter is emitted in the form of flyash, small cinders, or, in general, dusts.

The gaseous pollutants mentioned form acidic vapors when mixed with the water vapor formed in combustion and the natural water vapor of the air. These acid vapors are known to be corrosive to building materials and paints and, in large concentrations, to mankind.

Particulate matter yields the common problem of dirty surroundings. As the solid particles precipitate from the atmosphere, laundry, autos, draperies, etc., become rapidly soiled.

These then are the problems associated with pollution from coal-fired power plants and all other sources of atmospheric contamination. The need for corrective action is obvious, and the problem of removing or reducing the emission of pollutants from power plants will be considered in the remainder of this article.

### Methods of Removing Gaseous Pollutants

Many methods exist for removing gaseous pollutants from the flue gas of a power house. The problem at this time is not so much getting the contamination out of the flue gas as finding a way to do it economically.

*Sulfur Oxides.* Removal of sulfur from the coal before burning is the most logical first step towards controlling the emission of sulfur oxides from the flue gases, and this method has been attempted in many instances. The sulfur found in coal, however, is of two types: pyritic or free sulfur, and bonded sulfur, intimately associated with the carbon atoms.

Pyritic sulfur found embedded in layers between the carbonaceous ous material can be rather easily removed by crushing the coal and passing the pulverized mixture through an air separator. The finely broken sulfur is removed along with some of the finest carbon particles. The disadvantages of this method are the loss of desirable fuel and the fact that the remaining fuel is pulverized. For cyclone burning boiler furnaces, pulverized coal is very desirable, but for the stoker type of furnace, the pulverized coal cannot be handled or burned satisfactorily.

Organically-bonded sulfur in coal is much more difficult to remove than the pyritic sulfur. The method of removal incorporates rather drastic chemical reaction processes in an effort to break the very strong sulfur-carbon bonds. The process is quite complex and very costly in comparison to other methods of dealing with the overall sulfur pollution problem and will therefore receive no further discussion here.

Industrial groups in Europe (particularly Germany) have experimented with several new methods of removing gaseous sulfur oxides from the flue gases of power houses. In the Reinluft process, flue gases at approximately 300° F are fed upward through a bed of activate charcoal. Sulfur trioxide (the stable sulfur oxide at this temperature) is adsorbed by the charcoal bed as the flue gas is cooled to nearly 220° F. At this lower temperature the sulfur dioxide present is oxidized to sulfur trioxide, and it then combines with the water vapor in the flue gas to form dilute sulfuric acid.

The charcoal, laden with the sulfuric acid, is then fed to a regenerator where the sulfuric acid is vaporized by product gas at 700° F. The dissociated acid vapors react with some of the carbon inherently present in the absorbent to form a concentrated mixture of sulfur dioxide and carbon dioxide. These gases are then passed to a conventional contact acid plant where sulfuric acid is produced at a concentration of approximately seventy percent.

Two commercial installations of this Reinluft process are presently under construction in Germany, and the by-product sulfuric acid is expected to be sold commercially in an effort to amortize the initial equipment costs and the operating and maintenance costs of the process.

An outgrowth of another European process is under development by the Pennsylvania Electric Company. This catalytic sulfur oxide removal process also yields sulfuric acid of nearly seventy percent concentration as a salable by-product. The chemistry of the process is quite involved and will not be treated here; however, several problems are being investigated with a pilot plant operation.

The purpose of the pilot plant is to determine limiting conditions of the process and to obtain an economic evaluation of the process for the power industry. A deactivating effect of flue gas on the absorbent, along with fouling problems due to particulate matter in the flue gas stream, is being studied. In addition, reaction rates, pressure losses, and acid removal methods are being closely checked in order to make appropriate data available for sizing of the necessary process equipment. This data should be available within the near future.

A third new process for eliminating sulfur oxides from flue gas emissions has been developed and placed in pilot plant operation by the United States Bureau of Mines. The process is dependent on the adsorption of sulfur oxides on alkalized alumina, which occurs at approximately 625°F. The alumina is then regenerated with producer gas, or reformed natural gas, in a second vessel at a temperature of 1200° F. Regenerator product gas is then fed to a sulfur recovery plant where elemental sulfur is produced as a salable by-product.

The pilot plant for this process is being used to study optimum conditions for time and temperature of operation for both the adsorption and regeneration cycles. The main advantages of the process appear to be the low pressure drop across the adsorbent, the very high temperature of operation and the production of the elemental sulfur.

Older methods of sulfur oxide removal almost invariably consisted of some type of scrubbing of flue gases. Solutions used for the scrubbing ranged from water to various chemical solutions, some of a very exotic nature. Although some of these processes are still in use, they are being phased out due to the several complications involved.

Primary disadvantages of scrubbers are the cooling effects on the flue gases, the supersaturated plume emitted from the smoke stack, the reduced bouyancy of the gases and the relative ineffectiveness of lowering local sulfur oxide pollution concentrations. Although a large percentage of the sulfur oxides are removed by the processes, the saturated plume and reduced bouyancy cause the remaining oxides to stratify near the ground in the immediate area of the power plant. Thus, while overall pollution problems are improved the problem on a local basis is not improved, and in many cases has been found to worsen.

These then are the primary methods of handling sulfur-caused air pollution. Other methods exist, but most are merely modifications of these processes, or ineffective in controlling the problem. An optimum solution is not available at this time, and much more research and experimentation will be necessary before adequate data are available for installation of appropriate sulfur-removal equipment.

*Nitrogen oxides.* The removal of nitrogen oxides from flue gases has been primarily accomplished with the scrubbing processes discussed above. The same problems affecting sulfur removal apply, causing the same disadvantages. It has been shown, however, that the contribution of nitrogen oxides from coal-fired power plants to the pollution problem is quite insignificant. For this reason, little development is in progress for new processes and nitrogen oxides will not be discussed further.

### Methods of Removing Particulate Pollutants

The most obvious pollution problem is that of particulate matter, for it can usually be seen readily in the vicinity of a power house, and the effects of particulate matter in the air are readily felt financially through increased cleaning costs. Particulate pollution is interpreted by most laymen as the entire source of the pollution problem, but this interpretation is far from sound.

Particulate matter can be grouped into two categories on the basis of particle size. Matter ten microns in size when introduced to the air is essentially in a permanent suspension. These particles then, do not settle out of the air, but remain airborne to form haze or smog, and present the most difficulty to a pollution control system.

The larger-sized particles, on the other hand, tend to settle out of the air, and the larger the particle, the faster this precipitation occurs. As the velocity of the plume decreases above the smoke stack, the particles begin traveling with the prevailing air currents, eventually settling out of the air in the vicinity of the power plant. These particles are relatively easy to remove from flue gases. The problem arises in disposing of the ash particles once they have been collected.

*Control in the boiler furnace.* Two methods exist for reducing the amount of particulate (flyash) emission from the boiler furnace itself. Probably the most elementary method involves selection of a properly sized coal. In general, the smaller the coal size, the greater the flyash problem will be. It would appear from this statement that the solution would be to burn larger sizes of coal. However, to obtain efficient combustion and to reduce gaseous emissions it is necessary to increase the surface area of the coal to be burned by decreasing the size. The smallest size in which coal is used, and, therefore, the most efficient combustion, is obtained from the cyclone furnaces which burn a finely powdered coal.

No one size of coal is best for all boiler furnaces. Thus the proper coal size depends on the fuel feed system (i.e., stoker, chain grate, pneumatic, etc.) and the size of the furnace.

The second method of reducing the flyash problem in the furnace is to introduce only part of the required air for combustion below the fire bed. This reduces the velocity of the air through the bed and thus reduces the amount of ash lifted from the fire bed into the furnace gases. Since the combustion will be incomplete at this stage, the remainder of the required air for combustion is introduced above the furnace fuel bed. This air must be added at relatively low velocity for the same reasons as indicated for the air through the fuel bed. The combustion is then completed above the fuel bed and the combustion area in the furnace is increased. Slightly lower combustion efficiency results, but the flyash reduction can be considerable.

*Control in the ducts and smoke stack.* Again, two basic methods may be defined for removal of flyash in the ducting between the furnace and the smoke stack and from the smoke stack. Scrubbing processes have the same limitations that were indicated for the gaseous vapor scrubbers, and will therefore not be discussed. Various filtering methods have been employed for flyash removal, and filtering processes appear to be the best solution to the flyash problem.

Cyclone, centrifugal, and venturi filters are all constructed from the same principle, that of accelerating these particles in a rotary motion and causing the particles to be forced to the outer radius of the container, while the gases are free to traverse axialy through the rotating device. Flyash is then collected at the outer limit of the precipitating device by means of small openings in the outer wall or by gravity collection at the bottom of the device. These filters operate fairly efficiently for large sized flyash (in excess of fifty microns), but the overall efficiency is generally less than 75 or 80 percent.

The various filtering methods used for the removal of flyash all depend on a low velocity pass of the flue gases through a finely woven fabric. The particles carried by the gas at high velocity are allowed to precipitate and the smaller particles are trapped by the fabric fibers. The greatest problem associated with the fabric filtering material is the large pressure drop across the filter and the rapid increase in presure drop as the fabric becomes bound with the ash particles. Frequent cleaning of the fabric is necessary, and this cleaning is hampered by moisture in the gases collecting on the fabric. This tends to cake the particulate matter on the fabric, making drastic vibration or reverse air flow necessary for adequate cleaning.

Early fabrics could not withstand the acidic vapors in the flue gases or the repeated cleaning operations. In addition, the characteristic high temperature of the gases during the filtering process led to rapid degradation of the filter. The required size of the early filtering devices necessary to reduce the gas flow velocity was a very limiting factor in their use. Recent technology has alleviated this problem to a large extent.

Of all the filtering processes in use today, two are considered to be the most desirable and efficient. The filterhouse method using flue gas additives and the electronic precipitator both offer flyash removal efficiencies of greater than 99% when properly sized. This is well in excess of the accepted industrial standard of 95 percent flyash removal for tolerable pollution.

The bag filterhouse method of flyash removal uses many large filter "bags" installed in compartments. The individual bags are usually one to two feet in diameter and approximately thirty feet in length. The problems of high temperature operation were recently eliminated with the development of a siliconized glass-fiber cloth which is capable of withstanding both the acidic vapors in the flue gas and the gas temperatures in the range of 500°F. The addition of alkaline additives further improves the air pollution control capabilities of the process by removing the acidic vapors and the associated sulfur oxides from the flue gases. Thus, this process seems to be a high-efficiency, all-purpose solution to the problem of air pollution.

