THE JOURNAL OF
ENGINEERING DRAWING

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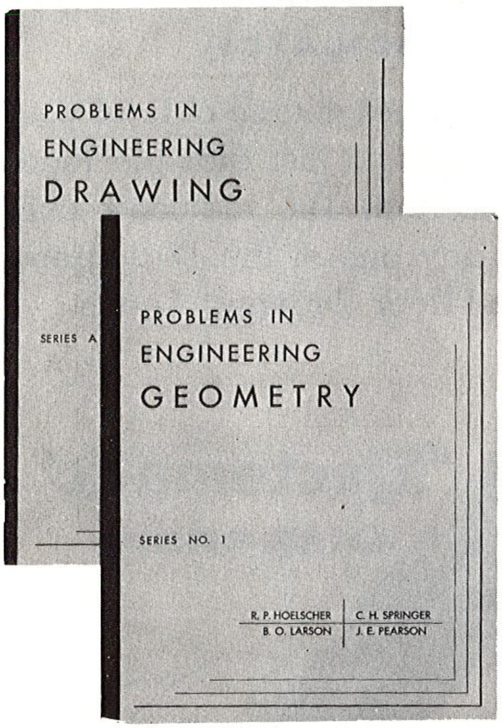
with B. O. LARSON and J. E. PEARSON



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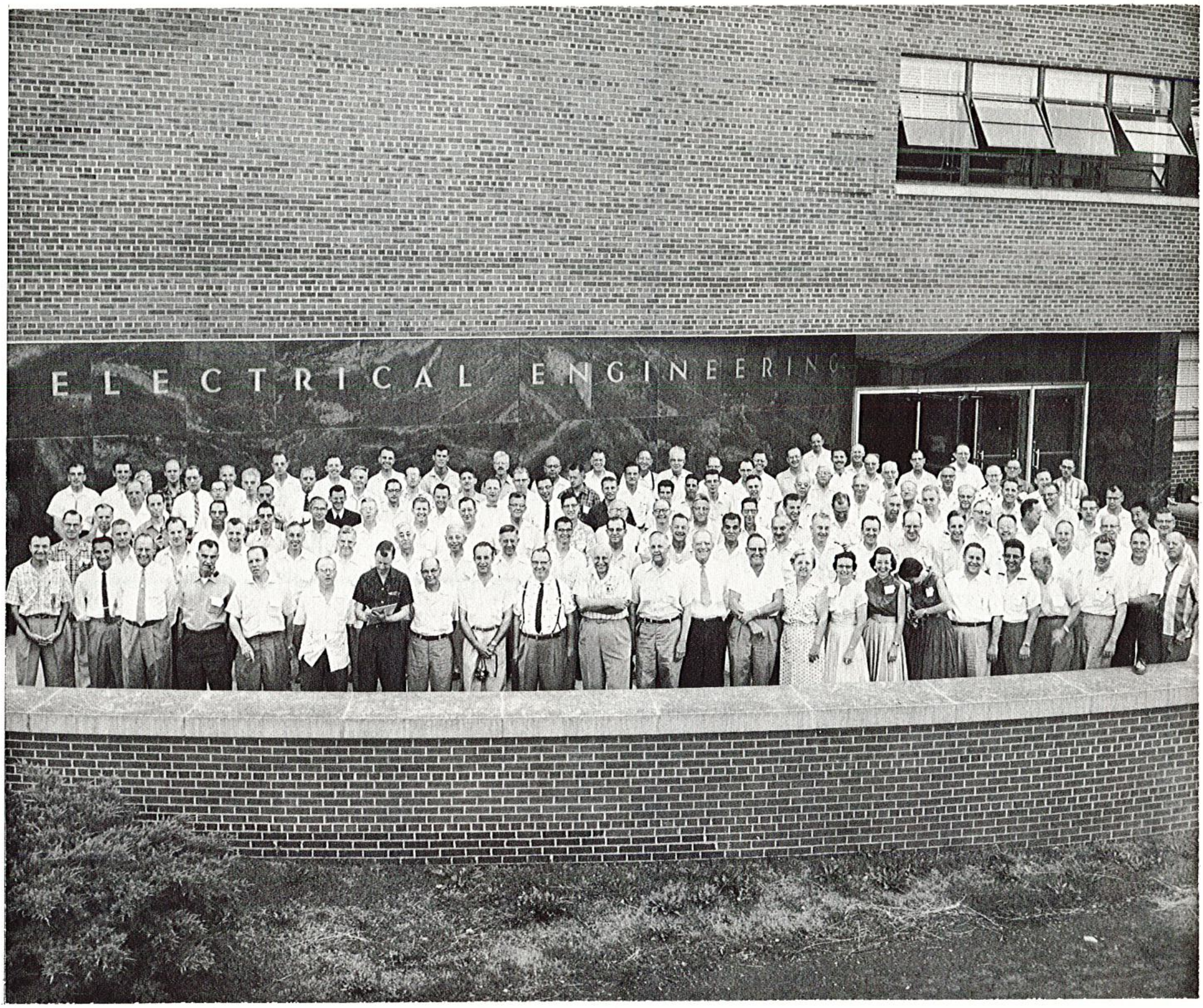

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IOWA STATE COLLEGE – AMES, IOWA – JUNE 1956

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ROW 7: Burdick, Luzadder, Porsch.

Editorial Page

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Published in the Interest of Teachers and Others
Interested in Engineering Graphics

INTEGRATION AND GRAPHICS

During the past few years two words have assailed our unwilling ears at every turn. Those two omnipresent words are Integration and Graphics.

No one likes to be thought of as reactionary. Each of us wants to be considered at most conservative, if not liberal or progressive. But the words Integration and Graphics make many of us wince and we often wonder why. Is it that while we call ourselves progressive, we are actually reactionary, afraid to welcome change and so set in our ways that we can't countenance the new, the different, the unaccustomed? Or is it something else entirely?

We think it is indeed something else entirely. We believe that every teacher in the Drawing Division realizes that the fundamental concepts of engineering education are undergoing vital upheavals, not only in our special field but in every aspect imaginable. And yet many of us are uneasy, not because we refuse to accept the inevitability of change but rather because we aren't quite sure of the right direction to go.

Perhaps our answers lie in the words Integration and Graphics. Perhaps. But we feel very sure that more people don't know what these words imply than do. Some of us feel that Integration means a method of disguising the fact that descriptive geometry is still in the program. Somebody said it at the Ames Summer School: "You change the statement in the bulletin but you keep right on doing what you did before." As for Graphics, you wonder about the possible acceptance of nomography, graphical calculus, charts and graphs, graphical solutions, with just a little descriptive geometry thrown in — or thrown out.

Well, here's a challenge to the Integrationists and the Graphicists. What do you mean by Integration? Exactly what? Do you mean the way a deck of cards is integrated by shuffling? If not, then how do you integrate? What do you include? In what order? Why? How many hours a week for how many weeks? And what about Graphics? Some down to earth answers would get a wide welcome.

In other words, chapter and verse. Double space and on one side of the paper only. Figures and diagrams reducible to the width of one column, as a rule.

Or does everybody except the editor know the answers?

PROBLEM SOLUTIONS

In the Twentieth Anniversary issue, we complained that no one had sent in a solution to Professor Tea's teaser, the upper and lower limits of the sum of the angles a line can make with the three principal planes of projection. The day after that issue went to press we received in the mail an article by Professor Kliphardt. His article, published in this issue, includes an analytical solution of that intriguing problem.

Now, how about a graphical solution? Anybody for graphics? Hm?

CREATIVITY

In the Twentieth Anniversary issue, Professor Shick and Professor McNeary both wrote provocative articles about creativity. In today's issue Mr. Healy claims that creativity can be learned by everybody. This is a fascinating topic for speculation and exploration.

WE THANK YOU

Many of our good friends have taken time out to write complimentary things about the Twentieth Anniversary issue of last November and we do appreciate and acknowledge their kindness and generosity. Actually there were portentous pre-publication and post-publication crises lasting through many anxious days. But now, happily, all we have to worry about is the future. However, the proverb warns: "The things you worry about most don't happen; it's the things you don't worry about that you should worry about."

The Functions of the Engineer, Designer and Draftsman in Industry

By William L. Healy

General Electric Company, Philadelphia, Pa.

The subject is a broad one. It reminds me of the teacher who gave her class an assignment to write an essay describing the universe in a hundred words. So frequently the term "engineer" is misused or loosely used. Anyone doing some technical work at least thinks he is an engineer. Webster says that an "engineer" is one who designs or contrives." He has another definition, "one who carries through an enterprise by skillful or artful contrivance," There is a more up-to-date definition used in industry today. Engineering is the work of applying understanding and knowledge of materials and natural phenomena and experience in the industrial arts to determining, manufacturing and marketing products. Of course, there is the mechanical engineer, the electrical engineer, the civil engineer, the structural engineer; and a long, long list, more being added every day: the systems engineer, the planning engineer, the wage-rate engineer, the manufacturing engineer, are some of the newer terms heard today. Whenever one needs something to be expertly done that may have a little technical "know-how" involved, an engineer is picked.

The generic term "engineer" is used so losely today that it has lost its real meaning. What is the function of the engineer? I suppose I could say, To do engineering! That would be rather silly, wouldn't it?, or is it? The average engineering job today is loaded with assignments, other than engineering. It is not unusual to find that as much as 30, 40 or even 50% of the job content assigned to an engineer is clerical.

Today, when technically trained men are so hard to find and keep, it is highly important that engineering assignments be examined objectively to make sure that the technical graduate is spending the maximum amount of his time on engineering and not on paper work such as writing and filing letters, typing, and other jobs that can be done by supporting personnel. The engineer also has no time these days to make drawings. Clerks, engineering assistants and supporting personnel for the engineer can be hired, but it is well nigh possible to secure the number of engineers that could be used in our expanding economy.

Perhaps the electrical industry will lead us in an economic expansion such as the world has never seen. In 1955, Americans used more electricity than ever before in history--a record high of 547 billion kilowatt-hours. This is over 40% of the world's entire production of electric power.

We are told that by 1965 the electric utilities in the United States will be required to produce as many kilowatt hours of electric energy as were produced since the beginning of the industry. It is predicted again, by those whose business it is to know, that the electric power required by 1975 will be double that required by 1965. New markets, new processes, atomic energy, increased population, new uses for electricity, domestic and industrial; all have contributed to the slogan now being used — "A trillion kilowatt hours by 1965." This expanded electrical age has dawned upon us almost overnight. This new industry, only 75 years old, has grown so rapidly and in many ways so astoundingly that our schools and colleges seem not to be able to supply the technical trained manpower needed to keep it rolling.

Some of our leaders see the shortage of engineers as a real threat to our freedom. This year American industries could use 40,000 technical graduates and about half that number will be available. Our company, alone, could use 3,000 new engineers in 1956, but expect to get less than 1/3 of that number.

There are many causes that have contributed to this shortage but they are not important. What is important is the fact that this lack of technically trained people poses a real threat to our freedom during the years immediately ahead when we will be competing with the Communist economy.

Since the need for engineering graduates in industry is so critical, industry must see to it that the engineers that are available make their maximum contribution.

It wasn't so long ago when the natural expectation of the technical graduate, accepting employment with a concern, was to spend a year or two in the drafting room before he was given an engineering assignment. Drafting is the language of the engineer. By the use of this graphic language, engineers, designers, draftsman and manufacturing personnel, as well as customers, are able to convey their thoughts to one another easily, clearly and without question. Some concerns, feeling so strongly that service in the drafting room is to engineering what interning is to the doctor, are still insisting that the engineer, after graduation, spend a year or two on the drafting board. But this practice is losing ground.

Mr. Ellsworth A. Kehoe of the General Motors in a recent magazine article states: "There is a trend during today's shortage of engineers for recent graduates to short-cut the drafting and design room. Expedient as this now may seem to industry and opportunistic as it may look to the young engineer, by-passing this important career-development phase may be to the long-range detriment both of industry and of young engineers as well."

In most companies today, however, engineers are not put on the drafting board. All the knowledge of orthographic projection that they possess must be acquired before coming with the company of their choice. Engineers must know the language of design, for their work is with drawings and the users of drawings, such as planners, wage-rate and manufacturing people, customers and construction personnel. Drawings are the medium through which thoughts and ideas are exchanged. The engineer must be able to read the drawing accurately and quickly. Generally speaking, one who can make a drawing can also read it, and since the engineer works so closely and directly with draftsmen, he must be able to direct drafting and instruct the draftsman with such sketches as are necessary to make his ideas immediately understandable to the draftsman or designer. These can be freehand and unfinished. I still favor the inclusion of engineering graphics in the college curriculum. So it is in our Company, as a general practice, the engineer does not make drawings but he directs and instructs the draftsman in their making. The draftsman is a part of the engineering team.

In the production engineering field, for instance, the main objective is to adapt, modify and improve existing products, manufacturing processes or equipments and the application or service of these equipments to prospective customers. The production engineer is involved with considerable drafting in applying existing or modified designs in his particular field to a customer's needs.

Let us look at the engineering and drafting contribution of such an engineering group. An order for a piece of equipment, purchased by a customer, is placed on a product department. It is assigned a shop order, a requisition number so that it can be identified all the way through the factory. After these preliminaries, the new requisition will be turned over to the engineering section where the engineering supervisor will examine the papers to get an approximate idea of the equipment involved and the amount of engineering work to be done (both engineering and drafting). The completion of the engineering, design and drafting details can then be scheduled and the shipping date of the equipment promised the customer.

Planning is one very important means of securing the greater utilization of the particular skills of both engineers and draftsmen. The more perfectly a job is planned and scheduled, the more efficient is the engineering contribution. You have heard it said, "Brains can't be scheduled." "Thinking and creativity can't be timed." Don't you believe it! Someone is getting pure science and research mixed up with design and production. If a modified design or even a new design has no schedule, that is, a target to shoot at, you can rest assured that it will never be completed. Perhaps there is some case for the apparent inability to force the human brain to create something new. I am even not too sure about that. The human brain, if it were used, can do some mighty big things. Overall scheduling of engineering assignments is not only healthful to the organization, but necessary.

After the scheduling of a new order, the engineering supervisor assigns the job to one of his product engineers who will, after careful study of the specifications and other papers, ascertain the following:

(1) Exactly what was sold to the customer and whether the price is approximately right.
(2) Total engineering content in the job.
(3) Whether there is necessary information still lacking. The engineer must take the entire responsibility at this point that the job is not held up somewhere along the line for lack of information. Once a requisition is started, it is very costly to hold up work.
(4) Whether the specifications were checked in regard to Underwriters' Lab. rules, ASA standards, NEMA and AIEE rules and specifications, as well as local restrictions at the customer's address.
(5) Whether all limiting equipment, that is, equipment that takes time to be manufactured or delivered, such as instruments, transformers, switches, power circuit breakers and other switchgear is ordered.
(6) Whether or not authorization has been issued for special designs as may be required.

The following are some of the functions of the engineer:

(1) Write a summary listing and ordering every piece of equipment required to complete the entire construction of the job.
(2) Keep the marketing and production sections informed all the way along the way as to the progress of the job.
(3) Prepare rough freehand sketches (both mechanical and electrical) so that both electrical and mechanical design drafting can be started. (Up to this time no drafting work has been done except as was necessary by the proposal and marketing people to sell the job).

The sketches showing all general information are as follows:

A. <u>MECHANICAL</u>

A front view sketch is made which shows space limitations, number of units, size of units, the equipment necessary for the function of the job, customer's special requirements, etc. From this sketch and information the mechanical designer can lay out the front elevation and sections of the new structure.

B. <u>ELECTRICAL</u>

One-line diagram showing the sequence of operation and other information necessary for the electrical designer to make a complete wiring diagram of the equipment.

The engineer will work closely with both the mechanical and electrical designers, consulting frequently with both until the job is completely designed, drafted and detailed for manufacturing. The mechanical and electrical designers will prepare arrangement drawings and electrical drawings for both customer's approval and manufacturing.

(4) The engineer will guide and direct the overall design of the job while it is in drafting. Working closely with the design draftsman, it is his responsibility to furnish all information necessary to complete the design and to detail and record on drawings not only the elevation and outline of the structure, but every component part of the equipment. The engineer is the "idea" man. He will give suggestions for incorporating new and modified designs in the equipment and pass these suggestions to the design draftsman in the form of freehand partial sketches. Any hold-up on the job, due to lack of information or from any cause whatsoever, will be the responsibility of the engineer. The design draftsman, under the direction of the engineer, will make necessary layouts and check diagrams to enable the detail and copy draftsman to complete manufacturing drawings. It is the responsibility of the design draftsman to make sure that the components and sub-assemblies in the structure are detailed, using standard parts as far as possible, correct materials, right manufacturing processes, realistic tolerances, etc. The design draftsman must know company standards, standard materials, standard hardware, preferred sizes, shop-run tolerances and manufacturing processes. Lack of knowledge in any of these things can cost the company considerable money beyond expected cost of the job.

The draftsman, by the very nature of his work, has considerable license in the expenditure of a company's funds. Did you ever consider how much a drawing is like a blank check? The draftsman orders materials, specifies labor and then signs his name to the drawing form (the company's name is already there). This drawing becomes a draft on which the company will spend money as directed in buying material and doing labor.

Let me illustrate how a draftsman can spend money or save money!

Figure 1 is a contact designed by one of our good draftsman for a simple relay. We manufacture a large number of these relays, actually two million per year. Let me hasten to say it was a good contact

Figure 1.

and performed well for several years. As far as I know there was never a complaint in regard to its function. It is composed of five parts. Let us look at it.

(1) SUPPORT (Fig. 2) This is a support made in the form of a bracket out of copper 1/16" thick x 5/16" wide. It has two tapped holes, each different and three drilled holes of different sizes. It is then silver-plated. This piece has a cost of $13 per M. What could the draftsman have done to furnish a part to perform equivalent function at lesser cost?

(a) Make the tapped holes the same size.
(b) Make the drilled holes the same size.
(c) Furnish tool to make bracket or secure from a specialty vendor.
(d) Make from silver-plated bar stock.

Taking advantage of these modifications, the price was reduced from $13 per M to $4 per M, or a saving of $18,000.

This designer could have saved his company $18,000 per year had he thought and taken advantage of these suggestions in the original design.

(2) SPRING — The draftsman who made the drawing for this spring spent considerable of the company's money by:
(a) Specifying music wire when it wasn't required.
(b) Close tolerances beyond that required.
(c) Added operation of grinding the ends.

A look at the spring and its function immediately tells us that the grinding operation on the ends is unnecessary. For its application, a closer tolerance, beyond shop-run, is unnecessary. The tolerances actually specified necessitated piece by

CONTACT

	Original Cost	Cost After Analysis	Saving	Total Saving
Support	$13.00/M	$ 4.00/M	$9.00/M	$18,000.
Spring	12.30/M	2.95/M	9.35/M	18,700.
Screw	8.00/M	.80/M	7.20/M	14,400.
Contact	8.00/M	2.00/M	6.00/M	12,000.
Eyelet	1.50/M	.37	1.13/M	2,260.
			TOTAL	$65,360.

Figure 2.

piece inspection instead of inspection by sampling, adding considerable to the cost of the spring. When the tolerance was relieved and the material changed from music wire to spring wire (which was more than adequate for the function of this spring), and the grinding operation eliminated, the cost of the spring was reduced from $12.30 per M to $2.95 per M, or a saving of -----$18,700.

(3) <u>SPECIAL SCREW</u> - In designing the contact the designer incorporated a special screw to provide tension in the spring. He designed it to be made in the Screw Machine Shop, with a milled slot. There seemed to be no reason why the designer didn't specify a standard screw which would reduce cost from $8 per M to 80¢ per M
Saving ------------------------------ $14,400.

(4) <u>CONTACT</u> — The draftsman detailed this contact for manufacture in the Screw Machine factory. He should have known the manufacturing process and specified cold heading. This would have reduced the cost from $8 per M to $2 per M, or a saving of -------------------- $12,000.

