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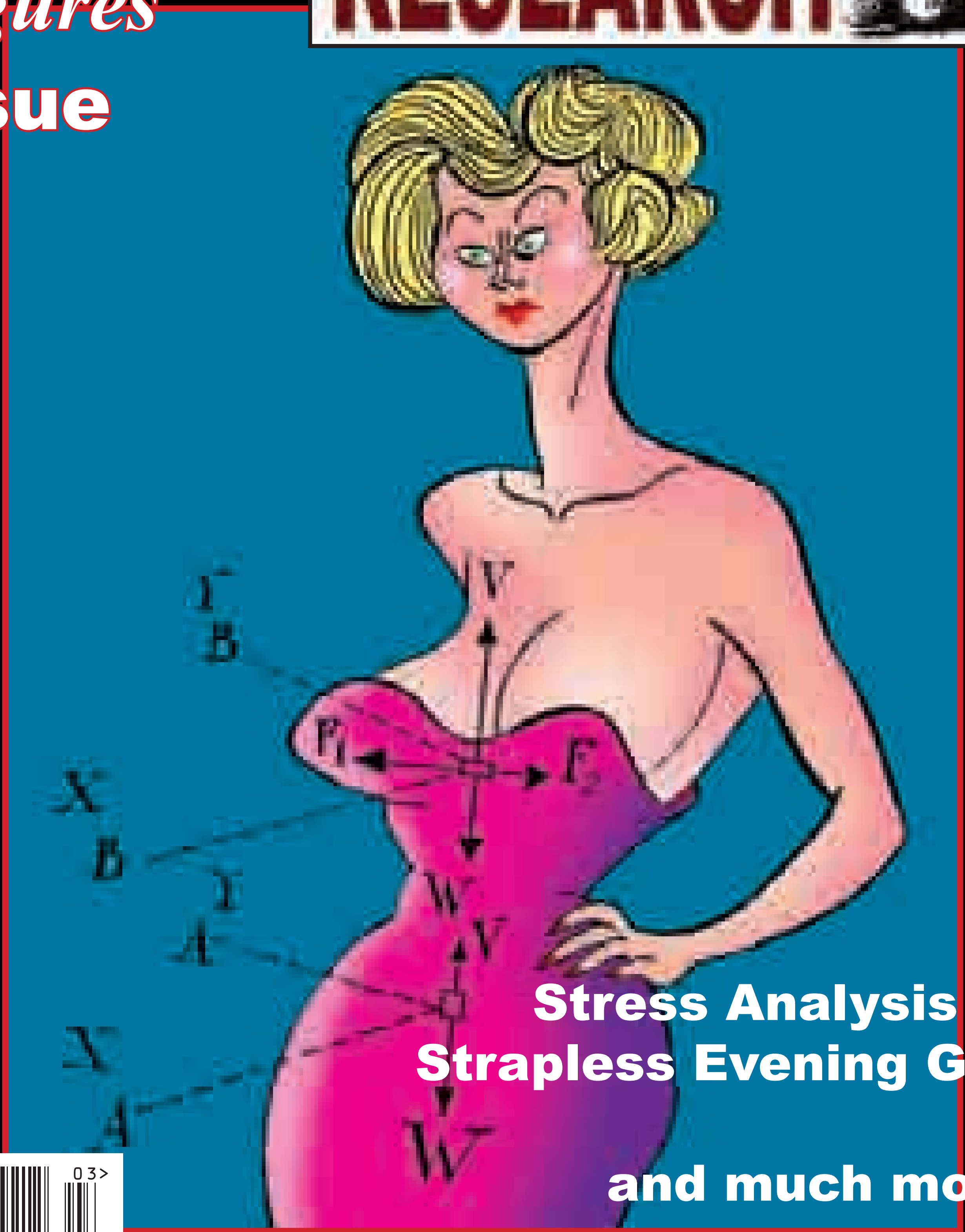

Stress Analysis of a Strapless Evening Gown

and much more...

