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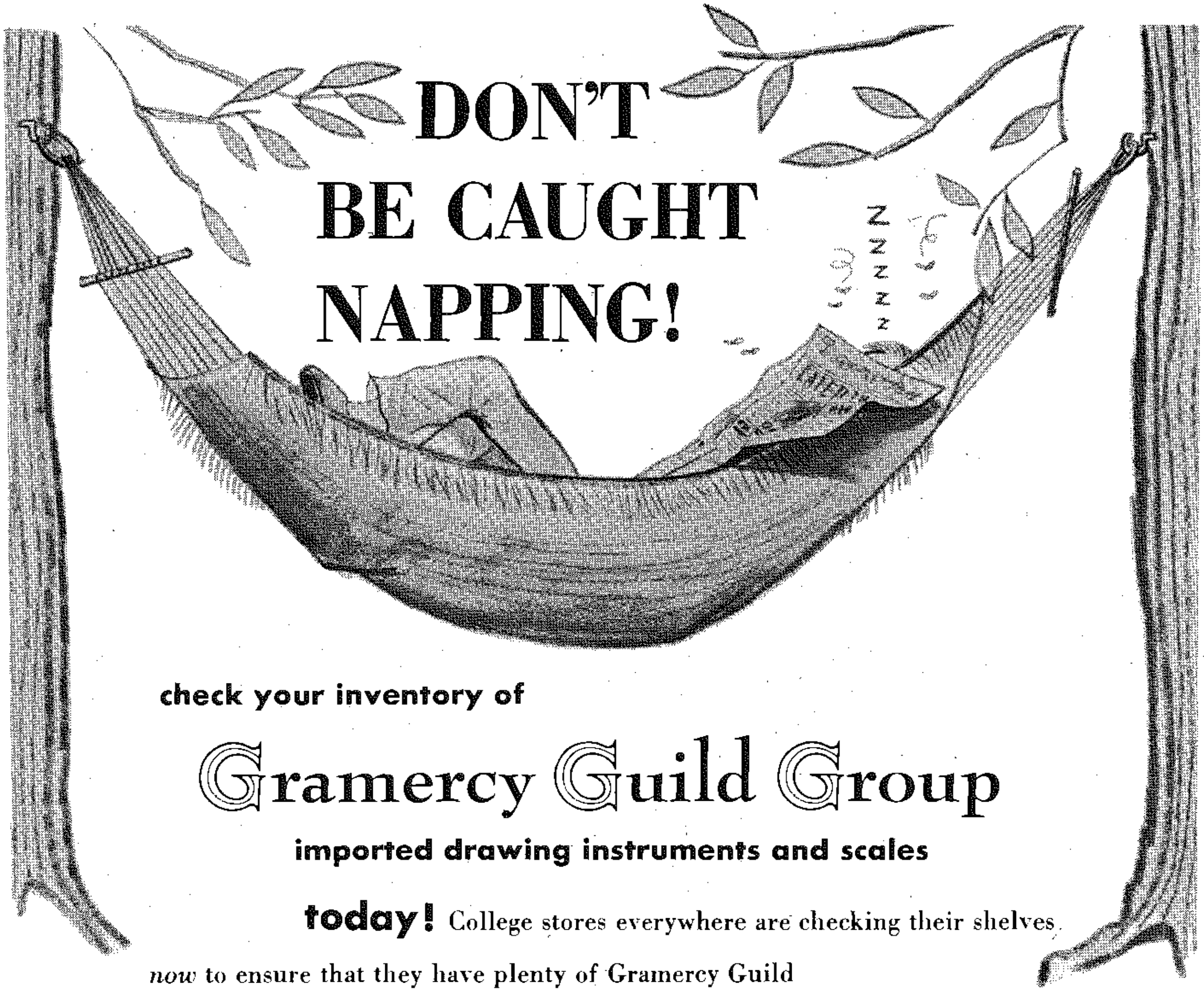

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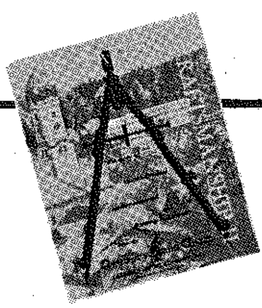

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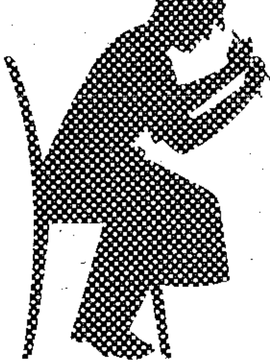

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GRAPHICS - THE CURSIVE WRITING OF SCIENCE

by

Douglas P. Adams

Massachusetts Institute of Technology

PART I

Faced with mid-century expanding curricula, each college subject must offer productivity and opportunities for research. A good definition of what we mean by the field of graphics would be a very useful first step in evaluating it in these respects. Indeed, a reasonable, practical conception of this field in the light of modern demands can actually establish a new unity here and lend to the parts of this field many of the benefits of their relations with the whole. Toward this end we first define what we mean by a graphical process.

Definition

WHEREVER THERE HAS BEEN AN EVALUATION OF THE POSITION OF A MARK OR A SERIES OF MARKS OF A CURVE, LINE OR SURFACE, A GRAPHICAL PROCESS HAS OCCURRED. THE CONVERSE IS TRUE.

The field of graphics can be defined as the practice (in the ways described below) of all the graphical processes.

Certain observations about the graphical process and the field of graphics can now be made.

A. The field of graphics consists of two parts--

(1) the adaption to the graphic process of analytic material, and

(2) the carrying through of the graphical processes.

B. The "mark" referred to could be an ordinary mark on a page, the position of a pointer on a scale, a fixed line seen against a moving scale, or a specified intensity of background. Also, flat surfaces are not the only ones on which a graphical process can be carried out, the sphere being useful in navigation, for instance.

C. A graphical reading is a physiological phenomenon . It is a function of the working angle of vision of the eye and the latter's resolving power. An 8½ X 11 sheet is a "natural" size for the human being and 1/1000 of this height, or approximately 0.01 in., is as close as the eye generally claims to be able to read. This seems to be the origin of "three places" for the natural graphical range, as found in the slide rule, network charts and all graphical reading. More places can be read, of course, by the use of larger sheets of paper, longer slide rules, etc., but these are invariably thought of as "jumbo" items.

D. Inexactness "is" the essence of the graphical process. This is at once its strength and its limitation. It is never known exactly where "the mark" is, nor can a mark be exactly placed. We say "the third place is uncertain." We can place "the mark" only in a neighborhood.

E. Graphics can never "prove" any proposition. A graphical figure being at best a rambling set of neighborhoods, it can serve merely as a check of sorts upon some precise proposition. As a computational device, it cannot give better than three figures' accuracy.

F. Graphics is a mere handmaiden to the various fields of science. Being a way of doing various limited jobs, it cannot be a pure subject. It can, however, be a separate study, consisting of all the possible applications that can be made of it.

G. The contribution of graphics is:

(1) to represent (as closely as possible)

(2) to illustrate (in a general sort of way)

(3) to compute (get solutions and checks as closely as the method permits but never to more than 3 places.)

H. The nature of the graphical representation and solution is distinctive. It tends to be open, legible, usually interpretable at intermediate stages and frequently conducive to good hunches.

I. Graphical representations have a certain continuity about them - purely isolated points do not occur too often - the line or curve is the important function here. There is a continuity, a flow of "the marks" upon the surface. Algebraic symbols, however, are discrete. They are unjoined and have no continuity of appearance. Cursive writing and script lettering differ in much the same way so that an analogy has been drawn in the title of the paper between graphical presentation and cursive writing on the one hand and hence (by implication) between algebraic representation and script writing on the other.

J. We exclude from graphics such processes as the placement of a decimal point to the right or left, or of a character above or below in subscript or superscript form. Such placements carry complete and perfect connotations, which we have said are not germane to graphics.

K. The field of graphics excludes the field of graphic Arts. Esthetic measure has no place under the particular definition we have made. Graphics needs no such "Anschluss".

L. Equality of line length, parallelism or perpendicularity of drawn lines are graphical attributes, because, although the connotations are exact, the true positions of the lines are never known. The labelling of the curves or lines of a network chart with exact lines is similarly a graphical process because the true position of the line is never known.

M. An engineering drawing, with or without dimensions, is a graphical process. The relative position of the marks is known strongly enough to convey notions of position and proportion and to permit three-figure evaluations. The dimensions can carry exact connotations which transcend the accuracy of the diagram. Where a rough sketch has been dimensioned, the drawer's casualness must be improved by an accurate imagination, based upon the attached dimensions or other details to suggest where the sketched lines really should have been placed.

N. The tools of graphics are limited in number - a vital fact. They include the geometries - Projective, Euclidean, Descriptive, etc., which include the projections of various kinds such as orthographic, central, stereographic, gnomonic, etc., vectors, charts and graphs, maps, conics, etc. Most of these are of freshman caliber; few exceed undergraduate caliber. The classroom teaching of these tools is a natural job for a Graphics Department, but their application by the professional graphics man conveys the strongest impression of their worth.

The definition of graphics given above, if acceptable, has the clarifying effect for us here today that:

> IT ESTABLISHES ENGINEERING DRAWING AND DESCRIPTIVE GEOMETRY SQUARELY IN THE MIDDLE OF THE GENERAL FIELD OF GRAPHICS OVER WHICH THEY HOLD NO NATURAL DOMINION:

Hence this field need not logically be mainly dependent upon the popularity of these two parts. Other portions can surely undergo development and contribute to the strength of the whole without derogating from their welfare. A campaign designed to maximize the contribution that this broad field could make in a modern world is our primary purpose.

We note further that the use of graphics can come about in two ways:

(1) by a person primarily a specialist in some other field but trained to appreciate graphics, and

(2) by a person trained primarily in graphics and capable of adapting the material of other fields to graphics.

Under (1), a few years ago someone in navigation developed a way of working out sights by plotting directly on a sphere. As a further example, Katuhiko Morita of Kanazawa University, Japan, found a method for developing quickly the solution curve of an ordinary differential equation by placing the Katta-Runge equations in nomographic form. Under (2), the use of the direct method of descriptive geometry in solving many problems can be properly cited along with other recent development which our colleagues have made in many fields such as nomography. The type of person mentioned in (1) comes hy this appreciation for graphics through

(a) natural aptitude for the graphics method

(b) unusually skillful teaching by an enthusiastic professional graphics man

(c) required course work in graphical methods

(d) chance exposure to a wide variety of graphics

It is important to note here that, if our reasoning is correct, THE AMOUNT OF GRAPHICAL THEORY AND INGENUITY THAT HE USES WILL TAX THE EXPLORER LESS THAN THE BACKGROUND MATERIAL THAT HE HAS TO BECOME ACQUAINTED WITH. Just how and where he should select this portion I cannot recommend, but I do believe that chance brings many opportunities which are not hard to recognize and latch on to. The retention of the subject in the college curriculum may depend upon how much of such work gets done in the future years by the professional graphics man. Every conference in graphics such as the University of Wisconsin and Purdue University put on during the last school year adds measurably to the national stature of this subject.