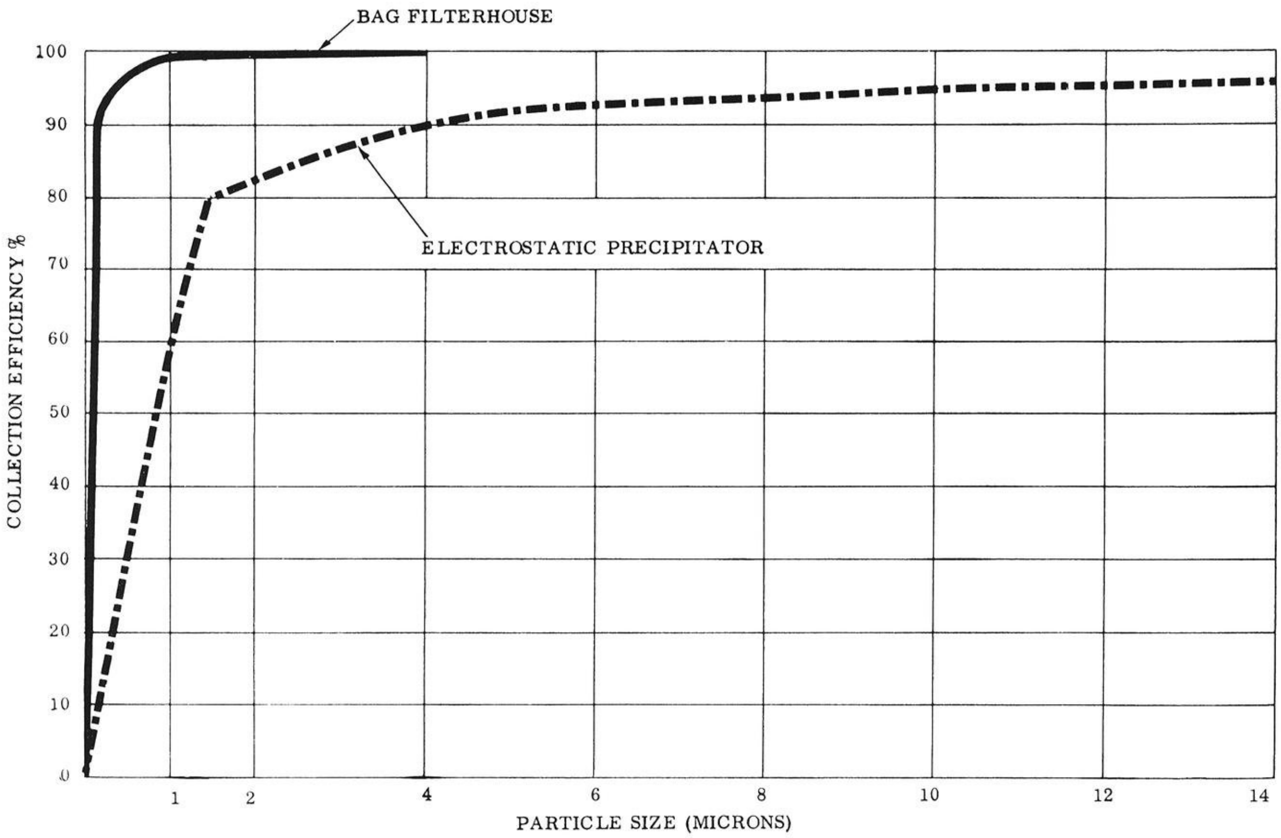
Experience with pilot plant operations indicates that while the filterhouse must be very large, and the filters must be cleaned very frequently (every thirty minutes for one pilot plant operation) the results obtained are quite significant.

A filter ratio is defined for bag filterhouse design as the cubic feet per minute of flue gas to be filtered divided by the square feet of filtering fabric. Recommended designs indicate that the filtering system should be set up with a filter ratio of 3:1, but that operation should be maintained at a filter ratio of 1:1 to reduce cleaning frequency and difficulty.

A further advantage of the bag filterhouse is that appreciable quantities of water vapor are condensed in the filter. Since these vapors may cause a visible plume which is interpreted as pollution by the layman, removal of the water eliminates this situation and thus can improve community public relations considerably.

Of the same efficiency as the filterhouse, the electronic precipitator has been used very frequently in series with previously mentioned mechanical precipitators. The effect is to get the large flyash out of the effluent stream before the electronic precipitator removes the smaller particles. The electronic device has the best effect on smaller particles and can remove much of the flyash in the ten micron and less sizes.

The principle of operation involves passing the flue gases




through an electrically charged grid to impart a negative charge to the flyash particles. The gases move upward toward positively charged plates where the electronic attractions precipitate the particles on the plates. Frequent cleaning is required, however, and the operational costs are quite high. Power consumption is thirty to fifty kilowatts per hour of direct current for an average installation. Insulated heaters must be placed in the gas stream ahead of the electronic precipitator to raise the temperature of the effluent above the dew point and thus prevent arcing between the grid and the plates. Temperatures must be kept thirty-five to fifty degrees Fahrenheit above the effluent dew point.

### Basis for Choice of Pollution Control Methods

*Types of pollutants and required removal effectiveness.* To design air pollution control equipment, as to design any other kind of equipment, conditions of use must be known. The particle sizes, rate of pollution emission and type of pollutant must be known. If flyash is the important problem, one would not choose a system to remove gaseous matter.

The problem of the required effectiveness demands additional consideration. The cost of pollution control equipment will eventually come from the public, whether it be in the form of taxes for governmental operations or increased prices from commercial plants or both.

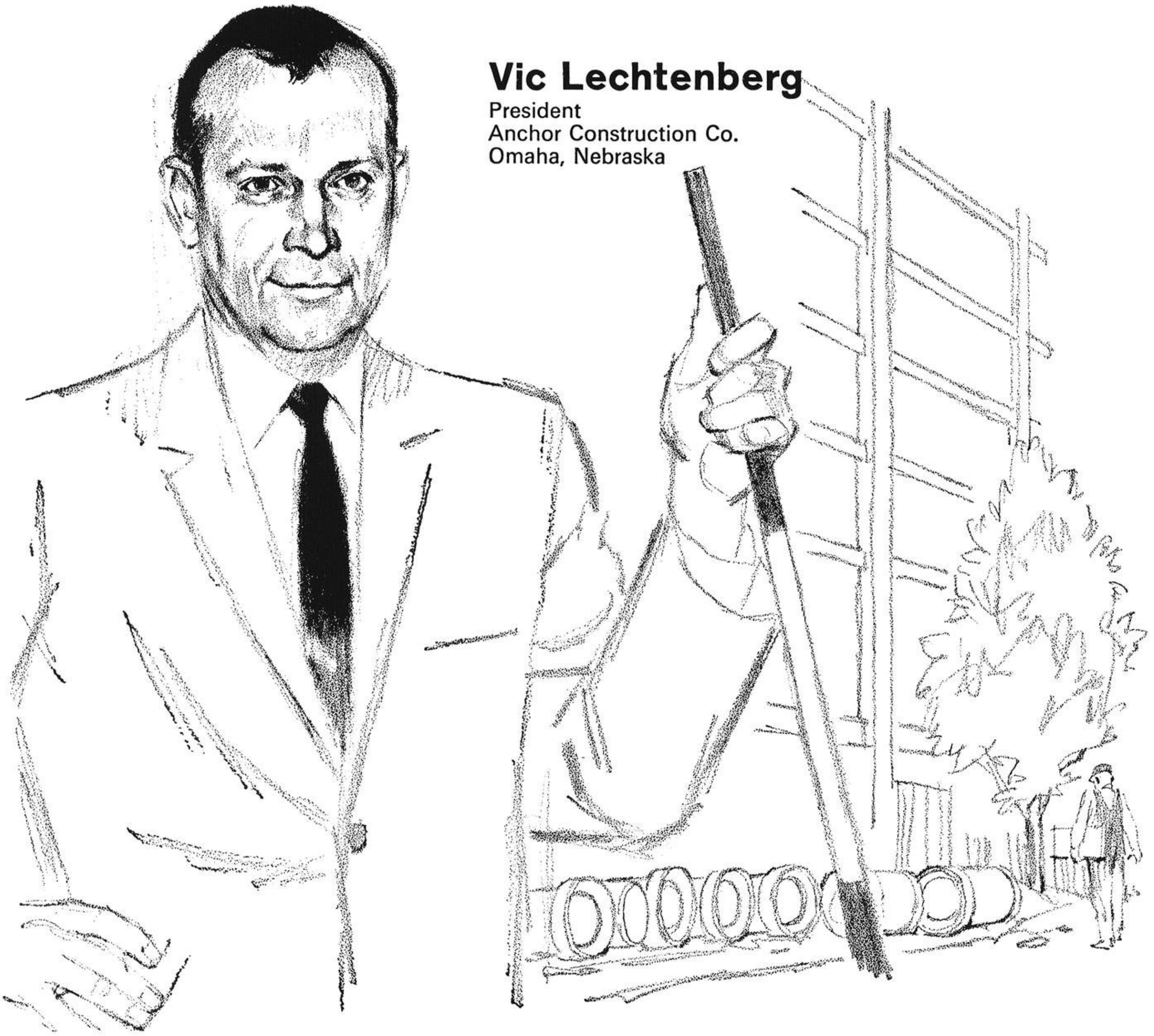
What, then, constitutes the degree of control required? There are many factors, including population of the area affected, other industry in the area, local laws governing pollution, and the prevailing wind directions. Large population centers will generally have a high degree of pollution from various sources and thus the additional contribution from a specific powerhouse must be limited. Similar reasons dictate extremely effective control in localities harboring many industrial plants. Local laws governing pollution control must be consulted and industry must conform.

Prevailing wind directions can be either a great benefit or a total hindrance to a pollution-control system. Assuming a prevailing westerly wind, a plant located on the east side of a population center with relatively little population to the east would need to worry very little about complaints of pollution. In areas of relatively stable wind direction this factor has been used to good advantage. The reverse situation, with prevailing winds from the west and the plant located on the western boundary of a population center would demand that the plant employ highly effective pollution control equipment.

*Obtainable by-products and their value.* The elemental sulfur and seventy percent concentration sulfuric acid from the sulfur oxide control processes are obviously salable by-products. The flyash collected by the mechanical filtering devices has also been found salable in certain areas of the country.

*(continued on page 34)*

**Vic Lechtenberg**
President
Anchor Construction Co.
Omaha, Nebraska



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# QUEUEING THEORY *(continued from page 14)*

average time of ten minutes between arrivals. The length of a phone call is assumed to be exponentially distributed with a mean of three minutes.

(a) What is the probability that a person arriving at the booth will have to wait?

$$P\,(\text{waiting}) = 1 - P\,(\text{no one in the system}) = 1 - P_o$$

since $P_o = 1 - \rho$

$$P\,(\text{waiting}) = \rho = \frac{\lambda}{\mu} = \frac{1/10}{3/10} = 0.3$$

(b) What is the average length of the queue?

$$Q = \frac{\rho^2}{1-\rho} = \frac{(0.3)^2}{0.7} = 0.13 \text{ persons}$$

(c) The telephone company will install a second booth when convinced that an arrival would expect to have to wait (on the average) three minutes for the phone. By how much must the flow of arrivals be increased to justify a second booth?

$$W = \frac{T}{\mu} = \frac{P/1-\rho}{\mu} = \frac{\lambda}{\mu(\mu-\lambda)} = 3 \text{ minutes}$$

Therefore, $\lambda = 1/6$ or interarrival time would have to increase to 6 minutes from the original 10 minute interarrival time.


