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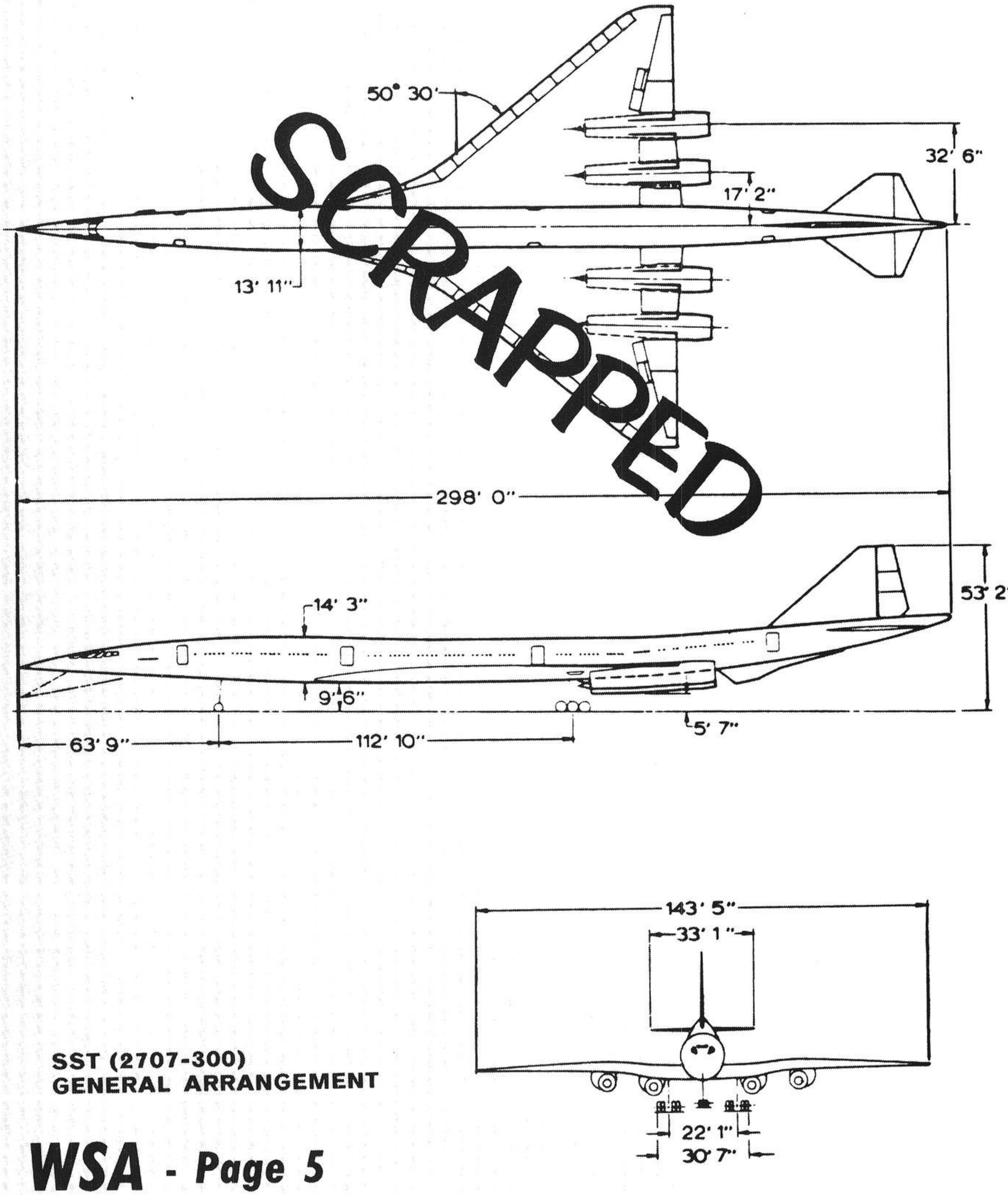
wisconsin engineer