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A Stress Analysis of a Strapless Evening Gown

by Charles Seim
Berkeley, California

[Editor's note: Charles Seim wrote this article in 1956. We are republishing it here with his permission. Seim went on to become one of the world's most renowned bridge designers. On February 16, 2007, for the first time ever, he presented "Stress Analysis" as a public lecture. This was a featured part of the Improbable Research show at the American Association for the Advancement of Science's Annual Meeting, held in San Francisco. Here is the full text of the original article.]

Since the beginning of recorded history, the human being has worn some sort of clothing either for protection or warmth. However, the present trend among the "fair sex" is to wear clothing not for protection or warmth, but solely to attract the attention of the opposite sex. To be more specific, it is through the use of clothing that the female most effectively catches the eye of the very appreciative but totally unsuspecting male.

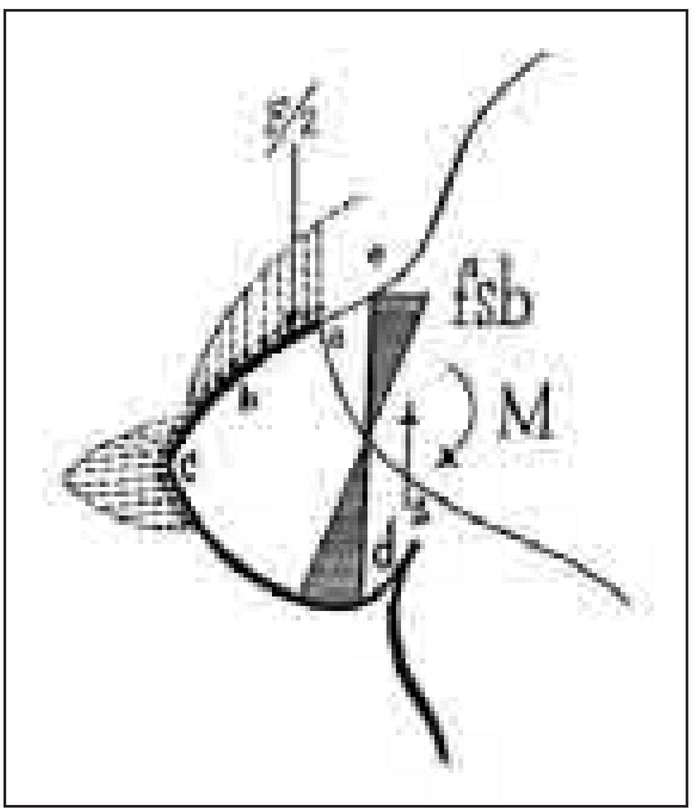


Figure 2. Force distribution of cantilever beam (fsb = flexural stress in beam).