Figure 5 Block Diagram of the Engineering Computer Laboratory as a Queueing System.

### Multiple-Channel Queues

Up to this point we have considered service facilities which handle only one person at a time. There are many systems which can not be successfully modelled this way. For example, automobiles arriving at the toll gate entrance to a super highway have the choice of many service channels. One can realize the difference in queueing between this and the situation where each booth at the gate is considered as a separate facility. A block diagram of the multiple-channel system is shown in Figure 4. With this model in mind, the same parameters of operational effectiveness as for the single-channel system can be found.

Another model used is where the service facilities offer different services for a specific population, as in maintenance analysis. This is an extension of the multiple-channel system where the customers form separate queues for each type of service involved.

While there are models which closely approximate many types of real systems, these can not be dealt with to any degree of reality un- *(continued on page 30)*

**Table 2. Summary Data of the Computer Laboratory Queue.**

ARRIVALS:

| minute time periods | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| observations in each period | 8 | 12 | 10 | 8 | 3 | 2 | 3 | 2 | 1 | 1 | 3 | 0 | 0 | 0 | 2 | 0 |

SERVICE:

| minute time periods | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| observations in each period | 14 | 15 | 11 | 4 | 5 | 1 | 2 | 2 | 0 | 0 | 1 |

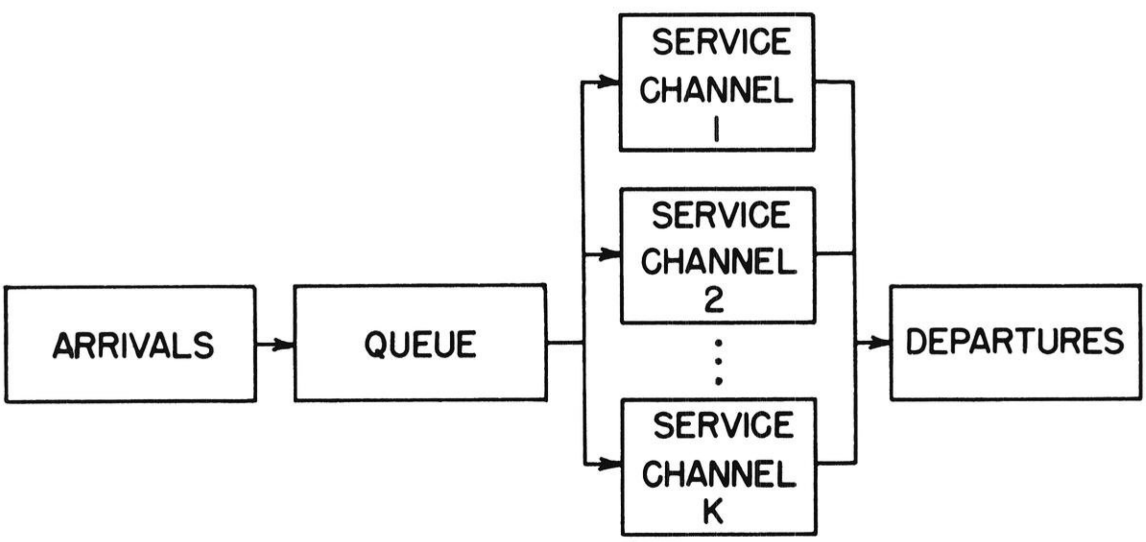


Figure 4 Block Diagram of a Multiple-channel System.

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# QUEUEING THEORY *(continued from page 27)*

less the arrival and servicing rates can be closely approximated.

To show, that in an actual situation, the arrival and service rates actually do follow the Poisson function, study was made of the Engineering Computing Laboratory where servicing is single-channel.

Arrival rate was recorded for 50 consecutive customers while, their time on the computer was also logged which is shown in Table 2.

From Table 2,

$$\frac{1}{\lambda} = \frac{\Sigma \text{ interarrival times}}{\text{number of observations}}$$

$$= \frac{201}{56} = 3.6 \text{ minutes/student}$$

$\lambda = 0.28$ students per minute arrival rate.

$$\frac{1}{\mu} = \frac{\Sigma \text{ service times}}{\text{number of observations}}$$

$$= \frac{110}{55} = 2 \text{ minutes/student}$$

$\mu = 0.50$ students per minute service rate.

These data are plotted in Figures 6 and 6, along with $\lambda e^{-\lambda t}$ and $\mu e^{-\mu t}$, to show how closely the observations come to falling on the line of the function used to model the system.

After seeing how closely the actual points come to what we thought they should be, we can find the parameters of operational effectiveness.

With

$$\lambda = 0.28$$
$$\mu = 0.50$$

we see

$$\rho = \frac{\lambda}{\mu} = 0.56$$

$$W = \frac{T}{\mu} = \frac{\rho/1-\rho}{\mu}$$
$$= 2.5 \text{ minutes}$$

$$Q = \frac{\rho^2}{1-\rho} = \frac{(0.56)^2}{0.44}$$
$$= 1.37 \text{ persons.}$$

With this information, a decision maker has a good idea of the situation and what changes may have to be made. Possibly a waiting time of 2½ minutes is uneconomical, so that an additional computer may have to be secured. He is probably best able to justify his decision to management with these conclusions of queueing theory.

Convincing management of your conclusions is probably the most powerful use for queueing theory. With these models, and others where appropriate, the real system can be illustrated by its measures of operational effectiveness.

**Latest Uses for Queueing Theory**

Out of the need for speed of operation and complexity of the models, digital computer techniques have been developed, and stock programs have been written for very large systems.

A program simulating airport operation as a queueing model has recently been devised by B. L. Marks and described in *Operations Research Quarterly*. He has taken a large airport and modelled it in an extremely realistic manner. His program includes provisions for the effects of emergency landings, changes in weather conditions, and differences in operation when various sizes of airplanes are served.

The technique used to model this airport could be used in the queueing of auto traffic. It is not inconceivable that in the future whole cities of traffic flow may be simulated in the same way as this airport. In this manner, changes in arterial routing can be included to study the effect on traffic flow.

Actually, the speed of operation acquired through the use of the digital computer in simulation has opened the door to queueing models which are beyond conception today.

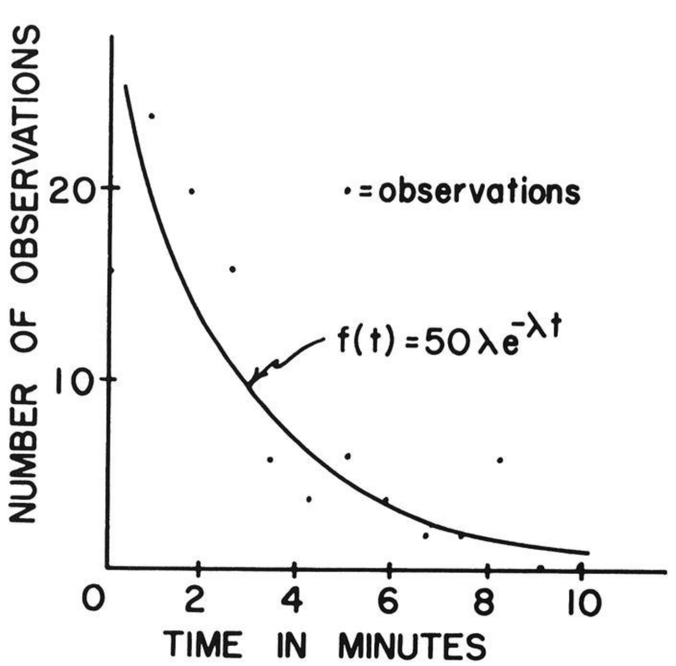



Figure 6 Distribution of Interarrival Times.

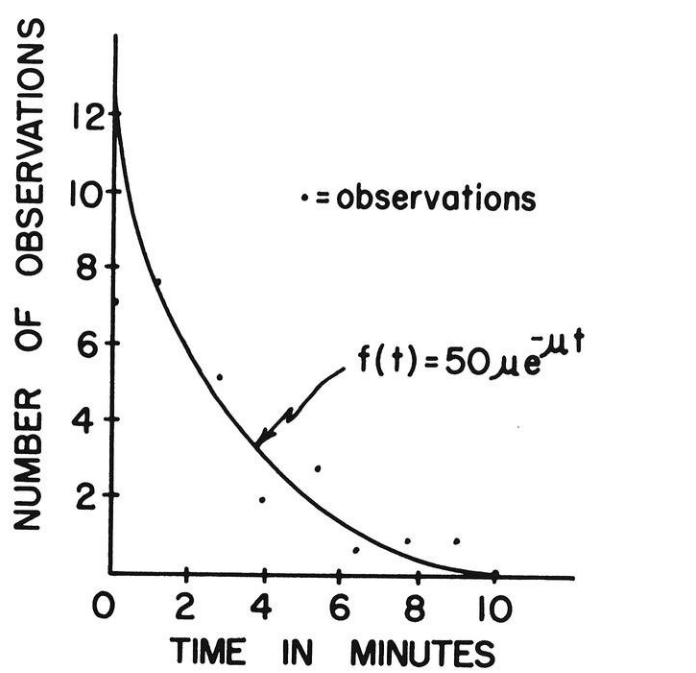
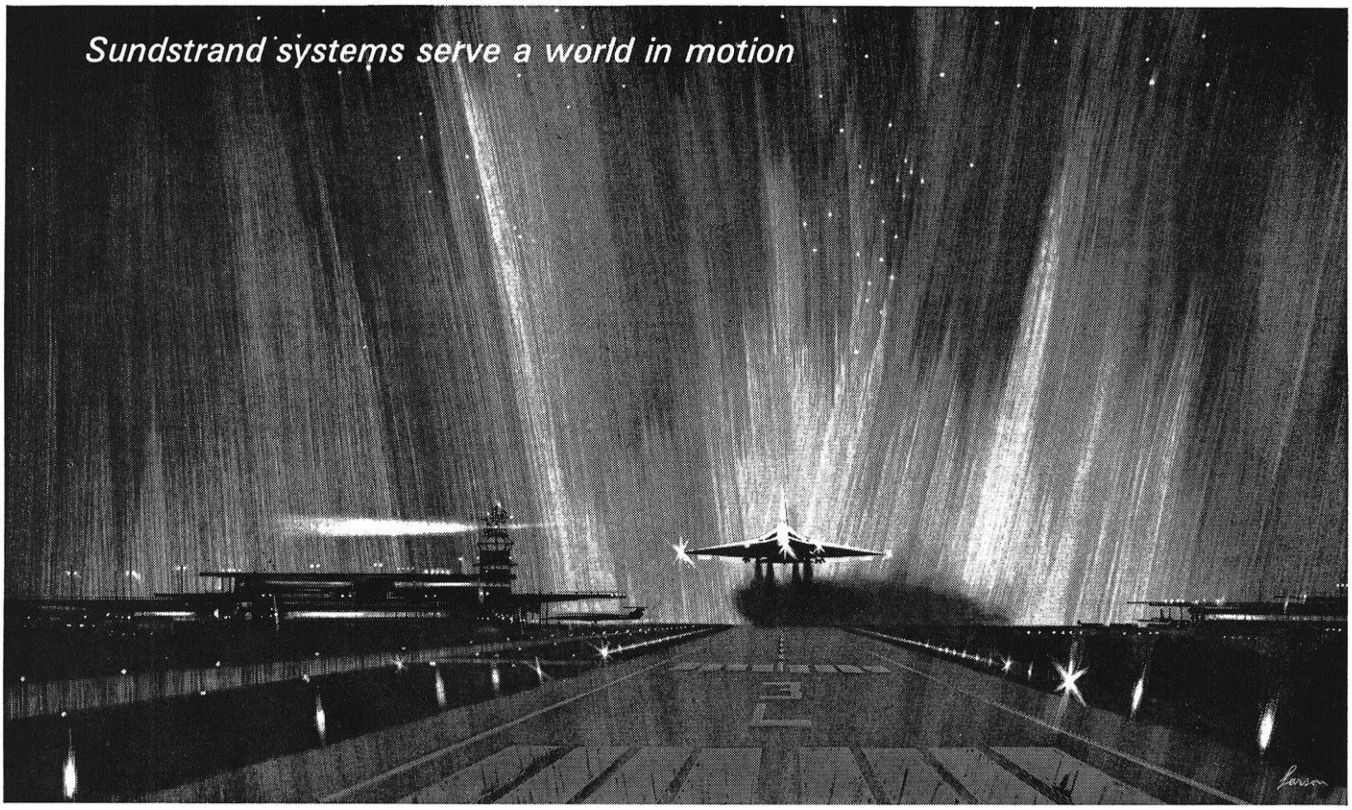
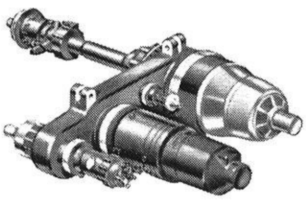