SST (2707-300)
GENERAL ARRANGEMENT

WSA - Page 5

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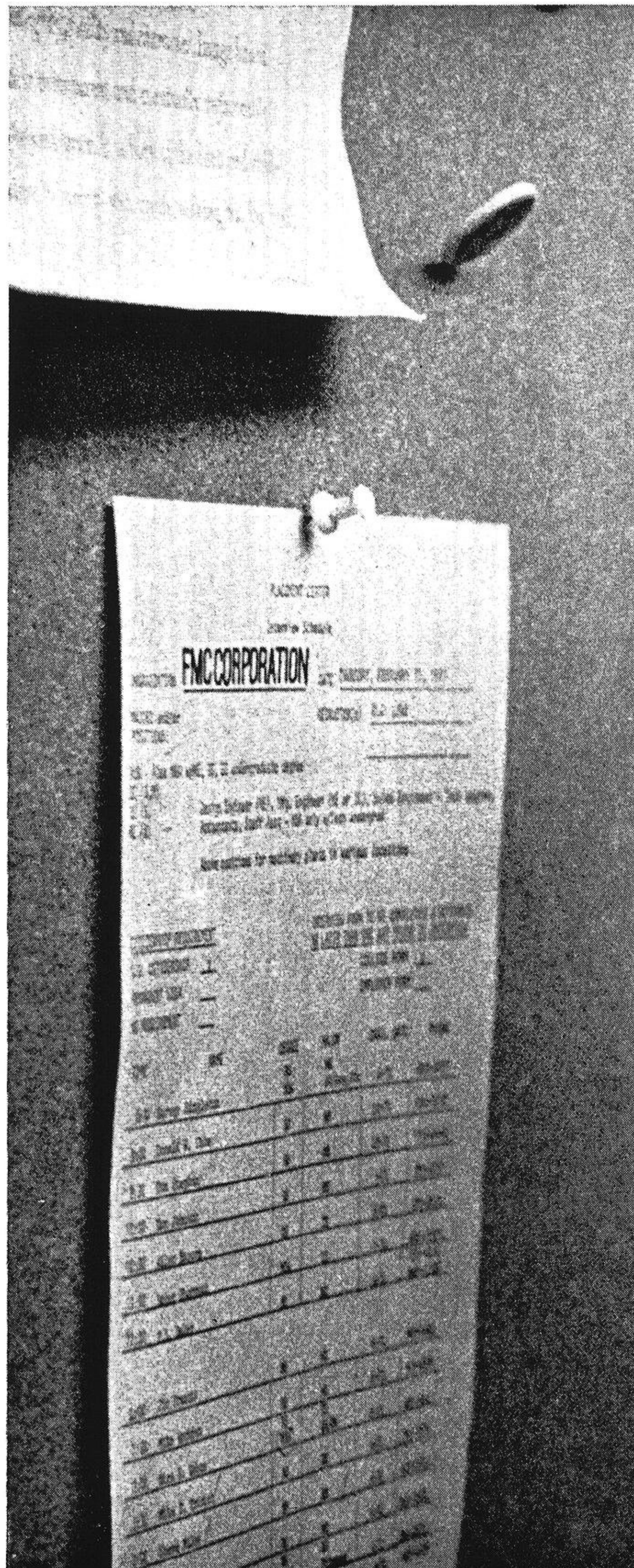

"We are drifting toward a catastrophe beyond comparison. We shall require a substantially new manner of thinking if mankind is to survive." – **(Albert Einstein)**

CONTENTS:

wisconsin engineer

MEMBER OF ENGINEERING COLLEGE MAGAZINES ASSOCIATED

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Horizon

Recall for a moment Feb. 21, 1967. Do you remember what happened that day? It was the Dow Demonstration and the beginning of the mass activist rock-throwing demonstrations which gained the University of Wisconsin international notoriety. The end (hopefully) to this senseless activity came with the death of Mr. Fassnacht and the bombing of the AMRC. The moral issue in some minds may have justified the acts but the means/end syndrome cannot be accepted in these situations or any other—remember Germany and the Jews and Calley and the commies.

Notice Mr. Engineer, where these activities took place. The Dow Rioters invaded the Engineering Placement Office (ask Prof. Marks, he remembers) and the bombing gutted Sterling Hall and Old Chem. Compare the number of times you've been in Bascom or Education to those in Engineering, Physics or Chem. Who and what were these people attacking? The answer is generally the Military-Industrial complex but this attack clearly indicted the scientist and the engineer for their societal indifference. This has always been a "popular" criticism of people persuing scientific knowledge and generating technological change. In some cases, the indictment is justified. In many others, however, the critic has often had a lack of knowledge of the facts or has been misinformed.

The breakdown of communication is also grounds for indictment of the engineer. For certainly in a plurality of situations, the engineer has not provided information to the public or has not lobbied to promote understanding. The topic of the Engineer's place in society has been debated by many within our own profession but rarely outside it. We must get out of our ivory towers and get actively involved with many interdisiplinary groups—then we can take that place we self-righteously claim.

We can start now by taking an important role in the upcoming campus elections. Do you recall the nationally televised interview with the present WSA president? Do you think he was representing the engineer or the scientist? Many companies cancelled interviews this year because they don't need people from an "activist" school and that's the image the present student government maintains and we must change that. Let's not move to the left or right, let's just make the middle wider by contributing our technical ability.

We need a new man to take over WSA, therefore, the *Wisconsin Engineer* endorses the candidacy of **Mark Wilder** for president of WSA, because we believe he represents the new leadership necessary to correct the problems which have plagued the student government on the campus for years. It is acknowledged that WSA is only what the letters indicate: Wisconsin Student Association—a representative association of student groups and individuals. WSA has no governing power; its function is to serve.

The present leadership of both leading campus parties view WSA as a vehicle for furthering their own political theologies rather than serving the real needs of the student community.

Student government as presently constituted is nothing but a sham and a farce, torn apart by personality disputes and with rumors of financial misconduct. It is no wonder that in the past only a small percentage of students have chosen to render legitimacy to this organization by participating in its elections.