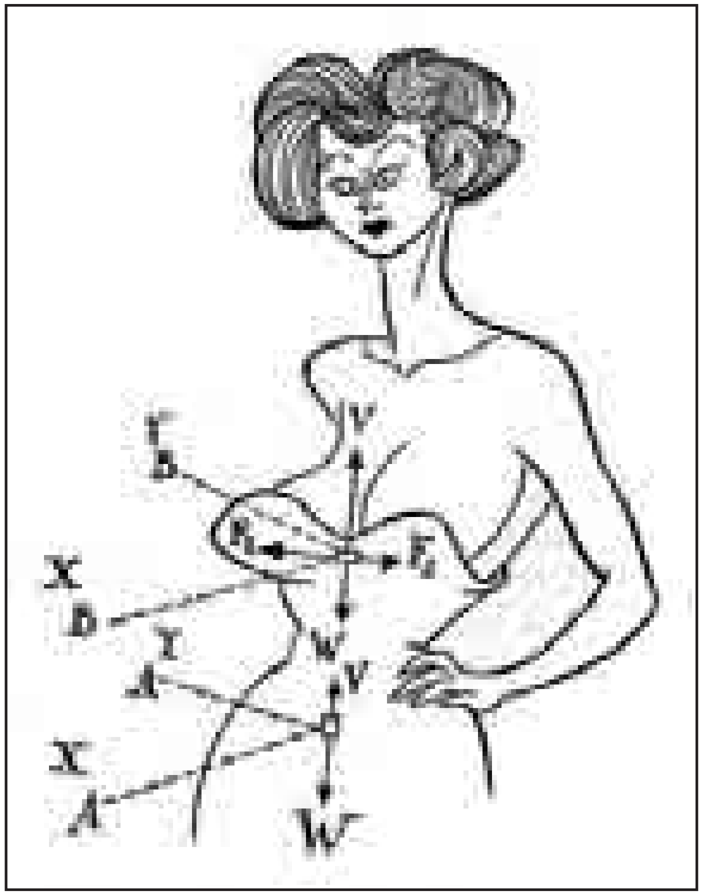
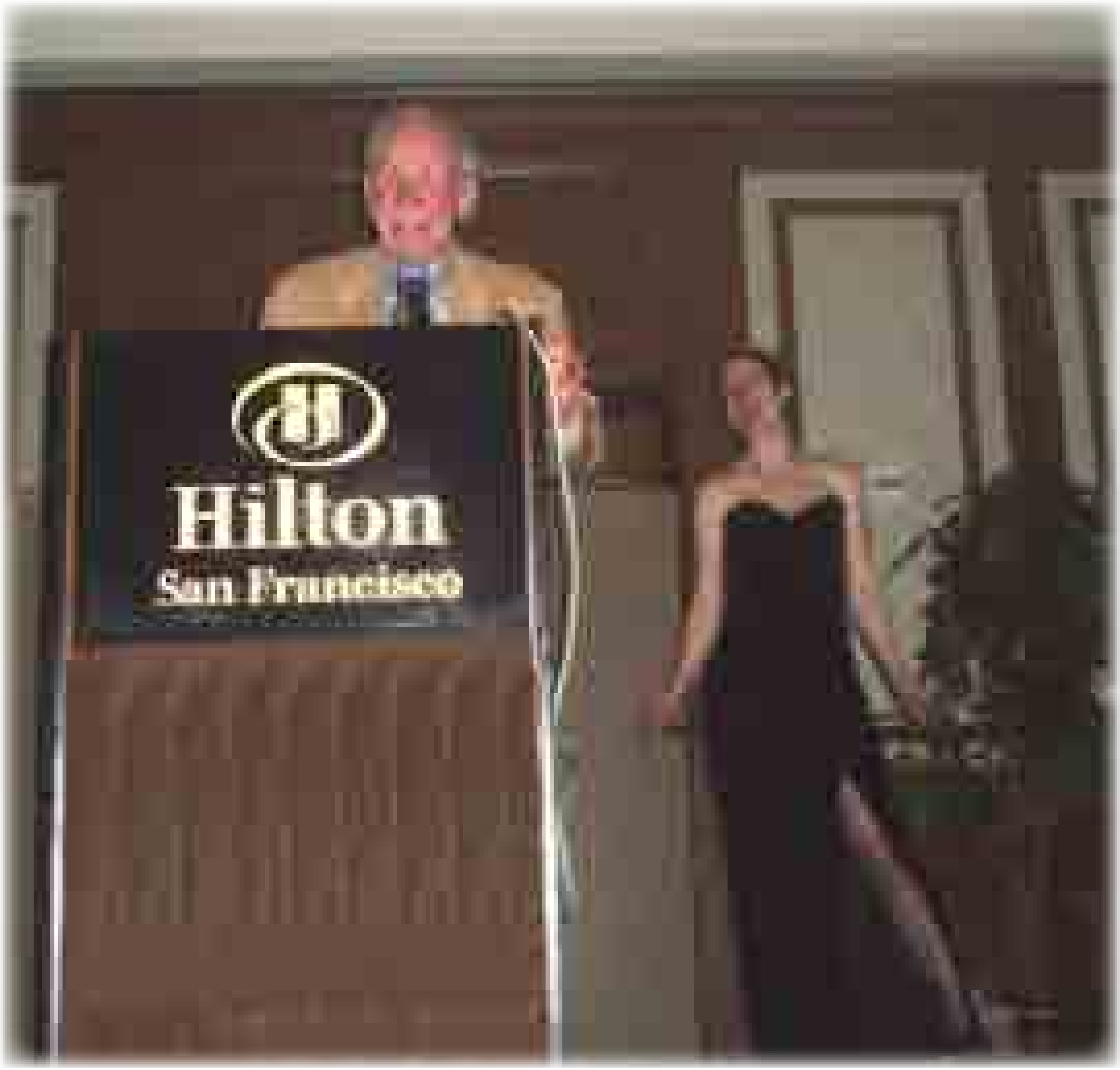