(5) <u>CUP WASHER</u> — The function of this little cup is to provide a seat for the screw so that when the screw is adjusted, pressure is applied to the spring evenly. The idea was good. It did the job that the designer wanted it to do. Its function, however, could have been performed by a little shoe eyelet manufactured by the Endicott Johnson Shoe Company which would have reduced the cost from $1.50 per M to 37¢ per M, or a saving of
---------- $2,260.

The total cost per year over above adequate function built into the product by a designer because he either didn't know his materials and processes or he just didn't think. (The results are the same in either case.)
Saving --------$65,360.

Let me show you one more example:

A draftsman detailed a little stainless steel pin 1/16" by 3/7" long and specified very close tolerances, closer than were actually required. The usage of this pin is 50 million per year, and the cost to the company is $3 per M, or 1/3 of a cent apiece. Is that good value? No, it isn't! The details were examined and our purchaser was requested to contact the vendor to see whether or not he could get a reduction on the cost of this pin.

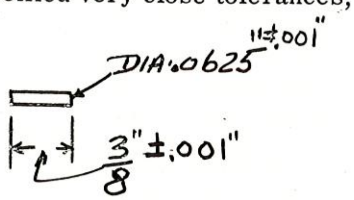


Figure 3.

In a two-page letter the vendor's sales manager explained how they couldn't take a single mil out of the cost, mainly because the tolerances were such that before they had the stock to make the pins it was necessary to perform two centerless grind operations. After review, it was determined that the tolerances were not realistic at all. The standard tolerances of a centerless ground rod was found to be adequate for the function of this job. By relieving the tolerances, the vendor was able to sell us the pins with a reasonable profit at $2 per M. This resulted in a saving of $50,000 per year.

It is indeed the function of the designer to know what is required in the way of tolerances for the particular design that he has at hand.

Let me give one more example of a design specifying the wrong manufacturing process. Figure 4 shows a copper disconnect punched from bar stock and then silver-plated. Coined and trimmed (Fig. 5) from a smaller silver-plated rectangular copper bar would result in a big saving of critical material while providing an improved contact surface.
Total saving per year --------- $12,000.

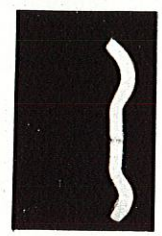


Figure 4.

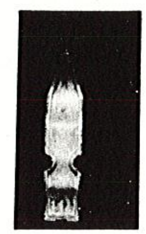


Figure 5.

The engineer, assigned a project in a Product Department, is responsible for that equipment until it is shipped to the customer. Every transaction, whether for drawings, parts, painting, finishing, photographs, instruction books, subcontracts, etc., is arranged for either by the engineer or with his knowledge. He must be given copies of all correspondence in any way relating to this particular requisition. He has had incorporated in its construction any or all the ideas that he may have had during its design and construction stages. The design draftsman has included them in the drawings.

The design draftsman, at the direction of the engineer, has had all drafting completed, including:
(a) drawings for customer's approval.
(b) drawings for manufacturing.
(c) drawings for record.

The detail and copy draftsmen, working with the design draftsman, has completed the delineation of all the detailed drawings and has incorporated in them all standard finishes, tolerances, manufacturing processes, standard materials, etc. The drawings are then delivered to the Production Department for the manufacture of the project. After its manufacture, the inspector assures himself that the structure has been manufactured in accordance with the drawings and specifications. He then releases the job for shipment. Any trouble or variation from standard that may be found in the structure by the inspector is the entire responsibility of the engineer and must be either reconciled or corrected before shipment.

I have tried to give rather sketchily the contributions made in the design of a project such as a switchboard by the engineering-drafting team. As indicated earlier, there are many kinds of engineers with many different assignments. Perhaps we could take one more example; that of the Design Engineer.

Suppose, for instance, the design engineer of a line of air circuit breakers has an idea of a new breaker This engineer will dream and dream, design and redesign until his ideas begin to take form in his mind. Perhaps he will even be benefited by illumination and inspiration. He will make many sketches. We in industry call them "thumb-nail" sketches. From these, together with some verbal instructions, the design draftsman will lay out the proposed breaker. The engineer and design draftsman, perhaps with many conferences over the drawing board, will agree on the elevation layouts of the new design. Then the dream becomes a reality, at least, on paper. The design draftsman will direct the detailing of the many assemblies and sub-assemblies, including all standards, and standard shop practices and will incorporate into the drawings the complete engineering record of the new breaker.

These drawings are now turned over to the Production and Planning Sections where the manufacturing work is planned and scheduled. The drawings and schedule then go to the Wage Rate and Pricing Sections where every operation is priced. In due time the work is released to the factory and every component part is manufactured in accordance with the drawing. After all these parts, assemblies and subassemblies have been manufactured and accumulated, the breaker is assembled and the engineer's dream has become, in fact, a reality. Thus you see the design engineer and draftsman working as a team.

The fact of the matter is, however, that when the breaker is finished and stands before you as it were in the flesh, the engineer will look at it and examine more closely some part or function and will exclaim: "What in the world was I thinking about." A new design is seldom perfect. Perhaps it would be more truthful for him to exclaim at that moment, "I just wasn't thinking." You know that is a universal exclamation.

James B. Wolf, Director of a large advertising agency, says in an article, "Limber Up Your Imagination," – "Millions of people travel from the cradle to the grave without thinking at all. Every individual, with a normal head on his shoulders, and possessing normal energy, normal ambitions, and normal curiosity, is potentially a thinker. The overwhelming tragedy is that so few people ever realize their potential, in fact, never come close to it. They simply do not have the habit of thinking."

An average brain worker uses a very small portion of the potential output of his brain. The question arises, "How can this output be increased?" "How can the average individual be brought to realize his great possibilities?" "How can we stress the potential imagination of individuals so that they will want to share more in the world's work?" If this can be brought about, our manpower shortage would be solved promptly.

In the last few years, schools, colleges, government agencies, and even industry, have latched on to this simple fact: Man can contribute many times more mentally than he is now doing if, by some way or some means, he can be brought to want to do it. He has tremendous potential mental power. Too many of us have accepted it as a matter of fact that the scientist is in the laboratory doing the creative thinking and that our job is to do the judicial thinking; that is, make two and two equal four.

Shipping of material ordered by a customer out the back door has been considered too often as the sole responsibility of engineers, and we have been content to let the job of creation to the Edisons, Steinmetz', Einsteins, Alexandersons, Bachs, Beethovens, Michelangelos and Leonardo da Vinci's. I am not saying that every man can be an Einstein, but every man has creative potential.

What has happened to that boy and girl born with unlimited imagination? Listen to the little girl as she talks to her doll and becomes a busy mother or society leader in her dream world. Listen to the boy as he builds his castles in the air and aspires to be nothing less than "top man." There is imagination unlimited. What has happened to it? What has happened to that inquiring mind of the youngster? Why Daddy, Why do the stars fall? Where does the rain come from? Too frequently one comes from his formal education without imagination, confirmed in his thinking that the inventor is a special kind of human being. The graduate engineer, saturated with theory and formulas, begins his career in an engineering office, in an atmosphere of judicial thinking. He builds his reputation on sound-proven laws, and travels the trodden path doing an acceptable job but exercising little or no imagination, with the result that his almost unlimited brain potential remains as it were, untapped.

Walter Lippman once said, "Where all think alike, no one thinks too much."

In an address at M.I.T. some time ago, Alex Osborne, the author of one of the best sellers, APPLIED IMAGINATION, says, "I submit that creativity will never be a science--in fact, much of it will always remain a mystery—as much of a mystery as 'what makes our heart tick?' At the same time, I submit that creativity is an art—an applied art—a workable art--a teachable art—a learnable art—an art in which all of us can make ourselves more and more proficient, if we will."

Creative power can be acquired. Is this not a challenge! Creativity can be taught; at least the student can be made aware of his potential. We need a greater contribution from everyone.

We are standing, as it were, in the dawn of a new decade of opportunity. Never has the young engineer had a greater opportunity to contribute to the world's work as he himself wills. He can share little or great as he wills. Never has the young engineer had a greater opportunity to serve his day and generation.

Motivation Needed in Teaching Engineering Drawing

By Earl D. Black

General Motors Institute

ANALYSIS OF THE TEACHING SITUATION

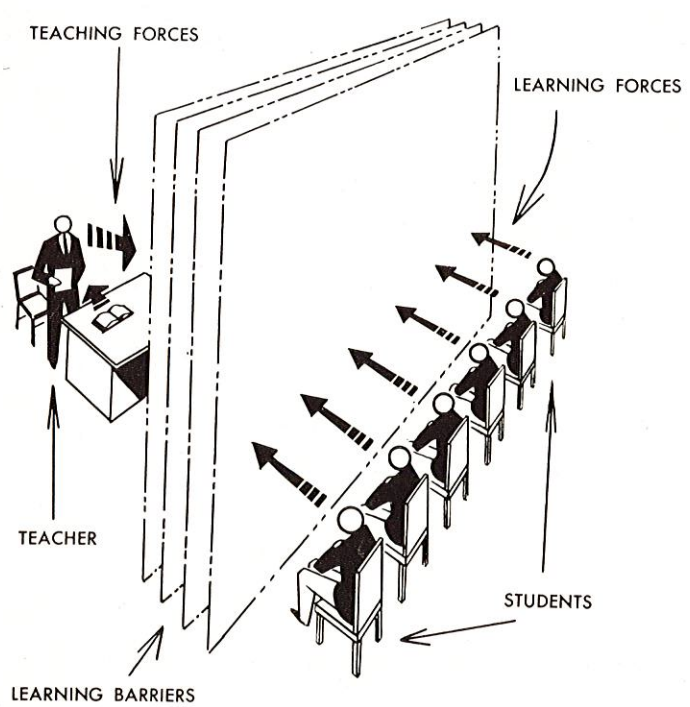
All of us have long recognized that it is extremely difficult to teach an individual new subject matter unless we begin with information that is closely related to that knowledge already acquired by the student.

The objective of any teaching situation is to associate, mix or integrate the combined activities performed by the teacher and the student so that the student is motivated to active effort in acquiring specific knowledge, techniques or procedures that will bring about the desired end results.

This process is controlled somewhat by the scope and difficulty of the subject matter, the time allotted for learning, the environment in which the learning activities take place, the physical and mental condition of the student, and the ability of the teacher to stimulate and lead the students to learn. These teaching process controls may very well be called "learning barriers" which must be penetrated before the student will learn.

MOTIVATION

As long as the subject assigned to this paper is "Motivation Needed in Teaching Engineering Drawing," let us use a drawing to illustrate.



Here we have a teacher who concentrates his efforts in penetrating the "learning barriers" to stimulate the student into learning the subject matter assigned. On the other side of these "learning barriers" are one or more students who may differ greatly both in capacity and willingness to learn.

Motivation stimulates the willingness to learn; it impels the student; it incites the student into an active attempt or desire to learn. Motivation is the one word which we use generally in describing necessary activities, methods of instruction, teaching aids and general conditions which induce learning.

True motivation will result in some learning. However, let us not lose sight of the fact that the student may learn facts or procedures correctly, incorrectly, or with a mixture of truth and fiction. That is why we give unit tests in order to verify our progress, direction and accuracy of teaching methods. Successful motivation is that activity which most effectively pierces the "learning barriers" and makes lasting contact in the learner's mind.

LEARNING BARRIERS

Let us examine these "learning barriers." We may have poor equipment (worn out or poor quality drafting instruments, inadequate drawing board space, not enough drafting texts, an inadequate number of reference books and limited teaching aids).

A second "barrier" may be poor environment—inadequate light, too many students in the same class for necessary individual instruction, disturbances by surrounding activities, irregular student schedules, course time conflicts, noises and interruptions.

A third common "barrier" to learning is the lack of individual student's ability to adjust to learning situations—heterogenous grouping of students, mixed interests on the part of individual members of the same class, varying capacities of class members to learn, lack of individual preparation or training necessary to learning, and physical or mental helath condition of individual members of the class.

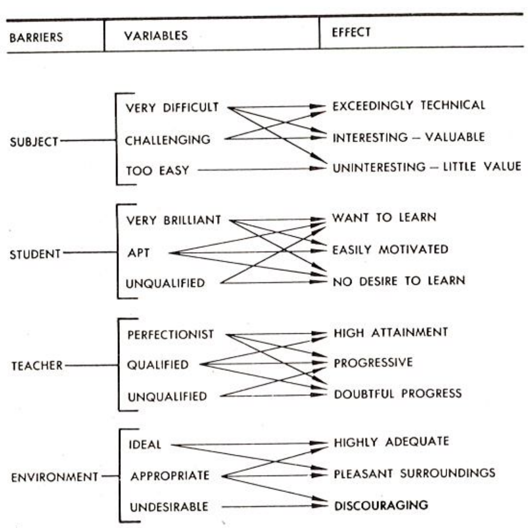
A fourth "barrier" to motivation and learning effectiveness may be the teacher himself. No institutional program is better than its teachers.

What are the teacher's qualifications? What of his appearance? Does his appearance detract from student learning? What of his poise and confidence? Does the teacher use mannerisms or language that detracts from his effectiveness? What of his personality, enthusiasm, force and indication of personal interest in the student? What is his attitude toward his students? Is he patient with the slow to learn? Are the teacher's voice quality, enuciation, articulation and pronunciation of words conducive to effective teaching? Is he orderly in his thinking? How does he handle the subject matter before the class? Does he have a full appreciation of the goals to be obtained?

Does the teacher act like an overlord or is he congenial? Does he recognize the intelligence of those who disagree with him? Does he exercise judgment and tact? Is he a recognized expert in his field? Does he keep abreast of the times? The answer to any one of these questions might well furnish the basis for extended discussion. Our purpose in this paper, however, is not to answer such questions or discuss them at great length but rather to use them as a springboard for discussing "motivation."

Let us summarize the teaching situation.

ANALYSIS OF THE TEACHING SITUATION



LEARNING AND TEACHING VARIABLES

Some of the many possible combinations of variables in a classroom situation are illustrated in this diagram. We have the elements of student, subject to be taught, the teacher and the environment. Each element is further divided into at least three grades of difficulty. The direction of learning and the degree of achievement may be an indefinite number of variables which challenge us in any classroom situation. Furthermore, the combination may change from day to day.

The subject may be very difficult, challenging or too easy. The very difficult subject matter may be exceedingly technical; it may be interesting and valuable to one student but uninteresting and of little value to another. The subject matter may also be only challenging but exceedingly technical, interesting and valuable or of little value and uninteresting. The third condition may have subject matter that is too easy, might be valuable or of little value and even uninteresting.

Similar variables persist in the teaching situation when we consider the student, the instructor and the environment.

Three conditions influence effective learning: namely, proper motivation—to establish the why to learn; clear and well formulated objectives -- the what to learn; and the required practice or use--the how to perform with what is learned. When any one or more of these contributions to a learning process is missing, the chances for forgetting increases to a high degree. We forget when the reason for learning is absent. We tend to forget that which appears unimportant or seems to lack a definite relationship to our lives. Thus, to establish a definite importance in the mind of the student regarding the desired end results of learning is successful motivation. Ideas are remembered in proportion to their meaningfulness and purpose rather than because of some novelty teaching technique used in motivating learning.

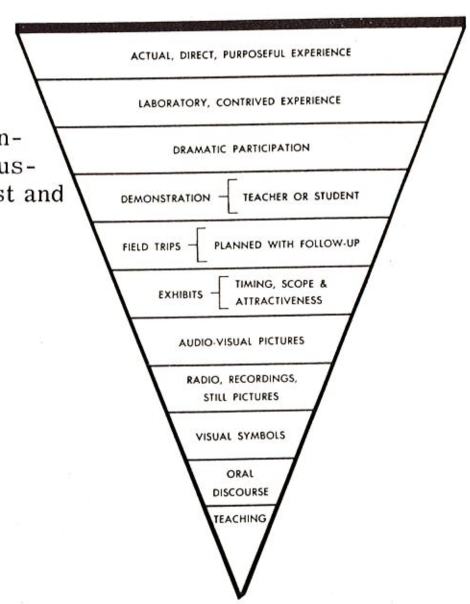
Each learning session must be examined for the degree of attainment expected. The student may study only to acquire an appreciation of the subject at hand. He may accumulate knowledge and know-how sufficient not only to appreciate the subject matter but also to be able to use that knowledge and know-how should the occasion arise. The student may be required to master the subject in scope and technique to the extent that he can use it in earning his daily bread.

Quality of instruction is not accidental; it is the result of intelligent planning and effort. Minds are like parachutes—they do not function unless they are open.

TEACHING TOOLS

Motivation is any word or act performed by the teacher which helps to penetrate the "learning barriers."

Let us take Professor Edgar Dale's* "Cone of Experience" and call it a "Wedge of Experience." Now let us add to it a piercing point called "teaching." The wedge idea may be likened to a teaching tool for breaking through the learning barriers illustrated in the first and second figures.



*Dale, Edgar. Audio-Visual Methods in Teaching: The Dryden Press, New York; p. 39. 1950.

ORAL DISCOURSE

Speech is our primary and natural means of communication. It is the handiest tool in our motivation kit. Therefore it seems appropriate that we place oral discourse adjacent to teaching — our piercing or cutting tool. But speech alone is soon lost in meaningless words and we need to combine other forces with it before we achieve effective teaching. An exceptional teacher may be able to use lectures effectively, but he who depends upon lectures alone for teaching must be interesting, strong in personality, and be expressive and forceful in his speech; otherwise, the students will sit mentally idle or go to sleep. A good lecturer must have a glowing sense of consecration to his special subject. He must use small words to shorten the distance between himself and the students as long words are road-blocks to learning. The lecturer must capture and retain the attention of his students. This demands unusual enthusiasm, inspiration and personal qualities which many of us lack.

Group or individual conferences also utilize oral discourse for motivation. But conferences can only arouse interest, act as a pool for exchanging information and modification of attitudes. Conferences may actually solidify agreement on false information if false prejudices and opinions are the only points of exchange. Conferences cannot result in the development of new knowledge unless some of the conference members have this new knowledge to exchange.

Oral discourse serves its purpose as a means of motivation; it may boost the student to the first rung of the ladder of learning but in itself is not sufficient to fix the learning in the student's mind. Students must be considerably on their own in order to increase their capacity and willingness to learn.

To achieve any training objective the teaching activities should include a balanced variety of methods of instruction as a tool for inciting students to learn. Training must be kept flexible if it is to be progressive and effective. The shortcomings of one technique in motivation will perhaps be the strong points of another.

The good teacher will lead the student to help himself discover how to learn rather than supply information outright or solve a detail of the problem situation. If a student fails to think properly, all other items in his training become of secondary importance and he will soon forget what he learns.

VISUAL SYMBOLS

Visual symbols (graphs, maps, drafting conventions, and even lines on drawings) are only substitutes for the real thing. This requires communication with a new language. The student must be motivated into mastering such short cuts to clearness. If this reasoning is not included in the teaching processes, the student will soon lose the meaning of the symbols and they become useless.

Symbols were used to represent students and the instructor in our first figure, but their idea representation will soon be lost to us unless we review their meaning and use them in conversation.

RADIO, RECORDINGS, STILL PICTURES

We can easily see that the radio--an audio device—has some limitations in its use for teaching mechanical drawing. However, combine radio with TV and the sound device may become an excellent method of motivation.

Recordings by themselves have little use in teaching drawing. Still pictures, however, add much to motivation in the learning of graphics when placed in the hands of an experienced teacher. Examples of their use are carefully chosen pictures, film-strips, slides and sample drawings which stick in the student's mind.

AUDIO-VISUAL PICTURES

Movies and sound pictures may be used to great advantage in motivating the learning of specific applications in engineering drawing. They serve to establish the importance of drafting to the engineering profession and motivate the student to greater efforts in mastering its scope and techniques. However, audio-visual pictures used without teacher preparation and follow-up are time consuming and should be replaced with more effective methods of instruction.