Mark Wilder offers the OPPORTUNITY FOR CHANGE. He knows that student government has important goals to accomplish, but realizes that alienating the very people and leaders who support this institution is no way to achieve these goals.

At a time when the university and its role in society are seriously in question; when the legislature itself has begun to take steps that may curtail the growth and functioning of this University; and when the quality of undergraduate education is itself suspect, the students on this campus need a student government that can do more than merely show contempt for the people who support this public institution.

When that very same student government has been tarnished by allegations of financial scandal; when, time and time again, only a small percentage of students have even participated in student government elections; and when student government leaders have deluded themselves into thinking they can affect foreign policy; even the need for a student government is questionable!

The fact of the matter is, however, that students do need an elected spokesman and an organization that can meet the demand for all student services.

There is also a need for someone "outside" of WSA to come in and bring new ideas and a fresh approach to the challenge that confronts the student community.

The engineers on this campus can help to bring this about. In the past we have not been noted for our participation in the elections and perhaps must take much of the blame for WSA's present lack of effectiveness. Now we have a chance to remedy this.

The elections are scheduled for April 28th and 29th; a candidate will probably need only 4,000 votes to be elected. Engineers will have an opportunity to prove that they do have a say in student affairs and do have an effect on the outcome of student elections. Engineers are a part of the student community and we must take steps to make our elected representatives speak for us as well as the rest of the student community.

VOTE FOR MARK WILDER
VOTE HORIZON
VOTE APRIL 28-29
VOTE FOR YOURSELF
VOTE — VOTE — VOTE — VOTE — VOTE

Monte

Simu

BY THOMAS J. HOOD

This article was entitled *"Monte Carlo Simulation as Applied to Mechanical Engineering"* and submitted as fulfillment of the Technical report requirement of the tech writing course.

INTRODUCTION

In problems involving uncertainty, a formal analytical solution may be difficult or impossible to achieve. One way to deal with such problems is by using the trial-and-error method. What is sometimes done is to try various potential solutions to the problem, and then to select the first one that "works". In this case, the best solution is possibly never reached. In other cases of trial-and-error, several potential solutions are tested. Their results are measured against some set of criteria, and the best solution is chosen.

In the more complex problems, the trial-and-error method would be too expensive and too time consuming to justify use. It is in cases such as this that the Monte Carlo method is valuable and economical.

The purpose of this paper is to show, by means of an example problem, how the mechanical engineer can be aided by the Monte Carlo Simulation Method. This particular example was chosen because it is a typical mechanical-engineering problem.

WHAT IS MONTE CARLO SIMULATION?

In its most elementary sense, Monte Carlo Simulation is the representation of reality. It is a technique whereby data is generated by some random number generator. More specifically, the Monte Carlo method consists of solving various problems of computational mathematics by means of some random process with the parameters of this process equal to the required quantities of the problem.

As applied in industry, the "random process" mentioned above is no more than the random numbers derived from a computer's random-number generator. We can think of these numbers as chosen "right out of a hat" because they are completely independent of one another.

There are three basic applications of Monte Carlo Simulation:

1) Simulation of practical systems
2) Management and war games
3) Engineering and physics applications

While all three applications are of interest to the scientist, the latter is obviously of primary concern to the engineer.

APPLICATION OF MONTE CARLO SIMULATION

A commonly practiced method of supporting one's viewpoint is to illustrate the point by means of an example. If the example is properly selected and expressed, it can add greatly to one's argument.

My point is that Monte Carlo Simulation is applicable to mechanical engineers. The example I use, thermal radiation of a body in outer space, is a typical mechanical engineering problem. I think, therefore, that if you appreciate the value of simulation in this example, you will see its usefulness to mechanical engineering problems in general.

Specific Example: Heat Dissipation in Outer Space

Many engineering applications must take into account the effects of heat dissipation. The heat dissipated from a body is usually made up of two components:

Carlo

ation

1) *The simultaneous action of conductive and convective heat transfer to a fluid medium surrounding the body.*
2) *Thermal radiation*

In deep outer space, however, the heat dissipated from a body is limited to thermal radiation. The effects of conductive and convective heat transfer are eliminated because of the negligible amount of atmosphere encountered there. The design of radiating surfaces and the thermalradiation characteristics of materials are very important in considering heat dissipation in such an environment.

The problem we will deal with here involves the analysis of the temperature distribution along fins of various designs. Since the operating temperature is constant, the problem is one of steady heat flow with the system in thermal equilibrium. The heat dissipated by the fin considered in this example involves:

1) *Conduction along the fin*
2) *Radiation from the fin surface*

Before we plunge into this example, we must develop the specific radiation and conduction equations.

