THE CREATIVE ENGINEER
The Art of Inventing

Winston E. Kock
Acting Director
The Herman Schneider Laboratory of Basic and Applied Science Research
University of Cincinnati
Cincinnati, Ohio

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PREFACE

The economic growth and strength of a nation are directly related to the ability of its people to make discoveries and their ability to transform these discoveries into useful products. Ninety percent of the increase in output per capita in the United States from 1909 to 1949 has been held to be attributable to technological advances. In this book, we examine the ways in which a number of important new technologies came into being and review the characteristic traits of inventors who *create* new technologies. Ways are suggested that could enable young and old alike to become more creative, and the various benefits they can thereby reap are also discussed.

A high level of creativity is an important asset for a nation, and therefore a knowledge of ways to increase inventiveness can be of great value. University of Cincinnati President Warren Bennis has noted that "creativity is something most of us seem to lose, or let atrophy, as we leave childhood."* To "rediscover it," he continues, "we must find ways of re-creating our sense of wondering why, of heightening, even altering, our consciousness." Thus the earlier in life one seeks to enhance his creativity, the more successful the results are likely to be. We therefore stress, in these discussions, the importance of parents' urging their children to become creative, so that their lives will be made fuller, happier, and more rewarding. But the process of influencing youngsters is not an easy one, because the bright, up-and-coming young person demands that he be shown by many examples that his parents' advice is sound.

* Warren Bennis, *University of Cincinnati Horizons,* p. 21 (January 1974).

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In this connection, one of my long-time friends, Nobel Laureate Luis Alvarez, pointed out to me recently that the majority of books on creativity have been written by authors who have not demonstrated extensive creative abilities. Because Alvarez has, over the years, been aware of my numerous inventions, he encouraged me to describe in great detail my various experiences in the fields of invention and creativity. In this book, I have followed this advice, because I belive that if youngsters can be shown concrete examples of how inventions have led to *rewards* the task of convincing them becomes a much easier one. (Chapter 9 deals with rewards at some length.)

Most of the references and photos dealing with my experiences have been relegated to the Appendix, enabling the reader to skip over them if he desires. But because they are there, parents can use them in helping their children to see the advantages of being creative. For innovators do reap benefits, and they also benefit their country and the world. The technological advances described were selected partly because I was involved in, or in close contact with, their progress, but more importantly because they exhibit certain attributes of invention that can suggest how to develop one's latent creativity. They were also chosen because they have largely involved engineers having interdisciplinary experience; it has been predicted that the demand will be strong in the 1980s for graduates who can apply engineering principles to medical, biological, and other sciences.

At Fairleigh Dickinson University, Professor Harold Rothbart has instituted a course which he refers to as "an invention workshop, intended to relate inventive activities of all sorts for the purpose of increasing the potential for creating original products." Students are encouraged, in a free environment, to evoke a flow of unstifled, creative expressions of ideas. "Everyone should share the excitement of invention," he continues, "and this interdisciplinary activity is catalytic to other creative activity."* The value of the interdisciplinary activity that Rothbart mentions was stressed in a recent report of the Enrico Fermi Institute at the University of Chicago,† a laboratory noted for the work done there during the early stages of the U.S. nuclear program. The report notes that the "interdisciplinary character of the Institute has strengthened the traditional departments of instruction within the

* *Industrial Research,* p. 80 (November 1974).

† *Enrico Fermi Institute* (University of Chicago pamphlet distributed to members of the Physical Sciences Visiting Committee, November 1, 1974).

University by providing a common base of intellectual inquiry and the free exchange of ideas. Out of this interdisciplinary environment have come fresh ideas leading to new fields of research." Through my work at the Herman Schneider Laboratory at the University of Cincinnati (which concentrates its support on interdisciplinary research programs), I have observed at first hand that this need to involve two or more disciplines has led to numerous proposals being submitted which describe novel and interesting concepts. Even a limited knowledge of several disciplines can often enable the owner of this knowledge to contribute in an important way to these disciplines. The existence of a new development in one field permits the interdisciplinary mind to consider related applications of this development in other fields, often with fruitful consequences. Obviously, a development which is novel in one field will constitute a novel development in another field when successfully applied thereto.

