A CREATIVE APPROACH TO DESIGN PROBLEMS

There has always been a good deal of discussion on the subject of whether creative ability is born in a man, or whether, possessing certain characteristics and traits, he can consciously and deliberately develop this ability. The Creative Engineering Program is in existence today because the Company believes in the latter theory. Successful creative engineering is in part a combination of: 1 - an active and inquisitive mind; 2 - an inner drive which enables a man to get a job done; 3 - a broad background of fundamental knowledge; and 4 - a creative approach to any problem. These first two are inherent characteristics of the individual while the latter two are the ones that can be stimulated and developed. This paper concerns itself only with the fourth quality, the method of approach to a design problem.

Before discussing a creative approach to design problems, it may be well to consider how problems are obtained. Generally you confine your attention to the problem presented to you by your supervisor or someone else. In order to be most effective as a creative engineer, you should learn to sense a need rather than to have someone else do this for you. An individual actually makes a true invention when he not only creates the form of the device but also is the one who recognized the need for such a device.

In order to develop to positions of engineering leadership, an engineer must learn to discover and develop new devices and concepts beyond the expressed needs of industry. A feeling of constructive discontent must be fostered. This means developing the habit of asking yourself – what other ways can we do this? – how can this be improved? – or, why don't we have a device to do this? It is only by looking for new fields to conquer that they will be found.

When Fleming observed the absence of bacteria around a spot of penicillin he was examining, he saw the same thing that many other scientists had seen. Fortunately, he did not stop with simply recording this phenomenon, but asked himself – what is the nature of this phenomenon and can it possibly be of some use to mankind? Fleming was not only curious about the laws of nature, he was also willing to make an effort to carry on research and development of the ideas he had.

A willingness to contribute, accompanied by a mind prepared to explore new avenues, is essential to creative thinking. Being content to devote full time to solving other people's problems is a form of mental laziness. As our efficiency in thinking up "new" practical solutions is generally quite low, it is necessary to be most prolific of ideas in order to produce a number of good inventions. The same is true in recognizing "new" problems. For example, hundreds of new ideas for new product lines were probably considered before the suggestion was made to produce the disposall. Still, it was a result of continual searching for new conveniences for the consumers before the one idea that "paid off" was found.

Deliberate and organized thinking is a vital part of creative thinking. It is especially important in the early years of an engineer's experience that he learn how to improve his creative ability.

He must increase his effectiveness to solve problems assigned to him and thus prove his ability before he is allowed to carry out his own projects.

The approach to almost any design problem may be broken down into four basic phases:

a. Definition of the problem
b. Search for method
c. Evaluation and selection of method
d. Solution

These constitute only the idea stage of the solution, the remainder of the design procedure will be omitted from this discussion. If one is to produce consistently usable and worthwhile solutions to problems, he will have to employ a creative approach.

A. DEFINITION OF THE PROBLEM

When the design engineer tackles a new project, he must pay particular attention to specifications. This is the first phase of solving a design problem. It is also a highly important phase that is often overlooked by engineers. By specifications we mean the actual definition of the problem, wherein the engineer is required to consider many more factors that the rating, weight, size, and other quantities that we normally consider as specifications. He must endeavor to investigate the fundamental problem involved.

Recently a division in the Company desired to increase the rate at which the paper capacitors were wound. The machine in question winds the alternate layers of paper and the foil on a bobbin thus making a basic part of a paper capacitor. In considering how these capacitors could be made at a higher rate, the immediate solution seemed to be to increase the speed of rotation. When this was tried, the paper would tear. From this the people experienced in capacitor manufacturing concluded the difficulty was caused by moisture conditions, etc., which weakened the paper in some manner that it would not stand the high speed. Actually, on closer study it was discovered that speed had very little to do with it. The whole problem was a matter of acceleration. This problem was easily solved by using Thymatrol to limit the acceleration of the machine.

After all this work had been accomplished, no appreciable increase in capacitor production resulted. It was at this stage that someone decided to make a time and motion study of the operation. Then it was discovered that most of the time consumed by the operation was spent in threading the machine and in feeding in the two little tabs which make the electrical connection between the plates and terminals on the finished capacitor. Thus, months after the program to develop a faster capacitor winder was started, the real problem was discovered.

In discussions on defining the problem, Mr. E. A. Raney of the Pittsfield Works Laboratory has used the example of pyranol capacitor leak testing to show how more basic problems are often present. For example, if the container can be made leakproof there is no need for leak testing – even more basic would be a capacitor with the desired characteristics that does not use a fluid and hence has nothing to leak.