Figure 7 Distribution of Servicing Times.




# Take off on SST at Sundstrand



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# AIR POLLUTION *(continued from page 22)*

Flyash is primarily useful as a filler in various construction materials. The ash waste of the power plant is sold to concrete producers to be used in manufacturing lightweight concrete, lightweight brick, concrete block, and bituminous concrete and asphalt. In addition, abrasives can be made from the flyash, binder for highway bases are made, and soil conditioners can be developed from the pollution elements removed from the power plant effluent. The United States Bureau of Mines is presently investigating the use of flyash as a coagulating agent for water treatment systems.

Thus, the products of pollution control can be sold in some instances to help defray the installation and operation costs of control equipment. Before selecting a method or methods of air pollution control on the basis of salable by-products, however, a thorough investigation must be made to reveal the production rates of these materials and the local market demand for them.

*Installation and operation costs.* Initial equipment and installation costs for a typical coal-fired power house are shown below on a per kilowatt of capacity basis for the various pollution control processes. Annual operational costs are shown on the same basis.

| Process | Initial Cost per Kilowatt Capacity (approximate) | Annual Operating Cost per Kilowatt Capacity (approximate) |
|---|---|---|
| Reinluft | \$20.00 | \$4.00 |
| Pennsylvania Electric | 22.00 | 2.10 |
| Bureau of Mines | 11.00 | 2.75 |
| Electronic Precipitators | 10.00 | .80 |
| Mechical Filters | 8.00 | .60 |
| Bag Filterhouse | 10.00 | 1.00 |

It should be noted that all costs shown are approximate and that the costs for a given installation may be expected to vary considerably from the data shown. By-product value must, of course, be evaluated for each marketing situation and power plant capacity.

### Analysis of Available Methods of Pollution Control

Present pollution control methods are costly to install and to operate, and the ability to eliminate these costs is non-existent in most applications. The methods under development at this time show promise for an economical solution to the pollution control problem, but the development of these processes for commercial-size installations is not in the near future.

Additional research is necessary for both pollution control processes and for new and better uses for the by-products. The United States Bureau of Mines is presently sponsoring limited research in this field. The need for this type of research is hard pressing as evidenced by viewing industrial areas from the air. But, response to the plea has been slow in coming. The Clean Air Act passed recently by Congress may provide the necessary impetus for extensive work on the air pollution control dilemma.

*University of Wisconsin Heating Plant.* The new power house of the University of Wisconsin has three Babcock–Wilcox boilers, and a fourth boiler from the same manufacturer is being installed at this time. The pollution control equipment now consists of four American Blower two-stage cyclone dust collectors. Expected efficiency of these collectors as published by the manufacturer is ninety-three percent; however, data from the power house superintendent, Mr. R. F. Warock, places the actual efficiency near eighty percent. The remainder of the flyash dust is discharged through the smoke stack with the sulfur oxides.

As might be expected from the performance data above, complaints of dust, odors and corrosion are numerous. Since the start-up of the new plant in 1958, the only corrective measure taken to reduce the pollution was to employ the over-fire air as previously described. The effects of this have been negligible.

Peak consumption for the plant is expected to be approximately four hundred and fifty tons of coal per day or nearly nineteen tons per hour when the fourth boiler is placed in operation. Analysis of the Southern Illinois coal burned follows:

| Ultimate Analysis Southern Illinois Coal | Percent |
|---|---|
| Carbon | 68.5 |
| Hydrogen | 5.3 |
| Oxygen | 14.2 |
| Sulfur | 2.0 |
| Ash—solid | 6.0 |
| Ash—flyash | 4.0 |
| Total | 100.0 |

Using this data, it can be predicted that the plant under maximum capacity is producing eighteen tons of flyash, twenty-seven tons of solid ash and burning nine tons of sulfur per day. Considering the necessary production rates to provide a market for the by-product sulfuric acid or the flyash, these supply rates do not indicate any economic advantage to be found by salvaging the possible products.

The present boilers cannot utilize pulverized coal due to the stoker and grate equipment. Therefore, removal of sulfur before burning must be eliminated as a solution to the sulfur oxide pollution problem.

The remaining choices, then, are mechanical dust collectors similar to those now in use, electrostatic precipitators, scrubbers, or filtering devices. Since the expected efficiency of eighty to ninety percent for mechanical dust collectors is so close to the efficiency already observed for the present dust removal system, further investment in this type of equipment would not be practical. Also, since the electrical power for the University is purchased from the Madison Gas and Electric Company, installation of electronic precipitators would increase the utility bill for the plant. These operating costs, not to mention the costs of obtaining and installing the equipment, would then be prohibitive.

As previously noted, scrubbers yield many undesirable plume characteristics and some increased pollution problems. These devices then, will not be considered for the heating plant.

The only remaining solution which appears to be feasible is the bag filterhouse system. While installation costs are high, operating costs are lower than like costs of most systems, and thus, the system appears to be the most economically sound.

#### Recommendations for the University of Wisconsin Heating Plant

In deciding on a method of air pollution control for the University, it must be realized that the prestige of the school is a predominant factor. Since research work for air pollution control and support for air pollution programs are coming from the University, it cannot settle for a second rate control for its own facilities. The University must educate by example, and this will be a deciding factor in the equipment choice. The problem then, is to remove pollutants and not necessarily to do this as economically as possible.

The bag filterhouse system provides the exceptional control which the University desires. The added advantage of this system is the removal of the sulfur oxides as well as the fine dusts which pass the mechanical filters. This equipment can be expected to improve the dust collection efficiency to ninety-nine plus percent and to remove essentially all of the sulfur oxides from the smoke stack gases.

The present method of ash disposal (trucking to areas for fill) should continue to be used unless a buyer for the limited amount of ash can be found. The acidic nature of the ash, however, makes its desirability as a salable product doubtful.

As the discharge rate of gases for the plant will be approximately three hundred thousand standard cubic feet per minute (scfm), the size of the installation should be one hundred sixty thousand square feet of filter. The estimated values were obtained by using recommended data given by A. E. Gosselin, Jr. The estimated cost for the equipment and installation is roughly six hundred thousand dollars, while operating costs should be nearly forty thousand dollars per year.

These cost figures indicate clearly the reason for industry's objection to legislated air pollution programs at this time. Experience of power plants using methods yielding salable by-products shows that profit from the control of pollution is non-existent at this time. The only help derived from by-products is a slight reduction in operating costs.

Industry and governmental researchers, therefore, are attempting to find new and better means of air pollution control. Their success or failure is dependent upon public approval and support. The elimination of the pollution problem in this country can most readily be accomplished by informing the public of pollution sources and methods of eliminating these many "small" contributions to the overall problem. Once the public is fully aware of the causes of air pollution, the country will be well on its way toward eliminating this problem.

#### University of Wisconsin Department of Buildings and Grounds Steam Generating Plant and Pumping Station

The University of Wisconsin Steam Generating plant is located in the block bounded by Charter, Mills, Dayton and Spring Streets. The plant supplies steam for all of the heating and hot water demands for about 170 campus buildings, in addition to the steam required for the various laboratories, sterilizers, cooking equipment, clothes dryers, stills and dishwashers. The Mechanical Engineering Department uses an appreciable amount of steam for testing purposes in engines and turbines. The Pumping Station pumps most of the lake water with steam-turbine driven pumps. It is estimated that during the heating season, 70% of the steam is required for heating, with the remainder required for miscellaneous purposes.

Steam is generated at 600 psig and 720°F. A typical winter day will require production of about 4,800,000 pounds of steam to satisfy the demands, and in the process will consume 250 tons of coal. The peak daily coal consumption was recorded January 10, 1962, at 310.4 tons of coal. Steam production on this day was 5,247,000 pounds. Even an average summer day requires about 800,000 pounds of steam, using 40 tons of coal.

The mechanical equipment for this plant was originally the property of the Hudson Division of American Motors, in Detroit, Michigan. It was purchased by the University in 1957 when American Motors suspended its Detroit operations. The equipment was initially installed for American Motors in 1953.