The level of the discussions here has been set so as to make them understandable to a second- or third-year college student, so that he can consider early in his college career the desirability of selecting courses on subjects in fields other than his major one. The examples which follow are intended to encourage the reader to acquire a multidisciplinary interest, thereby permitting him to add to the world's store of scientific knowledge and its application. I also hope that my background of patent activity (235 issued U.S. and foreign patents stemming from my 14 years as a member of the technical staff at the Bell Telephone Laboratories, plus many others at the D. H. Baldwin Company, the Bendix Corporation, and NASA), will enable me to communicate ways which can help the reader experience the excitement stemming from discovery and invention. Because of the level, the book could well find use as auxiliary reading in the sophomore and junior years.

For various photos and figures, I wish to express my indebtedness to the D. H. Baldwin Company, the Bendix Corporation, the University of Michigan, the National Aeronautics and Space Administration, the Communications Satellite Corporation, the Bell Telephone Laboratories, and the American Telephone and Telegraph Company.

Winston E. Kock

Ann Arbor

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STIMULATING ONE'S OWN CREATIVITY

The motivation for creativity can be simply the intriguing pleasure of seeing one's own ideas materialize into something worthwhile. We can easily imagine the many such pleasures experienced by Leonardo da Vinci, Galileo, Hertz, and similarly by Bardeen and Shockley with their beautiful semiconductor theory, by Brattain with his clever idea of the two-point-contact transistor, and by Gabor through his simple idea of recording the holographic interference pattern rather than the photographic light pattern. None of these innovators concerned himself with how his ideas might affect the world. They all generated *ideas* and would still have been very happy if the only result had been a successful experiment.

Ideas, even associative ideas (those that transfer a new concept from one field to another), are what brings the world new technologies. Michael Wolff* describes how the snap-action disk was invented by the MIT student Albert Spencer during a nighttime summer job tending a sawmill furnace in Maine. Spencer became intrigued with the fact that the sheet metal door *snapped* when the fire got very low. In his *wondering why,* the snapping set him to thinking, and soon he had hammered out a can of bimetal that would snap hard enough to jump off a table. By the 1940s, a multimillion-dollar industry had grown up on the basis of the "Spencer disk."

So what are some of the ways for extending our own "idea con-

* Michael E. Wolff, "Inventing at breakfast," *IEEE Spectrum,* pp. 44–49 (May 1975).

sciousness," our own inventiveness, ways for rediscovering and making use of that creative talent we all possess to some degree as children? For, as Warren Bennis reports, "an artist who worked with slum children, letting them draw or paint whatever their minds suggested, concluded that *every* child under ten can create things that have the unmistakable air of distinctive originality."* He suggests that "the reason for this is that, to every child, the world around him is a totally new discovery; the green grass, the nodding trees, the grace of animals, the poetry of wind, the grave silence of snow, the re-creating sun—all, each day, are born over and over. The child encounters this miracle with a sense of wonder, one that his elders lose as the familiarity, or tedium, of daily life shuts them out. In other words, creativity is something we all have, yet manage to lose."

How can we rekindle this sense of wonder, this sense of *wondering why,* so that more of us can share the excitement of invention? One way, suggested by Harold Rothbart, is to "encourage the flow of unstifled, creative expressions of ideas."

Along another line, Bennis observes that as we leave childhood "we do not really see the world around us, we see only a '*gloss*' of stereotyped expectations. We may see a leaf, but not the magic, the harmony, the incredible order of the intricate veining of the leaf." He mentions a Yaqui Indian wizard who taught a visitor that he could discover a "separate reality" quite different from our ordinary reality. The secret was learning to "'stop the world'—to break through the *gloss* by which we see only what we expect to see." He goes on to note that Eastern mystics have shown that periods of meditation can heighten one's consciousness, suggesting that all of us could benefit from such "private cathedrals of contemplation."

Along these lines, Bennis recommends that individuals seeking to reclaim their creativity must first break the pattern of the familiar, for instance, by taking up some new interests, redeveloping atrophied talents, or rekindling old enthusiasms. He points out that "the more our work makes us *specialists,* the more we must strive to become *generalists.*"†

The majority of the following chapters describe inventions dreamed up or contrived by *nonspecialists,* by persons who had a general

* Warren Bennis, *University of Cincinnati Horizons,* pp. 21–22 (January 1974).