I should like to quote here, by way of collateral support, from Professor Frank Heacock's talk last June at the University of Illinois where he stated,

on "Opportunities in Research":

> "One can made a useful start by acting as advisor to graduate students who are working on thesis projects and by assisting colleagues who are engaged in research. This experience in setting up research problems and solving them by graphic methods often leads to the discovery of unsolved problems that challenge our best efforts. Let me urge you to engage in fundamental research. Your Committee on Advanced Graphics is willing to offer suggestions and assistance if desired. Many research projects in engineering and science need your proficiency in applying graphic methods to their problems. In return this rewarding experience will make your teaching of engineering graphics more effective for today and tomorrow."

PART II

Up to now we have been concerned with the technical foundations of the subject. Whatever merit you may wish to ascribe to the foregoing definition of graphics and the analysis of its possibilities, there remains the separate question of whether or not the field, as represented professionally by the Drawing Division of the ASEE, is putting its best foot forward in presenting the wares it espouses.

Where you disagree with the suggestions listed below, it is hoped that you will frame and put into effect your own equivalent.

A. The field of graphics should participate in every professional development where it is welcome and its services can be of clear value. It should actively seek such opportunities. As an example, the American Standards Association welcomes the services of as able a group as ours. The Y14 standards for Drawing and Drafting Room Practices have established this ability on a very high plane. (Standards for Engineering and Scientific Graphs for Publication, Y15, lean heavily upon our profession. Standards for Nomographic Charts offer similar opportunities and work has begun upon them.) The graphics profession should provide leadership in the field of simplified drafting and especially in its standardization, which thus far has been advanced chiefly by a variety of industries. The diversity and the intensity of industry's views in this subject is a repetition of the history of standardization in almost any field prior to the moment a professional group took over. Simplified drafting has merit; it is a "natural" for the graphic field. We should not pass up leadership by default.

B. The amount of engineering drawing in use in industry has been a justifiable source of pride to the graphics profession. One assumes that industry appreciates the skill with which the subject is taught. It would be nice to have this appreciation take a tangible form in awards for outstanding contributions to this or various parts of the field. These could, of course, memorialize individuals or companies. Such an award could be for a paper, a process or a broad achievement. A committee to solicit such funds and administer them should be formed.

C. In like manner, a committee to obtain financial support from industry for graphical projects would be entirely appropriate. One such project would obviously be simplified drafting.

D. Grants for government sponsored research on particular graphical problems might well be sought. The fields of nomography and graphical solutions of differential equations have many such problems.

During the World War II, a national roster of scientific manpower was undertaken as the only businesslike way of establishing and recording the nations's assets in manpower. Recently, a similar plan has again been recommended. In preparation for war or as a foundation for efficient peacetime procedure such a roster should be available in this profession for its own use and to increase its usefulness to others.

F. A roster of graphical procedures would be a suitable undertaking for some committee. A great start has already been made here in Professor Frank Heacock's "Graphic Methods for Solving Problems" which should be continued and expanded.

G. As one last suggestion on ways in which the Division could advance the field, it could act as a clearing house for organizing new courses. It can have on record how any subject, particularly a new one, is taught in each college and make this information available to departments starting such courses anew.

H. An individual can work in behalf of graphics by studies in some established field. Such a program is distinguished from one devoted to solving a succession of isolated tricky problems which are primarily flashy and at best of academic value. What is wanted is an integrated, working program in a recognized field with the intention of advancing the field as such.

I. The greatest single ned we have today in graphics is for a Center for Graphical Analysis. Such an idea is possible only because of the tremendous contributions of the Division of Drawing over the past thirty years and, especially, the proven developments of graphics at Ohio State and Illinois Institute of Technology. Such a center could stress primarily the analytic phases of graphics. It could:

(1) Teach, or prepare course work in all aspects of analytical graphical material.

(2) Study and present the historical background of all aspects of analytical graphics.

(3) Serve as a clearing house for questions of practice in analytical graphics.

(4) Sponsor or carry out research in all aspects of the broad field of analytical graphics.

(5) Serve as a display center and provide storage and recording facilities for all types of analytical graphical material.

At this moment in engineering graphics we are faced with two possibilities. The first is that this field will continue to diminish in use and value because its separate parts, disunited, are separately whittled away. The second is that these parts, integrated and practiced under a moaningful definition of what is meant by the graphic process, can contribute a strength to the field which will permit its ever broader acceptance and wider use as the cursive writing of science.

THE ENGINEER — AND THE SECOND MILE *

by
Everett S. Lee
Editor, General Electric Review

It was Dr. William E. Wickenden who brought us the vision of the Second Mile.

From his life experience - great engineering educator that he was - he clearly saw the engineer as he daily worked to bring forth the products of his dreams. Beyond all this he saw the engineering serving his fellow men outside the line of duty. And he quoted from the Sermon on the Mount . . .

"Whosoever shall compel thee to go one mile, go with him twain."

This, said Dr. Wickenden, is the mark of the professional man. Every calling has its mile of compulsion, its round of tasks and duties, its code of man-to-man relations, which one must traverse day by day if he is to survive. Beyond that lies the mile of voluntary effort where men strive for special excellence, seek self expression more than material gain, and give that unrequired margin of service to the common good which alone can invest work with a wide and enduring significance. The best fun of life and most of its durable satisfaction lies in this Second Mile, and it is only here that a calling can attain to the dignity or distinction of a profession.

* Reprinted by special permission, an excerpt from an editorial in GENERAL ELECTRIC REVIEW, July 1955.


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RESOLVED:

THAT, WITH THE PRESENTATION OF THIS AWARD, THE ENGINEERING DRAWING DIVISION OF THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION BY THIS TOKEN ACKNOWLEDGES THE MANY DISTINGUISHED SERVICES RENDERED BY

Justus Rising

THE SOCIETY EXPRESSES ITS DEEP APPRECIATION FOR THOSE SERVICES, AND THE GREAT PERSONAL PLEASURE OF THE INDIVIDUAL MEMBERS IN HAVING HIS FRIENDSHIP.

June 21, 1955

Chairman of the Division

Secretary of the Division

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1950 - Frederic G. Higbee

1951 - Frederick E. Giesecke

1952 - George J. Hood

1953 - Carl L. Svensen

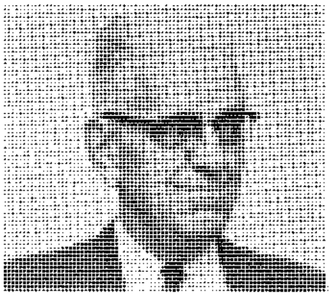
1954 - Randolph P. Hoelscher

1955 - Justus Rising

THE A.S.E.E. ENGINEERING DRAWING DISTINGUISHED SERVICE AWARD

1955

Justus Rising



Justus Rising

The responsibility of selecting the proper man to receive the Distinguished Service Award from the Drawing Division was especially difficult this year because of the large number of nominees. Everyone on the list was eminently qualified to receive the award, but we had only one award to give. The committee considered each one very carefully, but in making our selection, we had to go directly to the rules laid down by the division and compare the group on each individual point.

You may remember from the rules, that the recipient must qualify in the following fields:

1. Success as a teacher and ability to inspire the students.
2. Improvement of the tools and conditions for teaching.
3. Improvement of teaching through various activities.
4. Scholarly contribution.
5. Service to the Division of Engineering Drawing of A.S.E.E.

In considering all of these conditions, we found that one man was either at the top or near the top in each group. Therefore we have selected for this year's award a man known and respected by all of you - Justus Rising of Purdue.

Professor Rising was born January 17, 1890 at Corning New York, the son of Edwin Noble and Alice Hamilton Rising. The father was a railroad trainman who was killed in 1899. His mother married again and the stepfather provided the incentive for Justus to carry on his education. There is one brother, Walter Hamilton Rising and one sister, Margie Rising Conable.

Justus attended grade school and high school in Corning, graduating at the age of 16. After working for two years, he re-entered Northside High School to prepare for scholarship examination for Cornell University. He passed the scholarship exams with an outstanding score of 313 out of 350. During his four years at Cornell, he waited on tables and did odd jobs to pay expenses, and received his M.E. Degree in 1913.

On September 2, 1914 he married Genevieve Neva Lewis of Sonora and Bath, New York. Genevieve graduated from Syracuse University and the Corning Conservatory of Music.

After graduation Justus worked for Ingersoll-Rand and Corning Glass Works. Later he became director of Physical Education at Northside High School after which he became tool engineer and Director of the Apprentice School of the McCormick Reaper Works.

After a year at this job it was necessary for him to spend six months at Edward Tuberculosis Sanitarium in Naperville, Illinois. Because of the doctor's advice he did not return to industry, but became an instructor in engineering drawing at Michigan State College.

After four years at Michigan State he came to Purdue in 1923 as Head of Engineering Drawing, which post he held until 1941. This period brought about a large increase in enrollment and staff, necessitating the introduction of many new procedures and methods, such as home sheets, recitations, machine scorable examinations, and new methods for evaluating performance in drawing, as well as problem books that eliminated much of the repetitive work having little training value.

In 1932 they began the production of silent motion pictures to help in the teaching of drawing. Later sound track was added and another method in which a tape recorder can be connected by a flexible shaft to keep down the cost of movies was used.

From the beginning Justus Rising was a leading spirit in the production of movies; consequently it was to be expected that he would be relieved of many of his other duties to devote his time to this work. In 1940 he was relieved of administrative work in the drawing department to spend his time preparing aids for use in war training. He was active in E.S.M.W.T. and held a commission as First Lieutenant in the Ordnance Reserve Corps.

For the past seven years Justus has been official movie maker for the Purdue Band in addition to his other duties. Many educational films have been made on various subjects, which have been used in other universities as well as Purdue.

To the committe, these activities and many others gave Justus Rising a very high rating in the first three requirements for the Distinguished Service Award.

Professor Rising joined the Drawing Division of A S.E.E. at the Ohio State meeting in 1929 and has been a regular attendant at meetings ever since. He was secretary of the Division from 1931 to 1934 and chairman from 1944 to 1946. In 1946 the summer school at St. Louis was a great success due principally to the efforts of Rising and assisted by Professor Hoelscher. These two spent many hours preparing the minutes of that school for publication by McGraw-Hill Book Co.

The Articles of Procedure under which the division now operates are largely the result of work by Professor Rising. He has presented papers at meetings of the Division and contributed articles for the Journal of Engineering Drawing. These scholarly contributions and services to the Divsion of Engineering Drawing further qualify him for this award.

In addition to these things, Justus is a member of Lions Club, Pi Tau Sigma, University Club, Torch Club, Presbyterian Church, various Masonic orders, Triangle fraternity, and Merit Badge Counselor for the Boy Scouts.

In view of all these achievements and activities, it is a great pleasure to present this certificate representing the Distinguished Service Award of the Drawing Division of A.S.E.E. to Professor Justus Rising.

THE DESIGN GEOMETRY OF INFLATABLE BOATS

By
Mary and Ellis Blade
The Cooper Union

In this paper we show how vector analysis can sometimes be used to supplement graphical design methods. When graphical computations for large objects are done on the drawing board, a reduced scale has to be employed. A loss of accuracy results, which may have to be overcome later by full-scale lofting of the plans. Where applicable, the numberical method derived from vector analysis can not only give the designer a check on his graphical work, but can supply him with results to any desired number of significant figures. The additional cost of performing the supplementary numerical work is justifiable whenever the project is sufficiently important, for example, when quantity production is involved, or when great accuracy is demanded.

An unexpected outcome of our use of the vector method was a general simplification of the problem, through introduction of the point of view of the traverse. That is, whether graphical or numerical methods are employed, tube problems can be partly, and often completely, solved by means of the geometry of the tube centerline.