"Know-how" comes from trained doing. The big danger in using sight-sound teaching aids lies in our natural tendency to expect too much from them.

EXHIBITS

Even though we know that perfection may never be reached, it is wise to keep a picture of it before us that we may advance steadily toward it. Observation is one of the steps to orderly thinking and a good idea, passed along, makes all our thinking doubly strong.

Exhibits serve well to stimulate interest. The display of excellent drawings inspire the student to extend himself beyond his normal efforts. But timing, scope of exhibits, attractiveness of display and location accessibility should be a part of their use. If the exhibits are not scheduled and correlated with subject matter to be taught, they lose much of their effectiveness in motivation.

It is highly desirable to drive a single thought home at one time and replace it as it ceases to arouse curiosity. The scope of the exhibit is extremely important also. If too many ideas are exhibited at once, important ideas lose their impressiveness.

FIELD TRIPS

Field trips should be carefully planned with follow-up. They should be made with a special purpose in order to provide maximum motivation to learning.

The engineer is expected to be able to think in terms of shape, of size, of weights, of materials, of motion, of function, and of mathematical concepts in graphical form. He must know how to use or apply this knowledge on the job.

As an example let us think of an engineering student who is suddenly confronted with the assignment of making a design assembly layout of a die to blank, pierce, form or shape a given pressed metal part. The student has had no experience in the die room. He has possibly seen a punch press in action but he has paid little attention to its operation. So the instructor plans a field trip to the die laboratory or the production line. Here the student sees the various presses and parts of dies in action. Critical parts of the assembly are pointed out to him and questions are answered for him regarding function and processes in the manufacturing operations. Now he really knows how and why the job is done. He studies the proposed assignment with new desire and vigor. He is motivated to improve his design sketches and layouts. His attitude toward the assignment changes; his individual progress is much faster. The student is led to apply his knowledge of drafting to a new situation; his observations provide the fuel for new ideas.

The follow-up to this field trip is the project assignment. In completing the drawing the student will have to ascertain facts and act upon them. He must assimilate his knowledge with judgment and exercise his skills as a draftsman in the performance of the assignment.

Engineering drawing may be taught with deadly dullness or it may be taught with a purpose using techniques that will open the windows of the student's mind and stir his imagination. If the uninteresting teacher confines the student's learning activity with copy work or routine exercises, he will kill the student's enthusiasm and leave only the shell of mediocre performance.

DEMONSTRATION

The demands of time and lack of sufficient equipment places limitations on the extent of training and methods used in teaching engineering drawing. We are forced to use short cuts to teaching.

A demonstration, if properly performed, helps to emphasize and clarify important or complex subject matter. The demonstration may arouse interest and teach by example. The complete demonstration may be given by the teacher requiring nothing more than observation on the part of the student, but the student should be required to perform something similar to what he has just been shown how to do. A demonstration may bridge the gap from abstract to direct, purposeful experience.

DRAMATIC PARTICIPATION

Dramatic participation gets us closer to the use of direct and purposeful experience. But with the time restrictions prevalent today, dramatic participation does not lend itself well to use in the engineering drawing classroom or laboratory. Such activity may serve its purpose best in extra or co-curricular activities as in society meeting programs, staging design conferences, mock trials and court proceedings regarding drawings, operating technical school newspapers and the like.

We cannot directly experience something that has already happened. Dramatic participation provides a reconstructed experience and thereby has a teaching advantage in that subject material that has little meaning or distracts attention may be eliminated. We can focus student attention and emphasize the important ideas both to the participant and to the observer through this medium.

LABORATORY, A CONTRIVED EXPERIENCE

Classroom instruction must be supplemented by sufficient realistic practice on the board under proper guidance to make a well-rounded graduate of engineering fundamentals. The use of a project for student development and completion in the drawing laboratory is the most fundamental of teaching techniques next to actual experience. Here specific items of knowledge may be isolated and taught by the use of models, mock-ups, examples, demonstration and simulated experience. We can design project studies that will give the student short cuts to actual experience. We may actually edit the real experiences with laboratory experience and emphasize the more difficult items of knowledge. The laboratory experience helps us remove the road blocks to motivation through simulating reality.

We need to motivate the student to orderly thinking.

At General Motors Institute we first meet the student in a classroom where we demonstrate principles, give him established facts, show him peculiarities of the problem situation, and let him observe models or other teaching aids which we use to stimulate his interest.

Second, we define the problem through the use of assignment sheets, layouts, written specifications or other instruction.

Third, we individually discuss considerations and various satisfactory solutions as to design; we consider his drafting techniques for style, conventions and presentation; we discuss interchangeability and the effect of geometrical and positional tolerances on assembly, function, manufacturing processes, operation and service.

Fourth, we make regular visits to the student's drawing table where we check his progress, review classroom discussions for emphasis, and guide him into arriving at qualified conclusions or decisions which he must make for completion of the project. We encourage the student to develop speed, accuracy, and willingness to learn.

ACTUAL, DIRECT PURPOSEFUL EXPERIENCE

Ability is developed by doing but actual experience is not always the shortest line between belief and fact. The student may learn how to operate a machine faster if he is put to work with it. Experience is a good teacher but a hard one. It often gives the test first and the lesson afterward.

Students can mature into capable individuals only if they are placed in an atmosphere where a scientific approach is actively encouraged. The trainee needs guided training even on the job; otherwise his lack of experience may become prohibitive in cost or even dangerous. For this reason the co-operative student is assigned to a supervisor and an educational director at his plant who helps him plan his program and encourages his efforts toward learning. He is classified as a student and is required to write reports coordinating his work experience with his school experience.

The successful student learns how to make applications of what he knows to new situations. He keeps abreast of advances in technology and makes new developments a part of his own working knowledge.

Genuine student interest based on inquisitiveness and a growing desire to accomplish an ambition is the motivating force that generates a true desire to learn. Thinking comes from a combination of understanding known facts, power of recall, application and association of fundamental laws, and the ability to sense possible new relationships. Teaching begins with knowledge and ends with greater knowledge. Diligent study brings understanding, and understanding brings accomplishment and a desire to learn more.

SUMMARY

The objective of any teaching situation is to perform such activities as to motivate the individual students to active effort in acquiring specific knowledge, techniques or processes in just the proper proportion to attain maximum learning of end results. Motivation is every word or act that causes mental activity on the part of the student in this direction.

Teaching performance and motivation are controlled by numerous variables in classroom situations. Subject matter may be classified from too easy to very difficult; students in the same class may vary in capacity and willingness to learn from unqualified to very brilliant; teachers may differ in teaching abilities from unqualified to brilliant and effective performance; and we may have a general environment from discouraging to highly adequate. Students learn quickly and well under good conditions; they develop slowly under poor conditions. All these variables influence the general teaching activities which motivate learning.

Effective learning is closely related to the meaningfulness of the material presented and the student's interests and willingness to learn. Learning is most effective when the terminology of the new material is kept in the language of the student's former experience.

Each learning activity must be examined for the degree of attainment expected.

Quality of instruction is not accidental but rather the result of intelligent planning and effort. We may begin motivation by the use of oral discourse but speech alone is not sufficient for positive learning. We must progressively use more effective methods of motivation to support and strengthen the effect of speech, as: (1) use of visual symbols, (2) radio, recordings, and still pictures, (3) audio-visual pictures, (4) exhibits, (5) field trips, (6) demonstrations, (7) dramatic participation, (8) laboratory or contrived experience to (9) actual, direct and purposeful experience. To use any one of these teaching media singularly and alone places great limitations on effectiveness of motivation when measured by success. But the use of two or more of these methods in combination strengthens the effectiveness of each.

The good teacher will help the students help themselves discover how to learn rather than supply information outright. The effective teacher loves his work; he is happy in his outlook. He keeps up with the times. The good teacher directs rather than commands. He exhibits personal charm. He will refresh his good teaching techniques by research for better methods of instruction. The good teacher displays a mastery of subject matter, has intellectual capacity, quality of judgment, professional and personal character, leadership and ability to inspire students to learn.

Motivation requires the ability of the teacher to draw students into active participation in the learning processes in order to gain a mastery of the subject matter to the degree of being able to use it in everyday living.

Time limitations and a changing world place a premium on short cuts to effective teaching. The good teacher will not rely upon yesterday's advancements today. He will use enthusiasm, cheerfulness, and know-how as a lubricant to increase the effectiveness of his instruction.

The good teacher is aware of his shortcomings and strives continuously for self-improvement. He stimulates student interest and his desire to learn. He uses a variety and combination of methods and techniques of teaching that lead the student to make possible new applications and relationships of fundamental laws. The good teacher will inspire his students to diligent study, definite understanding and progressive accomplishment.

David Gessner Company Nomography Prize—Award

The $100 nomography prize offered through the Drawing Division by David Gessner Company, Worcester, Mass., for the best nomogram published within the academic year 1955-56 was won by Mr. C. H. Li, Metallurgist, Tube Division, Radio Corporation of America. The winning publication was "A Nomograph for Determining Significant Differences," Metal Progress, November, 1955, page 104-B.

Congratulations to Mr. Li, and thanks to the members of the Nomography Committee. And our appreciation to David Gessner Company.

Descriptive Geometry Courses which Comply with the Evaluation Report*

By Raymond A. Kliphardt
Northwestern University

The Engineering Drawing division of the ASEE has had outstanding leaders throughout its 28 years of service. From the very beginning these leaders have been pioneers on the frontiers of engineering progress, developing those techniques, materials and standards that would best serve the profession of engineering in the foreseeable future. Today, it is our opportunity to meet the greatly changed and rapidly changing requirements of engineering education. We must meet these requirements with the vision, the creativity and the spirit of our academic predecessors rather than with a misguided loyality to them which says, "Once the answer, always the answer," even though the problem is greatly different.

As we seek to build for our engineering specialty a future of service and importance equal to that built by yesterday's leaders we must welcome every forecast and "futurama" that illuminates the unknown problems and needs of tomorrow. The "Report on Evaluation of Engineering Education" thoughtfully attempts "to recommend the pattern or patterns that engineering education should take in order to keep pace with the rapid developments in science and technology, and to educate men who will be competent to serve the needs of and provide the leadership for the engineering profession over the next quarter-century," and "to clarify the curriculum content that differentiates engineering education from that in science on the one hand or in subprofessional technology on the other" (page 3).

That we recognize the value of this careful report is evidenced in many ways. That we have some disagreement with the report has been evident in much open and controversial discussion. Considering the report a sincere statement written by reasonable men we must not reject its unpopular sound any more than we smash the mirror that reveals we need a shave.

We agree that the goals of engineering drawing and the emphasis of its faculty are in complete alignment with the goals of all engineering education and the emphasis of all engineering faculty. We can then read page 5 of the Report to say that "the technical goal of engineering [drawing instruction] is preparation for the performance of the functions of analysis and creative design, or of the functions of construction, production, or operation where a full knowledge of the analysis and design of the structure, machine, or process is essential."

In the past the engineering drawing faculty "necessarily emphasized the art or practice of engineering. However, during the life-time of present faculties the art of engineering has come to depend greatly upon basic and engineering science. It must also be recognized that universities are better equipped to teach the science underlying professional practice, whereas industry is better adapted to provide experience in practical applications" (page 7).

The ultimate goal of engineering [drawing instruction] is the development of able and responsible men fully competent to practice on a professional plane, especially those who will eventually lead the profession to new heights of accomplishment through creative practice or research" (page 11).

"The instructional goals of engineering [drawing] include helping the student to learn to deal with the new situations in terms of fundamental principles, on his own initiative, with confidence and sound judgment" (page 11).

On page 16 "graphical expression" is referred to specifically. We remember that paragraph well with its endorsement of engineering drawing as a form of communication and a means for analysis and synthesis. It calls for an emphasis on spatial visualization, experience in creative thinking, and ability to convey ideas especially by free hand sketching. It further affirms that drawings are required to execute the engineer's designs and the engineer must be thoroughly familiar with graphical communications.

A course in descriptive geometry complying with the Report clearly must and wonderfully can

I. Emphasize spatial visualization
II. Provide experience in creative thinking
III. Increase ability to convey ideas by freehand sketching
IV. Develop the students' powers of analysis and synthesis
V. Promote competence in graphical recording and communication

To implement these natural derivatives of a course in descriptive geometry we must be careful to allow the problems to be experiences in creative analysis and synthesis rather than reduce them to pat solutions of stock problems by over-drilling a one-method approach that may or may not have basic meaning to the student. Isn't it better to solve five problems on one's own initiative than to complete twenty-five standardized pages of workbook by rote procedure? Have we become so overly impressed with the endless variety of descriptive geometry problems that we crowd too many samples into too little time? Do we really want a text book that is so complete the student doesn't need a teacher? Have we thought carefully about these step-by-step sample solutions that can be followed without being understood? Are we more concerned with getting a prescribed number of papers be filled up and a predetermined response on the final

* Presented at the Drawing Division Summer School, Iowa State College, Ames, Iowa, June 1956.

examination than we are with the real understanding and development the student experiences?

At one time I started to write a descriptive geometry book with no illustrations except for basic ideas—no sample solutions. I still wonder if it isn't what is needed, despite student delight in a book that quickly shows them how to finish their assignment and preferably without requiring any thinking.

The Report says clearly that the committee is not as concerned with WHAT we teach as with HOW we teach. A descriptive geometry course complying with the Report must aim at fostering a particular kind of experience and development for the student.

Let's examine the five emphases of the report individually.

I. EMPHASIZE SPATIAL VISUALIZATION

It seems to me that visualization may be thought of in three aspects. First, there is native ability in mental imagery. Can the student visualize familiar non-technical items such as his desk, the campus flag pole or the Union Building? There is wide variation in mental imagery from person to person. Secondly, there is the matter of accuracy in mental imagery. Can the student count the number of drawer handles on his desk when visualizing the desk? Can he estimate the height of the flag pole? Can he sketch the Union Building in reasonable proportion and with proper number, spacing and size of windows from his mental image? Can he visualize an equilateral triangle inscribed in a circle and estimate what percentage of the area of the circle is inside the triangle and outside the triangle? Finally, there is the aspect of generalization in mental imagery. Can the student visualize general and limiting conditions of a verbally described space configuration? Can he correctly answer such questions as,

1. Given any two planes is there always a third plane perpendicular to both of them?
2. Is every horizontal line perpendicular to every vertical plane?
3. Is every vertical line perpendicular to every horizontal plane?
4. If a plane contains one horizontal line is it a horizontal plane?
5. If a plane contains two horizontal lines is it a horizontal plane?
6. If a plane contains one vertical line is it a vertical plane?
7. If a plane contains two vertical lines is it a vertical plane?

II. PROVIDE EXPERIENCE IN CREATIVE THINKING

We can so organize the ideas of the course that some previously completed problems are the pieces of a "new" solution; new, that is, to the student. For example, when a class has learned to determine the true length of a given segment it can be asked to set off a segment of required length on a given line. When a class has the added ability to represent a line parallel to a given line or intersecting a given line, the problem of determining the angle between two skew lines is a creative experience provided the student does not have a book full of sample problems all worked out with specific labels so that he most naturally just copies the related one.

When I took some graduate work in architectural design and city planning at the Illinois Institute of Technology in 1939-40, we were forbidden the use of one of the finest architectural libraries in America—the Burnham Library of Architecture in the Art Institute. The library was in the same building as our drafting room. As students we loudly criticized this 'crazy' rule. Actually, we knew all along the reason for and the wisdom of the rule but found it easier to repeat the past, good and bad alike, rather than think and create a new solution which later could be compared with established solutions.

III. INCREASE ABILITY TO CONVEY IDEAS BY FREEHAND SKETCHING.

We have the students sketch on tracing paper over a pictorial grid. The grid is trimetric, which I believe is superior to isometric because of its more general representation. We have worked out the grid so that there are four sets of parallel lines on the paper. The one set represents horizontal east-west lines; the second set represents horizontal north-south lines; there is a line of the third set through each intersection of the first and second sets and each represents a vertical line. There is a line of the fourth set through each intersection of the first and second sets and each of these marks off a third of a unit of height on the verticals. Then the students draw freehand from verbal description as follows.

Locate a^H at the intersection of the first horizontal NS line and the fourth horizontal EW line counting from the lower left hand corner of the border. Draw A 5 units directly above a^H.

1. Locate b^H and B if B is 4 units north of, 3 units east of and 2 units above A.
2. Locate c^H and C if C is 1 unit south of, 2 units east of and 5 units below B.
3. Locate d^H and D if D is 3 units west of C, 2 units south of and 2 units above A.
4. Is BD a horizontal line?

Such exercises help the student learn to 'box' a sketch of a desired object in proper three-dimensional relation. This seems to be the weak spot of most students when attempting freehand sketching.

IV. DEVELOP THE STUDENTS' POWERS OF ANALYSIS AND SYNTHESIS.

How about such an exercise as this? Assume that an angle can project smaller than true size and prove that an angle can also project larger than true size.

The proof can be organized easily by considering a triangle ABC in space. Assume that angle A projects smaller than true size in the top view. Then recall that the three angles of any triangle add up to 180°. Thus the sum of the three angles of true triangle

ABC = 180°, and the sum of the three angles of the top-view triangle $a^H b^H c^H$ = 180°. If angle A projects smaller than true size in the top view at least one of the other two (B or C) must project larger than true size.

Professor Peter L. Tea of The City College, New York, asked the following question in the February, 1956 issue of THE JOURNAL OF ENGINEERING DRAWING: "The sum of the angles Alpha, Beta and Gamma, which a straight line makes respectively with the top, front and profile planes varies between what limits?"

That is a good question and answering it involves a little analysis. Just as we want others to add graphical analysis in their work we should, when desirable, add non-graphical analysis to our work to establish important ideas which will not be included in the educational experience of the students if we don't include them.

Consider Figure 1. Line OA is one unit long and the diagonal of a rectangular box x units wide, y units deep and z units high.

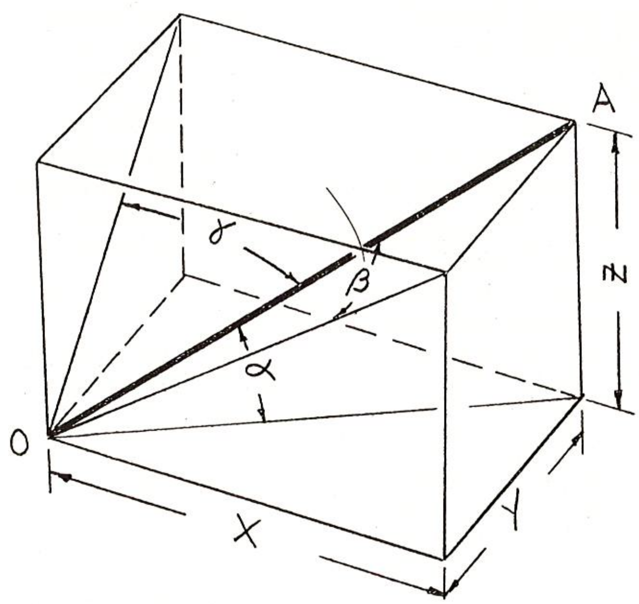


Figure 1.