Figure 1. Forces acting on cloth element.

A variety of methods are employed to bring about this libido-awakening infliction on the poor male. One very popular method employed by the female is to wear transparent or seemingly transparent cloth to good advantage in certain areas. A common example is the transparent nylon blouse. Another powerful attractant is the tightly fitted garment. A well-known example of the type of weapon is the sweater. Yet another provoking method is by actually reducing the extent of body surface covered by cloth. A good example of this method is the modern bathing suit (e.g., Bikini). A delightful device which has sufficiently aroused the masculine sex is the use of durable but fragile-appearing cloth which gives the impression that at any moment the garment will slip down or that, better yet, certain parts may slip out of place. The best example of this method of attracting the attention of the weak and susceptible male is the strapless evening gown.

Effective as the strapless evening gown is in attracting attention, it presents tremendous engineering problems to the structural engineer. He is faced with the problem of designing a dress which appears as if it will fall at any moment and yet actually stays up with some small



The author presenting a lecture based on this study, in February 2007 at the American Association for the Advancement of Science's annual meeting. Dr. Rebecca Slayton, right, helps demonstrate the basic concepts. Dr. Slayton has a Ph.D. in chemistry from Harvard University. She is a lecturer in the Science, Technology and Society Program at Stanford University. She is currently working on a book which uses the history of the U.S. ballistic missile defense program to study the relationships between and among technology, expertise, and the media.

factor of safety. Some of the problems faced by the engineer readily appear from the following structural analysis of strapless evening gowns.

If a small elemental strip of cloth from a strapless evening gown is isolated as a free body in the area of plane A in Figure 1, it can be seen that the tangential force F1 is balanced by the equal and opposite tangential force F2. The downward vertical force W(weight of the dress) is balanced by the force V acting vertically upward due to the stress in the cloth above plane A. Since the algebraic summation of vertical and horizontal forces is zero and no moments are acting, the elemental strip is at equilibrium.

Consider now an elemental strip of cloth isolated as a free body in the area of plane B of figure 1. The two tangible forces F1 and F2 are equal and opposite as before, but the force W(weight of dress) is not balanced by an upward force V because there is no cloth above plane B to supply this force. Thus, the algebraic summation of horizontal forces is zero, but the sum of the vertical forces is not zero. Therefore, this elemental strip is not in equilibrium; but it is imperative, for social reason, that this elemental strip be in equilibrium. If the female is naturally blessed with sufficient pectoral development, she can supply this very vital force and maintain the elemental strip at equilibrium. If she is not, the engineer has to supply this force by artificial methods.

In some instances, the engineer has made use of friction to supply this force. The friction force is expressed by F = fN, where F is the frictional force, f is the coefficient of friction and N is the normal force acting perpendicular to F. Since, for a given female and a given dress, f is constant, then to increase F, the normal force N has to be increased. One obvious method of increasing the normal force is to make the diameter of the dress at c in figure 2 smaller than the diameter of the female at this point. This has, however, the disadvantage of causing the fibers along the line c to collapse, and if too much force is applied, the wearer will experience discomfort.

As if the problem were not complex enough, some females require that the back of the gown be lowered to increase the exposure and correspondingly attract more attention.