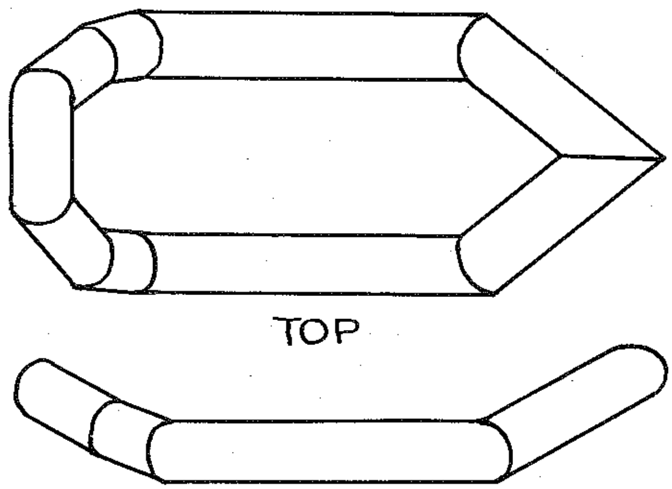
While our specific illustration is the design of an inflatable boat, the proposed numerical method usefully supplements descriptive geometry in a variety of other problems as well. It is suitable wherever distances and angles in space have to be measured. The inflatable boat design falls into this category because it can be reduced to the study of segmented straight lines in space. Other appropriate designs are: three dimensional piping, penstocks for hydroelectric plants, and ducts for air conditioning.

Problems involving continuous curves or surface are also amenable to the method, wherever the configuration can be based on a preliminary straight-line approximation. An example might be the calculation of warped surfaces, such as propeller contours and aircraft wing surfaces.

INFLATABLE BOATS

The boat or raft contemplated here (Fig. 1) is similar (but not identical) to those that came into use during World War II for emergency use on military aircraft. The buoyant element, which is the principal part we are interested in, consists of a continuous, jointed cylindrical tube of large, constant diameter, which completely encircles the boat. The tube, made of rubberized cloth held rigid by inflation, is the sole stiffening member of the boat.

FIG. 1



ELEVATION

In general appearance, the tube is like a jointed torus, distorted in three dimensions to roughly approximate a conventional boat shape. The bow and stern are raised above the level of the sides, for increased seaworthiness. The entire tube is made of short cylindrical sections, joined at suitable angles. The boat described here has nine joints; a typical military design has thirteen.

The design problem is to lay out the patterns of all the gores which join together to form the tube. The information needed is the axial lengths of the gores, the true angles at which they join, and the angular location on the gores of the sinusoidal curves that form the joints. The tube must meet close tolerances for total volume, since the boat will be inflated to standard pressure by a carbon dioxide cartridge.

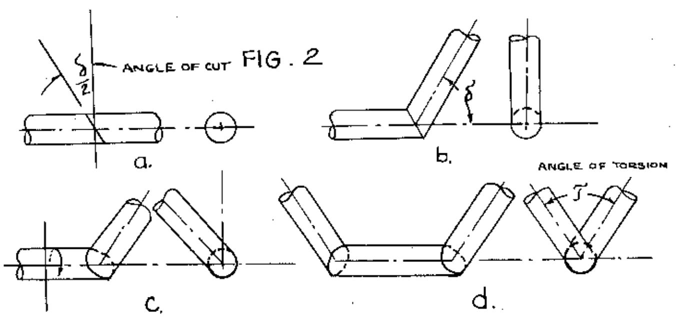
The preliminary design information specified by the purchaser usually includes the overall dimensions, the bow and stern rise, the bow and stern lengths, the tube diameter, and the tube volume. The volume may include allowance for one or more inflatable tubular seats.

For our present purpose we shall assume that the design date have been reduced to a table of coordinates of the segmented centerline of the tube. Certain of the coordinates may have been deliberately left undetermined by the purchaser, in order to allow the manufacturer leeway to meet the critical volume requirement.

GEOMETRY: VOLUME OF THE TUBE

In a common appraoch to the development of cylindrical intersections, the cylinders themselves are projected in suitable views. The patterns are then laid out by means of numbered points, from the views. We can simplify this procedure in the present problem, since the cylinders are all of the same diameter, and the intersections are therefore all ellipses.

Suppose the cylindrical tube, Fig. 2a, is cut across



diagonally. If the right hand piece is then rotated 180^{o}, while keeping the faces of the cut always in contact, the result is the typical elbow of Fig. 2b. The angle δ of the joint is twice the angle of the cut.

We could also make a second cut, perpendicular to the tube, so that by rotation on this second cut, the elbow (angle δ) can be given any desired angular lift above the horizontal, Fig. 2c. By such rotation, two adjacent elbows can be given any desired relative orientation, Fig. 2d.

Using these two kinds of cuts and rotations, we can produce a rectilinear tube of any configuration, but we have a better way which we shall describe later on. First we have to discuss the volume.

For the volume calculation of a tube made up of elbow joints, as in Fig. 1, let us imagine that the tube has been completely "straightened" by rotation of 180^{o} on each of the slant faces of the joints. This would be a reversal of the first kind of rotation just described. The total volume remains unchanged by such rotations. Similarly, the length of the centerline also remains unchanged. We conclude that the volume of a jointed tube is merely the total length of the centerline, multiplied by the cross-sectional area.

In the boat design, therefore, the specified volume is achieved merely by adjusting the total centerline length. This adjustment can be accomplished by suitable trial and error adjustments of coordinates of the vertices, as indicated in the previous section.

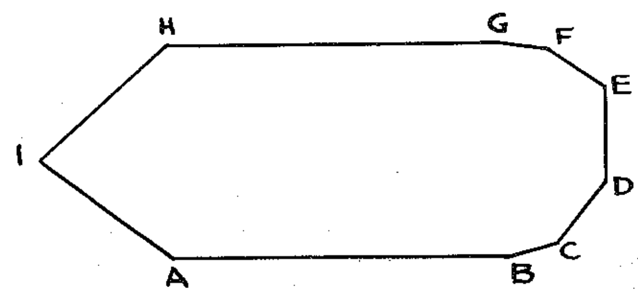
GEOMETRY: THE TORSION

As stated above, the elbow intersections are all ellipses, because all the tubes are cylinders of the same diameter. It follows that the developed intersections are all sinusoidal, hence can be completely characterized by just two parameters: the amplitude and phase. Since these parameters can be obtained from the geometry of the centerline segments, we are able to calculate the gores without drawing any projections of the tubes at all.

Since the centerline is a continuous three dimensional figure, we can adapt a fundamental idea from differential geometry, namely the torsion of a space curve.

Let us consider the boat centerline ABCDEFGHIA (Fig. 3).

FIG. 3.

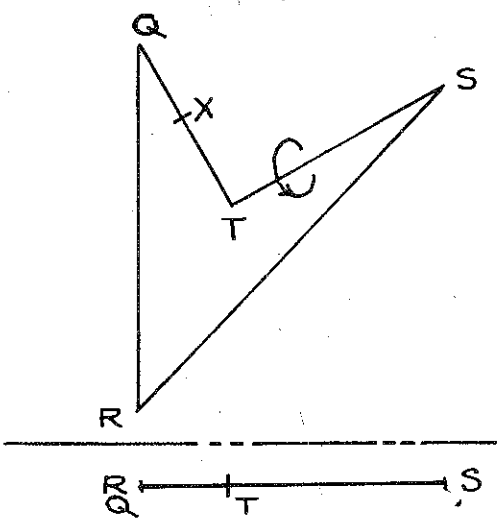


In certain respects, this figure resembles a closed traverse in land surveying. We shall think of an observer, as in surveying, starting at the initial point A, and "walking" the traverse to the successive vertices B,C,D, etc., where he measures the true deflection angles. As in surveying, we shall term AB, BC, CD, etc., the "courses" of the traverse.

As our observer "walks" along the course AB, he notices that the plane ABC lies in a different angular position from plane IAB behind him. The angular difference is the torsion of course BC with respect to course IA, or in simpler notation, the torsion in AB. We measure it by the amount of rotation required to bring the two planes into coincidence, using the algebraic sign convention from trigonometry. If it would be necessary to rotate the preceding course IA counterclockwise to bring its plane into coincidence with the forward course BC, the torsion is positive. Similarly, the torsion in BC is positive or negative accordingly as AB has to be rotated counterclockwise or clockwise to bring it into the plane of CD.

As an example of torsion, consider the plane traverse QRST, Fig. 4. According to the torsion rule just given, inspection shows that the torsions in QR and RS are both zero. Now, considering the end view of course ST, looking from S toward T, it is seen that RS and TQ, though coplanar, lie on opposite sides of ST. The torsion in ST is therefore not zero, but must be

FIG. 4



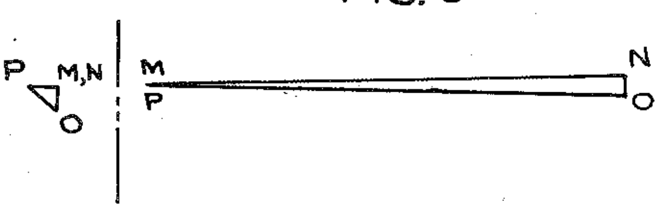
recorded as 180°. Unfortunately, this angle is ambiguously either positive or negative. The same remarks hold for TQ.

At this stage it might be anticipated that the sum of all the torsions in a closed figure is zero. Indeed, this would be a useful theorem, because it would offer a useful check for torsion calculations in closed traverses. This theorem, however, is false, as will be shown by an easy example.

First, however, suppose that traverse QRST is a physical object, made of wire. Let us cut the wire at the point x, somewhere in the course TQ. Then let us rotate the plane xTS counterclockwise a complete circle about axis ST, and weld the wire back together at x. In this way we have added a physical torsional strain to the course ST. The conclusion is, that from geometry alone, one cannot establish the torsion within closer than some whole number of revolutions, namely within an uncertainty of ±360°, ±720°, etc.

Now we must consider an example of a traverse whose total torsion is neither zero nor a multiple of 360°, namely traverse MNOP, Fig. 5. We have chosen extreme

FIG. 5



values of the lengths so that we can ignore small departures from right angles, and speed up our approximate calculations. The parameters are, approximately,

	Coordinates x	y	z	Deflection angles	Torsions	
M	0	0	0	90°	MN	90°
N	10,000	0	0	90°	NO	0
O	10,000	-1	0	90°	OP	90
P	0	0	-1	90°	PM	0
					total	180°

The total torsion is therefore approximately 180°, within some additive multiple of 360°.

If the figure were changed by shortening MN and PO, the total torsion would decrease, until, for a symmetrical traverse, with all sides and angles respectively equal, the total torsion would reduce to zero. We see from this example that the total torsion in a space traverse can have any numerical value. Only in exceptional cases will it be zero, for example, in certain symmetrical traverses.