Not always is the more basic problem easier to solve. The inventor of the revolutionary "Long Play" records took a more basic approach to the problem of producing continuous music than have those who developed the record changers. Likewise in the considerations of means of removing snow from city streets, it might be well to investigate Dr. Schaefer's man-made snow storms as a means of keeping the snow from even falling on city streets. From these few examples we can see the wisdom in the saying "The more fundamental the approach, the simpler the solution." This is generally true if it is realized that the "more fundamental the approach" does not always mean that the solution presented is for the basic problem. Instead, it may mean that the problem was thoroughly defined and the basic factors were considered in the forming of the solution.

After making a complete definition, the problem can be broken into three main groups of desired characteristics and requirements. As applied to a dynamic system they may be classified as 1 - input, 2 - limiting requirements or specifications, and 3 - output. A slightly different breakdown might be applied to static systems.

The three groupings may be explained by considering a typical design problem. For example, consider the design of a new type "noiseless" wall switch. The specifications can be subdivided as follows:

1 – Input

a. Mechanical motion of activating knob

b. Only a small force desired to activate the switch

2 – Limiting requirements

a. Must fit into standard outlet box

b. "Noiseless" operation

c. Must work satisfactorily and safely with 110 or 220 volts a-c or d-c

d. Cost must be in range of standard switches

e. Long trouble-free life

f. Allowable drop across the contacts

g. Current rating, etc.

h. Appearance

3 – Output

a. Mechanical movements of contacts

b. Required time and motion characteristics to break arc

The above is not complete and detailed but serves to show how the groupings can be made. In a relatively simple design as illustrated, complete quantitative data may not be necessary. In general, all dimensions, forces, voltages, etc., should be known quantitatively. If experience has been gained in the field, design sense or "feel" may give adequate measures, but to depend heavily upon mental extrapolation of past designs quite often results in costly failures.

B. SEARCH FOR METHODS

With the problem completely analyzed and broken down, means of bridging the gap between input and output are sought. This is the point where experience and background knowledge play the leading role. For it is here that a keen mind with a true sense of design curiosity can reveal its vast store of facts on materials, processes, phenomena, devices, mechanisms, etc., and more important, the sources of such information.

Some inventors believe there are at least eight ways of doing everything and strive to find out most of them before making a final selection. In a sense this belief is held by all highly creative people. As soon as a person becomes satisfied that a certain procedure is the <u>only</u> way, he is no longer creative. A creative mind is an active, nonhabitual mind that always seeks new and better ways of doing things. Not merely criticizing the present systems but weighing the "other seven ways" that might be employed.

As there are so many ways that things can be done, dependence upon memory alone is often an inefficient way of uncovering the possible means of solution. A notebook of ideas and devices seen or conceived in the past, serves as an excellent refresher. Any publication on inventions or mechanisms will often suggest ideas and stimulate thought toward a new system.

Another way to stimulate creative thinking is to "search for power." This is the attempt to perform the required motivation or sensitivity by electric, mechanical, hydraulic, electronic or chemical means. For example, in measuring temperature it is possible to use energy converters such as thermopiles to produce electricity, bimetal to produce mechanical energy, expansion of fluids and gasses to produce hydraulic or pneumatic pressure changes, etc.

More complex problems can seldom be solved by a single step. Then the method of attack becomes one of successive development or synthesis leading from the input to the final output by successive stages. All basic or fundamental theories and phenomena that might be applied to the solution should be sought. The creative engineer must approach this synthesis unbiased by leaning toward a particular field of engineering.

As an example of syntheses, consider the design of a thermal cutout for a motor. The input would be heat. The first part of the synthesis would be a search for all phenomena that respond to application of heat. The next phase would be to consider the "output" from these individual phenomena as the "input" to the next successive stage. This method recently led to the invention of an improved thermal cutout based on a radically new application of the fundamental concept that mercury will boil when enough heat is applied.

By using the method of synthesis a more creative and successful combination may be produced. A young engineer attempting to visualize the solution in one step will often adopt a standard system despite the fact that a new combination might be better. Only after considerable experience can an engineer expect to think of a complete system with much consistency unless he has made a thorough synthesis.

It is most important that the search for method not be hindered by judicial thinking. Note all ideas no matter how fantastic – the imagination works best when unrestrained. Consider the amount of skepticism, reason could have introduced in the early consideration of releasing the almost unbelievable amount of energy available in the atom. As another example, not too long ago very capable engineers "proved" that the ram jet engine "would not work." In this case, fortunately, the engine didn't know that. Besides at this point methods are being sought not selected.