Conduction Equation

According to Fourier, the instantaneous rate of heat flow is proportional to the area through which the heat flows at right angles, and to the temperature gradient along the axis of flow. Expressed as an equation, the preceding becomes:

$$\frac{\delta Q}{\delta \phi} = -kA\frac{\delta T}{\delta \chi}$$

where A is the perpendicular area, $\delta Q/\delta \chi$ is time, k is the termal conductivity proportionality factor, and $\delta Q/\delta \phi$ is the temperature gradient. In this example, however, because the conduction is steady-state, the temperature gradient and the rate of heat flow are independent of time. Therefore, the instantaneous rate of head flow $\delta Q/\delta \phi$ becomes a constant rate of heat flow commonly referred to as q_c. Transforming the above equation to reflect the steady head-flow condition, we have:

$$q_c = -kA\frac{dT}{dX} \qquad \text{(Equation 1)}$$

Thermal Radiation Equation

The emissive power W is the power formed when a heated body gives off radiant energy. This power varies with the surface temperature, surface roughness, and if the surface is metal, with the degree of surface oxidation. A surface which gives off radiant energy will also absorb incident radiation. The fractional part of the total incident radiation that a surface is capable of absorbing is called the absorptivity of the surface, and is designated by θ. According to Kirchoff's law, at thermal equilibrium the ratio of the emissive power of a surface to its absorptivity is the same for all bodies.

The ratio of the emissive power of an actual surface to that of a body with zero reflectivity is known as the emissivity of the surface and is denoted by ϵ. We find, again according to Kirchoff's law, that at thermal equilibrium the emissivity and absorptivity of a body are the same.

Because of the total emissive power of a body with zero reflectivity depends only on its temperature, we can use the Stephan-Boltzmann law to define the emissive power of such a body. It is

$$W = \sigma T^4$$

where σ is the Stephan-Boltzmann constant.

The net rate of loss of energy by radiation of a body at temperature T_1 into surroundings at temperature T_2 is given by:

$$q_r = \sigma A_r(\epsilon_1 T_1^4 - \theta_{1,2} T_2^4)$$

(Continued on Page 13)

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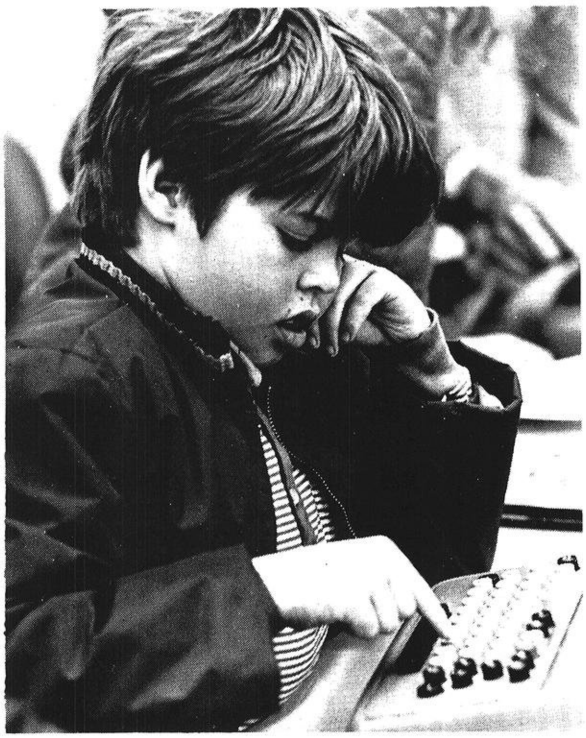
EXPO