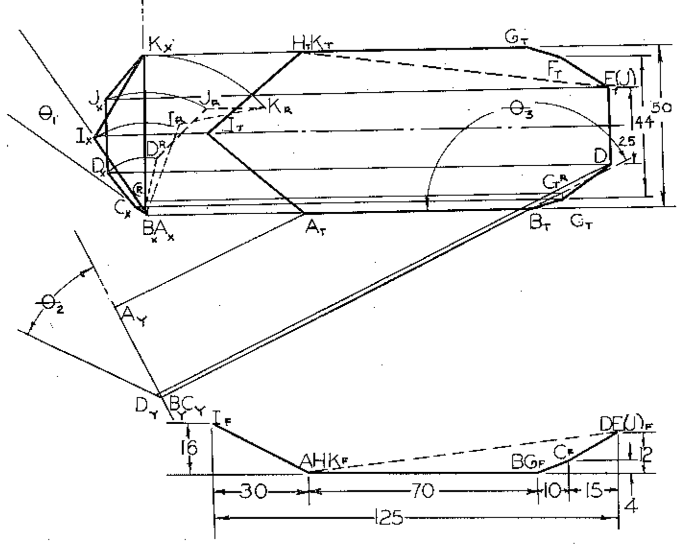
Now, returning to the boat problem, Fig. 3, we have to work out methods of calculating the torsions. This calculation can easily be done by descriptive geometry, but if errors are to be minimized, it must be done full scale.

One feature of this problem distinguishes it from the conventional lofting problem, however. That is, instead of involving continuous curves that have to be faired by eye in the loft, this problem involves only straight segments. Thus, it is ideal for analytical calculation to any number of significant figures desired. In other words, where quantity production or other important considerations warrant the expense, exact numerical solution is possible. Before going into the details of the solution, another point will be mentioned, namely the checking of the work. The fact that we deal with a symmetrical traverse suggests at once that the design might be accomplished with half the work, the other half being inferred by symmetry. True, but if some part of the calculation should be defective, through abnormally large errors or bad arithmetic, the difficulty might not be revealed until the first boat is assembled. It is therefore better to calculate the whole traverse, but even then the symmetry favors the possibility of compensating errors.

To avoid the possibility of undetected errors, we adopt an expedient from land surveying, known as the cut-off line. In our problem, we choose the line from E to H, re-lettered as JK, making the modified traverse ABCDJKIA, Fig. 6. This modification completely destroys the initial symmetry, while retaining all the essential elements needed in the design. Information for the missing vertices and courses can be obtained later by symmetry, after the calculations have been through-checked. The accurate closure of the modified traverse dispels all reasonable doubt about the accuracy of the whole computation whether done graphically or analytically.

Since we have destroyed the symmetry of the traverse, through the introduction of the cut-off line JK (EH), the

FIG 6.



total torsion can no longer be expected to be zero. Some other criterion of closure is therefore needed. Such a criterion appears naturally, when the vector method of calculation is employed.

GRAPHICAL SOLUTION

In the end elevation of the modified traverse, Fig. 6, AB appears as a point. In this view, the torsion in AB appears directly, as the angle between AI and BC.

Next, revolve the whole figure about axis AB, until BC lies in the horizontal plane. The vertex angle at B then appears in its true magnitude, and the course BC in its true length. The end view of BC can then be drawn, to disclose the torsion in BC.

By successive rotations, the parameters of all the vertices and courses can be determined. The final rotation must, of course, restore the figure to its original attitude in space. The work of projection can therefore be checked by comparing the final restored figure with the initial one. It is assumed that the assymmetry of the figure strongly mitigates the possibility of compensating errors. If the projections prove to have been accurately done, the only errors present will be in the actual measurement of the various individual angles.

ANALYTICAL SOLUTION

The data upon which the analytical solution is based are the coordinates of the centerline of the tube, that is. of the vertices of the space polygon. The desired information, as well as intermediate derived data, falls into two classes: that associated with the vertices, and tbat associated with the courses. The numerical work is therefore conveniently carried forward in two separate tabulations: one for the vertices, and one for the courses (designated V and C respectively). Successive entries may be made in the same table, or may move back and forth from one table to the other.

The information ultimately required for layout of the gores is: the lengths of the courses, the true deflection angles at the vertices, and the angles of torsion in the courses.

The lengths of the courses are obtained directly from the coordinates by the Pythagorean theorem:

$$l\ (EL) = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}$$

The true deflection angles are obtained from the scalar products of unit vectors along adjacent courses*

The torsion angles are obtained from the scalar products of unit normal vectors at successive vertices.

The program of calculation starts with (1) the coordinates of the vertices, entered in the vertex table (V table). Subtraction of successive coordinates yields (2) the components of the courses, entered in the course table (C table). The components are squared and summed (3), and the square roots taken (4), all in the course table (C table). This last operation gives us the lengths of the courses, which is the first of our required basic results needed for the design.

We also need the sum of all the lengths, in order to compute the total volume of the tube. If the volume thus found is not correct, we have the opportunity of correcting it by adjustment of coordinates of some of the vertices. The calculation can proceed as soon as the volume adjustment has been satisfactorily made.

5. Direction cosines (C table). When the course components are divided by the true length of the course, the three quotients are the direction cosines corresponding to the direction of the course. Since the direction cosines represent the components of a unit-length vector, we have here the possibility of a check on the numerical work: square each direction cosine, and add the squares. The result should be unity, by the Pythagorean theorem.

6. Scalar products; cosine deflection angles (V table). The arrangement of the direction cosines in the C table is convenient for scalar multiplication, which involves each vertical pair of cosines. The result is entered in the V table, with careful attention to algebraic signs. The scalar product consists of three parts, corresponding to the x, y, z directions. These parts must be added together algebraically, to yield the cosine of the deflection angle.

**The appendix contains a brief refresher on the elements of vector multiplication. For more complete information, the reader must be referred to standard texts.*

7. Sine δ, tangent $\delta/2$ (V table). Since these quantities are needed later, they might as well be computed immediately. The value of the deflection angle in degrees is not really essential, since the layout of the gore can most conveniently and accurately be done with the linear quantity R tan $\delta/2$.

8. Cross-products; normal vectors (V table). The arrangement of the direction cosines in the C table is also convenient for cross multiplication. Each cross product consists of the three components of a normal vector, and involves six direction cosines in the multiplication, arranged as follows:

$$\begin{array}{cccc} x & y & z & \\ a_1 & a_2 & a_3 & (a_1) \\ b_1 & b_2 & b_3 & (b_1) \end{array}$$

These direction cosines are multiplied pairwise, as shown by the arrows. The products represented by the solid arrows are given the plus sign; those by the broken arrows, the minus sign. These signs are applied additionally to the algebraic signs already possessed by the individual direction cosines. The result appears as follows:

$$\begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix} = a_1b_2 - a_2b_1 \qquad \text{(z component)}$$

$$\begin{vmatrix} a_2 & a_3 \\ b_2 & b_3 \end{vmatrix} = a_2b_3 - a_3b_1 \qquad \text{(x component)}$$

$$\begin{vmatrix} a_3 & a_1 \\ b_3 & b_1 \end{vmatrix} = a_3b_1 - a_1b_3 \qquad \text{(y component)}$$

These three results are the components of the normal vectors at the common vertex of the two courses. They appear in the V table.

9. Unit normals (V table). The components just calculated do not represent a unit normal vector, because they are too small by the factor: the sine of the vertex angle. This sine was already computed under item (7), so it only remains to make the division. The three resulting quotients are the direction cosines of the unit normal to the two adjacent courses at the vertex.

10. Squares: check on unit normals (V table). Since the components of the unit normals are direction cosines, the sum of their squares must sum to unity (Pythagorean theorem). This operation provides a check on the numerical accuracy up to this point.

11. Scalar products: cosine torsion angles (C table). The components of the unit normals in the V table are multiplied together pairwise, to form the three parts of the scalar product. These three parts, added together, become the cosine of the torsion angles.

12. Sine $\mathcal{T}$, $\mathcal{T}$ (C table). The sine of the torsion angles is not needed as a design parameter, but is computed in order to use the cross products of the unit normals as an over-all check on the work. The torsion angles are needed in radian form for layout of the gore.

13. Cross products. Algebraic sense of the torsion (C table). The cosine of a positive angle is indistinguishable from that of a negative angle, hence the sense of the torsion is left undetermined by the scalar product. Contrariwise, the sine of an angle reveals its sense. The sense relations of the cross product tell us that the cross product of normals at successive vertices is a vector which lies along the intervening course, but with the opposite direction. Therefore, if we observe the result of such cross multiplication to be opposite to the direction of the course, the torsion angle is positive.

14. Negative of direction cosines: check (C table). The equality of the quotients in (13) with the initially computed direction cosines of the courses constitutes an overall check on the computations, and engenders confidence in the work as a whole.

It may be noted that while six digits were carried throughout the computation, the precision deteriorated in the course of the work, so that only three to four digits were reliable in the final check operation. Such deterioration is a natural result for any numerical work based largely upon substractions, as this one is. Nevertheless, the worst discrepancy on the check was 7 parts in 10,000, representing about ½ minute of arc in the torsion angle, assuming all deterioration in precision had occurred prior to the computation of the cosine values. This precision is more than adequate for the design.

15. Development of the gores. We now return to the cylindrical tube which was cut across diagonally, and the free end rotated 180° to form an elbow joint, Fig. 2. The tube for the entire boat can be thought of as formed in this way by suitable diagonal cuts, Fig. 7a We think of the cylinder rotated by the amount of the torsion, between successive cuts. The developed tube appears in Fig. 7b. The sinusoidal curves have amplitude R tan $\delta/2$. The maxima of these curves occur on the "torsion line". The jogs in the torsion line are the torsions in each course, R$\mathcal{T}$. The solid line, which appears alternately at the middle and at the bottom of the gores, is a reference line that will join together all around the boat after assembly.

We note again, in closing, that the properties of the tube are introduced only at the very end, and that all calculations have been based on the geometry of the centerline.

APPENDIX
Multiplication of Vectors

Vector methods constitute a powerful tool for manipulating distances and angles in space. Let the reader recall that a vector is a directed line-segment

(Con't on page 21)

Marvelous are the things done . . .

Emerging from dubious antecedents, hypnotism is beginning to be recognized for what it can genuinely do . . . and for what it genuinely is. Hypnotism is merely suggestion according to most psychologists, and the marvelous feats performed during the "spell" simply dramatize the great power possessed by suggestion. But these exploits do not begin to tell of the extent to which suggestion is present in everyday life, or the extent to which men respond and are shaped by it.

In hypnotism, the subject agrees in advance to accept the preliminary suggestions of the hypnotist — and in so doing permits the operator later on to establish and control the content of the subject's mind.

The same thing happens when a person goes to a movie: he agrees in advance to accept what the movie announces, and as the picture unfolds, it establishes and controls the content of the person's mind.

And, in fact, when a boy comes to school he too is agreeing in advance to accept the educator's approach. Not that the educator strives to establish and control the content of the lad's mind but by subtle suggestion and impression he seeks to lead the youngster to the point where the *boy* establishes and controls the content of *his* mind. And when this is done right, there need be no further worry about the future outcome.

But just as hypnotist and movie maker are consistent so that no seeming contradiction breaks the *rapport,* so by consistent respect for his subject, for its outcome, for the students in his care, for the work they do, the educator must reinforce the hold he has on the youngster's enthusiasm, zeal, imagination and belief.

No instructor in mechanical drafting will risk vitiating all he has taught and all he will teach, by saying it does not matter whether the student work with cheap and childish drafting instruments. Rather, he insists upon full, honorable quality, full craftsmanship, worthy of the ends of the work and the great careers to which it can lead. This is the climax and *denouement* of *that story.* Nothing must prevent its being told to the end.