In this case, the horizontal forces F1 and F2 (Figure 1) are no longer acting horizontally, but are acting downward at an angle shown (on one side only) by T. Therefore, there is a total downward force equal to the weight of the dress below B + the vector summation of T1 and T2. This vector sum increases in magnitude as the back is lowered because F = 2Ts in a, and the angle a increases as the back is lowered. Therefore, the vertical uplifting force which has to be supplied for equilibrium is increased for low-back gowns.

Since there is no cloth around the back of the wearer which would supply a force perpendicular to the vertical axis of the female that would keep the gown of the lady from falling forward, the engineer has to resort to bone and wire frameworks to supply the sufficient perpendicular forces. (Falling of dress forward, away from the wearer, is considered unfair tactics among females.)

If the actual force supplied is divided by the minimum force that is required to hold the dress up, the resulting quotient defines a factor of safety. This factor could be made as large as desired, but the engineers are required to keep the framework light and inconspicuous. Therefore, a compromise must be made between a heavy framework and a low factor of safety.

With ingenious use of these frameworks, the backs of strapless gowns may be lowered until cleavage is impending.

Assuming that the female is naturally endowed to supply the vertical force V, the problem is still left incomplete unless an analysis is made of the structures supplying this force. These structures are of the nature of cantilever beams. Figure 2 shows one of these cantilever beams (minus any aesthetical details) removed as a free body (and indeed, many such beams can be, in reality, removed as free bodies; e.g., certain artifacts). Since there are usually two such divided, the force acting on any one beam is F/2 and it is distributed over the beam from a. to c. Here exposure and correspondingly more attention can be had by moving the dress line from a. toward b. Unfortunately,

there is a limit stress defined by S = F/2A (A being the area over which the stress acts). Since F/2 is constant, if the area A is decreased, the bearing stress must increase. The limit of exposure is reached when the area between b and c is reduced to a value of "danger point."

A second condition exists which limits the amount of exposure. Vertical force F/2 is balanced by sheer force S acting on an area from d to e and by an internal moment M. The moment M causes tension in the fibers over the beams between e and a, and compression in the fibers between c and d. As the dress line is moved from A toward B, the moment M is increased, increasing the tension and compression again till "danger point."