Pictorial

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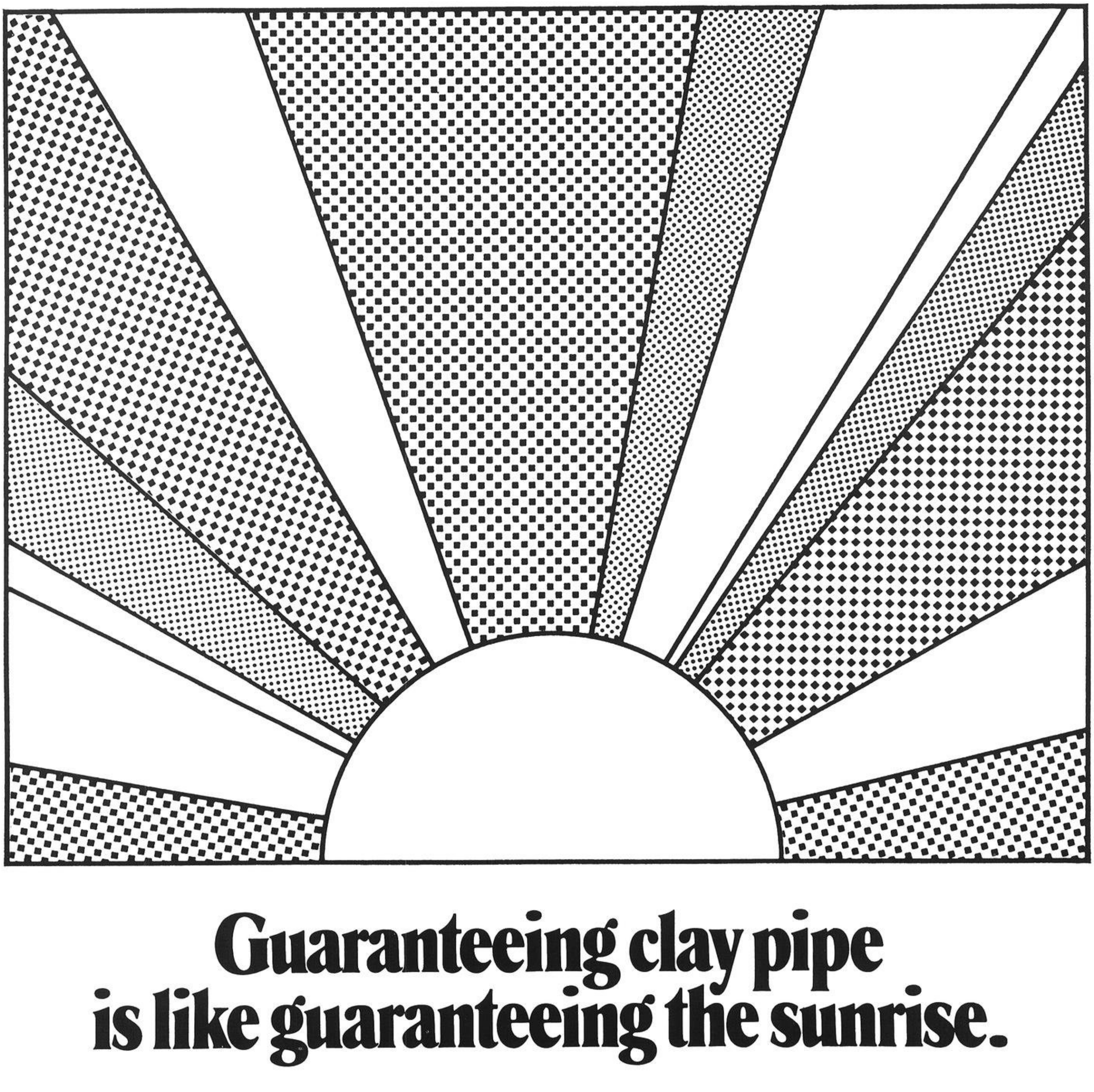
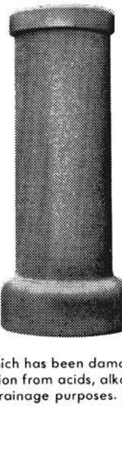




(Continued from Page 7)

A_r is the area of the radiating surface, ϵ_1 is the emissivity of the radiating body at temperature T_1, and T_1 and T_2 are the temperatures of the radiating and receiving bodies, respectively, measured in degrees Rankine. Because the emissivity and absorptivity of a body at thermal equilibrium are the same:

$$q_r = \sigma A_r \epsilon_i (T_1^4 - T_2^4) \qquad \text{(Equation 2)}$$

The Fin and Its Parameters

Since we have established the specific equations for a heat dissipating body in outer space, we are now in a position to describe the body itself. The body that we will use in this example is a fin. This fin is pictured below.

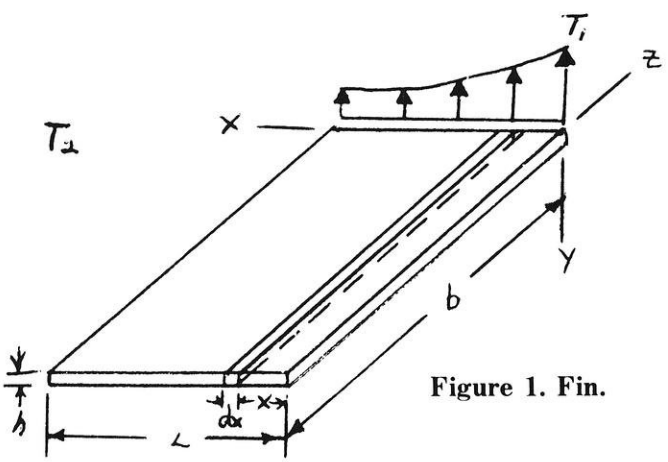


Figure 1. Fin.

The essential parameters are as follows:

T_1=absolute Fahrenheit temperature at any position along the fin, °R

T_2=absolute Fahrenheit temperature of surrounding space, 0° R

σ=Stephan-Boltzmann constant, 0.172 $(10)^{-8}$ Btu/$(ft)^2$ (hr) $(°R)^4$

ϵ_1=Emissivity of fin, 0.8

b=width of fin in z direction, 0.5 ft.

h=thickness of fin, $0.005 < h < 0.01$ ft.

k=thermal conductivity of fin, 25Btu/(hr) (ft) (°R)

$(T_1)_0$=the constant temperature of fin at root end (x=0), 2000°R

L=length of fin, 0.25 ft.