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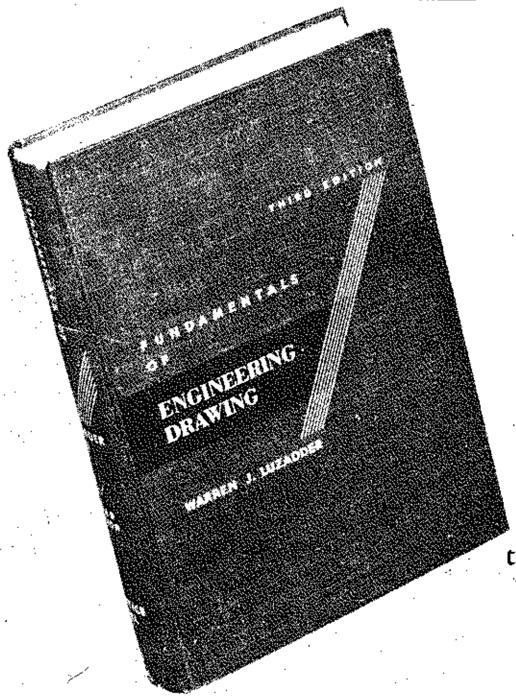

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(Continued from page 18)

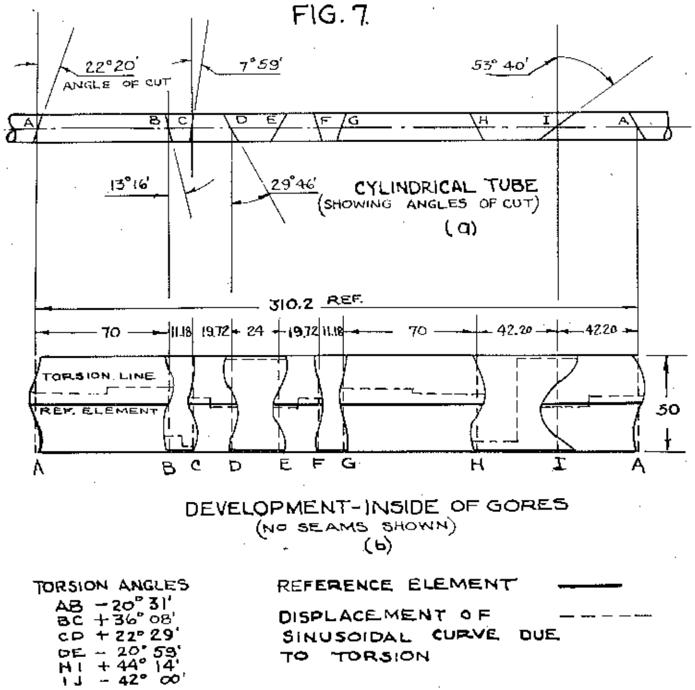


FIG. 7

in space, conventionally pictured as an arrow. Oddly, perhaps, the location of the vector is relatively unimportant, for the vector can be moved parallel to itself at pleasure. It is only the magnitude and direction that matter.

The first vectors that we shall consider are the unit-length vectors i,j,k, which have the directions of the coordinate axes, x,y,z, respectively. These vectors are important because they are the units of measurement in their particular directions. For example, any vector in the x-direction, whose length is a_1, is written $a_1 i$. Similarly, vectors in the y and z directions are written $a_2 j$ and $a_3 k$, respectively. The unit vectors i,j,k, serve to show the directions of the components, while the a's give their magnitudes. The a's are termed scalar magnitudes, meaning that they are ordinary numbers, distinguished from vectors.

If we add together the above three vectors which lie along the three axes, the sum represents a general vector in space.

$$a_1 i + a_2 j + a_3 k$$

We now recall the well-known fact that any vector in space can be decomposed into its x,y. and z components, and that these components are merely the projections of the vector upon the coordinate axes. Let A be some vector, of length a, and let the projections of this vector on the axes have the lengths a_1, a_2, and a_3. Then A can be written as the sum of three perpendicular vectors, $a_1 i$, $a_2 j$, and $a_3 k$, lying along the axes, or

$$A = a_1 i + a_2 j + a_3 k$$

By the Pythagorean theorem we have

$$a_1^2 + a_2^2 + a_3^2 = a^2$$

where a is the length of the vector. The angles that the vector makes with the three coordinates axes, called the direction angles, are symbolized by the three letters α, β, and γ, respectively. These angles are of not nearly as much significance as their cosines, expressed by the length ratios

$$\cos\alpha = \frac{a_1}{a} \qquad \cos\beta = \frac{a_2}{a} \qquad \cos\gamma = \frac{a_3}{a}$$

These ratios are called the direction cosines. From the Pythagorean theorem,

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

With this short introduction, we can describe vector multiplication. There are two distinct kinds, the scalar product and the cross product. In considering multiplication, we take advantage of the mobility of vectors, and imagine them brought together by parallel movement, in such a way that the tails of the arrows coincide at a common vertex. In this way we have a direct visualization of the included angle, needed for the multiplication.

The scalar multiplication is so called because the result of the operation is a scalar, or ordinary number. Its magnitude equals the length of either vector, multiplied by the projection of the other upon it. If a and b are the lengths of two vectors A and B, and if (A,B) designates the angle between them, then the scalar product is defined by

$$A \cdot B = B \cdot A = a\,b \cos(A,B)$$

The scalar product is often called the dot product, after the manner of writing, A·B (pronounced A dot B). It is immaterial whether A or B is written first, since A·B equals B·A

If A and B are two vectors,

$$A = a_1 i + a_2 j + a_3 k$$

then their scalar product is

$$A \cdot B = (a_1 j + a_2 j + a_3 k) \cdot (b_1 i + b_2 j + b_3 k)$$

This expression can be simplified, after multiplying out according to the usual rules of algebra, provided we apply the scalar product definition to the unit vectors i,j,k. Since these vectors are mutually perpendicular, the cosine of the angle between any dissimilar pair is identically zero. Hence i·j, i·k, k·i, etc. are all zero. On the other hand, the scalar products i·i, j·j, and k·k, are all unity, because the vectors are all of unit length, and the included angles are all zero.

Therefore, among the nine terms of the scalar product, six are identically zero, and only three remain, giving.

$$A \cdot B = a_1 b_1 + a_2 b_2 + a_3 b_3$$

Vectors of unit length play an especially important part in the present theory, because the components of such a vector are simply the direction cosines corresponding to the orientation of the vector. Moreover, since the scalar product is defined as ab cos(A,B), with a and b the lengths of the two vectors, the scalar product of two unit vectors ($a = 1$; $b = 1$) reduces to the cosine of the included angle, or

$$A \cdot B = (1)(1) \cos (A,B) = \cos (A,B)$$

Therefore, the scalar product of unit vectors provides a direct means of computing angles in space.

The second kind of multiplication, the cross product, results in a new vector, normal to both of the original vectors, with magnitude equal to

$$A \times B = a\, b \sin (A,B)$$

In this operation (pronounced A cross B), it is essential to distinguish the order of the letters A and B, since BxA turns out to be the negative of AxB, as will now be explained.

First, the axes x,y, z must be mutually perpendicular, moreover, they must constitute a right-hand system. Let the right hand be placed at the origin, and let the fingers curve in the direction of a rotation of x into y. Then the thumb indicates the direction of z. The same description tells the sense of the cross multiplication $i \times j = k$; Both i and j are unit vectors, and the sine of the angle between them is unity, so under the definition of a cross product the result is a unit vector in the z direction, namely k.

Contrariwise, the cross product jxi involves a rotation of the right hand from j into i, which makes the thumb point in the negative z direction, so $j \times i = -k$. The complete table of the elementary cross products is,

$i \times j = k$	$j \times i = -k$
$j \times k = i$	$k \times j = -i$
$k \times i = j$	$i \times k = -j$

Three more cross products must also be considered, namely ixi, jxj, and kxk. These are all zero, since the sine of the included angle is zero.

The general cross product employs the same right-hand rule for finding the sense of the result, which is perpendicular to both the original vectors, and in the direction of the right thumb. In terms of the components, this product is,

$$AxB = (a_1 i + a_2 j + a_3 k) \quad x \quad (b_1 + b_2 j\, i + b_3 k)$$

After multiplying out, and simplifying according to the rules just given, the result is,

$$AxB = (a_2 b_3 - a_3 b_2)i + (a_3 b_1 - a_1 b_3)j + (a_1 b_2 - a_2 b_1)k$$

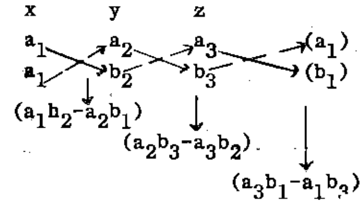
In view of the practical evaluation of the cross product, it is useful now to point out that the foregoing results really represent the expansion of three determinants:

$$A \times B = \begin{vmatrix} a_2 a_3 \\ b_2 b_2 \end{vmatrix} \quad \begin{vmatrix} a_3 a_1 \\ b_3 b_1 \end{vmatrix} \quad \begin{vmatrix} a_1 a_2 \\ b_1 b_2 \end{vmatrix}$$

and that these determinants, in turn, are an expanded form of the third order determinant

$$A \times B = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ i & j & k \end{vmatrix}$$

From this it can be seen that the cross product is formed by the cross multiplications of the determinent, with the solid arrow products taken positively and the broken arrow products negatively:



(z component)
(x component)
(y component)

As stated before, BxA is the negative of AxB. The two products can be distinguished by the right hand rule, which required that A, B, and AxB be a right hand system.

If A and B are taken parallel to two directions in space, then the cross product AxB must be normal to the plane of those two lines. Therefore the cross product provides the means of computing the angular position of a plane.

If A and B are taken as unit vectors ($a = 1$, $b = 1$), then from the defining formula,

$$AXB = ab \sin (A,B) = (1)(1) \sin (A,B) = \sin (A,B)$$

That is, their cross product reduces to a normal vector, whose magnitude equals the sine of the included angle. If the <u>unit</u> normal is desired, the components of the product must be divided by the sine of the angle, obtained from the scalar product A.B. Hence to find the unit normal to a given plane, first choose two unit vectors in that plane. Determine their included angle, by the scalar product. Then find the unit normal by the cross product AxB/sin (A,B).

To summarize the properties of vector multiplication, as described here: the scalar product is used for computing angles in space; the cross product is used for the erection of normals.

As an example of the two kinds of products, consider the points P(0,0.0), Q(10,0,0), and R(15,5,0). By subtracting coordinates, we find the vectors PQ and QR.

$$PQ = 10i + oj + ok \quad = 10i$$
$$QR = 5i + 5j + ok \quad = 5i + 5j$$

The <u>unit</u> vectors along PQ and QR are i and $\frac{\sqrt{2}}{2} i + \frac{\sqrt{2}}{2} j$

The cosine of the angle between PQ and QR is

$$\cos Q = i \cdot \left(\frac{\sqrt{2}}{2} i + \frac{\sqrt{2}}{2} j\right) = \frac{\sqrt{a}}{2} i.i + \frac{\sqrt{2}}{2} i.j = \frac{\sqrt{2}}{2} + 0$$

whence $Q = 45^{\circ}$

The normal to PQ and QR, found from the unit vectors, is

$$i \times \left(\frac{\sqrt{2}}{2} i + \frac{\sqrt{2}}{2} i\right) = \frac{\sqrt{2}i}{2} \times i + \frac{\sqrt{2}}{2} i \times j = 0 + \frac{\sqrt{2}}{2} k$$

But from the definition of the cross product, we know that the magnitude of this result is simply sin Q, since unit vectors were multiplied. To find the unit normal, we have to divide by sin 45°, $\frac{\sqrt{2}}{2} k / \sin 45^{\circ} = \frac{\sqrt{2}}{2} k / \frac{\sqrt{2}}{2} = K$

That is, the unit normal to the two lines is merely the unit vector k, which lies in the positive z direction. This result is easily verified by casual examination of the figure, which lies entirely in the xy plane, so the unit normal cannot be other than k or -k.