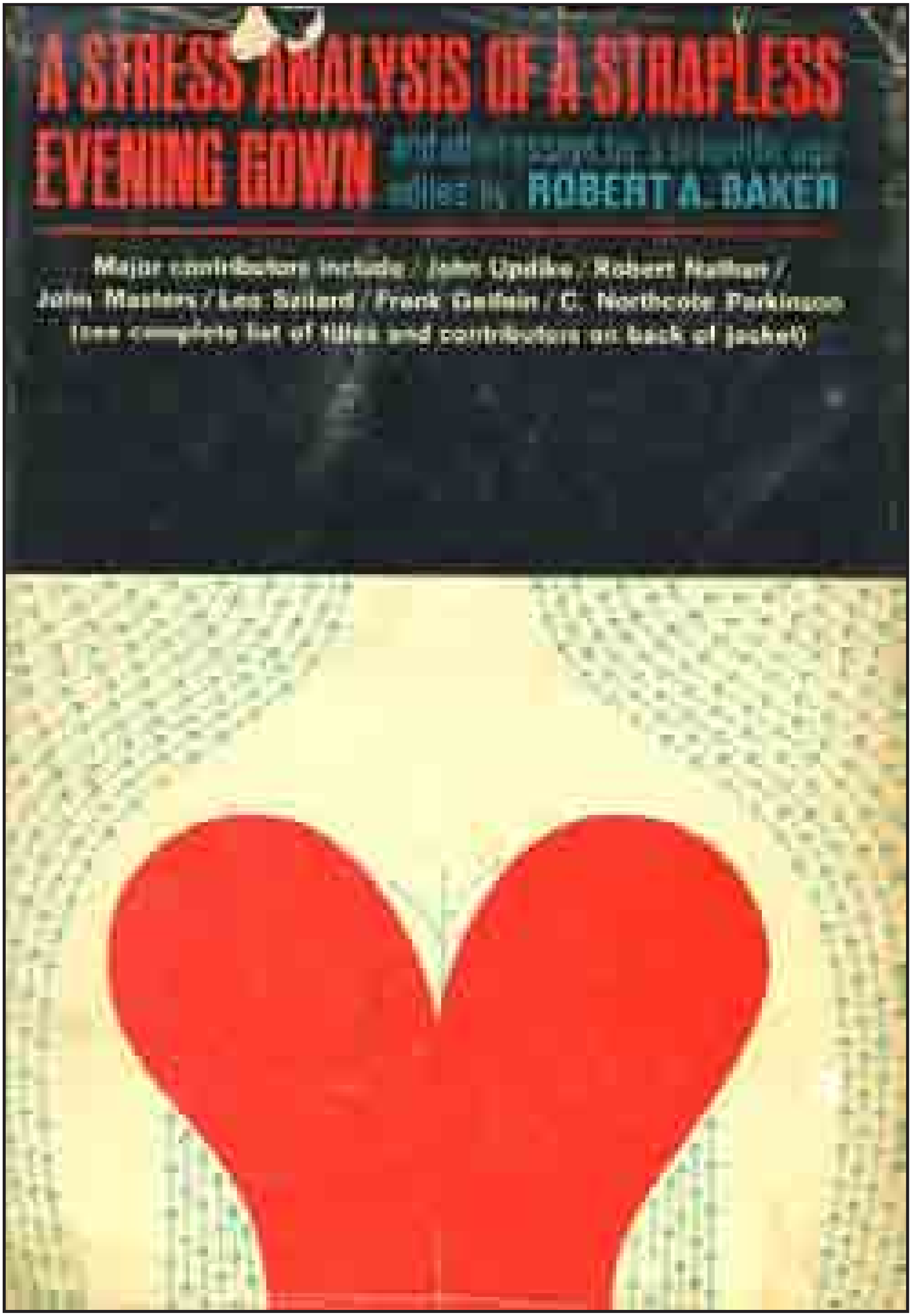
Since these evening gowns are worn to dances, an occasional horizontal force, shown in Figure 2 as i1, is accidentally delivered to the beam at the point c, causing impact loading, which compresses all the fibers of the beam. This compression tends to cancel the tension in the fibers between e and b, but it increases the compression between c and d. The critical area is at point d, as the fibers here are subject not only to compression due to moment and impact, but also to shear due to force S; a combination of low, heavy dress with impact loading may bring the fibers at point d to the "danger point."

There are several reasons why the properties discussed in this paper have never been determined. For one, there is a scarcity of these beams for experimental investigation. Many females have been asked to volunteer for experiments along these lines in the interest of science, but unfortunately, no cooperation was encountered. There is also the difficulty of the investigator having the strength of mind to ascertain purely the scientific facts. Meanwhile, trial and error and shrewd guesses will have to be used by the engineer in the design of strapless evening gowns until thorough investigations can be made.

In 1992, singer / jazz-harpist Deborah Henson-Conant composed a five-movement musical version of "Stress Analysis of a Strapless Evening Gown," based on Charles Seim's engineering essay. The movements are:

1. Introduction and waltz
2. Compression and tension
3. Gossamer
4. The Danger Zone
5. Curves

It premiered on Saturday night, November 21 of that year at the Regattabar Jazz Club in the Elliot Hotel in Harvard Square, Cambridge. Henson-Conant, wearing a strapless evening gown, performed it together with The Really Eclectic String Quartet. Subsequently, she performed the piece in jazz clubs around the world. On Saturday, February 10, 2001, Henson-Conant performed it together with the Springfield (Massachusetts) Symphony orchestra, and has since performed with other orchestras around the world. In 2006 Henson-Conant and the Grand Rapids Symphony released a DVD and CD titled "Invention & Alchemy," which featured part of the "Stress Analysis of a Strapless Evening Dress." The DVD was nominated for a Grammy Award in the category of "Best Classical Crossover Album."