The fin will be in thermal equilibrium when the heat dissipated per hour due to radiation is equal to the heat conducted along the fin per hour. Whenever the fin as a whole is in thermal equilibrium, each element or segment of the fin must also be in equilibrium. Following the same logic as before, the amount of heat conducted into and out of each elemental segment must be equal to the heat dissapated in that segment due to radiation over a common period of time. Referring back to figure 1, a differential element is chosen that has a cross-sectional area bh, an effective radiating surface of 2b dx, and a length of dx. We can now equate equations one and two developed previously.

$$\left[-kbh\left(\frac{dT_1}{dx}\right)x\right] - \left[-kbh\left(\frac{dT_1}{dx}\right)x+dx\right] =$$

$$\sigma\epsilon_1(2bdx)\ (T_1^4 - T_2^4)$$

After simplification, this equation becomes:

$$\frac{d^2T_1}{dx^2} = \frac{2\sigma\epsilon_1}{kh}\ (T^4 - T_2^4)$$

When the parameter values are substituted into the above equation, the result is:

$$\frac{d^2T_1}{dx^2} = \frac{0.011(10)^{-8}\,T_1^4}{h} \qquad \text{(Equation 3)}$$

The thickness of the fin, h, is left variable for programming purposes. In this example, three different fin thicknesses will be considered. They are 0.005, 0.0075, and 0.01 ft.

The boundary values we will place on the problem are as follows:

$$x=0 \left[\begin{array}{l} T_1 = 2000°R \\ \dfrac{dT_1}{dx} = ? \end{array}\right. \qquad x=0.25 \left[\ \dfrac{dT_1}{dx} = 0 \right.$$

The meaning of the first constraint is at a length x=0.0 ft., the temperature of the fin is equal to 2000° Rankine and the temperature gradient has some negative value. The second constraint says that the other end of the fin, at x=0.25 ft., the temperature gradient has a value of zero.

Equation 3 is the equation we have to solve in order to analyze the temperature distribution along the fin. Because this equation is so complex, we have to break it down into voltage equations. We can do this by remembering that the computing time corresponds to the x-coordinate along the fin. The voltage equations are as follows:

$$e_1 = -s\frac{dT_1}{dx} = \frac{-1}{D}\left[\,s_1(0.011)\ \ (10)^{-8}\,T_1^4\,\right] - s(-?)$$

$$e_2 = s_2T_1 = -\frac{1}{D}\left[-s_2\frac{dT_1}{dx} + s_2(2000)\right]$$

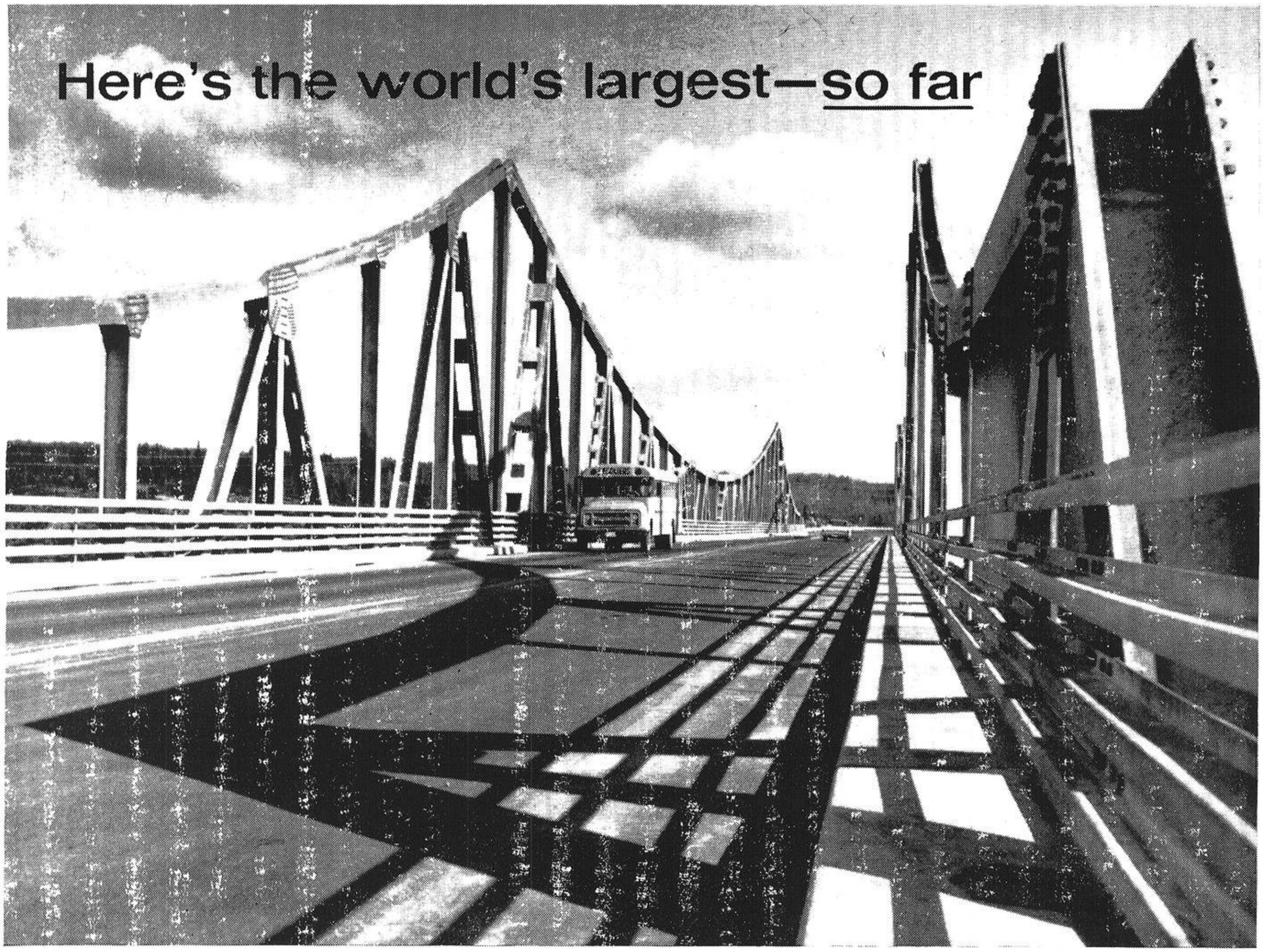
$$e_3 = s_3q_r = -\frac{1}{D}\left[-s_3(0.1384)\ \ (10)^{-8}\,T_1^4\right]$$