C TABLE

	② COMPONENTS			③ SQUARES				④ LENGTHS	⑤ DIRECTION COSINES		
									COS α	COS β	COS γ
AB	70	0	0	4900	0	0	4900	70.	1.000000	0.	0.
BC	10	3	4	100	9	16	125	11.1803	0.894430	0.268329	0.357772
CD	15	10	8	225	100	64	389	19.7231	0.760530	0.507020	0.405616
DJ	0	24	0	0	576	0	576	24.	0.	1.000000	0.
JK	-95	13	-12	9025	169	144	9338	96.6333	-0.983098	0.134529	-0.124181
KI	-30	-25	16	900	625	256	1781	42.2019	-0.710868	-0.592390	0.379130
IA	-30	-25	16	900	625	256	1781	42.2019	0.710868	-0.592390	-0.379130

⑪ SCALAR PRODUCTS

	Z	X	Y	COS $\mathcal{T}$	COS^2 $\mathcal{T}$	SIN $\mathcal{T}$	$\mathcal{T}$
AB	0.505370	0.	0.431249	= 0.936619	0.877255	0.350350	-20°31'
BC	0.543942	0.	0.263730	= 0.807672	0.652334	0.589632	+36°08'
CD	0.799903	0.124108	0.	= 0.924011	0.853796	0.382366	+22°29'
DJ	0.875397	0.058974	0.	= 0.934371	0.873049	0.356302	-20°59'
JK	0.820122	0.003442	0.	= 0.823564	0.678258	0.567222	-34°33'
KI	0.729386	0.012923	0.	= 0.716463	0.513319	0.697651	+44°14'
IA	0.743178	0.	0.	= 0.743178	0.552314	0.669093	-42°00'

⑬ CROSS PRODUCTS

	Y			Z		
AB	0.	0.	= 0.-	0.-	0.-	0.
BC	-0.158240	0.	= -0.158240	0.-	-0.210986	= -0.210986
CD	-0.426615	+0.232702	= -0.193913	0.-	-0.155133	= -0.155133
0J	-0.110576	+0.466878	= +0.356302	0.-	0.-	= 0.-
JK	-0.027245	+0.103594	= +0.076349	-0.070437	0.-	= -0.070437
KI	+0.389006	+0.024231	= +0.413237	0.-	-0.264497	= -0.264497
IA	0.	-0.396362	= -0.396632	0.-	-0.253672	= -0.253672

⑬ CONT'0. ⑭ NORMALIZED

	X			Y	Z	X	SIGN
AB	-0.323437	+0.673826	= +0.350389	0.	0.	+1.00011	-
BC	-0.725256	+0.197797	= -0.527459	-0.268370	-0.357836	-0.894556	+
CD	-0.290874	0.-	= -0.290874	-0.507139	-0.405611	-0.76072	+
DJ	0.-	0.-	= 0.-	1.000000	0.-	0.-	-
JK	0.-	+0.557625	= -0.557625	0.134601	-0.124179	-0.983078	-
KI	-0.495931	0.-	= +0.495931	D.592326	-0.379125	+0.710858	+
IA	0.-	+0.475634	= +0.475634	-0.592790	-0.379128	+0.710863	-

V TABLE

	① COORDINATES			⑥ SCALAR PRODUCTS			
	X	Y	Z	COS α	COS β	COS γ	COS δ
A	30	-25	0	0.710868	0.	0.	0.710868
B	100	-25	0	0.894430	0.	0.	0.894430
C	110	-22	4	0.680241	0.136048	0.145118	0.961407
D	125	-12	12	0.	0.507020	0.	0.507020
J	125	+12	12	0.	0.134529	0.	0.134529
K	30	+25	0	0.698853	-0.0796936	-0.0470807	0.572078
I	0	0	16	-0.505333	0.350926	-0.143740	-0.298147

⑦

	COS δ	SIN δ	SIN δ	TAN $\frac{\delta}{2}$
A	0.505333	0.494667	0.7D3326	0.411092
B	0.800005	0.199995	0.447208	0.236065
C	0.924303	0.075697	0.275131	0.140271
D	0.257069	0.742931	0.861934	0.571946
J	0.018098	0.981902	0.990910	0.873410
K	0.327273	0.672727	0.820199	0.521729
I	0.088892	0.911108	0.954520	0.136000

⑧ CROSS PRODUCTS

	Z			X		
A	0.	+ 0.592390	= 0.592390	0.	+ 0.	= 0.
B	0.268329	+ 0.	= 0.268329	0.	0.	= 0
C	0.453494	- 0.204072	= 0.249422	+ 0.108838	- 0.181398	= -0.072560
D	0.760530	+ 0.	= 0.760530	0.	- 0.405616	= -0.405616
J	0.	+ 0.983098	= 0.983098	- 0.124181	- 0	= -0.124181
K	0.582377	+ 0.095632	= 0.678009	+ 0.051040	- 0.073564	= -0.022524
I	0.421111	+ 0.421111	= 0.842222	+ 0.224593	+ 0.224593	= +0.449186

	Y		
A	-0.379130	- 0	= 0.379130
B	0	- 0.357772	=-0.357772
C	0.272096	- 0.362795	=-0.090699
D	0	0	0
J	0	0	0
K	0.088276	+ 0.372722	= 0.460998
I	0.269511	- 0.269511	= 0.

⑨ NORMALIZED ⑩ SQUARES

	Z	X	Y				
A	0.842270	+0.	-0.539053	0.709419	0	0.290578	= 1.000007
B	0.600009	+0.	-0.800012	0.360011	0	0.640019	= 1.000030
C	0.906557	-0.263729	-0.329657	0.821846	0.069553	0.108674	= 1.000073
D	0.882353	-0.470588	0.	0.778547	0.221453	0.	= 1.000000
J	0.992116	-0.125320	0.	0.984294	0.015705	0.	= 0.999999
K	0.826639	-0.027462	+0.562056	0.683332	0.000754	0.315907	= 0.999993
I	0.882351	+0.470588	0.	0.778543	0.221453	0	= 0.999996

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THE NEW AMERICAN SURFACE FINISH STANDARD

by
Roy P. Trowbridge
General Motors Corporation, Detroit, Michigan

In my presentation before the summer school for drawing teachers at Michigan State College in June 1951, I reviewed the history of the surface symbol and familiarized the audience with the contents of the American Standard B46.1-1947 and the SAE Surface Finish Standard. I also commented on instrumentation, calibration specimens, roughness comparison specimens, and general information on the "when, where and how" of surface finish specification and control.

Since then, culminating extensive activity on the part of ASA Sectional Committee B46, its subcommittees and parallel committees of technical societies and trade associations concerned with the subject of surface finish, the revised American standard for surface roughness, waviness and lay B46.1 was published in January 1955. Because of the wide participation in development of the revised standard a great deal of implementation was underway in American industry long before the standard was issued. Efforts on the part of individuals and companies in the form of educational lectures or programs are serving to stimulate further acceptance and implementation of the new standard.

Answering a need for the fullest possible coverage on the subject, the revised standard has been greatly expanded. In addition to the basic data carried over from the previous issue, the standard now includes sections on stylus type instruments, roughness specimens and supplemental appendices. Today I would like to review for you the contents of the 1955 standard giving special emphasis to revised or additional features and the reasons therefor.

The definitions contained in the previous issue remain essentially unchanged. However, one very important new definition has been added, namely the definition of roughness-width cutoff. It is defined as the maximum width in inches of surface irregularities to be included in the measurement of roughness height with explanation the roughness may be considered as superposed on a wavy surface. A footnote provides further clarification by stating that in an electrical integrating instrument, frequency response characteristics permit the exclusion of all wave lengths greater than the cutoff value when the sample is traced at a specified speed, and that electrical instruments with adjustable frequency response or variable speeds of trace can be set to measure only the very fine irregularities. Instruments may also be set to measure coarse irregularities in which case fine irregularities will be included in the reading obtained. The footnote warns that when selecting the roughness-width cutoff, care must be taken to choose a value which will include all of the pertinent surface irregularities.

We are indebted to Mr. M.E. Reason of the British firm of Taylor, Taylor and Hobson for calling attention of American technicians to the desirability of distinguishing roughness-width cutoff in surface specification and instrumentation and for his generous act of assigning his patent on circuitry for variable roughness-width cutoff response in instruments to the American people.

Prior to recognition of the need for controlling roughness-width cutoff, inspectors were plagued with extreme variations in readings taken with reputable instruments of different makes. Although instrument manufacturers were aware of the frequency response limitations of their instruments, users were not always so well informed and frequently ascribed such variations to improper calibration. Formal recognition of the roughness-width cutoff with establishment of standard values should serve to resolve for all time this type of inspection difficulty.

The effect of roughness-width cutoff variation is clarified by reference to Figure 1a., a theoretical surface of which the true profile has a peak to peak roughness width of .030, a major roughness height of 50 microinches peak to valley and a minor roughness height of 5 microinches peak to valley on the flanks of the major roughness. If analyzed by an instrument having .030 roughness width cutoff the true profile would be recorded. However, if a roughness-width cutoff of .010 were used the major roughness peaks would not be included in assessment of the roughness height and only the minor roughness would be recorded as shown in Figure 1b. When reduced to roughness rating, the average roughness of the true profile is approximately 13 microinches, whereas the average roughness obtained with an instrument having .010 roughness-width cutoff would be approximately 1.2 microinches.

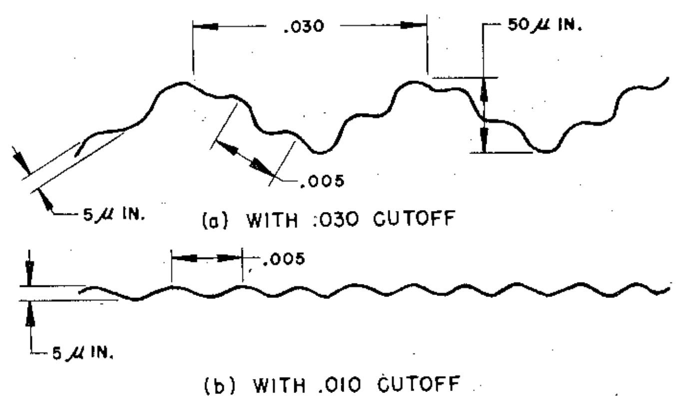


FIGURE 1

It can readily be seen that care should be exercised in the specification and measurement of roughness to insure that the roughness-width cutoff of the inspecting instrument is the same as that intended by the designer. The standard roughness width cutoff values are .003, .010, .030, .100, .300 and 1". The B46 standard states that the value .030 is preferred for most surfaces and should be used unless otherwise specified. Later on I will demonstrate placement of the rating value in the symbol.

By varying the roughness-width cutoff on instruments, a great deal more control may be exercised over the roughness than has heretofore been practical. It is known for example that roughnesses having small width spacings are detrimental to fatigue life of highly stressed parts. Accordingly those surfaces should be examined with the smaller roughness-width cutoffs so that the roughness values of the comparatively fine scratches may be controlled. However, where fit-up of mating parts requires closely controlled bearing areas, coarse roughness spacing is of greater importance than fine, and the larger roughness-width cutoffs should be used.