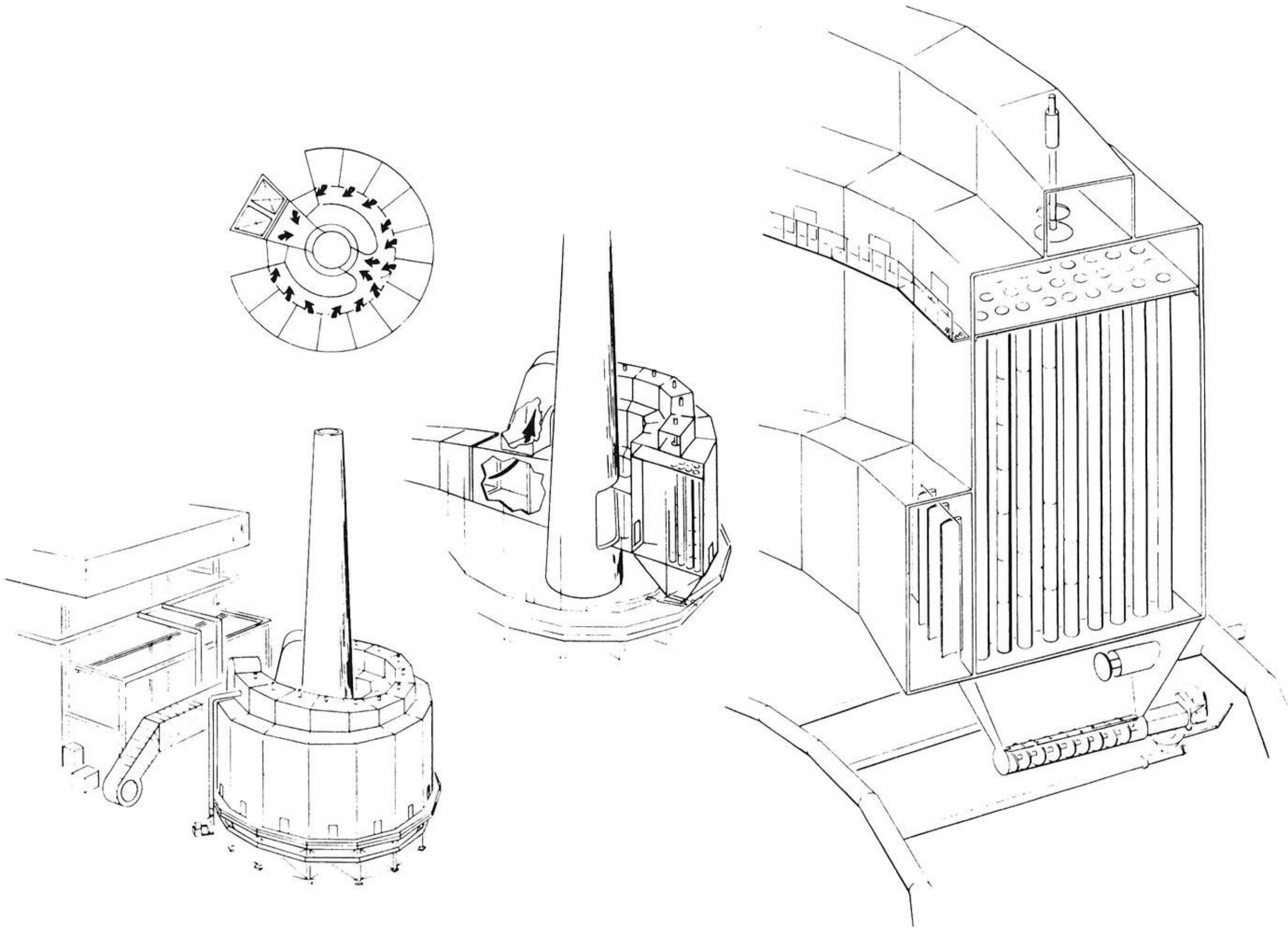
The total cost of dismantling the plant in Detroit and re-erecting it in Madison was $2,501,360. This did not include the cost of the land, site preparation and the piping necessary to connect the new plant to the steam distributional system.

Steam is generated with 3-Babcock and Wilcox, two-drum Stirling boilers. The boilers have 9228 square feet of heating surface, the economizers on each boiler have 5200 square feet. The nominal capacity of each boiler is 100,000 pounds per hour but they are capable of short-period overloads to 120,000 pounds per hour. This gives a total capacity of 360,000 pounds per hour. The guaranteed efficiency of these boilers is 85.3%.

The boilers are equipped with two methods for blowdown. One is a continuous blowdown and the other is manual. Daily blowdown is regulated according to concentration of dissolved solids as determined by test. The blowdown discharge is into a vented, selfcleaning catch basin, from which it goes to the sewer.

Forced and induced draft is supplied by American Blower fans, driven by Elliott turbines. The overfire air fans are driven by electric motors. Each boiler has an individual glass lined steel stack. The outlet of the stacks is about 105 feet above grade. Stokers are Westinghouse Electric Company (now merged with Detroit Stoker Company), 10,450 pound-per-hour coal. The boilers are equipped with American blower 2-stage cyclone dust collectors having an expected efficiency of 93%.

The coal burned is a bituminous 12,500 Btu per pound. At present 1962, it is estimated that it will take 50,000 tons of coal per year to fulfill steam demands. Cost of coal



PROPOSED FILTRATION SYSTEM SURROUNDING THE SMOKE STACK

is $8.87 per ton delivered on track. The stockpile contains 15,000 tons. This is about a 45 day supply of coal during peak demands.

The plants' coal handling system consists of a double railroad track into the plant site. However, there is only a track hopper on one track. A second hopper, called a reclaim hopper, is located in the storage yard to facilitate moving coal from the pile directly into the conveying system. Ordinarily, coal is unloaded directly from the railroad car into the trackhopper. The coal is conveyed from the hopper on a belt conveyor, and a bucket elevator to the top of the plant and into the coal bunkers. The coal conveying equipment has a capacity of 75 tons per hour. The bunkers have a capacity of 900 tons of coal.

Coal is fed by gravity from the bunkers through Richardson coal scales. The scales self dumping and recording for each 200 pounds. The coal is then directed to each stoker by means of distributing hoppers. The coal handling system includes an underbunker conveyor, Fairfield, by means of which, coal from any part of the bunker may be transferred to any boiler. This gives full utilization of the bunker capacity to any boiler. It also removes coal from any "dead" spots in the bunker so as to reduce the possibility of fires due to spontaneous combustion in the coal. The coal handling system includes two car pullers and one car shaker.

An automatic vacuum ash conveyor removes collected flyash, as well as bottom ash to a storage bin. Here a rotary, dustless, unloader discharges it to trucks for final disposition. The vacuum conveyor is made by United Conveyor Company with a capacity of 15 tons of ash per hour.

The boiler feed pump turbines and large turbine generator and the Worthington turbine driven air compressor use steam at 600 psi. The remainder of the auxiliaries use steam at 175 psi. Exhaust from the 175 psi drives is to the low pressure steam line that serves the campus. This pressure is maintained between 5–10 psig.

The piping system consists of a conduit that joins the new plant to a valve room located directly in front of the Service Building on University Avenue. The steam lines leaving the plant are 20″ and 18″ for the low and high pressure steam lines, respectively. Condensate is returned in an 8″ stainless steel condensate return line. There is also a 3″ high pressure air line, 90 psi. In front of the Service building the distribution system becomes a loop system branching out from the old plant in East and West tunnels traversing approximately 2 miles of tunnels and 4 additional miles of conduit. The principal pipes in the tunnels are the 170 psig main steam line, the 10 psig heating line, the condensate return line, and the compressed air line. The return lines have booster pumps installed in the buildings or

in some cases building groups forcing the condensate back to the feedwater system where it comprises 87% to 92% of the feed. Pipes in the tunnels have an expansion joint every 150 feet, gate valves every block to isolate sections, nearly 200 steam traps, and about 40 branch lines in conduits which serve individual buildings or groups of buildings. Typical installation of this type are the take-off lines to Wisconsin General Hospital which uses about 3% of the total steam produced. The branch lines are a four-inch main steam, a ten-inch heating line, and a four-inch return. In addition to the steam piping, the tunnels are crossed by city water mains, lake water mains and also contain electrical conduit, telephone lines, and a drainage system. Sump pumps are located at regularly-spaced intervals and emergency use, steam siphons have been installed. In each branch of the high pressure line going into the East and West tunnels there has been installed a motor operated quick-closing valve which can be closed in 15 seconds.

A furnace draft controller operates independently of the other controllers, maintaining the draft at the desired value for maximum combustion efficiency.

Water for boiler feed is supplied from a 6″ lake water main in Charter Street. This water is about 186 ppm hardness. There is a cross connection to the city distributional system but this is not a solid connection and would require about one hour to install. As a general rule the water pressure in the mains is sufficient for service in the plant, but booster pumps are installed to raise the pressure in case it is insufficient. The water is treated in a hot-lime-zeolite system with 125 gpm of outlet capacity. The zeolite softeners are in duplicate so one can be in service while the other is regenerated. Make-up water constitutes 8%–20% depending on losses in the plant and on the campus. The return water is returned to the plant to a hot well. It is mixed with make-up water in the deaerating heater, heated in a second stage heater and pumped into the boilers.

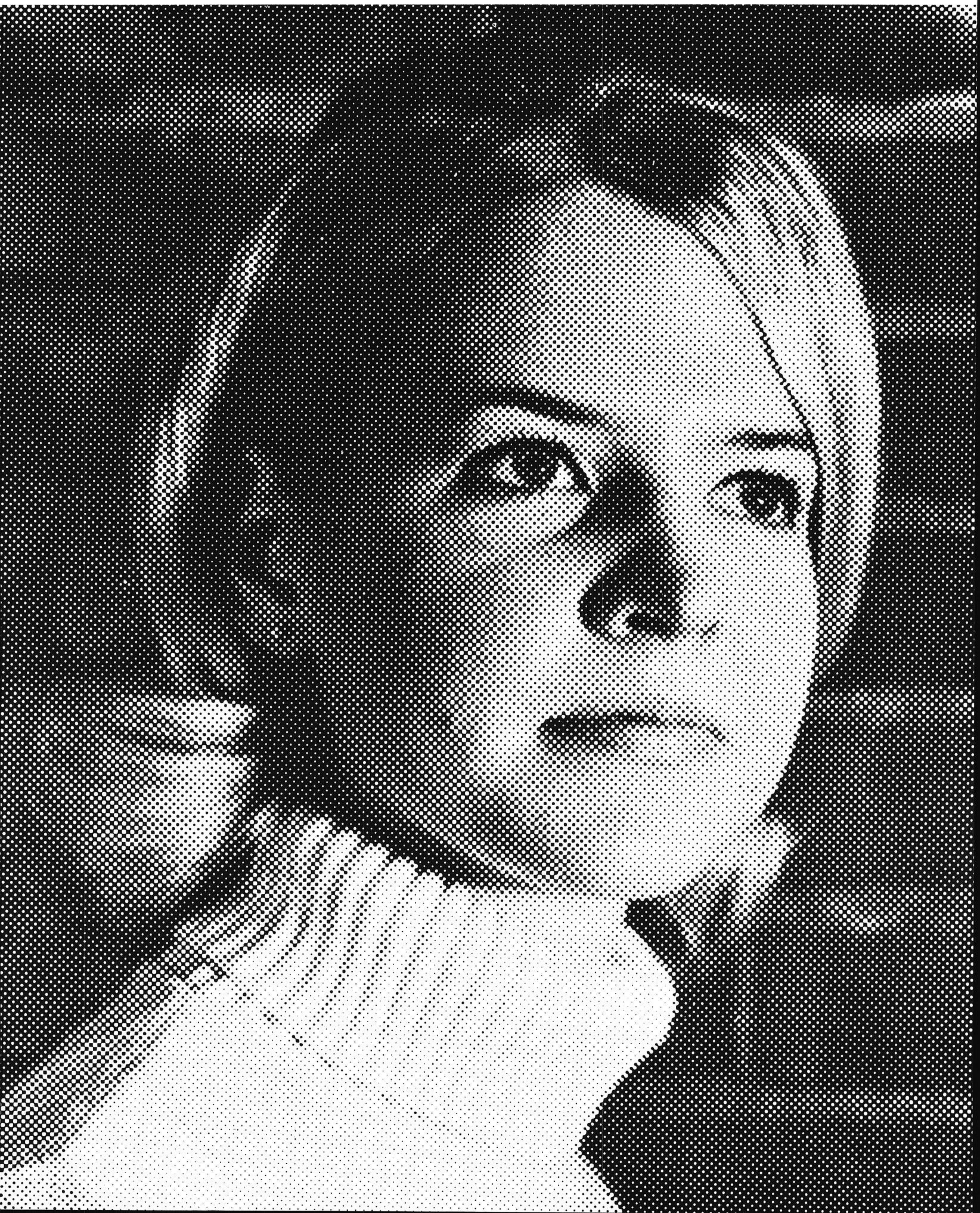
In addition a Worthington non-condensing turbine drives a 300 KVA, 3 phase, 60 cycle, generator that supplies emergency power for all the electric drives in the steam generating station. The starting of this unit will be controlled from the panel board with the steam valve operated with a direct current motor, operated from emergency batteries.