Since OA is one unit long we have that

$$x^2 + y^2 + z^2 = 1. \qquad (A)$$

Also, $\sin\alpha = z$

$\sin\beta = y$

$\sin\gamma = x$

or

$\alpha = \arcsin z$

$\beta = \arcsin y$

$\gamma = \arcsin x$

Then the sum of the angles is $S = \alpha + \beta + \gamma$ or

$S = \arcsin x + \arcsin y + \arcsin z.$

We want to know the minimum and maximum values of the sum, S. Any two of the distances, say x and y, can be chosen independently but the third, z must equal $\sqrt{1 - x^2 - y^2}$. We can express the sum, S as follows.

$$S = \arcsin x + \arcsin y + \arcsin \sqrt{1 - x^2 - y^2} \qquad (B)$$

We then take the first partial derivative of S with respect to x and obtain,

$$\frac{\delta S}{\delta x} = \frac{1}{\sqrt{1 - x^2}} + \frac{1/2(1 - x^2 - y^2)^{-1/2}(-2x)}{\sqrt{x^2 + y^2}}$$

or

$$\frac{\delta S}{\delta x} = \frac{1}{\sqrt{1 - x^2}} - \frac{x}{\sqrt{x^2 + y^2}\ \sqrt{1 - x^2 - y^2}}$$

or

$$\frac{\delta S}{\delta x} = \frac{\sqrt{x^2 + y^2}\ \sqrt{1 - x^2 - y^2} - x\sqrt{1 - x^2}}{\sqrt{1 - x^2}\ \sqrt{x^2 + y^2}\ \sqrt{1 - x^2 - y^2}}$$

Then setting this first derivative to zero as is necessary for a maximum or minimum we have

$$\sqrt{x^2 + y^2}\ \sqrt{1 - x^2 - y^2} = x\sqrt{1 - x^2}$$

or

$$(x^2 + y^2)\ (1 - x^2 - y^2) = x\ (1 - x^2)$$

or

$$x^2 - x^4 - x^2y^2 + y^2 - x^2y^2 - y^4 = x^2 - x^4$$

This gives us

$$y^2 - 2x^2y^2 - y^4 = 0$$

If we leave this for a moment and repeat the partial differentiation of S (equation B) with respect to y we obtain

$$x^2 - 2x^2 y^2 - x^4 = 0$$

The maximum and minimum conditions occur when

$$y^2 - 2x^2 y^2 - y^4 = 0$$

and

$$x^2 - 2x^2 y^2 - x^4 = 0$$

are solved simultaneously. If we subtract the second equation from the first we have

$$y^2 - y^4 - x^2 + x^4 = 0$$

or

$$y^2\ (1 - y^2) = x^2\ (1 - x^2)$$

1. This is satisfied if x = 0 and y = 0. Then z = 1 (from equation A) when x = 0, y = 0 and z = 1, $\alpha = 90°$, $\beta = 0°$, $\gamma = 0°$. This is a minimum sum.
2. This equation is satisfied if x = 0 and y = 1. Then z = 0 (from equation A). When x = 0, y = 1 and z = 0, $\alpha = 0°$, $\beta = 90°$, $\gamma = 0°$. This is another minimum sum.
3. This equation is satisfied if x = 1 and y = 0. Then z = 0 (from equation A). When x = 1, y = 0 and z = 0, $\alpha = 0°$, $\beta = 0°$, $\gamma = 90°$. This is another minimum sum.

The minimum sum is 90°.

The equation is also satisfied when x = y. If we repeat the foregoing differentiation starting with S; $\arcsin x + \arcsin \sqrt{1 - x^2 - z^2} + \arcsin z$ and differentiate partially with respect to x and then with respect to z

(Continued on Page 32)

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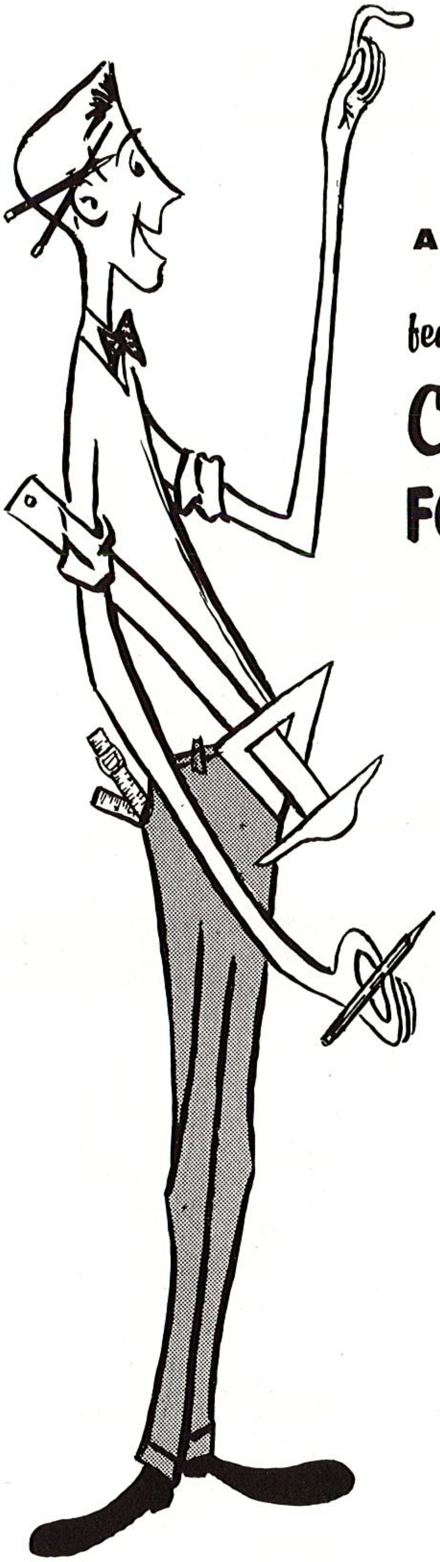

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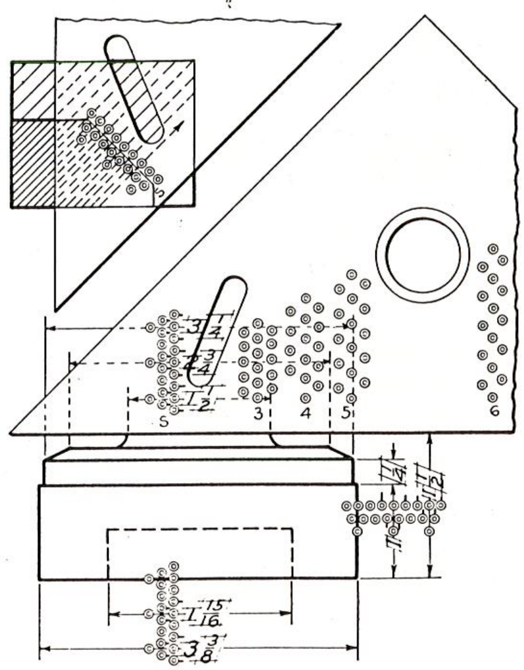

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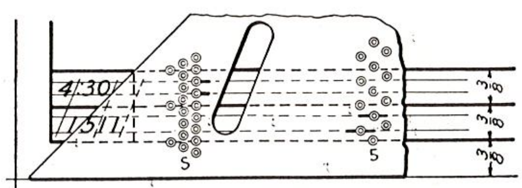

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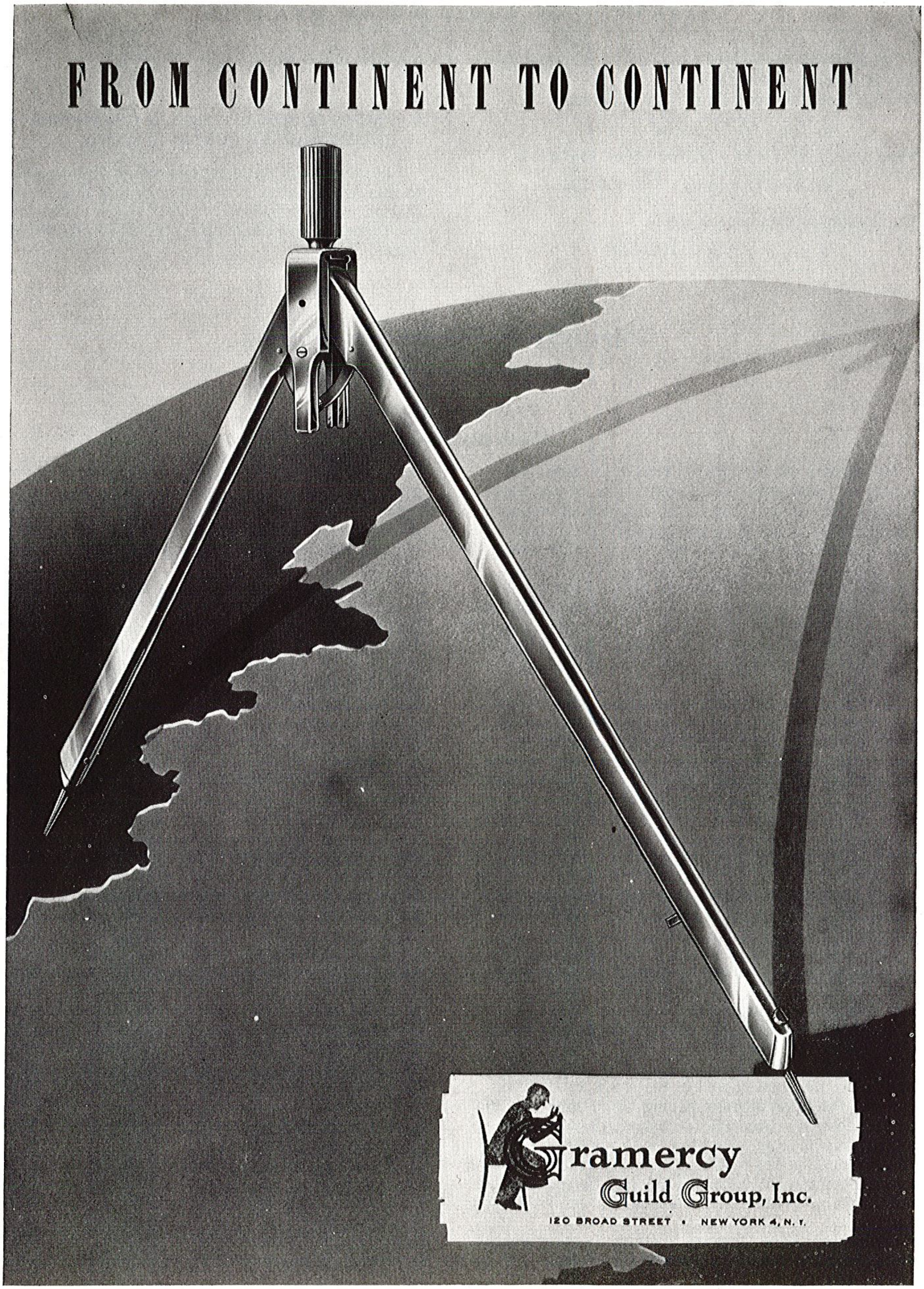
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we will obtain the requirement that x = z. Thus the maximum occurs when x = y = z.
For any line the three angles are such that

$$\sin^2\alpha + \sin^2\beta + \sin^2\gamma = 1$$

When x = y = z, $\alpha = \beta = \gamma$ and we have $3\sin^2\alpha = 1$

$$\sin^2\alpha = 1/3, \ \sin\alpha = \frac{\sqrt{3}}{3} = .57735$$

The maximum sum occurs when

$$\alpha = \beta = \gamma = 35° \ 15' \ 52.2''$$

The maximum sum is 105° 47' 36.6"

V. PROMOTE COMPETENCE IN GRAPHICAL RECORDING AND COMMUNICATION

I believe all of the foregoing comments are related to this overall goal. I also believe that this is a goal that all of the members of the Division of Engineering Drawing have admirably striven toward for many years.

Objectives of Engineering Drawing in Engineering Education *

By R. R. Worsencroft

University of Wisconsin

My assignment for this session of the Summer School is a discussion of the objectives of our engineering drawing courses in the program of engineering education. I shall limit my remarks to a consideration of those basic drawing courses given generally in the freshman year and consisting of from 4 to 8 credits of the normal freshman load. For it is my contention that once a sound base of fundamentals has been established, further education in drawing may be successfully continued in any direction that might be demanded by the requirements of any engineering program.

In spite of the tremendous scientific advances of this atomic and electronic age; despite increasing pressures from degree-granting departments to compress, condense and dilute our courses; despite the varying opinions existing within this very group as to the proper content of basic drawing courses; I have no new or startling objectives to offer you. The same ones that have guided our courses for many years—changed, perhaps, in order of importance, phrased in different words, more limited in coverage due to curtailment in time—are still sound and legitimate objectives for our present day courses. For the graphical language is one of those basic elements which an engineer must learn to use with considerable fluency if he expects to advance in his profession. It is then, upon the premise of establishing a sound base of fundamentals, that I offer you this statement of the objectives for our basic courses in engineering drawing.

Commenting on the objectives of an engineering education, the final report of the A.S.E.E. Committee on Evaluation of Engineering Education[1] has this to say, in part, "The first objective, the technical goal of engineering education, is preparation for the performance of the functions of analysis and creative design." If you will examine the various engineering curricula, you will find in them innumerable courses for developing the technical theory necessary for engineering design in the various fields. You will also discover that engineering drawing is the only one of them that is concerned primarily with developing the fundamental processes of visual thinking and analysis implied in this objective.

Let us consider briefly some of these fundamental processes of visual thinking, particularly those that are affected by our basic courses in drawing. Professor L. L. Thurstone, psychologist at the University of North Carolina, in his paper on "The Mechanism of Thinking,"[2] says, "As a result of studies during the last two decades, we no longer speak of visualizing as a single trait. We know of some seven or eight primary factors that are quite distinct, and which are all related to visual thinking." (I am going to quote from Professor Thurstone only those factors applying specifically to drawing My quotation continues.) "The first space factor consists in the ability to imagine a solid object as it looks in different directions. This is ability that will be called for in ordinary orthographic projection. A second space factor consists in the ability to imagine a three dimensional configuration which has internal displacement among the parts. It seems rather curious that these two factors are distinct. A person may be able to visualize rigid objects quite successfully, and then fail markedly when he attempts to deal with configurations that are flexible, such as a mechanism. ------ The second closure factor is represented by the ability to keep a configuration in mind, in spite of distracting surrounding detail. Here the subject is shown a simple figure, and asked to identify it as part of a more complex figure. The subject must destroy the gestalt of the larger figure in order to identify the smaller figure which is buried in the more complex design."

Now it is evident that these three factors of visual thinking will be quite specifically affected by improvement in spatial, or three dimensional visualization. Thus our first, and most important objective in the basic courses should be to develop the student's ability to (a) visualize spatially, and (b) apply this process

* Presented at the Drawing Division Summer School, Iowa State College, Ames, Iowa, June 1956.

in analyzing problems of engineering design. The value of engineering drawing lies primarily in the degree of success it can claim in developing this latent and essential visualizing ability. And I believe it has been satisfactorily established that drawing can and does develop it.

Studies on this subject by M. F. Blade and W. S. Watson of Cooper Union[3] and bv this writer,[4] covering three separate institutions, have indicated several very significant facts concerning it.

First both studies have shown that there is a very large, and generally universal development in visualizing ability among engineering students during their freshmen year, a gain that was very significantly greater than chance.

Second, the study by this writer has further indicated that non-engineering freshmen, taking courses similar to engineers (math, English, science, etc.) but not including engineering drawing, had a far smaller, and very sporadic degree of development in ability. In fact, 23% of these freshmen actually showed a decrease in the ability.

Third, the Blade and Watson study of their own Cooper Union group in the senior year indicated that no further appreciable gain had occurred during the intervening three years, altho the freshman gain had been maintained.

I think we may fairly conclude from these facts that engineering drawing is the salient factor in any significant increase in visualizing ability among engineering students; that it can fulfill the requirements of our first objective, and in fulfilling these requirements becomes an essential subject for engineers.

Our second objective, a corollary of the first and of equal importance, is to teach the student to translate his analysis of problems into the graphical terms of orthographic projection.

This objective involves learning the grammar of this graphical language, and I do not believe we have to go into any lengthy discussion to demonstrate the value of that. It is evident that if the student solves a problem by means of visual thinking and analysis, he must set that solution down on paper in a form that is understandable to others. A visualized solution requires a drafting board solution written in the graphical language used by all engineers, whatever their nationality. That language is, of course, orthographic projection.

Neither the ability to visualize (our first objective) nor the facility with orthographic projection (our second objective) dawn suddenly upon the student in a "moment of insight" after he has been initiated into the mechanics of orthographic projection. Rather it is a gradual growth extending over the entire length of the course. We should, therefore, see to it that each problem we use has in it elements that require him to exercise his visualizing ability to solve it, and his knowledge of orthographic projection to put his solution down on paper. Moreover, as these abilities develop, the problems should keep pace with them. Each new problem should present a challenge to him, extending his ability to the utmost to obtain the solution, for it is only in this way that continuing development can be assured.

If our students are to learn to read and write in the language of orthographic projection, they must have some knowledge of its syntax and its idioms, as well as its grammar. This leads us directly to our third objective, which is to teach him the fundamental elements of conventions, standards, and methods of dimensioning used in preparing drawings, so that he may present his ideas in acceptable form, or interpret ideas presented by others.

This is an essential objective, if reasonable proficiency in the making of working drawings is to be obtained. Since the working drawing is often the end result of a solution to an engineering problem, certainly the student should be familiar enough with these fundamentals to use them in that solution, and to recognize their value in making the solution clear and complete. However, I believe it is secondary to the two preceding objectives as far as basic engineering training is concerned, for the following reasons.

Much of the material concerned in the subjects mentioned is of the "handbook" type, and requires the exercise of memory, rather than developing the ability to think. Another portion of it involves such advanced concepts that it cannot be properly assimilated by most freshman engineers. Moreover, the amount of material involved is large, continually expanding, and often changing. (Note, for one example, the considerable increase in size and content of our new ASA—Z-14 standard.) If we are not careful in limiting our work to the "fundamental elements," we are likely to find ourselves devoting a considerable portion of our time to this "memory" material which is promptly forgotten at the conclusion of the course, to the detriment of other more important objectives. If the student is interested in mechanical design, or if any of the degree-granting departments desire more adequate training along these lines, it should be made available in a separate and more advanced course offered in the higher years when the student will be better able to appreciate its content.

The "fundamental elements" of these subjects can be covered quite satisfactorily in a reasonably short period of time. Our department has recently completed a study[5] of the allotment of course time to the various objectives being presented here. We have found that the total time allotment (on the basis of a year's course) for the work covering this particular objective was 14% of the total course time. The time allotment for the first two objectives mentioned, amounted to 60% of the total course time. Actually, it was found quite feasible to design satisfactory problems for some of these subjects that would also include material applicable to objectives one and two.

Our fourth objective, and also fourth in order of importance in training engineers, is to train the student in drawing techniques (including habits of neatness, thoroughness, and accuracy in both freehand and mechanical media) so that he can make engineering drawings of acceptable quality, or recognize such quality in drawings made under his supervision or his use.

This is the objective which, it seems to me, has steadily declined in importance with the passing years. We no longer have time available to develop a superior technique—there are too many other things we must teach; nor do we find it in industrial work as much as formerly— it costs too much. It may be argued, and with some truth, that we are training engineers, not draftsmen, and they do not need to develop the manual techniques of the draftsman. As the A.S.E.E. report[6] put it, "Its (drawing's) value as a skill alone does not justify its inclusion in a curriculum."

But, nevertheless, set in its proper perspective, drafting technique does have its place in our courses. The freshman drafting room is the place where these embryo engineers get their first taste of the engineering method. This early point in their education is the proper place to inculcate habits of neatness, of clearness, of completeness, and of accuracy. These, in conjunction with skill in using the pencil, and the principal components of good drafting technique. If they do not acquire the rudiments of these habits in our classes, where will they acquire them? Certainly few enough of the courses in higher years will take the time to train them, although they will expect the habits to exist in the men they get. By what magic will they acquire them if we do not teach them in our courses?

While the abilities to think visually and write graphically are developed to a considerable degree in our courses, drafting technique is unfortunately the one tangible result of drawing that is patently visible to instructors in the higher years. If we descend to the level where anything goes for technique, so long as the student masters the theory, repercussions from above would be thunderous indeed, and we would promptly be cut another couple of credits. Thus it is important that we teach them to draw with, and to recognize what is at least, an acceptable drafting technique.

And now, to recapitulate briefly, I have given you four objectives for our elementary drawing courses. One, to develop spatial visualizing and analyzing ability; two, to teach thoroughly the grammar of orthographic projection; three, to teach the fundamental elements of conventions, standards, and dimensioning methods; and four, to train the student up to an acceptable standard of drafting technique.