An equally important new feature in the latest standard is recognition of the arithmetical average deviation from the mean line as the only parameter for roughness designation and measurement. The previous standard allowed any one of four methods for rating roughness - maximum peak to valley, average peak to valley, average deviation from the mean line and the square root of the average of the squares of the deviations from the mean line (also known as root mean square). Prolonged debate and investigation by the Sectional Committee and canvasses of industry indicated that there was a decided preference for the arithmetical average as the most easily understood rating and the most adaptable when it comes to instrumentation.

Some users of root mean square averaging instruments who specified RMS on their drawings were concerned regarding limitation to the arithmetical average rating. It was demonstrated to them, however, that root mean square averaging instruments actually respond to the arithmetical average with scales offset 11% to approximate a so-called root mean square average. Conversion of existing instruments from root mean square rating to arithmetical average rating is a minor adjustment. The approximate 11% differential between arithmetical average and the RMS average roughness is not sufficient to warrant revision of roughness designation on drawings other than those for parts which are critical with regard to maximum and minimum roughness values as the differential is considerably less than the normal variation in roughness at different points on any one surface. The direction of the difference is such that continued use of drawings which previously specified RMS would not result in rejection by instruments calibrated in arithmetical average units.

I realize the surface symbol and its application to drawings is of particular interest to you and all drafting instructors. The design and proportions of the surface

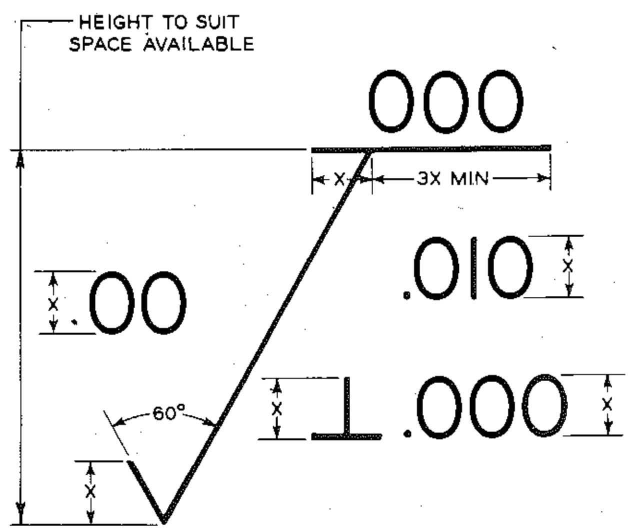


FIGURE 2

symbol as explained in the B46 appendix are shown in Figure 2. Placement of symbol ratings is demonstrated in Figure 3, which also shows the relationship of the ratings to various characteristics of a hypothetical surface. You will note that the positions of the ratings are the same as in the previous standard with the additional rating for the roughness-width cutoff located under the horizontal extension line. Typical applications of the symbol are shown in Figures 4, 5 and 6. The apex of the symbol may be on a line indicating a surface, on a witness line, or a leader line. The long leg of the symbol is preferably to the right as the drawing is read.

With regard to the condition of the surface or stage of operations to which the symbol applies, the standard provides that surface roughness symbols, unless otherwise specified, shall apply to the completed surface. Further that drawings or specifications for plated or coated parts shall definitely indicate whether the surface roughness symbols apply before plating, apply after plating, or apply both before and after plating as shown in Figure 7. This should serve to eliminate much of the confusion which has existed in the past.

At this juncture it might be well to emphasize that promiscuous use of the surface symbol is discouraged by the standard which in Appendix D states that in the mechanical field comparatively few surface require any control of smoothness or roughness beyond that afforded by the processes required to obtain the necessary dimensional characteristics

It cites working surface such as bearings, pistons, and gears as typical of those for which optimum performance may require control of the surface characteristics in accordance with the standard. Non-working surfaces such as the walls of transmission cases, crank cases, or differential housing are cited as typical of those which seldom require any surface control. However, for purposes of process control, it is sometimes desirable to specify surface finish on processing sheets for intermediate steps

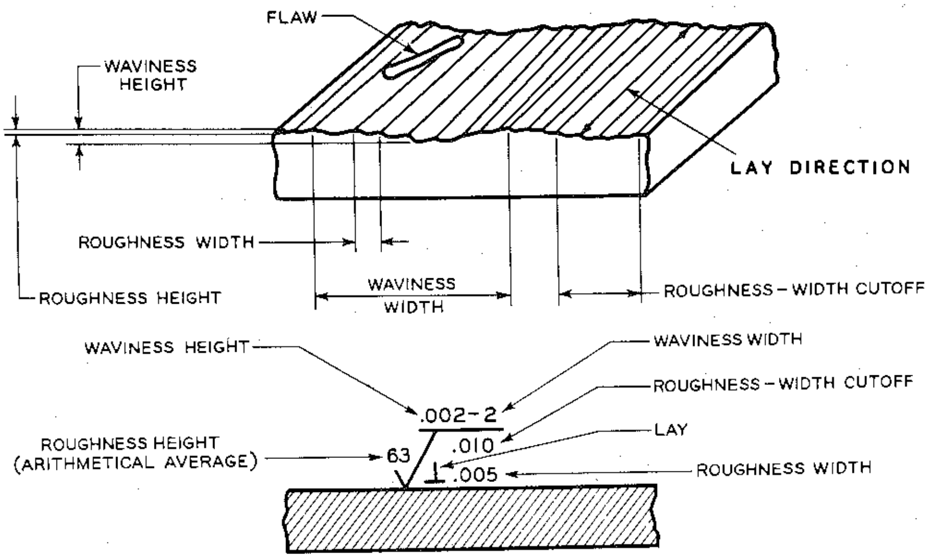


FIGURE 3

to assure meeting close dimensional limits in the final operation. Surface finish analysis is also useful as an indication of excessive deterioration of cutting tools and has been used successfully as a signal for controlling dimensional accuracy.

To promote uniformity and assist users in simplified specification of surface requirements the wording of various general notes which may be required is suggested in the B46 appendix. A few examples are shown in Figure 8.

As I mentioned earlier, the standard has been expanded to include specifications for stylus-type instruments. The instrument section was prepared by a subcommittee of technical experts representing major instrument manufacturers and several principal users. A stylus radius of 500 microinches was chosen as standard with a shank angle of 90° and a maximum stylus force of 2-1/2 grams. The standard specifies the minimum practical radii of skids and defines the minimum practicable length of trace suitable for accurate, consistent readings. The response characteristics of the circuitry are also given.

The purpose of the instrument section is to establish minimum requirements which should assure comparability of surface roughness data taken with instruments of different manufacture. The specifications will not restrict new designs nor will they penalize instruments in current

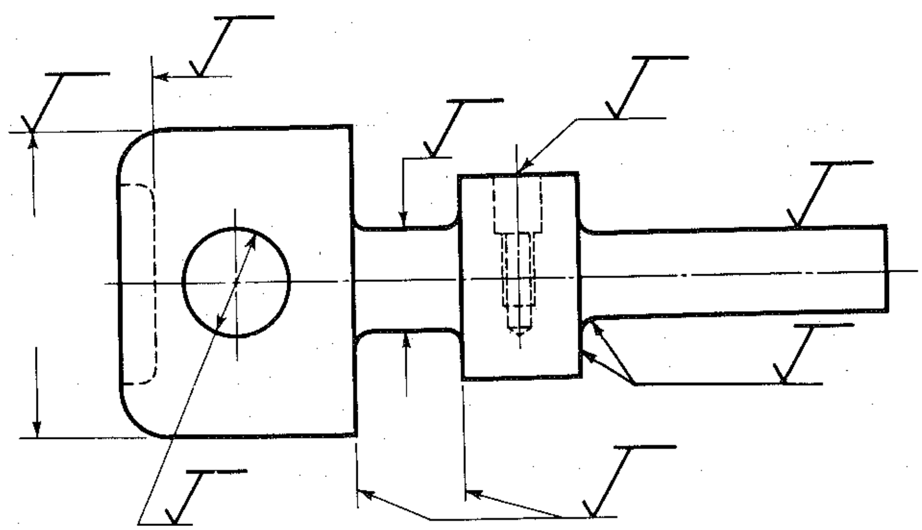


FIGURE 4

use. Coverage was limited to the stylus type instruments on account of their wide popularity compared to non-stylus types. It is not intended that instruments other than stylus-type should be considered non-standard, and when instrumentation based on principles such as light reflection, air metering or others have reached the popularity now enjoyed by stylus-type instruments, I am certain that adequate coverage will be afforded in future revisions of the B46 standard.

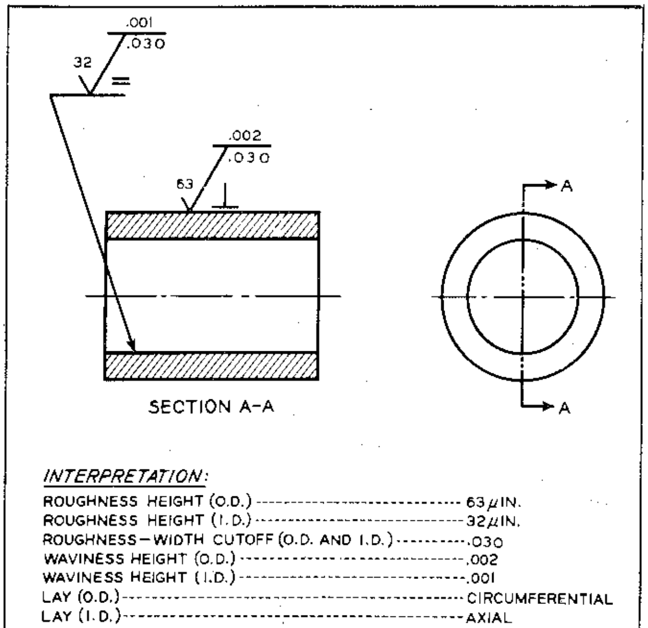


FIGURE 5

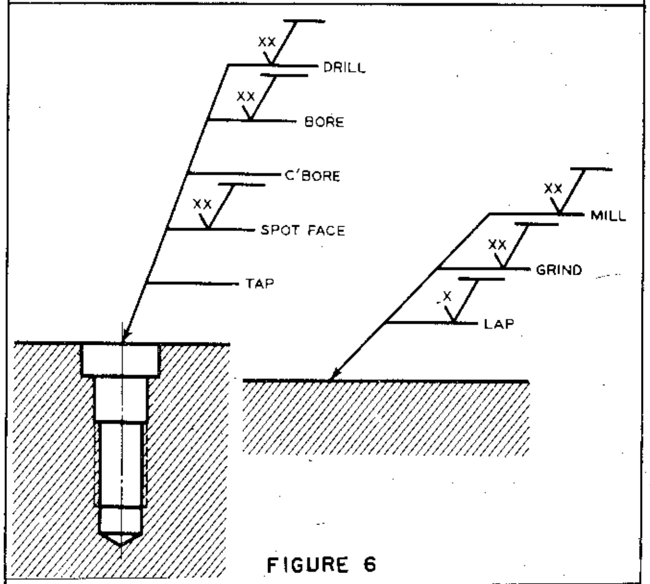


FIGURE 6

The American Standard B46.2 for Physical Specimens of Surface Roughness and Lay was published in 1952. It included specifications for Roughness Comparison Specimens and Precision Reference Specimens. With only minor modifications this standard has been incorporated into the revised B46.1-1955 standard. The Precision Reference Specimens are the geometric specimens which I described to you in my 1951 paper. You will recall that these specimens are not intended to resemble machined surfaces, but because of their extremely close tolerance and uniformity they may be used to calibrate and adjust instruments. The specimens are electroformed nickel replicas of gold masters. The profile of the specimens is shown in Figure 9. The Roughness Comparison Specimens described in the standard are machined surfaces or replicas of machine surface intended for measurement of roughness