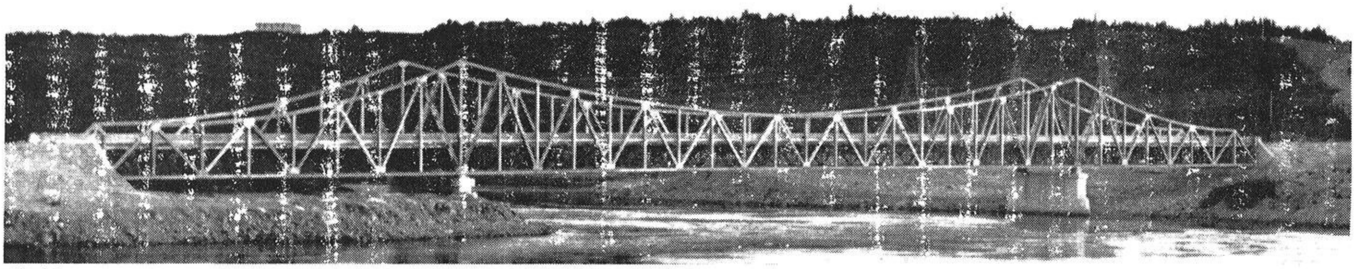
The s's in the above equations are simply scale factors. Their function is to rid the three equations of units and to make 0.25 ft. correspond to five seconds. Their values are as follows:

s_1=0.0002 volt/ (°R/ft)
s_2=0.04 volt/°R
s_3=0.04 volt/(Btu/hr)

(Continued from Page 13)

Galvanized Steel Bridges save the taxpayers dollars—





This new 900 foot long bridge is the latest example of the trend to maintenance-free galvanized steel bridges. It is the Hauterive Bridge over the Manicougan River, 250 miles north of Quebec City, Canada. ☐ Because of its relatively remote location, designer Emile Laurence gave special consideration to the taxpayers maintenance dollar. He specified a zinc overcoat to protect the bridge against corrosion and also avoided possible damage from tall loads by eliminating any upper wind bracing. The designer placed the deck higher than usual—approximately 14 ft from the lower chord. This made it possible to use very deep bridging to insure stability. The composite deck also acts as wind bracing, supplementing the stiffness provided by the horizontal bracing at the lower chord, so that the whole acts as a tubular truss. ☐ Most of the steel was hot dip galvanized while other members were metallized with zinc. ☐ In bridges and guard rails, steel's strength guards human life and zinc guards steel's strength against corrosion.

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(Continued on Page 15)

The next step initiates the actual simulation process. All the work done thus far, while not really simulation, is required before the method can be used. What we do is solve the three voltage equations simultaneously, making sure we satisfy both of the boundary conditions. We accomplish this by generating random numbers from a uniform probability density function to represent the temperature gradient dT_1/dx. This procedure must be repeated until a solution is obtained in which the temperature gradient is parallel to the x— axis at a time corresponding to x=0.25 ft.

I think you can see the important role simulation plays in this problem by noting that the solution can be obtained only by using the simulation trial-and-error method. It would be impossible for a person to solve the three voltage equations simultaneously thousands of times by algebraic manipulations; it would require too much work. Also, we could set up a test area with conditions similar to those prescribed before, but there are so many interacting variables that it would be extremely difficult to arrive at a solution.

The results of the simulation of this problem are shown graphically in Figures 2 and 3. The temperature distribution curve shows us that the temperatures along the fin are lower as the fin is made thinner. The radiation curves demonstrate that the heat dissipated per hour is less as the fin is made thinner.