These are objectives from which we cannot deviate, nor can we slight them to wander off into fields we think it would be nice for our students to have a smattering of. Ours are not general survey courses; they are courses to develop specific and essential abilities, both tangible and intangible. The material included should be relevant to the objectives; the treatment should be thorough and rigorous. We should allow the time, supply the necessary practice work, and provide the proper teaching to enable our students to thoroughly assimilate the subject matter we cover, and the amount of that course material should be adjusted so that such assimilation is possible.

Whether our allotted course credit is large or small, let us teach thoroughly that material which we do teach. Then I think we can honestly say that we have done our best to carry out that injunction given in the A.S.E.E. committee[7] report, "Graphical expression is both a form of communication and a means for analysis and synthesis. The extent to which it is successful for these purposes is a measure of its professional usefulness. The emphasis should be on spatial visualization, experience in creative thinking, and ability to convey ideas."

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VISUALIZATION

One of the virtues attributed to descriptive geometry is that it develops in students the ability to visualize in three dimensions. We believe that this is correct, but correct only to the extent that visualization is taught deliberately and directly. In our opinion, the ability to visualize will not develop as an incidental by-product. Does anyone have any evidence either way? Professor Kliphardt deals with this matter to some extent in his current article. Do you agree with what he has to say?

COMMITTEE ON TESTS

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The Committee on Tests for the academic year 1956-57 has the following membership:

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Universities of the Far East*

By F. E. Jordan

University of Arizona

On my second day in Manila I visited a few of the universities there. Manila certainly is a university city. There are at least a dozen large universities and an equal number of smaller ones. The Philippine people seem intent on mass education. One of the teachers told me that they are intent on obtaining degrees but not much interested in obtaining knowledge.

The first I visited was the University of Santo Thomas, which is older than any of the universities in the States. One of the original buildings still stands and is now used as the administration building. I soon fell into conversation with one of the engineering students who took me to meet his strength of materials professor. The man, a Philippino, was a practicing design engineer. He gave me an impressive list of buildings in the city that he had designed. He had about forty students in the class and said that was about the usual number for a class of that type.

There are over 23,000 students at Santo Thomas and it is one of the smaller of the important universities. All classes are conducted in English and all textbooks are in English. Most of the students talk a native language among themselves, known as Tagalog. On the same grounds there were also an elementary and high school. The engineering building was relatively new (four or five years old) but of very poor construction and of nondescript architecture. There were huge cracks in the concrete walls and ceilings.

When the professor learned that I was interested in collecting rocks he dismissed one of the students from the approaching class and delegated him to escort me around the campus. We went to the Department of Sciences and were shown thru a large natural history museum jammed with every type of animal imaginable, but no mineral specimens. The curator of the museum suggested that I visit the Bureau of Mines. The student escorted me there in a jeepney (a jeep converted to a bus) although it was clear across town. There I was given some mineral specimens which, I regret, were of very poor quality.

In most of the universities in the Philippines the girls are in the majority, frequently with a ratio of five to one. The majority of the teachers are women although there is none in engineering. When the students graduate they look forward to a strongly competitive struggle for a job because there are far more graduates than openings. An engineer just out of college can expect a starting salary of around a hundred dollars a month and living isn't cheap in the Philippines.

From Manila we sailed to Iloilo, a twenty-three hour journey. When we dropped anchor a Mr. Knox from the Central Philippine University came out on the customs boat to meet me. He informed me that the Dean of Engineering had delegated him to show me around the campus and the city. I was surprised and delighted. He first took me to his home for lunch; the boat had dropped anchor about eleven o'clock.

Immediately after lunch Professor Knox took me on an extensive tour of the campus. The Central Philippine University is a Baptist mission school with around 1700 students and twice that many elementary and high school students. Here again all three levels were in close proximity on the same campus. All of the students are charged a tuition. This is a self-supporting school, which is truly a rarity. There are about one hundred teachers, eight families of which are American.

After what I had seen in Manila I was truly delighted here. The buildings had all been rebuilt or at least renovated after the war. All the roofs had been bombed away or had fallen in during the war. There were patches in the concrete floors where the soldiers had driven their tent pegs into the floor. But the buildings now were in excellent shape, well painted in a light cool green. Professor Knox said that their enrollment was increasing whereas in most of the universities in the islands it was dropping. He thought it was due to a great extent in how well they kept their buildings and grounds.

Besides the school facilities they had an experimental farm with rice paddies, chickens and pigs. They were trying to upgrade the animals of the locality.

In the engineering school they offer degrees only in civil engineering. The first two years are offered in chemical, mechanical and electrical engineering, but the student must then go elsewhere to obtain his degree. The Dean of Engineering was a wizened little Philippino. He spoke with such a strong accent that I had difficulty understanding him. Next semester they are going to introduce a five year curriculum to satisfy a government decree. Since there are only eight years of previous schooling many students enter the universities at the age of sixteen or younger and are not prepared for university work.

Professor and Mrs. Knox then took me to visit a home in the suburbs where the family wove josi cloth. This is a local fiber which produces a cloth soft as silk and as gossamer as a spiderweb. We then went on a brief tour of the city; by that time it was time to return to the ship. This was by far the most enjoyable day of the journey so far.

From Iloilo we sailed to Hong Kong. On my second day there I visited Professor Tunnell of the University of Hong Kong with whom I had corresponded. The layout of the U. of Hong Kong is much the same as Cornell. The buildings cling to little shelves in the side of a mountain. All of Hong Kong Island is a mountain except the level part that has been built up in the bay.

* Professor Jordan spent part of the summer of 1956 traveling on what she described as a slow boat to China. This is one part of the diary of her safari. (Ed. note)

During the war the buildings had been reduced to mere shells. The Japanese had removed every piece of movable equipment and had destroyed what remained. The buildings have been repaired but there is little in them. Repairs and an additional two stories are in the process of being added to the Engineering Building.

I first called on Professor Davis, head of the Geology Department. He was a friendly Englishman with the usual English reserve and accent. As soon as I was settled in a chair in his office a glass of hot tea was placed before me, weak and without sugar. He then showed me through the geology laboratories which had a few pieces of good equipment in them and gave me a few specimens of the local minerals although they seemed to have, unfortunately, very few really good specimens.

Professor Davis had one of the Chinese laboratory assistants escort me to the Engineering Building where I met Prof. Tunnell, who is head of the Civil Engineering Department, and Professor King, a Chinese, is head of the Civil Engineering Department. A degree is offered only in civil engineering. The school does not have facilities for laboratory courses to offer degrees in other branches of engineering. Most of their equipment is sent out from England and it takes at least a year or more for delivery. About half of the equipment that they do have is American on which they can expect delivery in about three months.

Although the university has space for two or three thousand students they now have only nine hundred, fifty of whom are studying engineering. They had thirteen graduates this past spring. Their semesters occur at the same time as ours; so there were few classes in session. In engineering there was only a short machine shop course in progress.

In Hong Kong it is difficult for the students to find suitable employment when they do graduate. There is little industry there. Steps are being taken to encourage outside capital to set up facilities here though.

After traveling to Singapore and Indonesia we returned to the Philippines. One of our stops was at Dumagete City where Silliman University is located. This university was started as a mission school in 1901 by the Presbyterian Church in the U.S. and has grown until today it is one of the top universities in this part of the world. It is in a typical little college town which is however also typically Philippine. The campus is indeed beautiful with most of the buildings facing a long rectangle lined with huge mimosa trees.

There are about 2400 students. Of the almost three hundred faculty members only thirty-five are American. Of course the majority of the students are Philippinos, but I met one Navajo Indian girl from Arizona. There are a few Indonesian and Korean students also. The buildings suffered extensive damage during the war; in fact the school was used as a Japanese army headquarters. Recovery has been remarkable. The buildings have been renovated and new wings added.

The engineering school is the most sadly neglected department. Professor Branogan, an energetic pleasant Philippino, is head of it. There are around 400 students but only the first two years are offered. The students must go elsewhere to obtain a degree in engineering. Plans have been made to improve and enlarge the engineering school, offer more courses and perhaps a degree. The church in the U.S. is now in the process of raising funds for this purpose.

Only a few minutes after I met Professor Branogan he invited me to an alumni dinner the following night. He was due at a conference but on his way he introduced me to the vice-president, Dr. Silliman, who he said is no relation to the founder. After a short visit with Dr. Silliman he had his secretary show me around the campus and introduced me to the heads of the various departments.

The next morning at nine o'clock I attended their weekly convocation or religious service. It lasted less than an hour so that the students might meet their next class. The church choir of students sang and a brief talk was given by a visiting Japanese minister.

After the service one of the American teachers invited me to visit her class, which was on Bible history. She then invited me to her home for tea at four o'clock. Until four I wandered around the town and campus. After tea the teacher drove me to the home where the Overseas Alumni dinner was being held. The members of the group consisted of Philippine faculty members who had studied in the States. The wives of the members were also present. I was the only American present.

Everyone relaxed and had a wonderful time. The dinner was served cafeteria style and consisted of two whole pigs which had been roasted on a spit over an open fire outside. The skin was sweet and crisp. There were rice dishes with sauces and several other concoctions which to me didn't seem to have much taste. For a beverage we had Coca Cola. After dinner there was an M.C. who told jokes on everyone and kept things moving. The group broke up early about eight-thirty and Professor Branogan and another faculty member with their wives drove me back to the ship.

We sailed the next morning and I had a contented feeling of having been really welcomed by a friendly, sincere group of people.

The University of the Philippines is the largest and most modern of the universities in this part of the world. I didn't get to visit there because it rained continually on our second visit to Manila.

<u>IF YOU DISAGREE</u> with something you read in the JOURNAL OF ENGINEERING DRAWING, don't take it out on your students. Write your objections down and send them in to the editor. Controversy is a good thing they say, especially for our circulation!

The fact is, if we had had a letter from you, it might have been in this very spot in place of this innocuous effusion, otherwise known as a filler.

Concerning Ellipses

By Martin J. Orbeck
University of Michigan

Two concentric circles in the same plane will bound an area of uniform radial width. Years ago it came to the author's attention that if an arch section was to be of uniform thickness (or width) and had for its intrados an ellipse, the extrados could not be another ellipse, and vica versa. For the moment he was satisfied with the general proof that two coplanar concentric circles produced two ellipses, enclosing an area of varying width. However, there was still to be considered the possibility of two circles of different obliquity producing two ellipses for which the difference in length could be equal to the difference in width.

In a recent circular accompanying a device for drawing ellipses, appears the following statement: "Around a .... ellipse draw an outer ellipse .... distant at all points of the curve". (Figures are omitted here as irrelevant). The following discussion is intended to show that such a specification is impossible of strict fulfillment.

Given an ellipse (I) with its center at the origin. Write the equation of a series of circles of constant radius R, and with their centers on the ellipse (I). For clarity of notation, write the coordinates of the centers on ellipse (I) in terms of "X" and "Y", considered as parameters, in place of "x" and "y" — but using the same axes for both notations.

"X" and "Y" will then be connected by the relation

$$\frac{X^2}{a^2} + \frac{Y^2}{b^2} = 1 \qquad (1)$$

where a, b are the semi-major and semi-minor diameters of ellipse (I), and therefore $[X] \leq [a]$ and $[Y] \leq [b]$. For a pair of axes through the center of the circle, the equation for the latter is

$$x_1^2 + y_1^2 = R^2$$

But referred to the original axes, through the center of the ellipse,

$$x_1 = x - X \quad \text{and} \quad y_1 = y - Y$$

The equation of the circle referred to the original axes, is therefore

$$(x - X)^2 + (y - Y)^2 = R^2 \qquad (2)$$

in which X and Y are now parameters connected by equation (1).

The inside (or outside) envelope to this family of circles will be a second curve (II) at distance of "R" from the given ellipse (I). But will it be another ellipse?

To find the answer, let us tackle the problem in another way, indirectly. We know that we can have two ellipses so proportioned that the perpendicular distance between the two parallel tangents at the extremities of each of the major and minor diameters (concentric ellipses with major and minor axes superimposed, respectively) can all be equal to a given fixed value. But will this be true for any other pair of points, one on each ellipse? This question can be more readily answered than the previous one.

First let us look at the graphics of the trammel method for the construction of an ellipse. (See Fig. 1). Along one edge of a card, lay off lengths MP and NP, respectively, equal to the semi-major and semi-minor diameters of ellipse (I). If M now travels along the minor axis and N travels along the major axis, P will describe ellipse (I). Similarly with distances MQ and NQ; Q will describe ellipse (II).

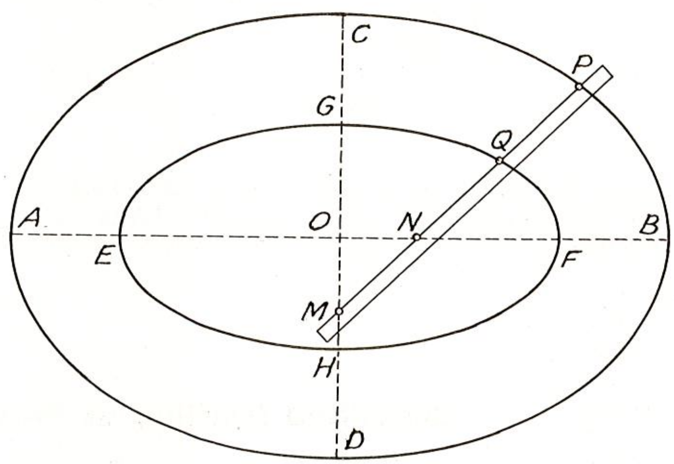


FIG. 1.

At A, B, C and D, the distance PQ will also be the distance between the parallel tangents at the extremities of the axes, and therefore the distance between the two ellipses at these four points, i.e. AE = CG = FB = HD = PQ.

However, note that for the position of the trammel scale shown in Fig. 1, the length of PQ certainly is not perpendicular to the ellipses at either of points P and Q; and since PQ is a fixed distance, the perpendicular distance between the ellipses must here be less than the distance PQ.

Hence, an ellipse being uniquely determined by the lengths of the major and minor diameters, no two concentric ellipses can be drawn so as to give a uniform distance between them at all points along the curve, such as we find for the case of two concentric circles. But the result may be a sufficiently close approximation for many purposes.

In a specific case (See Fig. 2) where the major and

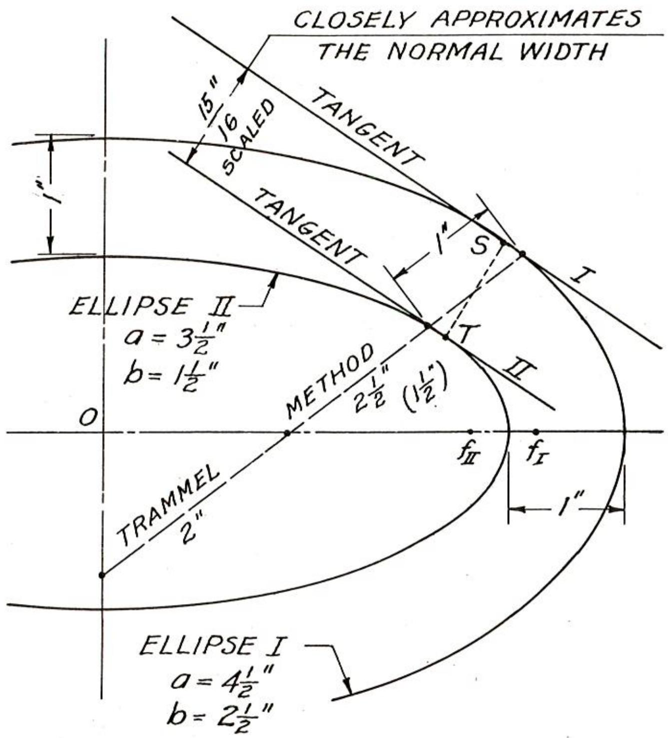


FIG. 2.

minor diameters are 9" and 5" for ellipse (I) and 7" and 3" for ellipse (II), and the abscissa of S is 3.45", the distance between S and T, scaled approximately 1/16" less than the corresponding distances at the extremities of the axes. Neither were the parallel tangents quite perpendicular to the line ST.

An attempt was made to check the foregoing by calculation. The details are not reproduced here. The method briefly consisted of:

(1) Writing the expression for the slope of the tangent to (I) and evaluating it for the selected point S (3.45, y).

(2) Writing a similar expression for the slope of the tangent to (II) and setting it equal to the specific slope for (I). Solve the resulting expression for the value of the ratio x/y.

(3) Into the equation for the ellipse (II) set the value of ratio x/y and solve for the point of tangency at T (x, y).

(4) From the coordinates of S and T determine the distance ST; also the slope of line ST.

(5) Find the slope of the line perpendicular to ST; compare this slope with that of the tangents.

Results for the Assumed Numerical Cases:

Length of segment ST: 0.941
Distance between corresponding extremities of the axes for ellipses (I) and (II): 1.000
Difference: 0.059, approximately 6%
Slope of tangents to (I) and (II) at S and T, respectively: − 0.664
Slope of normal to ST: −0.645
Difference: approximately 3%
(ST is therefore slightly greater than the perpendicular distance between the tangents.)

Simplified Drafting as Proposed by the Bureau of Ships *

By R. Wallace Reynolds
California State Polytechnic College

By way of introduction, it should be mentioned that the title of this paper might be amended to read "Functional Drafting" instead of "Simplified Drafting." It was found early in the history of the project that the term "simplified" at times evoked some rather degrading comments on the part of some personnel. Quoting from a talk presented by one of the project engineers at an East Coast shipyard in 1955, "Our former name—Simplified Drafting—has proved a poor choice. Apparently the term "simplified" applied to drafting carries the connotation to some people of incompleteness or lack of clarity. Such is definitely not the case, as our shop response has proven. However, we are now using the term "Functional." We feel this more correctly describes the drafting and dimensioning phase of the program." Accordingly, the name was early changed to "Functional" and the project is now officially known as the Functional Engineering Practices Program—FEPP.

As a point of clarification, the author's connection with the project should be explained. Since the scope of the project dealt with some aspects of the content of engineering training and might be involved with training of technical personnel at certain phases, it was desired to secure somebody from the engineering teaching ranks to serve in an advisory capacity. The author had the privilege of filling this position as a temporary member of the project staff during the summers of 1955 and 1956. Accordingly, the comments here are written from the viewpoint of an observer who has had full access to the work of the project. However, any statements which are qualitative represent the opinions of the author and not necessarily those of the Bureau of Ships or other FEPP personnel.

* Presented at the Drawing Division Summer School, at Iowa State College, Ames, Iowa, June 1956.

Background

Early in 1955 the Bureau of Ships found themselves faced with personnel problems in the Design Division. During the fiscal year of 1955-56 the Naval Shipyards expected to experience a net loss of 250 engineering personnel during a period when the work load would not decrease. It was felt that a partial solution to the resulting manpower shortage would be the practicing of functional engineering methods. Quoting from an article written for the Bureau of Ships Journal, the program started as a gleam in the eye of the office of Value Engineering, Bureau of Ships, in the latter part of the year 1954. They looked for a shipyard whose Design Division was actively using some functional engineering methods and, more important, was eager to undertake the development and coordination of such a program. The Naval shipyard chosen was San Francisco. In May 1955 an engineer, a draftsman and a stenographer were assigned under the head engineer of the Design Division as the program staff. The duties of the staff are:

1. Undertake studies for the improvement and simplification of the preparation of drawings, reproduction of drawings, reproduction methods and associated drawing communications between Naval Shipyards.
2. Coordinate the efforts of all Naval Shipyard design divisions in undertaking similar studies.
3. Gather for evaluation all functional engineering methods now being used by the design divisions of industrial organizations and the various Shipyards.
4. Prepare literature in the form of bulletins, pamphlets and instructional courses.
5. Prepare a drafting room manual for use in the Design Divisions of Naval Shipyards.