C. EVALUATION AND SELECTION OF METHOD

The next step is the evaluation of the various methods. Each system must be thoroughly considered as it affects all the design requirements. Particular emphasis is placed on time and economic factors. Each problem will largely determine the weight a given factor carries in the final selection. Some of the considerations are as follows:

1 - Cost
  a. Development program
  b. Finished product

2 - Time allowed
  a. For development
  b. For reaching production stage

3 - Accuracy
  a. Sufficient for specifications
  b. Better than specifications

4 - Power requirements

5 - Space requirements

6 - Tools and machines available
  a. Adequate for production
  b. New machines required

7 - Materials required
  a. Common and easily obtained
  b. New materials of scarce materials

8 - Production difficulties
  a. Standard tolerances and procedures
  b. High tolerances and involved processes

9 - Patent difficulties
  a. All patents involved held by Company
  b. Patents held by competitors

10 - Appearance

11 - Complexity
  a. Operation (type of people who will operate it)
  b. Maintenance (type of people who will maintain it)

12 - Consequence of faulty operation

13 - Versatility of application
  a. Coverage of field desired
  b. Supersedes predecessor and competitors device

14 - Operating environment effects
  a. Corrosive atmosphere
  b. Dust
  c. Vibration and shock

15 - Safety features

The considerations listed do not apply to all development and design problems. Often in the early stages of a development program such points as the requirement of new tools and machines may be set aside until models have been built and tested. Then the test results can help determine if retooling is feasible. The engineer usually must decide at what part of the development program he should consider all factors of evaluation. He may even recommend a change in the specifications when his evaluation shows that a better product would result from such a change.

Sometimes the evaluation of the methods listed will show the necessity of redefining the problem and a new search for method. Preliminary tests and mathematical calculations should be made to verify expected results. Poor application of engineering fundamentals in the early stages will usually result in loss of time, money and prestige.

D. SOLUTION

When working out the details of the method selected, the steps outlined above are repeated on the various components required. Thus the various phases are used simultaneously in other than simple problems, and each portion of the design is evaluated as the details are solved. Component designs should be checked with the specifications of the over-all design as well as the listed requirements of the component.

Beware of the fascinating tangents that lead the unwary astray. When building a better mousetrap do not become a connoisseur of fine cheeses when ordinary store cheese will do. Stop your digging at details occasionally and look at them in the light of the over-all job. Keep your nose to the grindstone, but do not become cross-eyed to the rest of the subject.

When the problem involves primarily test work or calculation, you should remember that the numbers you obtain are seldom a salable item but rather pose the question: "So What?" In other words, you are not finished until you can show how the results effect the finished product. Having lived with the details of the analysis or test, you should be able to make recommendations to improve quality and price of the device.

Strive to meet all specifications and time schedules by proper planning. Have parts completed in sequence and that will best permit partial testing. Do not delay design and construction of one part that will needlessly prevent proper testing of many other parts. Keep in mind the fact that instructions for manufacturing and operation can be as important as the design itself. The customer may not know exactly how to operate your brainchild unless you tell him.

Little details are important, too. Nuts, bolts, washers, and bearings are part of the design. Perhaps the draftsmen can select these for you, but it is your responsibility to check and approve all of these "minor" details. Little things like insufficient wrench clearance to requiring special adjustment tools can destroy the market for a particular model. In the final analysis the proof of the solution is in customer acceptance and profit to the Company.

SUMMARY

The processes as outlined here are recommended as a guide for the individual in establishing his own approach. After practical experience is gained in a given field, early methods of attack will be modified accordingly. Time and effort spent on the analysis, search for method and evaluation will often be reduced by previous consideration of similar problems.

The first four stages of a creative approach are 1 - definition of the problem, 2 - search for method, 3 - evaluation and selection, and 4 - solution. These stages are somewhat flexible in application and must be employed as dictated by the problem. Such organization of mental effort will aid rather than hinder creative thinking.

The definition must be a complete breakdown and study of the design data and requirements. The fundamental or basic problem should be sought. A grouping of facts and characteristics might be 1 - input, 2 - limiting requirements, and 3 - output. This stage must be well considered if the final design is to meet specifications.

The second stage, "search for method," is the place where creative thinking can be stimulated. Here the use of synthesis in the search for a method is apt to be most creative. Fundamental theories and phenomena are the keynotes of this synthesis. The basic plan might be the search for power or the seeking of the "eight ways." Keep your judicial mind suppressed in this phase.

In the evaluation stage the engineer picks the most practical system from the standpoint of engineering and economics. His choice is not overly influenced by the novelty and ingenuity of a method or by the established acceptance of a method. In short, he picks the best solution for the problem at hand thus striving to be a practical creative engineer and not a Rube Goldberg.

The solution of the problem in a form suitable for practical use is the prime function of an engineer. All the factors determining the quality, adherence to specifications, and salability at a profit of a product stand as a composite rating of the engineer that made it. As he enters by the front door he makes room for himself by sending products out the back door.

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