**Plant Description of University Pumping Station**

The University Pumping Station is located on Lake Mendota several hundred feet west of Park Street. From this building is pumped 60% of the total water used on the campus. This is an average daily consumption of 1.5 million gallons with an annual total of 660 million gallons.

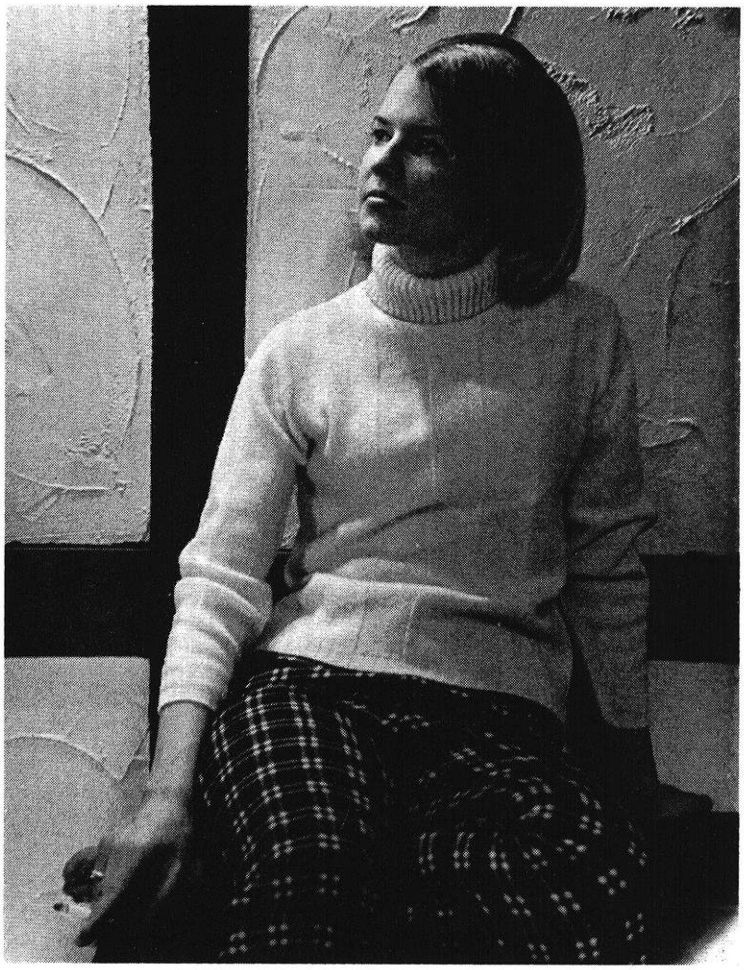
In the fall of 1959 a new intake was constructed into Lake Mendota. This is a 24″ diameter concrete that exends 600 feet into the lake.

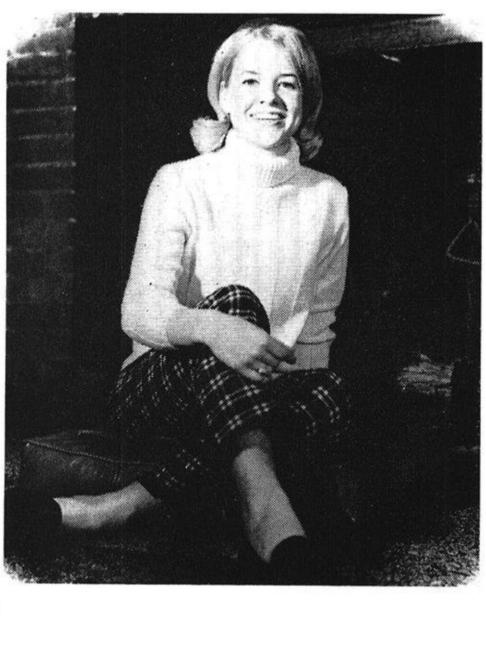
**PICTORIAL:**

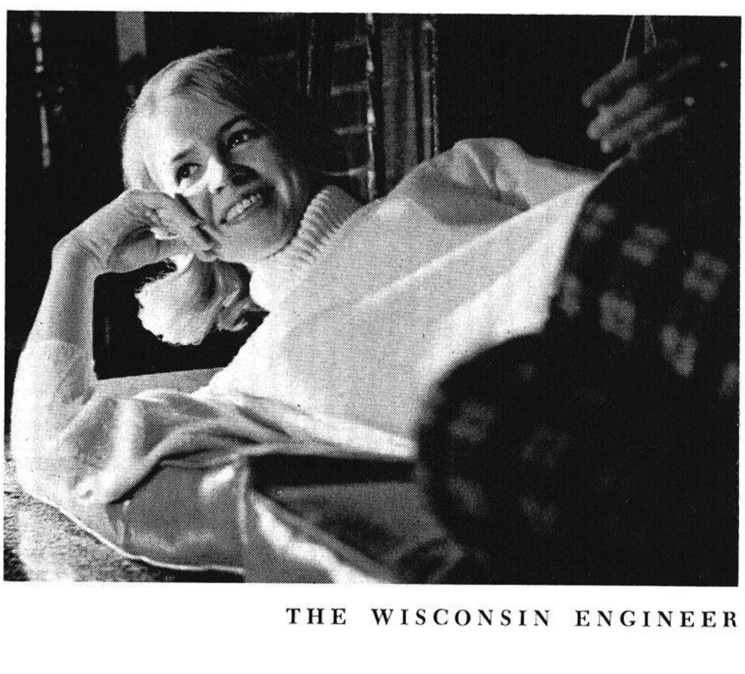


# wisconsin's finest

Beth Borsum is our cool blonde for February. Beth was reared in Appleton, moving to Canada where she enjoyed skiing and figure skating. Alpha Chi Omega was quite lucky to pledge her to their sorority; nevertheless, Beth finds herself socially successful being somewhat independent. She is warm, attractive and easy to talk to. One can go on and on about Beth—but as the saying states, "a picture can say a thousand words."