The project goal is the generation, testing and promulgation of methods of saving time and money in the processing of normal naval design work. This is to be accomplished without sacrificing needed production shop information or requiring training of shop mechanics."

Methods, techniques, plans of organization, new mechanical devices and other developments which might possibly affect the efficiency of engineering work are given a cursory investigation by the project staff, then assigned to a Design Division technical branch (not necessarily at the San Francisco Shipyard) for development and evaluation. After evaluation, an interim bulletin is prepared. This bulletin will contain a complete description of the new method or system, instructions for its use, time savings possible, and any other pertinent facts that would be required by another shipyard in adopting the method or system indicated by the bulletin. This interim bulletin is then used on a trial basis throughout the Design Division. Comments are gathered from all interested parties, particularly from shop personnel. Any new drafting method or system which would require training of shop personnel in order to fit them to read the drawings will not be adopted. If an interim bulletin, after a practical trial period, seems applicable as a standard procedure it is made into a formal bulletin by the project staff and forwarded to the Bureau of Ships for consideration as applicable for field activity use. Bulletins prepared and issued in this manner will form the nucleus of a Design Division drafting manual.

PROJECT PROGRESS

From the preceding explanation it will be evident that the work of the project falls into several phases. First was the investigation and compilation of all existing literature and material pertaining to "simplified drafting." A visit was made by the project engineers to the General Electric Company and consultations were held with Mr. Rau and Mr. Healy of that organization. It might be noted here that visits to other industrial organizations, particularly the Ford Motor Company, the International Harvester Company, the Westinghouse Corporation and the American Machine and Foundry Company are scheduled for some future date during the project period.

A second phase was the preparation of interim and formal bulletins, described previously, which is currently proceeding.

In order to expedite the processing, certain areas of investigation have been assigned to other Shipyards. For example, the Portsmouth Shipyard has been assigned the investigation of the use of scale model mockups for the arrangements of equipment in submarine compartments. The New York Naval Shipyard is evaluating the Magne-Plastic template system for ship compartment arrangements. The Magne-Plastic template system consists essentially of a steel covered layout table equipped with an overhead lighting arrangement. Scale models of equipment, machine tools, or other furnishings are then arranged in the desired manner on a transparent plastic or paper board cover which contains an outline of the space being arranged. These models contain magnetized inserts which hold them securely in any position in which they are placed. When the models are arranged as desired the transparent board cover is slid onto another steel table which contains a sheet of sensitized print paper on top of the metal cover. The board and models are then exposed to the overhead light which provides a print, on the sensitized paper, showing the outlines of the space and the position of each model. This system provides an economical means of producing prints showing various arrangements of the furnishings without actually drawing each item in the desired position. This system has long been used in some branches of industry for planning plant arrangements.

Other areas of investigation which have been delegated include the preparation of standard foundation drawings for ship equipment, the preparation of templates for drawing certain symbols which will be standard on certain types of damage control drawings, the use of the polaroid camera in the preparation of Design Division drafting work, and the substitution of booklet type (using "B", 11 x 17 inch; and "C", 17 x 22 inch size sheets only) drawings for large drawings.

In the proposed booklet type drawing, each page of the booklet would show only one, two, or three compartments of a deck, depending on the size and system involved.

In the case of each of these particular areas of investigation, the shipyard assigned will prepare a bulletin giving a detailed explanation and application of the methods devised, along with reasons for its adoption, time and money to be saved by the new methods, and the particular advantages and disadvantages to all departments of the shipyard which are affected by this particular application.

This current progress report will reveal that these various phases of the project are being carried on in overlapping sequences. For instance, the investigation of progress in simplified drafting methods by industrial firms was begun at the outset of the project but is still continuing. As the project stretches over a period of several years, I presume that the project personnel will continue to keep abreast of current developments in this field as they occur in industrial organizations and other government bureaus. The interim bulletins have been under preparation in various stages since the early period of the project. They have now evolved in the first Functional Drafting Pamphlet which the Bureau of Ships expected to publish in September of 1956. Dates for completion of the special areas of investigation delegated to other shipyards range to August of 1957.

FUNCTIONAL DRAFTING METHODS

The Machinery Design section at the San Francisco Shipyard has developed and used some of these functional techniques during the last ten years. It has been found that the predominate time saver is free hand drafting and simplified delineation. Such short cuts as the elimination of circles to represent holes and similar practices are much less significant. In general, it is felt that whatever views are shown

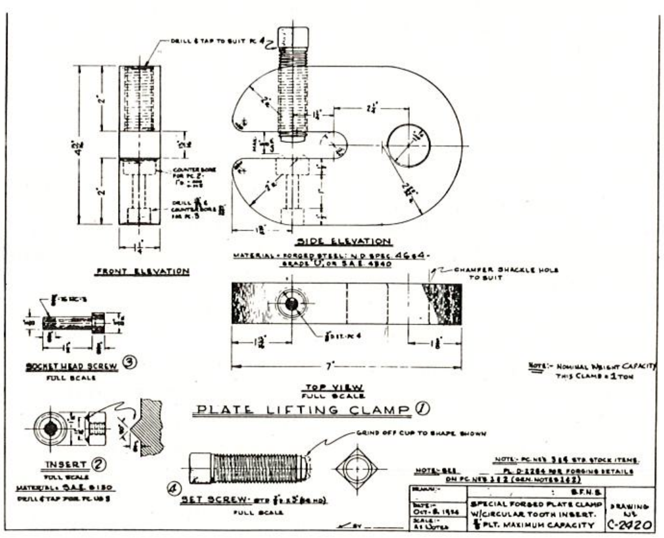


FIG. 1.

should be complete in order to convey an undistorted picture of the finished part. Figures 1 and 2 illustrate the application of some of the more important techniques of functional drafting. Figure 1* shows a classic example of intricate delineation. The finely etched line shading on the bottom view, the beautifully delineated conventional thread representation, the painstaking reproduction of hidden lines all indicate that the draftsman on this job belonged to the "old school" who took pride in a masterpiece of well executed line work. Figure 2 shows the same drawing reproduced according to the techniques of functional drafting as taught in a course given in the Machinery Design section during 1953. While no direct data are

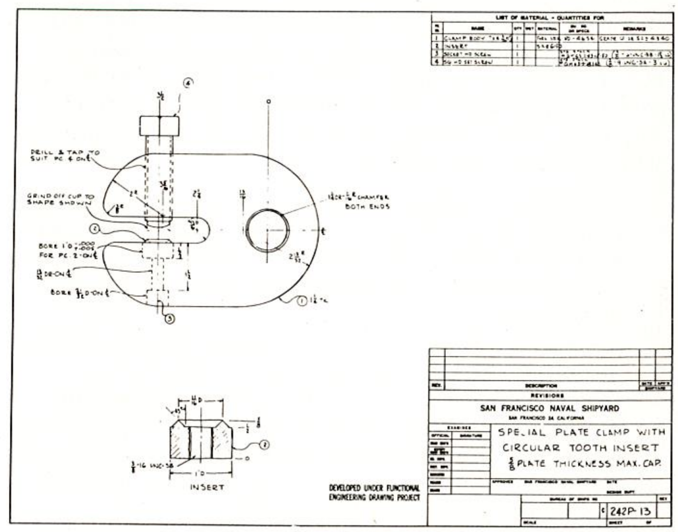


FIG. 2.

available on the actual time required to produce each of these two versions of the same drawing, it might be safe to estimate that the second example was produced in about one-sixth of the time required for the elaborate rendition. The important point is that the shops involved in making the part stated that it could be made from either drawing with equal ease.

Quoting from a paper written by the project staff: "The graphic language of the engineer is drawing. However, it is necessary to point out that the tools of drafting do not constitute the subject of drafting and, under many conditions the conventional tools can be dispensed with to great advantage. It has been the experience at the San Francisco Shipyard that freehand drawings, properly delineated, are acceptable to the production shops. Freehand drafting can be employed apart from several of the other functional techniques and has been found to be the most significant time saver."

* All of the Figures of this article were subjected to reduction in the interest of space, perhaps to the injury of the Author's purpose. If so, it was not intentional. (Ed. note)

It might be noted here that the comments regarding the use of freehand drafting pertain to the production of working drawings and are not applicable in the case of layout drawings for intricate parts where accuracy in the view will affect the design and function of the mechanism being drawn.

Freehand drafting as it has been used at the San Francisco Yard can roughly be grouped into three basic types. First is freehand tracings made from the layout of design drawing. This is probably the most frequent application in machine drawing. While, admittedly, a certain amount of contrast and line weight is sacrificed on the freehand sketch, apparently the shop workers are not in the least handicapped by this feature. It should also be noted that the draftsmen at the San Francisco Yard have been encouraged to make their freehand drawings with a combination of instrumental and freehand techniques in cases where use of the instruments can be quicker than doing the drawing entirely freehand. This is the case in drawing large circles where a compass is quicker than sketching, the drawing of small holes with a circle template, and the use of a large triangle or straight edge for long straight lines.

A second type of freehand drafting is the production of working drawings using plain tracing paper with a square grid underlay on the table top, or using paper which is printed with non-actinic grid lines. A third type is referred to as "offhand" freehand work using no scale or guides. Figure 3 is a sample of a drawing done by that method. Sketches produced by this method are somewhat rougher in configuration than those done by tracing over the layout drawings. This figure also illustrates the use of freehand techniques for producing simple assembly views. Close inspection will show that some lines such as the centerlines have been laid out with mechanical guides but the bulk of the assembly is a freehand sketch. In this case the designer also produced the detail sketches so that one design sketch of assembly and details served as a complete shop drawing for this particular product. It should be of general interest to note that this par-

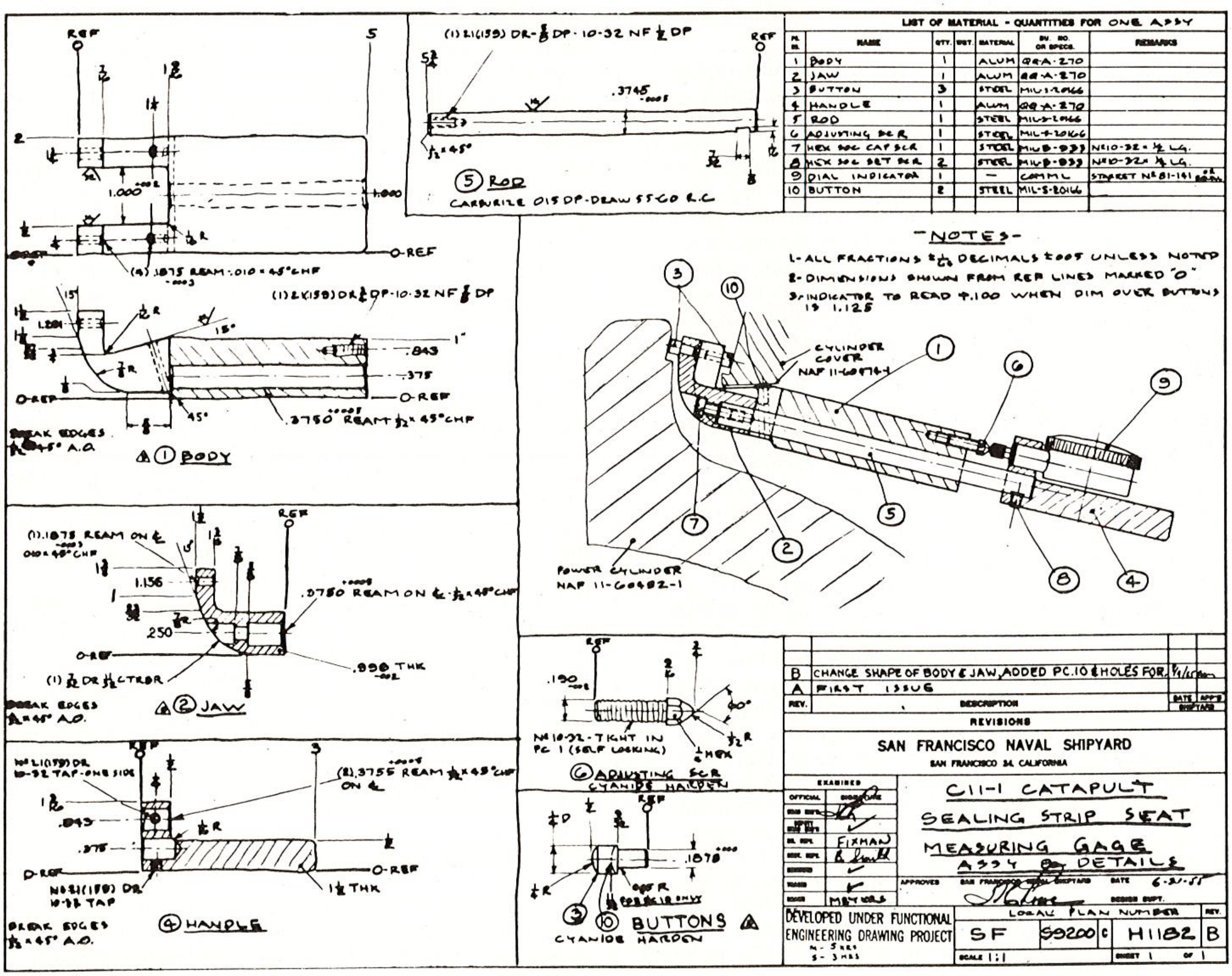


FIG. 3.

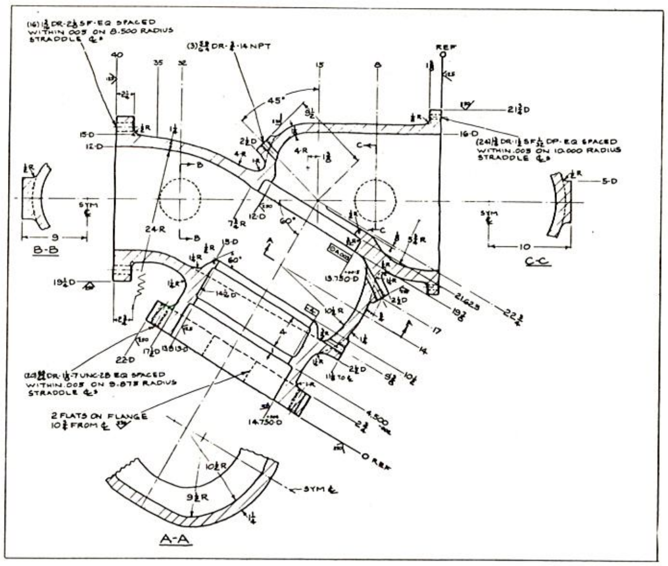


FIG. 4.

ticular gauge was used in the final machining operation on the main cylinder for the steam catapults being installed on all of the Navy's carriers, which you may have recently seen in action in the newsreels.

In the opinion of the supervisors of the Machinery Design section, any draftsman or designer capable of making a multiview drawing with instruments can also learn and use freehand drawing. Once the barrier of classical and hidebound drafting practice is broken through he usually realizes the advantages of the 20 to 50% overall time saving that can be achieved through the use of this technique. They have found that the human element is the big problem. In telling a draftsman who has spent 10 to 20 years on the drafting board using his instruments and mechanical aids to set aside the drafting machine and make all drawings freehand, except where an instrument drawing is absolutely necessary, is obviously inviting quite a collision with the normal human instincts.

Figure 4 shows a drawing of a casting used for a valve on a steam catapult. The drawing was produced by the methods of freehand sketching, using ordinate dimensioning and all of the new functional techniques for reducing delineation. It replaced an earlier drawing made according to the conventional system. The original drawing contained a total of seven views, of which five were views of the complete casting while the remaining two were small detail views. Even though a larger size sheet had been used, the views on the original drawing were shown in such small scale as to make them difficult to read on the print. On four of the full views there was a total of only eight dimensions, leaving all of the remaining dimensions for the fifth view. These dimensions, represented by the conventional method, resulted in an undecipherable clutter on the blueprint. Again evidence of the validity of the functional methods is found in the fact that the shops readily produced the desired casting from the drawing shown in Figure 4. It is felt that the freehand technique plus simplified delineation accomplished a two-fold purpose in furnishing more information in a more easily read form while taking less time to produce the drawing.

One other point deserves mention—it has been decided that all lettering on drawings should be capital Gothics, vertical preferred. On all of the "H" size drawings (30" x 54" minimum), where the print will be produced by a photographic process and reduced to one half the size of the original drawing, the recommended size for lettering on notes is 3/16 high. It might also be mentioned that the unidirectional system of positioning dimensions is much preferred in the San Francisco Shipyard shops.

For those unfamiliar with the ordinate dimensioning system it should be noted that it is essentially a base-line dimensioning system with all dimensions in a given direction being given from the line representing a base plane. The base-line system is further refined by leaving off all dimension lines and arrowheads. The numerical value written at the end of any particular extension line represents the distance from the base plane to that extension line. Since it may be impossible to give all distances from the same base plane, because of functional demands of the design or shop convenience, the conventional system utilizing dimension lines and arrowheads is used for those dimensions which cannot be given to the base plane. It is generally felt by the Design Division supervisors that use of the ordinate dimensioning system requires good judgment based on a knowledge of finer points. For that reason it is the feeling of some of the personnel that the classical drafting training is still a prerequisite to furnish the necessary background for this type of reasoning.

PICTORIAL DRAWINGS

Pictorial projection has been introduced into the work of the Machinery Design section in cases where it can aid the functional drafting program. It has served primarily two purposes. Parts of simple shape can sometimes be pictured more rapidly by a pictorial type of view than by the conventional multiview drawing. This is particularly true of parts containing a number of holes, slots, etc., which can readily be described by means of notes. Considerable success has also been achieved in the use of pictorial sketches to aid in the visualization of more complex parts, combining the pictorial view with a multiview drawing. Figure 5 illustrates a welded body on one of the steam catapult valves. With the additional visualization provided by the isometric sketch the shop had no difficulty in constructing the valve, obtaining the size description from the single section view.