Fig. 2

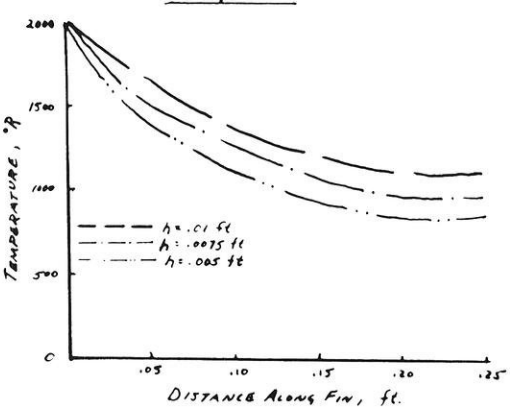
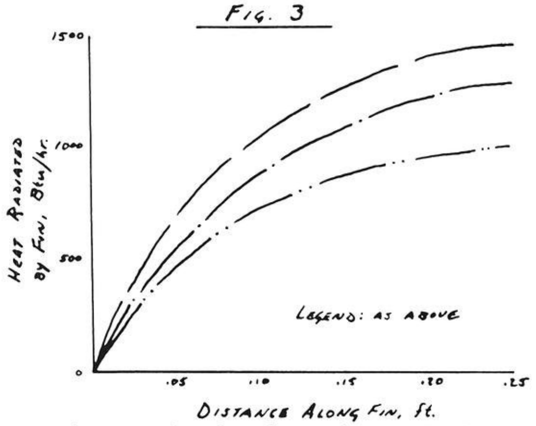


Fig. 3



A more interesting fact brought out is that as the fin is made thinner, the distribution of the heat dissipation shifts. Because all three fins dissipated approximately seventy-five percent of their total heat along the first forty percent of the fin, we should analyze the possibility of using shorter fins. Use of this method would undoubtedly result in a much better fin dissipation per unit of weight involved.

As demonstrated in the preceding paragraph, one of the primary assets of Monte Carlo Simulation is that it can lead to assumptions that were previously not considered. These assumptions usually lead to modifications that improve the system being modeled by simulation.

Reflecting on the example just presented, we see that Monte Carlo Simulation was a valuable aid for two reasons. First of all, it drastically reduced the time, and therefore the cost, required to solve the problem. Second, it led to an important assumption that was previously overlooked; in this case, the possibility of using shorter fins was bypassed. I feel that the simulation method demonstrates its value in this example and, in turn, its value to mechanical engineering problems in general.

FUTURE PROSPECTS

The mechanical engineer is wise if he uses the Monte Carlo technique in his work. Especially in the field of design, the Monte Carlo method has unlimited possibilities. It can prescribe the best thickness, shape, and size of a job, and can also reveal overlooked assumptions. Another justification for its application is that if used properly, the technique can save a company much time and money.

Despite its usefulness, few mechanical engineers use the Monte Carlo method to date. This is primarily because most mechanical engineers are not aware of its existence. However, because of the complexity of problems that face today's engineer, this method hopefully will become more widely used in the future.

SUMMARY

Monte Carlo Simulation is the representation of reality. It is used in the more complex problems where the trial-and-error method would be too time consuming and too expensive to justify use.

The Monte Carlo method is valuable not only for the specific values it obtains, but also for the insights it introduces. It enables the engineer to make deductions, and in turn changes in a system, which will improve that system.

The Monte Carlo technique can be a valuable tool for the mechanical engineer, especially in the area of design. While mechanical engineers do not use the technique extensively at present, its application will probably grow in the future.

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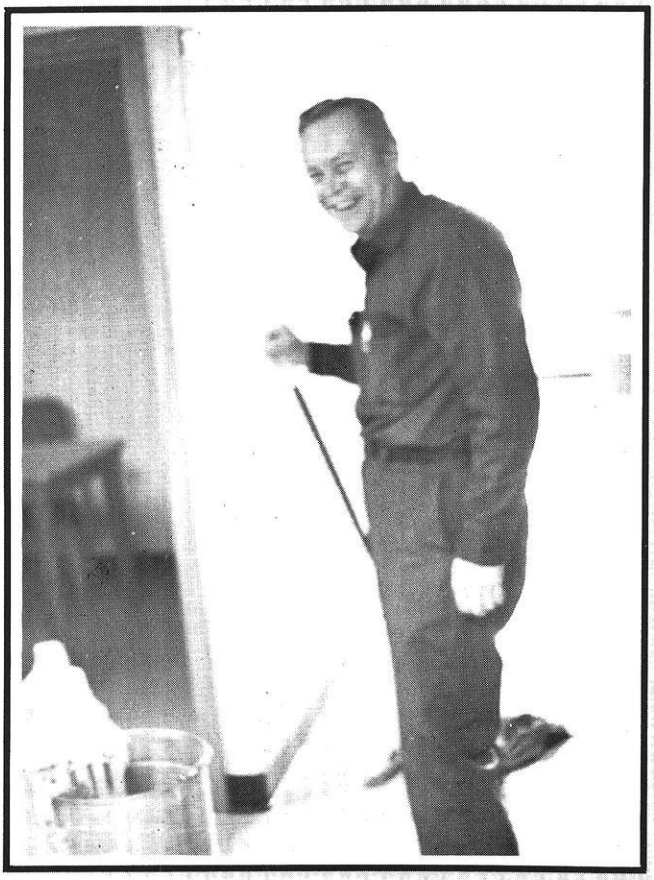

Caption 1: "There's no job crisis."
Caption 2: Peters Principle Personified?