The cover of the 1963 book.

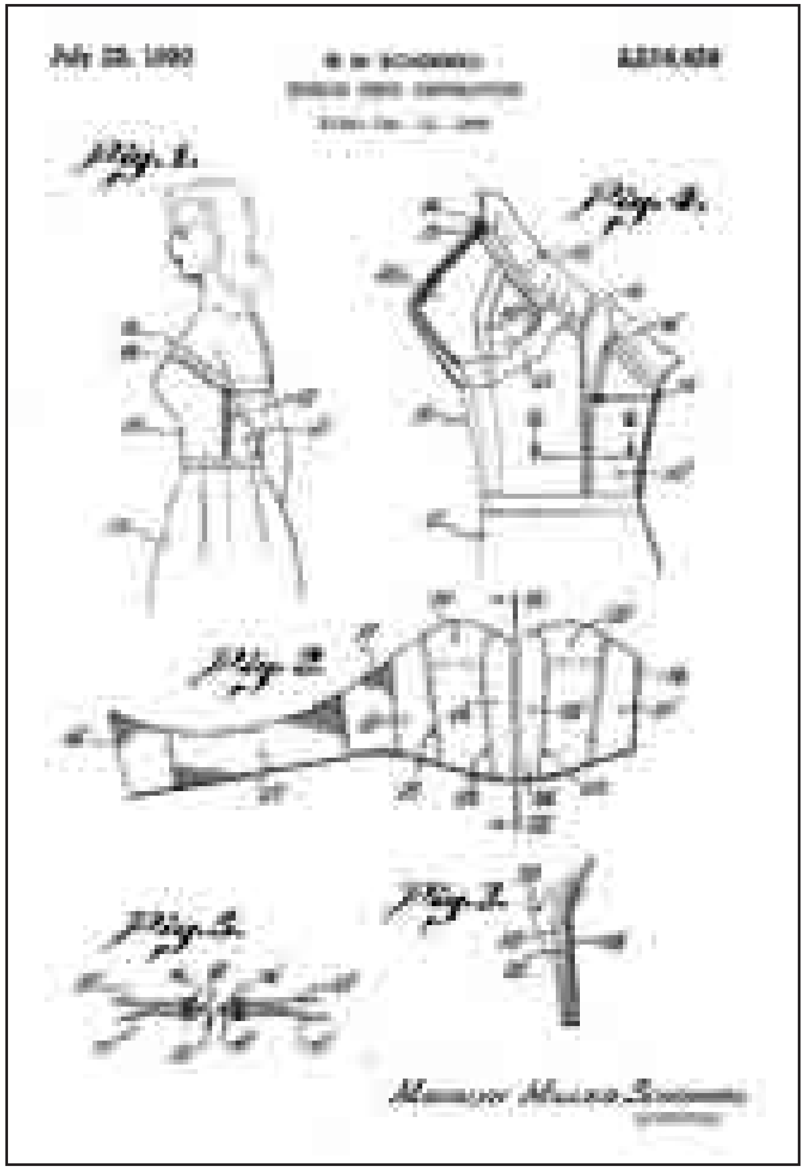
The Birth of "Strapless Evening Gown"

by Charles Seim
El Cerrito, California

[Editor's note: This was written in February 2007, a few days after Charles Seim gave his first public lecture about Stress Analysis of a Strapless Evening Gown*.]*

I wrote "Stress Analysis of a Strapless Evening Gown" in my senior year in Civil Engineering at the University of California, Berkeley. At the time I was the Associate Editor of the *Cal Engineer*, a monthly magazine produced by students in the College of Engineering.

The editor of the *Cal Engineer* had seen a short article in an engineering magazine from another university on the topic and he showed it to me, asking if I could write a better essay. I replied, "Sure I can!"



Technical drawings from a 1950 patent for a strapless evening gown.