FUNCTIONAL DRAFTING PAMPHLET

Culmination of the project efforts to this date has been the production of the first Instructional Pamphlet, published by the Bureau of Ships during September 1956. This pamphlet summarizes the functional drafting practices which have been investigated and prac-

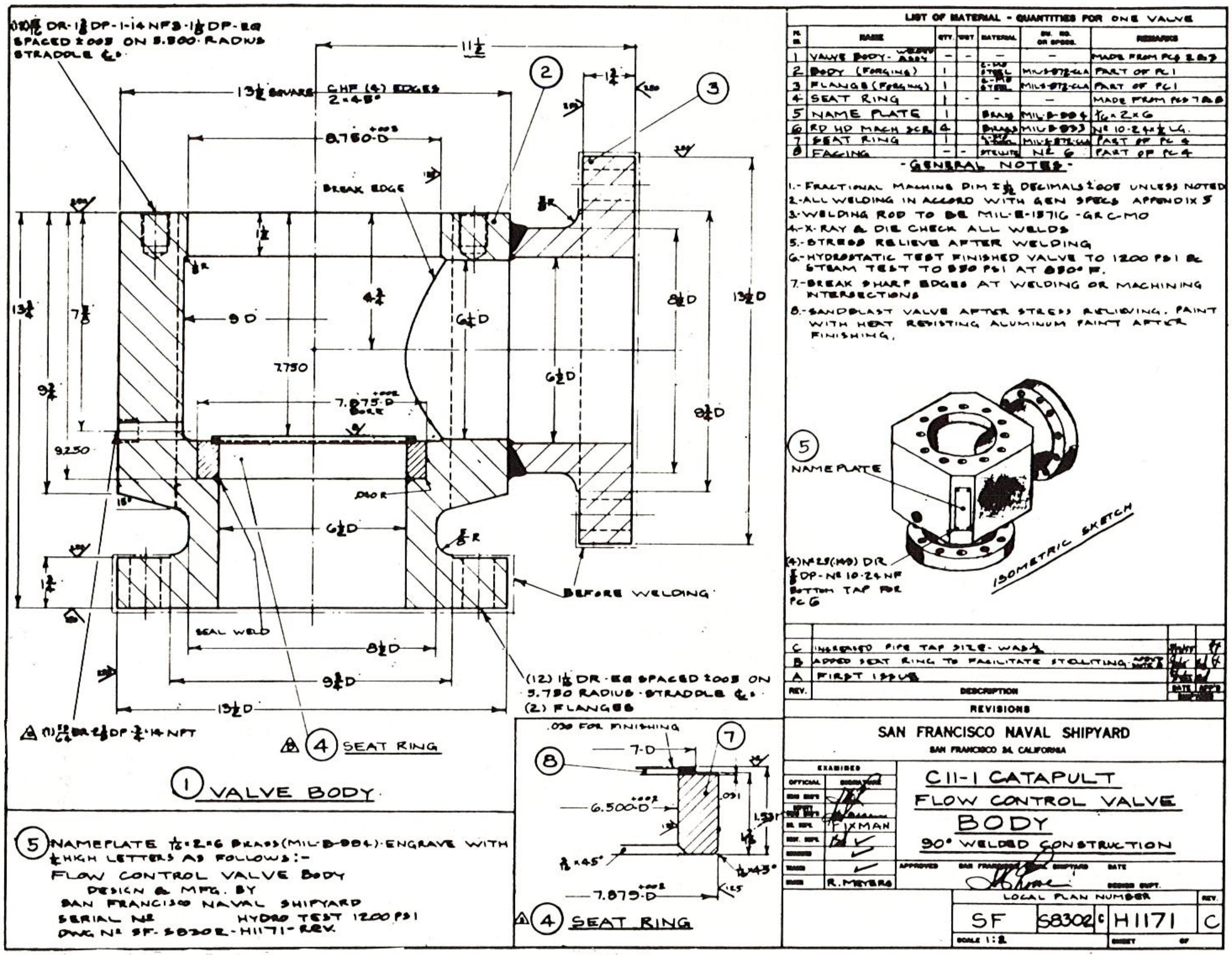


FIG. 5.

ticed on a preliminary basis, in the form of ten rules which read as follows:

1. If it's easier to describe with words, don't draw it.
2. Use word description to eliminate projected views.
3. Omit elaborate, pictorial or repetitive detail.
4. Use numbered symbols to indicate nuts, bolts and standard hardware.
5. Avoid the use of dotted lines that do not add clarification.
6. Use cross-hatching for clarification only.
7. Avoid hand lettering of lengthy notes and lists—use the typewriter whenever practical.
8. Make freehand drawings where possible.
9. Use ordinate dimensioning to reduce drafting time.
10. Make drawings suitable for issuing half size prints to Production.

As presented in the pamphlet, each rule is illustrated by means of samples which portray a drawing on which the rule has been neglected with an example on the opposite page showing the application of the rule to the same drawing. All of the drawings used as samples in this case were selected from actual production drawings issued by the various Design Divisions of the Naval Shipyards. To many drafting instructors it may seem that several of the rules here cover practices which have long been taught in engineering drafting courses as the recommended procedure, and that such practices would have long been obsolete in industrial drafting. Such is not the case in many Bureau of Ships activities, along with many industrial drafting rooms. It could be noted that the ordinate dimensioning system is the only functional technique which is really new with regard to established textbook exposition.

The practice of using typewriters for the lettering of lengthy notes on drawings is closely connected with the evaluation of the use of special electrical typewriters which provide a means of typing notes on large size sheets. The early investigation in this area indicates that several problems involving both mechanical and personnel matters will have to be solved in order to effect an overall savings with this method.

With regard to the application of Rule 10, the reduction in the cost of making prints of engineering drawings is a major area of improvement for this project. The cost of reproducing Naval Shipyard drawing exceeds five million dollars a year. If all "H" size drawings could be reduced to half size in the printing process the savings would be about $750,000 per year.

In concluding, another quotation from a talk present sented by the project staff at the East Coast shipyards seems apt. "We have seen the savings that freehand drafting and simplification can bring about. We have experienced the caution with which it is received by engineering people and later the enthusiasm with which it is used by these same people. We have tested and felt shop response. In other words, we are convinced."

To this could be added the reminder that this is an interim report. The overall evaluation phase for this project lies primarily in the future. We in the Drawing Division might look forward to a more conclusive report on the final results at our Annual Meeting in 1957 or perhaps in 1958.

Introducing Design Considerations into Drawing Courses

By Harold C. Messinides

Chicago City Junior College, Wright Branch

Some time ago, the Interim Report of the Committee on Evaluation of Engineering Education was presented.[1] In a sense, this report formalized the fact that there is competition for space in engineering curricula. Such competition may be met by improving both the product and the sales effort. Regardless of what opinions may be expressed concerning the status and prestige of the engineering drawing courses, it may be agreed that a greater effort is in order so as to increase the value of the drawing courses to the engineering student.

Let us review the objectives of the G.E.D. courses, which may be stated as:

1. Teaching the language of drawing.
2. Giving the student opportunity to use this language in situations involving fundamental engineering principles.

Should an additional approach to these objectives be tried? Can the engineering student be given a broad picture of what lies ahead, not only in the drawing course, but in many of his other courses as well? Perhaps this can be done, while retaining all the present values of the engineering drawing courses.

In general such an approach can be thought of as one which leads the student to develop a broad approach to basic engineering problems. Such a concept also furnishes the student with a goal; and it is appropriate that the student, who is expected to exercise initiative and judgment upon graduation, should be shown the broad purpose of his studies. Furthermore, the earlier such a goal is revealed the better is the chance to stimulate the student's motivation.

In addition, the student's integrated concept of engineering can promote a correct attitude toward the entire curriculum. Most students just out of high school and starting their engineering education have little understanding of the role of the engineer in the industrial economy. In some instances, certain engineering orientation courses have been introduced at the freshman level. However, where such a course does not exist, engineering drawing is in the best position to give the student this important understanding. Consider these courses: English, chemistry, and math. None is by its nature and content equipped for this important task.

Graphical expression is a vital part of the future engineer's education, whether he is aiming for design or industrial engineering. From the idea for a product springs the industrial complex that will produce that product. It is important that the engineering student learn, not only the language of graphics but concurrently, the very important relationships resulting when a staff of engineers cooperates to solve production problems. To restate this situation, while the student is drawing an object, he can study the factors that determined the shape of the object. Further, he may be concerned with why a particular material was chosen for the object. Again, there is the question of how such an object is to be given its shape. The presentation of problems so as to introduce these relationships is one way in which the student can be encouraged to think with the aid of the language of graphics.

Fig. 1 shows a relationship of some design considerations. Although the order of these fundamental considerations, as shown, is: 1. Materials; 2. Shape; 3. How to Shape; it should be emphasized to the student that any of these could be the primary consideration. Furthermore, in some instances all three would be considered simultaneously. This latter point is underlined by the fact that many of the subordinate considerations appear in more than one place. For example, strength is related to the material, shape, and also the means of shaping. It follows that the number and kind of variables encourage the student to exercise judgment in choosing a material for an assigned problem. Some of the considerations involving the choice of a material could be represented on a graph to aid in making a decision. An example: with a given object the variables could be quantity and cost for each of several materials being considered.[2] Fig. 6 illustrates this type of graph when "material" is substituted for "equipment."

The form of the problems in Figs. 2, 3, and 4, makes

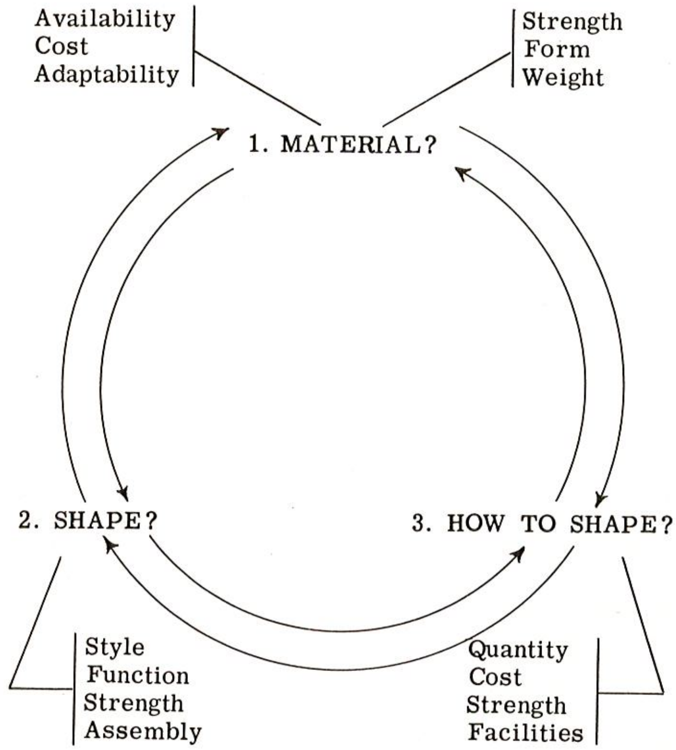


FIG. 1. A Relationship of Some Design Considerations

it possible to use them for class or home assignments. They can also be modified to supplement such assignments. The problem in Fig. 2 could be used to aid the student in choosing a material for an assignment. Relative cost could take into consideration the fact

Considerations	Cast Iron	Steel (Carbon)	Zinc Alloy	Aluminum
Relative Cost				
Available Form				
Weight				
Strength: 1 Tension 2 Compress 3 Shear				
Adaptability: 1 Machining 2 Casting 3 Forging 4 Other				

The student is to consider certain materials for the ______ (assigned problem) and provide the information to help select the material.
The instructor will explain the function of the part and the resulting loads and stresses.

FIG. 2. A Consideration of Material

that some light materials, such as aluminum, though more expensive per pound, are economical choices. It is suggested that the more common materials be considered first so as to stress fundamentals. Later, five grades of carbon steel could be studied to show the variation within one type of material. The data for such an assignment should be obtained by the student outside of class, leaving for the class lecture a discussion of the principles involved.

How to shape an object, that is, whether the fundamental method will be forging, sand casting, etc., depends on many factors such as (see Fig. 1):

1. Number of parts required.
2. Strength (is a high strength forging required to cut down weight?)
3. Facilities (could the present equipment of the concern be used, or would it be jobbed out?)
4. Cost (is low cost a primary consideration or secondary to maximum strength at minimum weight?)

An understandable approach for the student to this type of problem can be made by considering only one of the above variables at a time. For example, as in Fig. 3, let the number of parts required vary from 1 to 10, to 100, etc., and have the student name the basic method and, what is more important, give the reasons for his choice. The effect may be to place the student in a situation where there may be no simple answer. The student must exercise judgment in choosing between alternate solutions. Because the response involves giving reasons for the method chosen, the student is led into a consideration of the probability of changing method with a corresponding change in a variable; here, the number of parts required.

The routing of a part, the best sequence of the required operations, is closely related to the shape of that part. That is, a change in shape by redesign can effect a change in routing. The form shown in

Number Req'd.	Method	Reasons
1	Welded Ass'y.	1. Minimum Time 2. Availability of Material
10		
100		
1000		

Assume that the ______________ (assigned prob.) can be made by any of the following methods:

1. SAND CAST, THEN MACHINED.
2. MACHINED FROM SOLID STOCK.
3. WELDED ASSEMBLY.
4. (OTHER METHODS?).

FIG. 3. A Consideration of "How to Shape"

Fig. 4 is a very simple one that eliminates much data that is peculiar to a given industrial plant. The intent is to further emphasize the fundamental relationships between the shape of an object and the way it is given that shape; that is, to lead the student beyond the rendering of a correct set of dimensioned views, and into

Operation No.	Operation	Machine	Cutting Tool	Remarks
1.	Finish base	Mill	Face Mill	
2.				
3.				

Using the form provided, the student is to list the operations required to complete the ______________ (assigned problem).

The instructor will assign one of these assumed conditions:

1. Universal type machine tools
2. Jobbing Shop, small volume
3. Production Machines, large volume

FIG. 4. A Further Consideration of "How To Shape" (A Routing Form)

some of the reasons for the dimensions and notes. Again, a knowledge of manufacturing processes is not the end sought (although this is valuable). Rather, it is that the student should recognize and be concerned with the fact that shape is related to means available to effect that shape, as well as to the material.

Some students may object to such an assignment on the basis of their not having had shop work in school or industry. Such students should be encouraged to obtain this information on their initiative as an outside assignment. Such objections, however, are no more valid than a student in college math complaining that he has had only two or three years of high school math instead of four, as some students do. Referring again to Fig. 4, in this type of problem there is an opportunity for elementary synthesis. The student can start with a given object of a certain shape and make a correct operations list having an appropriate sequence. Fortunately, there is usually more than one correct sequence for a given object.

An alternate solution to such a problem is to give the student a list of universal type machine tools. Within the limits of these means to shape the object, the student then can modify some features and dimensions of that object. Still another variation of this problem is considered in Figs. 5 and 6.

Plant layout (i.e. the location of machines within a given plant area) sometimes follows routing. Logically, the previous problems or assignments could be extended in a manner illustrated by Fig. 5. After the

1. From the "Route Sheet" list the machines to be required.
2. Cut templates to represent machine floor areas.
3. Arrange in a logical order and draw the Flow Chart.

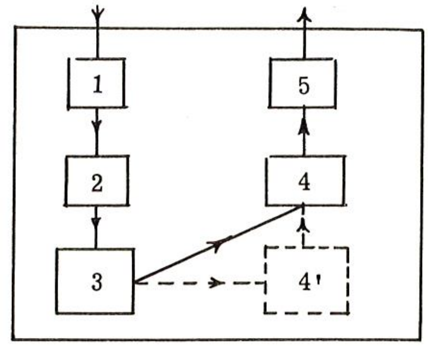
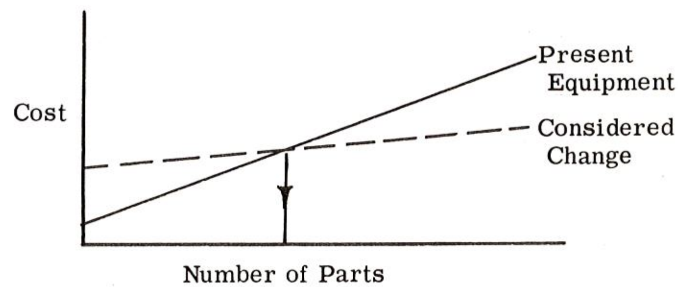


FIG. 5. Routing and Layout

final form of a routing sheet has been decided upon, a list of the machine tools could be made. From this, the student would layout the machines in some logical order, referring to the route sheet. The use of templates parallels an industrial practice and is an intermediate step that may aid the student to visualize this problem.[3]

Fig. 6 illustrates one of many possible variations of a production control problem, which has here been simplified to emphasize fundamentals. A machine part requires five operations, one at each of five existing machines. Total operation time at four of the five



1. Operation time for machines 1, 2, 3 & 5 is assumed the same; but the time for No. 4 is twice this value. What production situation results?
2. Should machine No. 4 be duplicated?
3. When would machine No. 4 be duplicated?
4. What relationship exists between operation time and machines available?

FIG. 6. Some Equipment Considerations

existing machines is assumed equal, but at the other machine, operation time is twice this value. Obviously, the partly processed parts will pile up at machine No. 4, and machine No. 5 will work about half the time. The student could decide to duplicate machine No. 4. If so, such a decision should be justified by some cost data in the form of a graph. The graph shown is a common type.[4] Cost would include labor and investment in the machines (including accessories, fixtures, etc.). The decision may involve the acquisition of a second machine. Then machines Nos. 4 and 4' would both do the same operation, dividing the work between them and both feeding to machine No. 5.

Concerning a variation of the above, another design consideration that relates to a production control problem can be introduced. Assume that two separate operations were previously performed on machine No. 4 (and only one operation on each of machines 1, 2, 3, and 5 as before.) Again, all operations are equal in duration. The student could be asked to modify the design of an assigned machine part so as to best use the existing production facilities and eliminate the need for the additional operation, and therefore dispense with the need for the additional machine. An attempt also could be made to reduce the time to perform the present two operations, again through redesign of the object.

It may be appropriate at this time to speak of the "transfer of learning." Transfer occurs when the student can successfully apply his educational experience to problems after graduation. To quote one author in the educational field: "The curriculum should (therefore) consist of situations where the student can develop responses which will be useful in future situations."[5]

Admittedly, specific industrial problems cannot be represented by classroom assignments in the identical way that such situations are presented to the graduate engineer. But maximum transfer is obtainable if the class problems stress fundamental principles.[6] The student should be aided in recognizing the fundamentals of a problem; and, in seeing these fundamental concepts and principles as present in many problems, the student may effect a transfer of learning.

Transfer can be made between different problems within the same course. Then, too, the student may effect a transfer to other courses. For a specific example: some schools have metal processing courses. Prints of a set of working drawings from the drawing course can be sent to this shop. The students in the metal processing course could now make a list of the required operations and a route sheet. Then a series of machine tools designated in advance by the instructor could be set up to perform these operations in the sequence specified in the route sheet. Such a situation gives students the opportunity to work together to meet such exigencies as may arise because of possible errors on the working drawings or route sheets.

To summarize: In dealing with a graphical means of communication, the engineering drawing courses are a vital part of engineering education. However, in some instances these courses can be made more valuable to the engineering student without losing any of the present values of the courses. In a sense, the suggestions that have been made are a logical extension of the material that is presently a part of all engineering drawing courses.

One objective of the problems here illustrated is to integrate certain fundamental considerations that are present in many engineering problems.[7] Such an integration may help the student to appreciate the relationship between the drawing courses and other courses of the engineering curricula. The transfer of learning is then improved both within and beyond the drawing courses. It is hoped that the particular problems described have at least indicated one way of achieving an integrated approach.

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Barber-Colman Company Nomography Prize–Announcement

A $100 prize is offered once again, this time by the Barber-Colman Company, Rockford, Illinois. The period of competition will run for 18 months, from July 1, 1956 to January 1, 1958. The award will be made in June, 1958. Any nomogram appearing within this period in a regular periodical will be eligible.

The Committee would appreciate having called to their attention the publication of any unusual nomograms. Please get in touch with one of the following Committee members if you learn about a nomogram that you think is worthy of consideration for the prize:

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Dimensioning and Checking of Drawings *

By R. M. Coleman

Texas Western College

Our present system of dimensioning is the result of the process of evolution for a period of approximately 175 years. In my discussion of dimensioning and checking of drawing, I shall not make any attempt to take you through the historical facts in this process of evolution. Perhaps the greatest effort in standardization of dimensioning and methods of checking has come about in the last 35 years. As college teachers of engineering drawing, we are all more or less familiar with these changes and the efforts and results of the work of the various standards committees.

It would be of little value for me to tell you how I teach dimensioning or how I think you should teach the subject. Therefore, I wish to approach the subject strictly from the standpoint of industry. First of all, why do we have our standards in dimensioning? The answer is obvious. We are a nation which produces almost everything that can be manufactured by the so-called mass production method. Complex parts of one machine may be manufactured in a hundred or more separate organizations. The assembly of these complex parts must function properly and efficiently. The aim of a set of drawings can be none other than to have the product manufactured at the least possible cost yet function properly and efficiently.

To determine what industry of to-day is thinking about dimensioning and checking, I have contacted 52 industrial and consulting engineering companies, both large and small. There are approximately 30,000 people preparing drawings for these firms. It is my belief that what the chief engineers of these firms have to say about dimensioning and checking should have some bearing on our efforts as drawing teachers. In my survey on dimensioning and checking, I purposely gave the questions a slant toward simplification of dimensioning and its effect on checking.

The questions went directly to the chief engineer or executive engineer in charge of production. All questions were answered by responsible personnel in the industry surveyed.

The following is a list of the key questions asked concerning dimensioning. Because of the length of the questionnaire, no attempt will be made to give the complete list in this discussion.