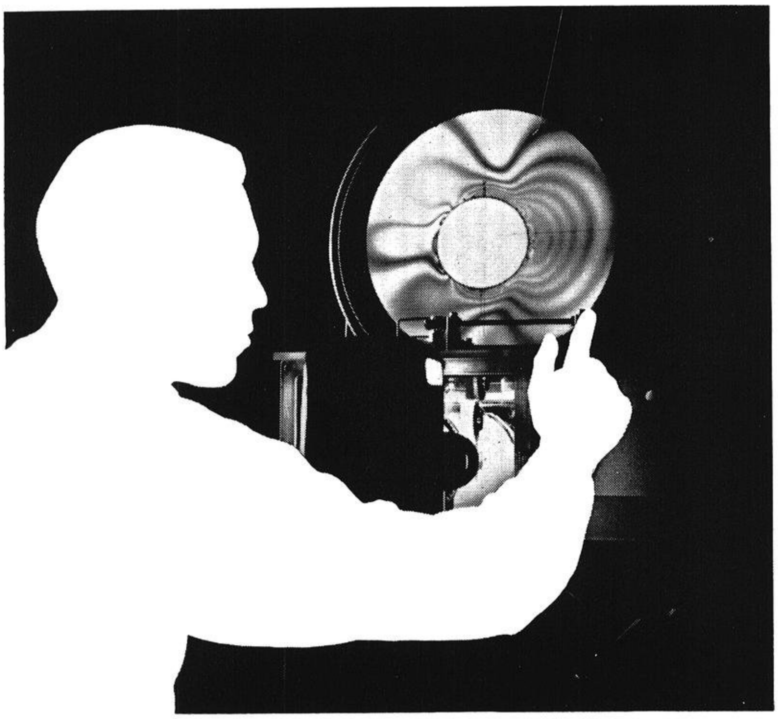






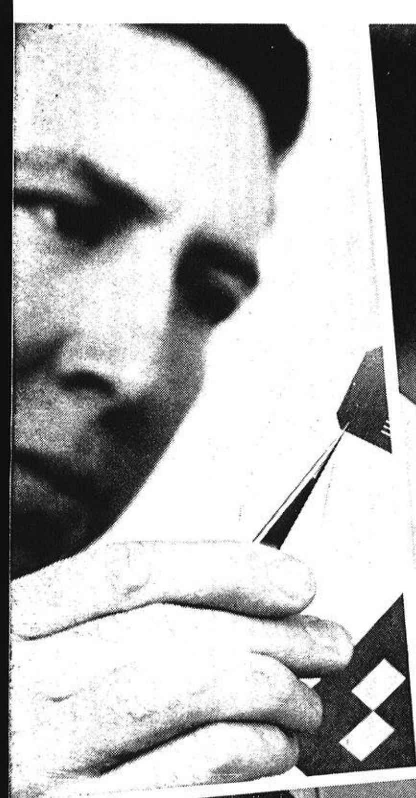
wisconsin's finest presents

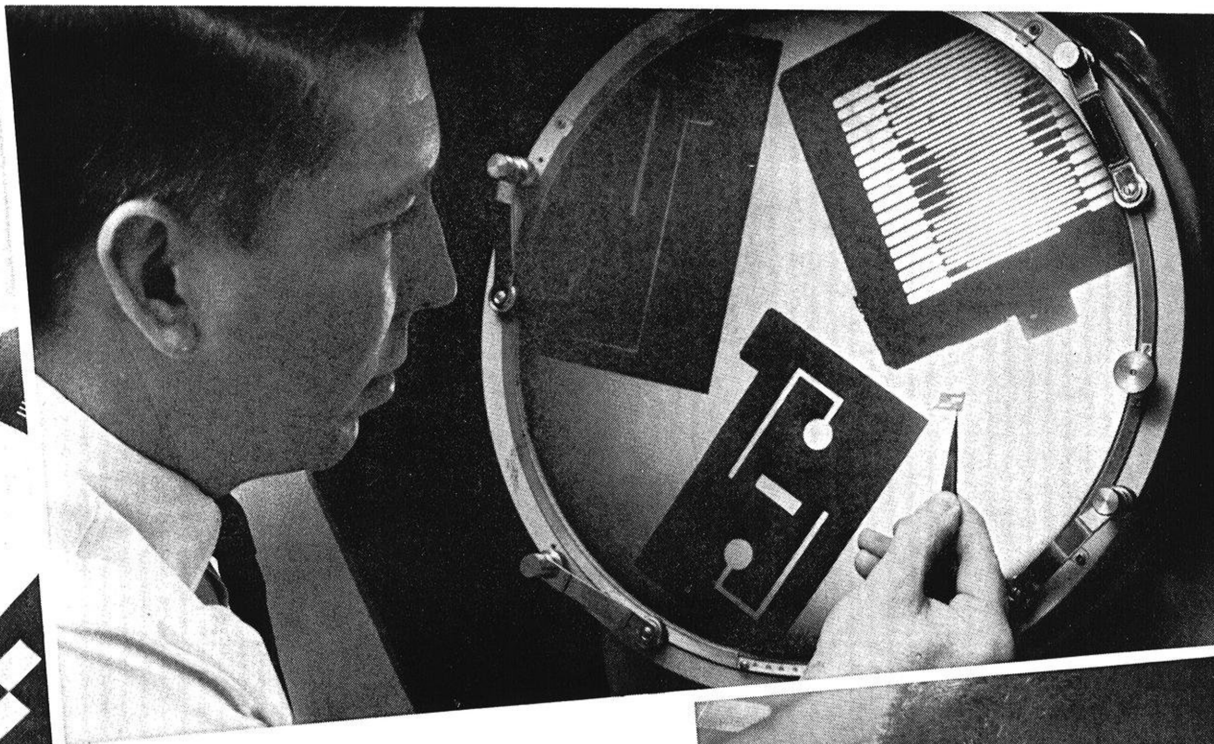
# BETH BORSUM

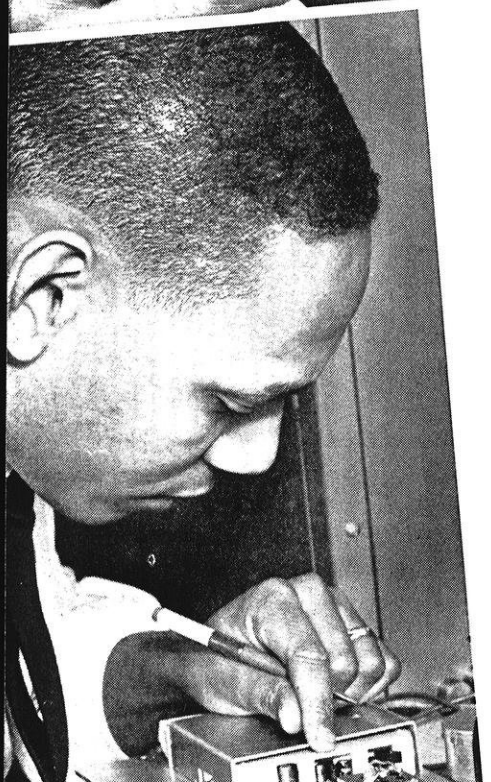


# PICTORIAL:
### *(Remember St. Pat's)*

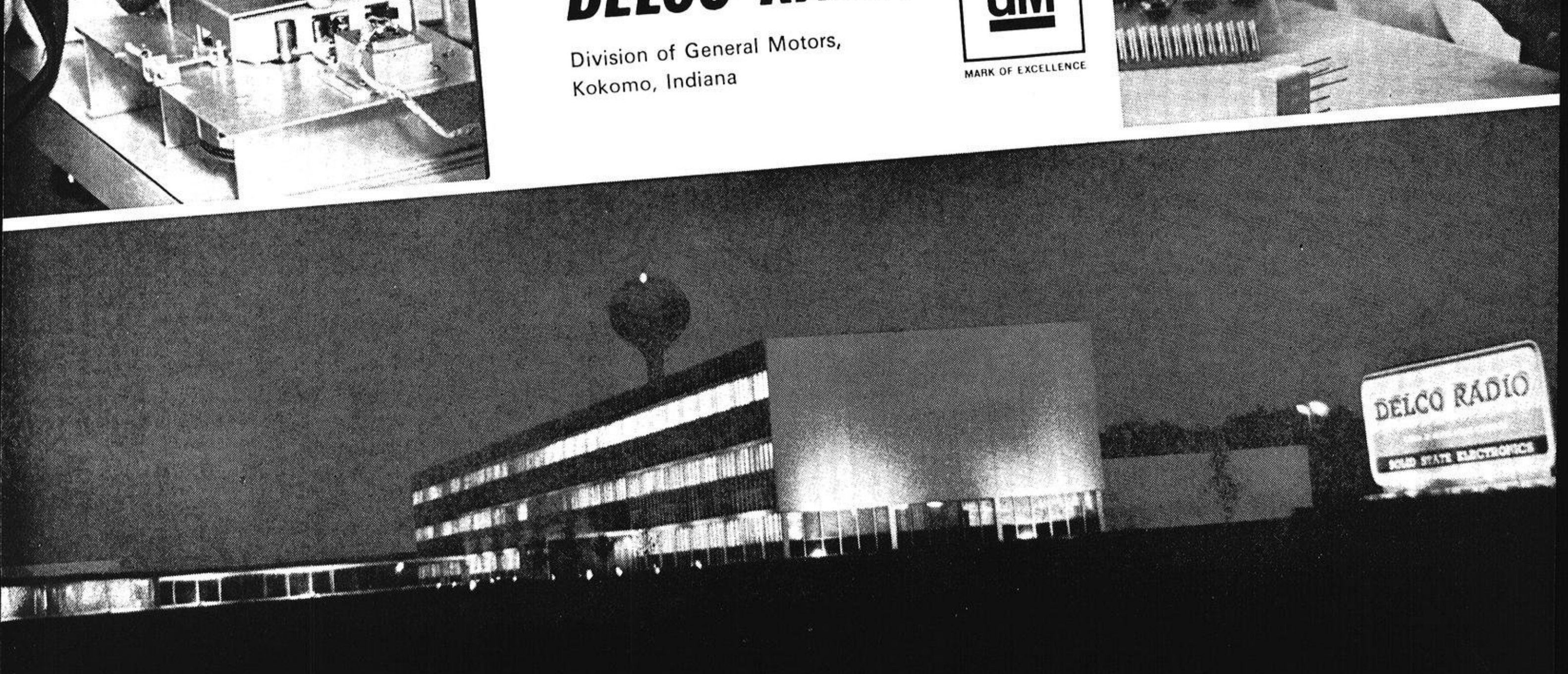
## wisconsin's album










DELCO RADIO
SOLID STATE ELECTRONICS

# Twenty-five hundred dollars in cash awards to engineering and metallurgy students.

The Forging Industry Educational and Research Foundation announces a $2,500 award competition for the best paper on the subject "How Mechanical and Physical Properties of Impression Die Forgings Are Best Utilized in Designing Forgings for New Applications." First prize, $1,000, plus eight other awards totaling $1,500.

Competition is open to senior and graduate engineering and metallurgy students. Length of the paper, 3,000 to 3,500 words. Deadline for completed paper: May 10, 1967.

Winner and his faculty advisor will also receive an all-expense-paid trip to White Sulphur Springs, West Virginia, where the award presentation will be made at the 1967 meeting of the Foundation.

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16-millimeter sound and color film, *TO BE FORGED*, describes forging process and design considerations. Length 18 minutes. Sponsored by Forging Industry Association, available on loan free from regional film libraries of Modern Talking Picture Service, Inc., 1212 Avenue of the Americas, New York, N.Y. 10036.

# TEASERS:

# PRAY FOR SNOW

**THE BYRD** B.S. '69

The Byrd sends to you the warmest of greetings on that holiday to end all holidays—St. Pat's Day. This month's puzzlers are short enough to read while refilling your glass with that green beer, and hard enough to confuse you mug after mug after mug. . .

* * *

Now to get down to business. A large circular table is pushed into the corner of a room so that it touches both walls. A beer stain on the very edge of the table, on the side nearest the wall, is known to be exactly 8 inches from one wall and 9 inches from the other. What is the diameter of the table?

* * *

A conical glass of 60° included angle is 3 inches high. What is the radius of a ball bearing which will displace the maximum amount of wine in the glass without spilling and which will bring the level of the wine to the rim of the glass" What is the original level of the wine?

* * *

Three persons are to divide among themselves 21 casks of equal size, 7 of which are full, 7 are half full, and 7 are empty. How can an equal division be made without pouring any wine from one cask into another and in such a way that each of the three receives an equal amount of wine and the same number of barrels?

* * *

Two candles of equal length are lit at the same time. One candle will burn for 4 hours and the other for 5 hours. At a particular instant one candle was 4 times the length of the other. How long had they been burning?

* * *

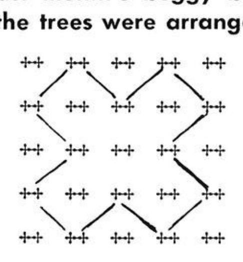
A farmer has a square piece of property, which in his will, he left to his wife, daughter, and three sons. The will specified that the wife should receive ¼ of the area in the form of a square. The balance was to be equally divided between the four children, each receiving identically shaped areas. Furthermore, the daughter's section could not border or touch the outer perimeter of the original area. How was the land divided?

* * *

There are four flies on the four corners of a square. Each one faces the fly next to him, in a clockwise direction. Each one starts walking at a certain instant, always walking directly towards the fly he was originally facing. All walk at the same speed. When they meet at the center, how far has each walked?

* * *

For those of you interested in the solution to the problem created by last month's buggy botanists and their box elder grove, the trees were arranged thusly:



* * *

Any readers who think they have a solution to any of this month's problems (with the help of the luck of the Irish) can send them in to the Byrd c/o the Wisconsin Engineer.

# HUMOR:

# FILEABLES CONTINUED . . .

Judge: "So they caught you with this bundle of silverware? Whom did you plunder?"