The Research

I spent many more hours developing the engineering (it is a legitimate analysis) and writing the article than I ever dreamed it would take; the writing of the article definitely cut into my homework time (engineering students at that time were given 4 to 5 hours of homework every night!).

When the *Cal Engineer* published my essay, that issue sold out immediately! The essay was the talk of the engineering campus, and every one seemed to appreciate and enjoy the article.

During the time I was writing, I kept wondering if the article was too risqué. By today's standards, it is merely "lukewarm" and doesn't even come close to being "risqué." How times have changed in 55 years!

A Stressed Analyst of a Strapless Evening Gown

Near the close of my senior year, I was feeling very cocky. I had made it all the way through my other exams and through all the homework, so (I thought) I must know every thing about Engineering! Besides, I had even written a successfully-received story about the lack of straps on a garment!

In the next to last meeting of my four-hour long, weekly Statics of Structures class, the professor told the class to be sure to bring slide rules to the last class because he was going to give us one last exam. I thought he was joking—give one more test on the last day of our last class as an undergraduate!

But I took my slide rule to that last class, just in case. My jaw dropped a foot when the professor walked into the room carrying a stack of papers that could only be—*another test*! So he hadn't been joking, after all!

I was sitting by a window that overlooked the campanile (a phallic symbol standing at the center of the campus). The campanile had a large clock on each of its four faces and I could see one face very clearly from my perch on the second floor.

The professor passed out the test and stated in a very serious tone that he believed no Senior Engineering student should graduate from the Berkeley campus without a thorough understanding of the theory of the Statics of Structures—and he obviously meant exactly that!

I opened the test and found six problems, that the professor had assured the class were *simple*, on the fundamentals of statics. I could not figure out solutions to any of them! Damn the "Stress Analysis of a Strapless Evening Gown" and the study time I had wasted in writing that essay! I was struck by the irony that the first title I had given to the essay was "The *Static* Analysis of a Strapless Evening Gown."

I looked at the campanile clock—it was then 1:30 p.m. and I had three and a half hours to go! I frantically searched for one problem that I could at least start to solve. I was petrified with fear. Damn that strapless evening gown essay and damn me for wasting my study time on writing the evil thing! I thumbed through my test pages so many tines that the papers were crinkled!

Why can't I find a starting point? Damn that strapless evening gown! The clock kept moving—2 p.m., 3 p.m.! Damn that gown! Because of that gown, I was going to flunk out of school in my last year! Almost every one else had finished and left. One hour and three students remained—at least I wasn't the only student still there!

I turned the pages one more, desperate time, and then I saw it! I saw the start of a solution to one problem! I finished that page and turned to the next page; again, I saw another solution! I worked my slide rule back and forth. The clock said 3:30, but I was moving and my slide rule was going! I turned to the next page and another solution popped out, then another! At 4:45 pm, exhausted, and now blessing the Goddess of the Gown, I smugly handed my paper to my professor!

I now wish to convey my profound respect for this professor, widely known for his contributions to engineering, and who was an excellent teacher and a mentor to me; and I passed.

Recurrences of the Analysis

The essay was first published in the *Cal Engineer* in 1952 and then appeared in a 1963 as the title essay of a book of "Essays for a Scientific Age" published by Prentice Hall, Inc. It reappeared in 1969 in an Anchor Book Edition and again in 1987 by Prentice Hall, Inc., both in paperback editions.

From Busts to Bridges

Many good things have happened to me in the 55 intervening years. I was hired by Caltrans to work on the design and construction of several state-owned toll bridges. Later, I was invited to assume a position at T.Y. Lin International under the personal guidance of Prof. T.Y. Lin (or TY as he preferred to be addressed) who was my professor in several engineering courses at Berkeley.

I have worked on bridges throughout the United States and South America. For the last ten years, I have worked on a number of bridge projects in Asia.

Along the way, I bumped into many friends and engineers who have asked me about the Strapless Evening Gown essay; one even characterized it as the "The Gownless Evening Strap."

I would like to be recognized for my work in bridge engineering but I am also pleased to be known as the author of the SAOASEG!