1. What system of dimensioning does your company use?
2. Do you consider that there is an overall saving of time when the unidirectional system is used?
3. Do the checkers, in the process of checking, find it easier or harder to check dimensions when the unidirectional system is used?
4. Do you consider manufacturing processes a controlling factor in dimensioning?
5. When a standard product is to be made, do you use a maximum and a minimum tolerance?
6. Is this maximum and minimum tolerance stated in you title block?
7. Do you think there would be a worthwhile saving if decimal dimensioning were used throughout a drawing?
8. Have you developed any simplified methods of dimensioning?
9. If you have not developed any simplified methods of dimensioning, would you say that your firm follows the general basic recommendations as set forth by the various Standards Associations?
10. Colleges and universities are teaching engineering students dimensioning from texts that give standard rules and practices as established by the various Standards Associations. Do you advocate the revision of these standards to show a more simple form of dimensioning?
11. Additional comments on dimensioning and the possible use of simplified dimensioning will be appreciated.

It was found that the aligned as well as the unidirectional system was used. However, 65 percent of all firms contacted were using the unidirectional system. After studying the type of industry making the reply and the occasional comments furnished, it is a normal conclusion to say that the unidirectional system of dimensioning is gaining ground in its usage, more especially on large drawings.

Seventy per cent of all firms answering said that they thought there was, or would be, a saving in time if the unidirectional system were used. A majority of the firms said that it was easier for the checkers to check a drawing if this system was used.

Manufacturing processes were listed as a controlling factor in dimensioning by 95 per cent of all firms answering this question.

This statement must not be misunderstood. Process of manufacturing is a deciding factor because of its limitations of materials and machines, but proper function and interchangeability is and must be the number-one factor in dimensioning. In other words, dimensions must not be given for machineability unless this can be done without basically affecting the accuracy and the utility of the design. Too many of our graduate engineers think that a drawing should be dimensioned to show how the drawing was made and not to show the size and shape of the finished parts.

This survey of industry showed that the firms generally dimension holes by the coordinate system with occasional use of the angular system. The method of manufacture and degree of accuracy required would determine the method of dimensioning to be used. As an example, for any part that might be held in an

* Presented at the Drawing Division Summer School, Iowa State College, Ames, Iowa, June 1956.

indexing head the angular system would more than likely be used. This is one simple illustration of how manufacturing processes would determine method of dimensioning.

Over 80 per cent of the industrial firms said specifically that there would be a saving in time and money if the decimal system was used throughout a drawing. The 20 per cent answering in the negative to this question were engineering firms which deal with highway construction, bridges, and other general engineering problems. It can be seen that there might be specific jobs where dimensioning other than by the decimal system would be advantageous. The trend in industry is toward the use of a decimal system. The automotive industry has adopted this method of dimensioning more than any other single industry. Boeing Aircraft Company has used the decimal system for 20 years, not to mention Ford and many others. Regardless of the type of industry or their engineering problems, over 95 per cent of the companies reported the use of a stated tolerance limit in the title block. Naturally this tolerance would vary with each specific company, but where a standard product was manufactured the stated tolerance would generally remain the same.

Sixty-five percent of all firms reporting said that they have not developed any simplified method of dimensioning as such. It might be interesting to quote some of the chief engineers of the various industries. The staff engineer of a firm which employs over 150 draftsmen has this to say: "There is little chance for simplification in dimensioning. It takes just about as many dimensions to turn out a satisfactory product as it did twenty-five years ago. The finish may be finer and tolerances closer, but the dimensions still have to be there, —production of parts has been speeded by machinery and not by simplification of dimensioning." He further states, "Advocates of simplified dimensioning are, in the main, theorists with limited production drawing experience and no responsibility for the quality or fit of a part made by their system. If they were responsible for the changes necessary when their system is tried, and the cost of the changes and scrapped material came out of their pockets, they would devote mote time on the reasons for the existing methods of dimensioning. Attempts at simplification have resulted in excessive changes, loss of time, strained friendships, and loss of money."

A project engineer whose firm has over 600 people preparing drawings says, "Simplification of drawing requirements is a function which is closely allied to the operation of a particular company. Good draftsmen and engineers will adapt to the particular company requirements. Basic drafting requirements and good technique are the prime requirements for training an engineer."

Again, a staff engineer whose company has over 1,250 people preparing drawings speaks for his company. "We have very definite opinions concerning alleged 'simplified' drafting practices in dimensioning. Stated briefly, we believe that any drafting practice that gets the finished product completed quicker or cheaper is a true economical practice. In other words, by spending an additional hour of drafting time in adding more dimensions, notes or even additional views, or otherwise making the drawing more clear, it might be possible to save a hundred hours for the many persons that work with and from the drawing. This results in an overall saving in the cost of the completed part; obviously, intricate and complex crosshatching, shading, etc., are discouraged as wasteful and without purpose. We are particularly sensitive about the current flood of magazine articles which are promoting a so-called simplified drafting which requires the draftsman and all persons working from the drawing to learn a new "language of symbols."

Another chief engineer says, "We have over 400 people preparing drawing and we do not concur with the so-called 'simplified drafting.' We have simplified our drawings in regard to notes, field callouts, and the use of undimensioned drawings on stable material, but on the whole we do not care to simplify our dimensioning beyond the basic standards."

It would be possible to quote many more similar statements, but let it suffice to state that the majority of industrial firms contacted were opposed to a revision in our present standards in so far as dimensioning is concerned. I repeat, in so far as dimensions are concerned.

Now, this does not mean that all industry is radically opposed to simplification in dimensioning, or that industry has not tried, or is not willing to try, simplification in dimensioning. It does mean, and this is a personal opinion of my own, that a new set of standards on simplification of dimensioning would have to be formulated and submitted to industry and be accepted before college or universities should tamper with "short-cuts" of their own.

Some of the so-called "short-cuts" or simplification in dimensioning given by those firms which said they are using simplification include the use of cross section stock for drawing board covers where freehand drawings are used, the omission of notes relating to manufacturing methods; notes frequently used are printed on transparent adhesive film which is applied directly to a drawing. Also employed are thread callouts, omission of cross hatching, shading, etc., and demanding speed and completeness rather than the "art." You will note that none of these "short-cuts" is really new. They all make good sense and save time. There was only one firm which showed a probable "short-cut" in dimensioning. The bottom half of the diameter dimensions, extension lines and arrows are omitted. It is possible that this might save some time, but I personally would go along with the chief production engineer of one of the divisions of the largest industrial firms in the U.S. when he says: "The simplified drafting practices that advocate the deletion of arrow heads on dimension lines, omission of circles for holes, etc., are not recommended because the drawing is too difficult to read and subject to misinterpretation." Or as stated by a chief engineer of a firm employing over 550 engineers and draftsmen, "It is our belief that good basic dimensioning should be taught in school. This may be adopted or abbreviated to meet the requirements of each company after the student gets into industry. We have investigated a number of short cut methods now in use and find many of them too extreme."

Let us now see what industry has to say about checking of drawings. All firms reported the use of a system of checking. Over 95 per cent have specific persons charged with checking of drawings, with about 30 per cent using checkers on other work. When changes are to be made on a drawing one hundred per cent of firms use a specific system of drawing change control with very few drawings completely re-drawn. About 50 per cent of firms give the checker authority to reject a drawing either because of design factors or manufacturing limitations. Where firms are using the so-called simplification of dimensioning, 60 per cent said that the checkers had no difficulty or loss of time in checking; 40 per cent said that there was, or would be, a loss of time and that it was harder for a checker to detect errors in the drawing when arrow heads, extension lines, circles, etc., were omitted on a drawing. About 20 per cent of the firms said they thought extra training would be necessary for checkers if any short cuts were used in dimensioning.

Most of the large industries use what might be known as a Checker's and Designer's Guide. These guides are prepared for the purpose of providing uniform policies in all sections of the checking group, and is studied by the Design Group Personnel in the interest of reducing the number of errors on a drawing.

Here are some of the most important items of which the checkers are concerned:

1. Are sufficient layouts, detail drawings, assembly drawings, and installation drawings provided to permit an intelligent check?
2. Is the principle of design correct?
3. Will the design perform the desired function?
4. Can the part be fabricated?
5. Are all necessary views, projections and sections shown to define the part clearly and in third angle projection?
6. Are all necessary dimensions given? Do dimensions check on all mating details and with assembling parts? Are dimensions given from common surfaces, points or holes, and do they conform with specifications as required by the individual firms?
7. Are tolerances shown on the drawing practical and as liberal as possible, permitting fabrication, assembly, installation, proper fit and function of all parts. Has proper regard to the build-up of tolerances been given?
8. Has consideration been given to dimensioning to avoid unnecessary calculations in the shop?
9. Are notes for holes, threads, drills, reams, chamfers, counter bores, countersinks, reliefs, splines, springs, cams, gears, etc., properly applied? (These notes might be improperly called simplification of dimensioning and drafting by some people.)
10. Does any duplication of information exist: for example, are dimensions duplicated on the drawings?

Naturally there are many other items to be checked by the checking group: such items would fall under main headings such as: General Notes, Bill of Material, Title Block, Changed Drawings, Engineering Orders, and Manufacturing Information Notice. Each company has some checking methods which would vary with the complexity of the items manufactured and their methods of checking would fit their own situation. One hundred per cent of industrial firms reporting said that when checkers indicated a change was to be made on a drawing, the original draftsman was required to make the change.

There will be a result in saving of time and confusion when the changes are made by the original draftsman because he is already familiar with the work on the drawing and knows its function and its relationship to the completed project.

In summary it must be pointed out that the majority of industries are not willing at this time to go along with any extreme short cuts or simplification in dimensioning. Over eighty-five per cent of all firms contacted said that simplification of basic principles and standards of dimensioning needed little or no revision at this time. There are many factors to be considered in dimensioning. The inescapable fact remains that mass production is very complex even within the confines of a single industry. Also, the fact remains that mass production is an international matter to-day. During the time of a crisis a lack of approved standards could very well cause a breakdown in the line of supply.

The excellent work that has been done and the work that is being done now by our Standards Committee of SAE, the ASA-14, and others must continue to be the guide for basic instruction in our colleges and universities. If simplified dimensioning must be used, the design engineer can and will adapt himself to those ideas as set up by the individual industry. It is recommended that extreme caution be taken before an individual instructor takes upon himself to teach anything other than the established standards of dimensioning.

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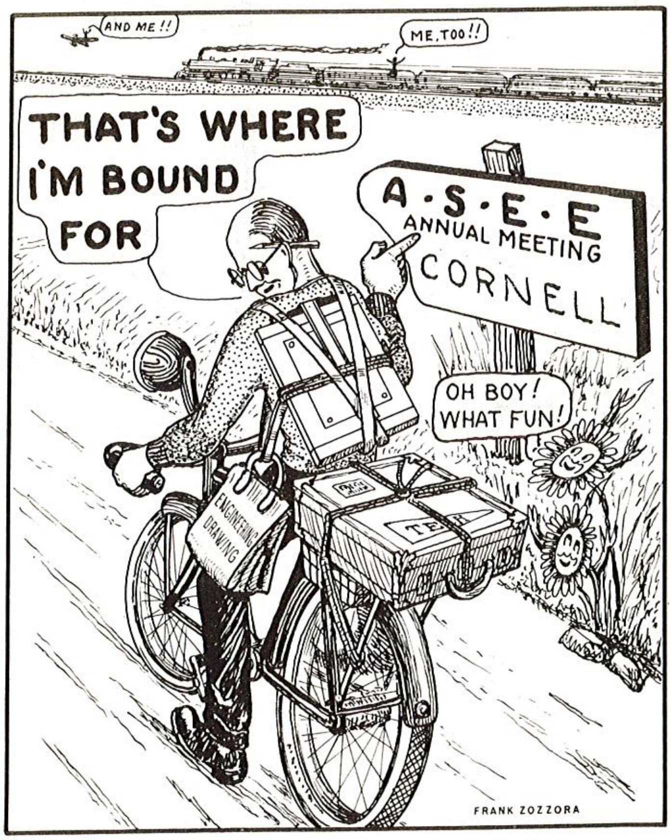

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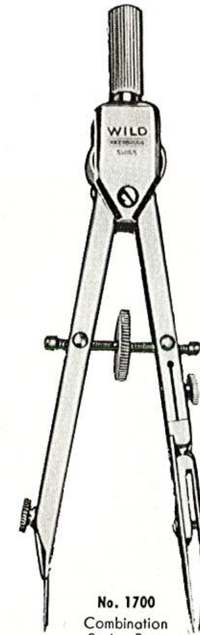

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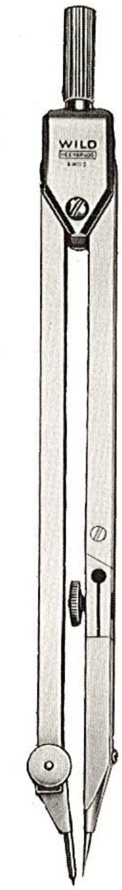

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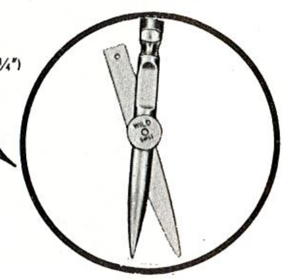

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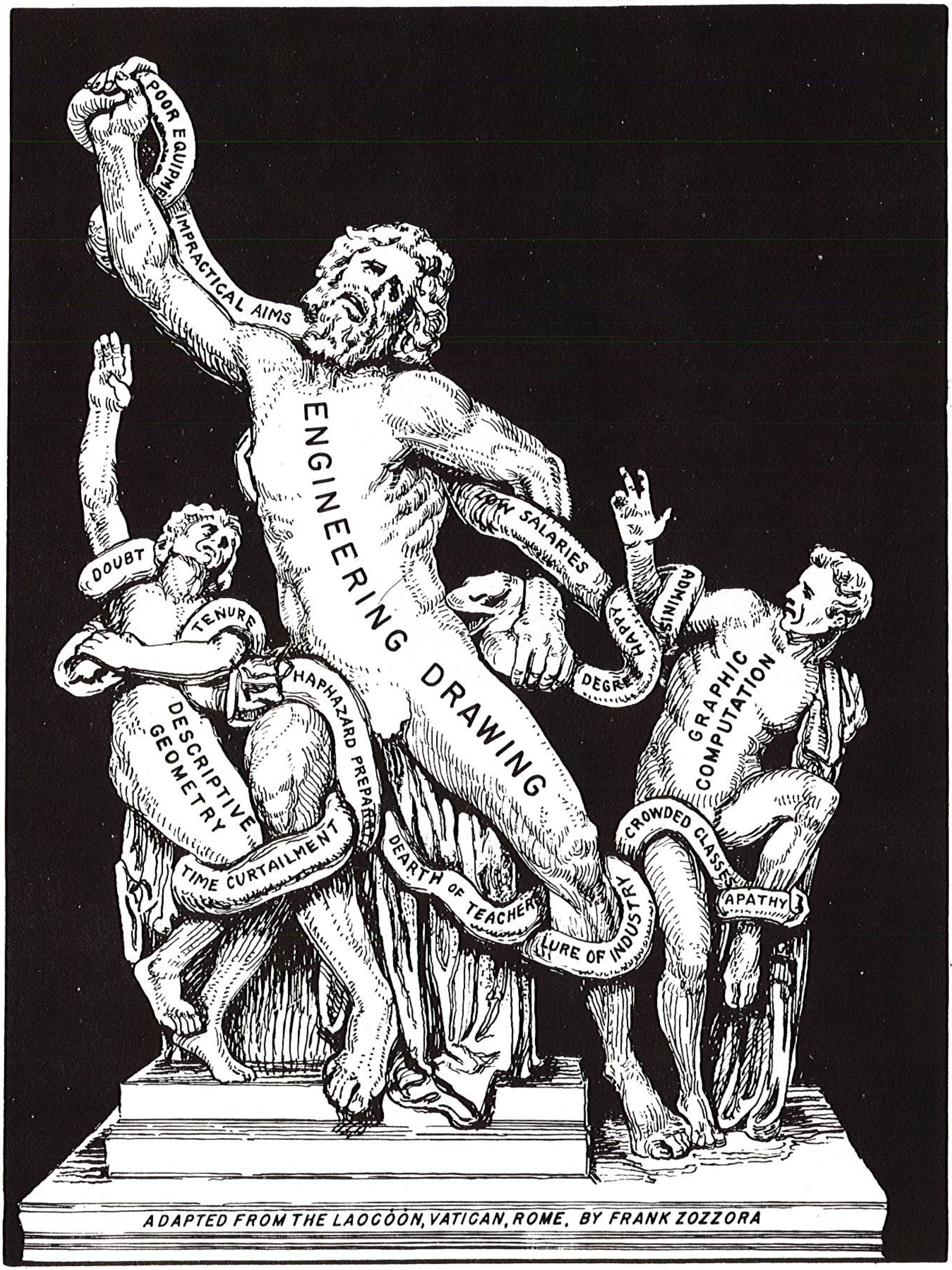


ADAPTED FROM THE LAOCOÖN, VATICAN, ROME. BY FRANK ZOZZORA

A NEW DRAFTING TECHNIQUE

IMAGINE — drawing a perfect, uniform thin line miles long without sharpening the lead. Here is the most remarkable drawing tool ever invented — something busy draftsmen have been dreaming about.

the *IMPROVED* A.W.FABER-*CASTELL*

PROPELLING — FLAT LEAD

LOCKTITE

FLEETLINE HOLDER 9600

AND IMPORTED 9040

CASTELL

FLEETLINE

LEAD

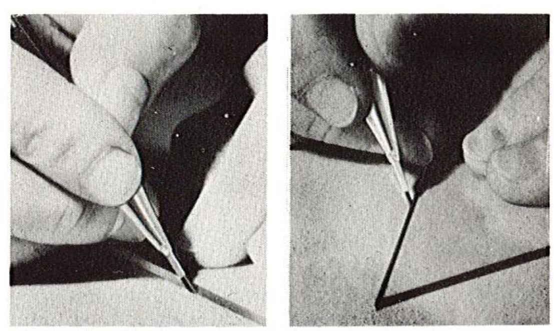
LOCKTITE Fleetline is equipped with Tel-A-Grade, our new patent-pending degree marking device. A turn of the collar exposes the degree of lead in use.

A.W.Faber's new LOCKTITE Fleetline 9600 enables you to draw a continuous thin line of uniform width for hours at a time — without ever stopping to sand or sharpen the lead. The point never changes or varies. That's right — LOCKTITE Fleetline 9600 never needs sanding or sharpening. It is the greatest time-saving drawing tool ever conceived. Knowing, as you do, the time needed to point or sand lead — especially if you want a chisel edge — you can quickly see the advantage of having a ready-made thin ribbon lead which creates for you a perfect solid black line of unvarying width. You get a new point by simply propelling the lead. Hold the flat metal point between the fingers of your left hand and with your right hand turn the barrel to the right. The lead will protrude to the length desired. If you wish to shorten the graphite lead point reverse the turning process and push the lead back.

CASTELL FLEETLINE lead is made in degrees HB to 10H inclusive, 12 grades in all. Each lead is imprinted with its own degree designation. For drawing in color FLEETLINE leads are available in red, blue, green and yellow. All graphite and colored leads fit one standard LOCKTITE 9600 holder as illustrated. Leads are packed 18 of a degree or color to a tube.

LOCKTITE Fleetline Holder and Fleetline leads are ideally suited for full scale master layouts (lofting), and for most designing and drafting. In addition to straight lines, you can use this pencil and lead with French curves. LOCKTITE Fleetline 9600 will do 75% of the day's work, hence saves you much time and labor. Try it — you will never be without it.

Ask your dealer for this new time-saving drawing tool. It heralds a new drafting technique.



Our new drawing tool — LOCKTITE Fleetline — is especially recommended for use on glass cloth, using the very hard degrees of lead, 6H to 10H.

A.W.FABER-*CASTELL* PENCIL CO., INC. NEWARK 3, N. J.