† Bennis, *op. cit.*

knowledge, even though somewhat limited, of fields other than the particular field of science involved in their invention or discovery. It is this nonspecialist nature which led us to stress, in the Preface, the value of multidisciplinary knowledge. Perhaps even more important, however, are the pervading characteristics of inventors, their constant feeling of curiosity, their continual search for new possibilities, and their refusal to accept stock answers. For example, once there was a young boy whom his neighbors (who were annoyed by his constant questions) jokingly called "Mr. Wonder Why." Everyone scoffed at him until suddenly he began making unusual discoveries, and then his detractors had to backpedal vigorously. The constant curiosity of "Mr. Wonder Why" is a characteristic found in almost all innovators, and they are not deterred by the scoffing of others. Charles F. Kettering had his own argument for taking the edge off such derision. He said, "People think of the inventor as a screwball, but no one asks the inventor what he thinks of other people."

The famous MIT research engineer H. Stark Draper (who gave his name to the MIT Draper Laboratory) also had some favorite sayings about research. Here are a few: "Research is a gamble. It cannot be conducted according to the rules of efficiency engineering. The best advice is, don't quit easily. Don't trust anyone's judgment but your own. The best person to decide what research work should be done is the man who is doing the research."

Draper's admonition about not quitting easily is reminiscent of one of Will Rogers's well-known sayings, "Even if you're on the right track, you'll get run over if you just sit there." And Draper's contention about efficiency engineering was echoed recently by E. Bruce Peters,* who noted that creative individuals are not likely to fit the common mold of organizational activities but must be granted far greater autonomy and independence than other employees, because the creative person is driven by his work, rather than by directives from his boss. Peters also contends that creative individuals cannot be forced to produce usable ideas on a regular, measured basis.

Next, let us turn to a discussion of *who* can acquire, or reacquire from his childhood days, a stronger talent for creativity. First, must the highly creative person have received unusually high grades in school?

* E. Bruce Peters, "Creativity in Conflict," *Industrial Research,* pp. 69–82 (April 1975).

Roland S. Illingsworth has compiled a list of "school failures"* which includes "bottom of the class," Thomas A. Edison; "poor mathematicians," Benjamin Franklin; "expelled from school," Wilhelm Roentgen; and "mentally slow," Albert Einstein.

Second, must the person seeking to improve his creative ability be young? Apparently not. Lissy F. Jarvik† has shown that the common belief that intellectual functioning peaks at about age 17 and then declines progressively is not based on fact; his studies show that a decline in knowledge or reasoning power does not generally occur even during one's 60s and 70s.

Finally, has a hard scientific analysis of creativity been made? Here the answer is suggested by a *Science News* report‡ of the results of tests made by Colin Martindale, who studied at some length the brain-wave patterns (electroencephalograms) of high-, medium-, and low-creativity people and discovered interesting facts about their "cortical arousal":

> when incoming information is on its way to the brain, the cortex is alerted. During sleep, with little input, cortical arousal is at a minimum. It increases as people go from sleep to states of reverie and daydreaming to alert concentration and finally to emotional agitation and panic. With electroencephalograms (EEG's) the degree of cortical arousal can be measured. The slow alpha waves, for instance, are produced during periods of complete relaxation and meditation. As arousal increases, alpha decreases. And when people react to strong stimuli, for instance, alpha is blocked and replaced by faster waves.
>
> Martindale's studies of the EEG's of high, medium, and low creative people suggest that cortical arousal is directly related to creativity. Brainwave measurements were taken during a resting state. Highly creative people were found to produce alpha waves only 37 percent of the time (62 percent of the time they produced the faster waves). Medium and low creative people produce alpha up to 50 percent of the time. In other words, when tested during a resting state, creative people have higher levels of brain-wave activity than average people. Highly creative people also had higher levels of skin conductance, another measure of arousal.
>
> Martindale's findings suggest that creative people may be more sensitive to and conscious of incoming stimuli. Experiments designed to test the sensitivity of individuals to various stimuli did show that creative people

* Roland S. Illingsworth, in *Learning, the Magazine for Creative Thinking,* as reported in *Reader's Digest,* p. 102 (September 1975).

† Lissy F. Jarvik, UCLA, as reported in the *Reader's Digest* (September 1975).

‡ Colin Martindale, University of Maine, as reported in "Creativity and cortical arousal," *Science News, 108,* p. 53 (July 26, 1973).

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