Thief: "Two fraternity houses, your honor."

Judge: "Call up the downtown hotels, sergeant, and distribute this stuff."

* * *

**An entrant in a long distance swimming contest in the English Channel was a girl from Italy. She amazed everybody by outswimming, all the top athletes from the rest of the world." Questioned by reporters on her background, she explained the formula for success: "I was a street walker in Venice for two years."**

* * *

Journalism Prof's exam question: "Coleridge was a drug addict, Poe was an alcoholic, Marlowe was killed by a man whom he tried to stab, Chatterton killed himself, Byron was accused of incest. Do you still want to be a writer and if so why?"

* * *

**The maharajah of an interior Indian province decreed that no wild animals could be killed by the populace. Soon the country was overrun by man-eating tigers, lions, panthers, elephants and boars. The people could stand it no longer and gave the maharajah the heave-ho. This was the first instance on record where the reign was called on account of game.**

* * *

The weird scientist looked over reports on his life-preserving tonic. "Hmmmmmm . . ." he mused, "I see where my elixir has had its first failure—a ninety-eight year old woman. Ah, but what's this? They saved the baby."

**Advice to exhausted students: When wine, women and song become too much for you, give up singing.**

* * *

The reason today's coeds will do things their mothers wouldn't think of doing is that their mothers didn't think of doing them.

* * *

**The messenger had just caught sight of Birnam Wood descending upon Dunsinane. He turned to Macbeth and shouted: "Your majesty, cheese it, the copse!"**

* * *

Theta: "I finally consulted Doctor Jones about this craving I have for kisses every time I have a few drinks."

M.E.: "Good, what did he give you?"

Theta: "A few drinks."

* * *

**"Halt, who goes there?"**

**"American."**

**"Advance and recite the second verse of the 'Star Spangled Banner'".**

**"I don't know it."**

**"Proceed, American."**

* * *

The salesman's knock was answered by something beautiful.

"Oh, good morning, Madam. May I speak to your husband?"

"Sorry, he's gone away on business and won't be back for a week."

He took another long look, sighed, and asked, "May I come in and wait?"

* * *

**The eager relatives gathered for the reading of the will. It contained one sentence: "Being of sound mind, I spent every damn cent I had."**

**"Wanna sell that horse?"**

**"Sure I wanna sell the horse," the farmer replied.**

**"Can he run?"**

**"Are you serious? Watch."**

**The farmer reached over and slapped the horse on his posterior and the animal went galloping away. As the horse reached full speed, he ran smack into a tree.**

**"Is he blind?" the buyer gulped."**

**"Hell no," the farmer said easily, "he just don't give a damn."**

* * *

"I take the next turn, don't I?" asked the driver of the car.

The muffled reply from the back seat: "Like hell you do!"

* * *

**Did you hear about the millionaire who had his swimming pool full of martinis? It was impossible to drown—the deeper you sank, the higher you got.**

* * *

We've heard that poultry has gone up a nickel, but pigeons continue to drop a little.

* * *

**You unattached?**

**No, I'm just put together pretty sloppy.**

* * *

**Mother: "Well, children, what have you been doing while I've been shopping?"**

**Child: "Oh, Mommy, we've been having so much fun! We've got Granny's hearing aid up to 50,000 watts—and you should see her nose glow!"**

* * *

Chief: "When anything goes wrong around the house I always fix it."

Wife: "Oh, yeah? Since you fixed the clock, the cuckoo backs out and asks 'What time is it?'"

# FILEABLES

A medium, giving a seance, was bringing back people from the other world. A nine-year-old boy was among those present.

"I want to talk to Grandpa," he said.

"Quiet! Quiet! hushed the medium.

"I want to talk to Grandpa," repeated the kid.

"Very well, little boy," conceded the medium, making a few hocus-pocus passes. "Here's your Grandpa."

"Hello, Grandpa, what are you doing up there? You ain't dead."

* * *

An astronaut set his rocket down on a strange planet. The moment he stepped off the rocket, a number of little furry animals came running to him. "Take me to your leader," the astronaut requested. A little furry took him by the hand and led him to a large glass building. Sitting majestically on a throne was a large furry with a long pointed needle on his head. "Why do you have the needle on your head?" asked the puzzled astronaut. "Why, I'm the furry with the syringe on top!" was the reply.

* * *

The little boy wanted $100 so badly he decided to pray for it. He prayed several weeks with no results. So he wrote God. The post office finally forwarded the letter to the White House. The President chuckled and ordered $5 sent to the boy. The lad, delighted that his prayers had been answered, in part at least, wrote a thank-you note to God, but added this P.S.: "I notice you routed my letter through Washington and, as usual, the damn bureaucrats deducted 95%."

* * *

Two duck hunters were sitting behind the blind, one drinking from a thermos bottle of coffee, the other from a jug of whiskey. After some hours of sipping they spotted a lone duck winging through the sky. Taking aim, the coffee drinker rose, left fire, and missed. The whiskey drinker rose, let fire, and brought the duck down. His companion, properly amazed, complimented him on the shot. He replied, "Aw, it's nothing. I usually get five or six out of a flock like that."

A jealous husband returned home early from a business trip and found his wife in the undress.

"There's a man in the house," he said searching every room. When he went into the bathrom he discovered a shadow behind the shower curtain. Immediately he opened it and found a man standing in the tub. The man jerked the curtain closed again. "Please," he said, "I haven't finished voting yet!"

* * *

An elderly man approached a small boy and asked: "Tell me young man, do you have a fairy godfather?"

"No," replied the little boy, "but I have an uncle we're all a little suspicious of."

* * *

A young school teacher said to her best student, aged seven, "Tommy, if I lay one egg on the table and two on the chair, how many will I have altogether?"

"Personally," answered Tommy, "I don't think you can do it."

* * *

A Ch.E. was experimenting with new formulas for beer. He labored on his various theories for over a year, and when finally hitting upon what he thought was a revolutionary process, he sent the formula to a laboratory to be analyzed.

The reply came back, "Your horse has diabetes."

* * *

Victims of an accident in Scotland were still lying on the road. Along came a native and said to a man lying on his back: "Has the insurance man been 'roon yet?"

"No," was the reply.

"Ah, weel," said the Scot, "I'll just lie doon aside ye."

* * *

Definition of Robot—A girl an engineer can make.

* * *

At a recent convention of the American Institute for the Preservation of Wooden Toilet Seats it was decided that the organization's name was too long. Consequently they named it the Birch john Society.

* * *

"Use a bottle opener, granny. You'll ruin your gums."

LIFE OF A JOKE

1 minute: Freshman thinks of a joke and tells it one night to his girl friend.

1 day: Joke circulates through the women's dorm and senior engineer overhears it.

1 week: Senior sends jokes in to humor editor, claiming origination to himself. Humor editor thinks joke is miserable, but since deadline has been set up one day and he is desperate for five more lines he decides to use it.

1 month: Joke appears at bottom of gag page. Humor editor is forced into exile.

1 year: Joke circulates through every engineering college magazine from Alabama to Canada, and from New York to Washington.

2 years: Gag writer for a radio program finds local college magazine on a bus and sees joke therein. Joke appears on next week's program. Gag writer loses union card.

2½ years: Reader's Digest prints joke from radio program.

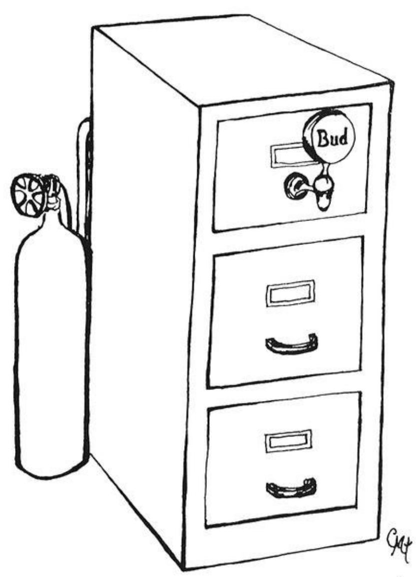
4 years: College professor finally gets around to reading the issue of Reader's Digest and laughs heartily at joke.

5–30 years: College professor uses joke to start off his lectures at beginning of each term.

35 years: Joke passes on as does college professor.

* * *

A wedding ring is like a tourniquet: it stops circulation.

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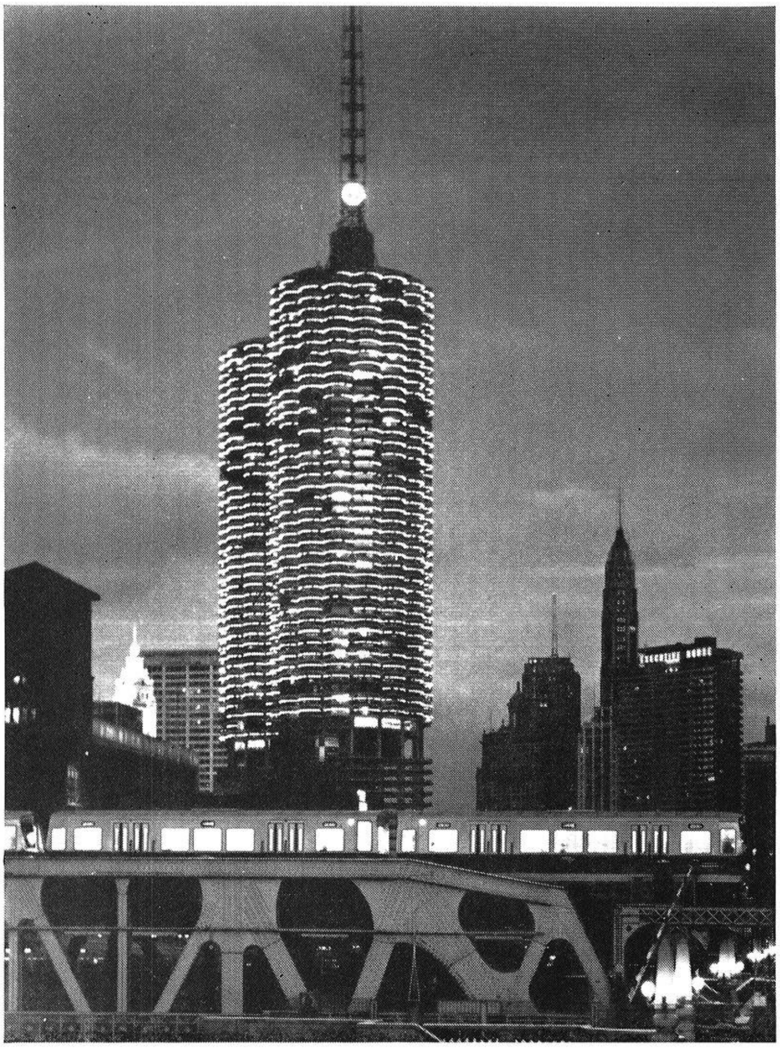

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