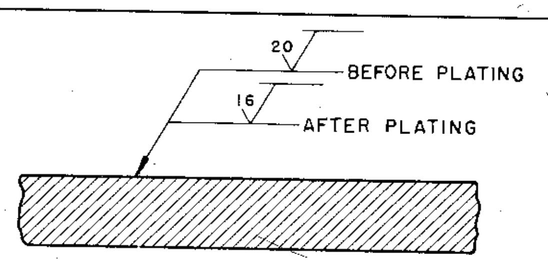


FIGURE 7

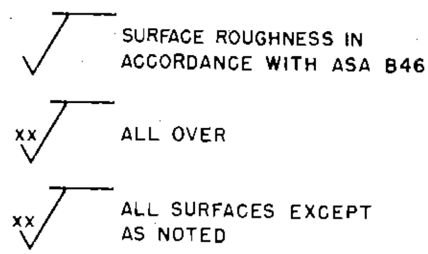


FIGURE 8

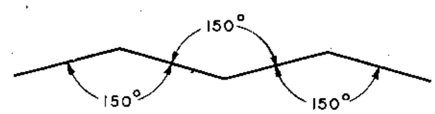


FIGURE 9

by direct tactual and visual comparison of the specimens with production parts. Because of their comparative lack of uniformity, Roughness Comparison Specimens are not suitable for instrument calibration.

The appendices to the standard include information on application of the surface symbol, calibration of instruments, and the general practice of surface roughness control. Obviously these data must be limited to generalities inasmuch as no rules of thumb can be established for specific applications. In surface finish applications, as with fits between mating parts, the large number of variables affecting proper functioning requires that individual and separate consideration be given to specific applications. The standard only provides a basis which the user or designer can supplement with his own experience to establish requirements for specific applications.

When asked the secret of his success in designing a new diesel engine, C.F. Kettering once observed that instead of trying to design the engine he and his colleagues had let the engine design itself. Similarly in choosing an optimum surface, the final decision, the proof of the pudding as it were, will continue to depend on the functioning of the individual surface in its environment.

Supplemental Reading & References

Surface Roughness, Waviness and Lay - ASA B46.1-1955. American Standards Association, 70 East 45th Street, New York 17, New York.

SAE Surface Finish Standard, Society of Automotive Engineers Handbook, SAE, 29 West 39th Street, New York 18, New York.

Control of Surface Quality - Fifth Edition, July 1953. James A. Broadston, Surface Checking Gage Co., Hollywood 28, California.

"Design Considerations Applying to Specification of Surface Finish for Machined Parts", and "A Discussion of Instrumentation for Determining Surface Roughness of Machined Parts." J.F. Hagen and E.E. Lindberg, GM Engineering Journal, Vol. 1, #7, July-August 1954. Educational Relations Section, Dept. of Public Relations, GM Technical Center, P.O. Box 177, North End Station, Detroit 2, Mich.

"Surface Roughness and the Design Engineer", Joseph Manuele. Paper presented before ASME meeting, Baltimore, Md., April 18 - 21, 1955.

"The Surfagage". A.F. Underwood, J.B. Bidwell J.H. Brems. Paper presented at ASTE, Chicago, Illinois, March 19, 1952.

Credits: Figures 2, 3, 4, 5, 6 and 9 courtesy of ASA B46.1-1955.

NOMOGRAPHY PRIZE - ANNOUNCEMENT

By
Douglas P. Adams
Chairman, Committee on Nomography
Division of Engineering Drawing, ASEE

The Drawing Division's Committee on Nomography is pleased to announce that the David Gessner Company, Worcester, Mass., has contributed $100 for a prize in Nomography. It has requested the Committee to administer the competition. The Committee has removed itself from the contest and has laid down the following rules for eligibility and standards of excellence.

1. A nomogram or an article on nomography may compete.

2. The nomogram or article must have been published in a periodical.

3. It must have appeared in an issue between the dates of June, 1955 and May, 1956, inclusive.

4. It must be the primary interest of the article.

5. It must be brought to the attention of the committee. They are not personally responsible for finding and evaluating all such articles, although they will surely be as diligent as they can.

6. It will be judged on orginality, resourcefulness and effectiveness. The drafting and the use of keys, etc., should be competent but are secondary considerations.

7. A majority of the committee votes received will be decisive.

8. The winner will be announced at the Annual Dinner in Iowa next June and the award made at that time.

The Committee is undertaking at this time a searching of the periodical literature for other purposes which would uncover just such diagrams. This is an extensive job because of the large number to be covered. The Committee would especially appreciate any help which individuals would care to give and will mention such help at the Annual Meeting.

The Committee's names and locations are appended, and you need merely get in touch with the member you prefer. The searching will be systematized and coordinated so that there will be a minimum of effort and no duplication.

Committee: J. Norman Arnold (Purdue University)
Clyde Kearns (Ohio State University)
Alexander S. Levens (University of California)
Frank Heacock (Princeton)
Dale S. Davis (Virginia Polytechnic Institute)
Douglas P. Adams Chairman (M.I.T.)

GEORGE J. HOOD - HOLLEY MEDAL RECIPIENT

George J. Hood, professor emeritus of the University of Kansas and one of the long time stalwarts of the Division of Engineering Drawing, has again been honored. The president of the Amderican Society of Mechanical Engineers, Mr. David W.R. Morgan, recently announced that Professor George Hood had been named its 1955 Holley Medal winner.

The award, which is administered by the Society's Board on Honors, is bestowed "For some great and unique act of genius of an engineering nature that has accomplished a great and timely public benefit." The citation accompaning the Holley Medal honors Professor Hood "For his act of genius in inventing the dermatome, a skin-grafting machine, making possible surgical treatment of severe burns and other denuding injuries."

Professor Hood joins a distinguished roster of Holley medalists including Henry Ford, Irving Langmuir, John Garand and Vannevar Bush. His inventions find a place beside others similarly recognized such as the cyclotron and the Norden bombsight. The Holley Medal was established in 1924, in recognition of the contributions of Alexander Lyman Holley to the industrial development of the United States. Holley, one of the founders of ASME, was responsible for bringing the Bessemer process of steelmaking to this country.

The following account appeared in the June 29, 1955, issue of PEOPLE TODAY and is reprinted with their permission:

"Can you make me a machine to cut a piece of skin from a man's body, eight by fifteen inches big, all in one piece?"

That was the gist of an urgent phone call in '53 from a surgeon to a famous engineer, prompted by the fire-scarred face of a captain of a U.S.A.F. plane that had crashed. The engineer went right to work and thanks to him, hundreds of Americans who suffer critical burns each year can now be saved from death, from loss of arms and legs and from total disfigurement.

The story of the remarkable machine which makes this possible, the dermatome, is told for PEOPLE TODAY by its inventor, Professor George Hood of the University of Kansas' Engineering School:

"Long before the dermatome existed a few surgeons became expert at cutting skin grafts freehand. But it was nearly impossible to cut a graft of uniform thickness and reasonable size. Grafts to the face were seldom attempted, since the result would have been patchwork, making the new face look like a map.

"Dr. E.C. Padgett of Kansas City came to my university one day in '30, looking for a man to design an instrument to cut large, uniform skin grafts. I'd been concerned with gas engines, but I worked at it at odd hours in my basement

Holley Medal
1955
Awarded to
George J. Hood
For His Act of Genius in Inventing the Dermatome, a Skin-Grafting Machine, Making Possible Surgical Treatment of Severe Burns and Other Denuding Injuries

The American Society of Mechanical Engineers

D.W.R. Morgan
President
C.E. Davies
Secretary

shop and designed the first workable dermatome by '36. When it was to be used for the first time in an operation, the surgeon hesitated. I was there. I took the machine out of his hands, and cut the first calibrated skin graft myself."

"Essentially, the dermatome is a cylinder. A knife edge is fixed to rotate parallel to the cylinder's outside, always close to the curved surface.

"To cut a graft, both the cylinder and the patient's skin are coated with rubber cement. In early experiments honey was used. The sticky cylinder is put on the sticky skin of the "donor area" - chest, back, thigh or abdominal wall. The skin sticks to the cylinder. As the cylinder is rolled, it lifts the skin - so that the knife edge can cut it and keep cutting. The cut skin is care-carefully lifted from the cylinder with tweezers.

"Early dermatomes, cutting 4" x 8" grafts, are credited with saving the lives of thousands injured in fires and industrial and combat explosions. Now some 7,000 dermatomes are in use throug throughout the world. The U.S. Armed forces keep hundreds ready. Russia has 12.

"The thickness of skin grafts can be varied from from on eight-thousandth of an inch to one three-hundredth. If the freshly-cut skin is left stuck to the cylinder, and the knife then set closer, it'll cut two thin grafts from one thick one. This cuts the donor area required in half.

"The donor area heals quickly. In 5 or 6 weeks another graft can be taken from the same place. the latest "giant dermatome", cutting 8" x 15" grafts, saved a man's arms and hands by providing 5 square feet of thin skin, sliced from 2½ square feet of thicker skin. If Prof. Hood's machine hadn't been available, the man's arms would probably have had to be cut off."

Professor Hood is a member of Sigma Xi, Tau Beta Pi, and Alpha Tau Omega. The Drawing Division of the A.S.E.E. in 1952 bestowed its Distinguished Service Award upon him. And now the Drawing Division add congratulations to the 1955 Holley Medal Recipient, George J. Hood.

PROGRAM
MID WINTER MEETING — 1956

Engineering Drawing Division, ASEE

AT

ILLINOIS INSTITUTE OF TECHNOLOGY

Chicago, Illinois

January 26 - 28, 1956

Thurs. Jan. 26th

1 - 5 P.M.	Registration - Room 405, Main Bldg.
6:30 P.M.	Executive Committee Dinner - Executive Conference Room, Student Union Bldg.

Fri. Jan. 27th

8-10 A.M.	Registration - Lobby, M.C. Bldg. 1. Coffee and Doughnuts in Conference Room 2. Open House, T.D. Dept, 4th & 5th floors, Main Bldg.
10 - 12 noon	General Session - Smith-Olson Hall, M.C. Bldg. W.E. Street - Chairman Engineering Drawing Division - presiding 1. Welcome by Pres. Rettaliata and Dean Owens 2. Response by W.E. Street 3. Papers a. Paré, E.G .(IIT) - "Technical Drawing for Science Majors." b. Messinides, H.C. (Wilson Jr. College) "Design Consideration in Engineering Drawing". c. Sahag, L.M. (Ala. Poly. Inst.) "Relation between Engr. Drwg. and Machine Design."
12:15 A.M.	Luncheon and Business Meeting - Lounge, Commons Bldg.
2 P.M.	Inspection Trip (Chartered buses) 1. Chicago Tribune Plant a. "Trees to Tribune" - 30 min. color sound film on paper making operations b. Editorial Section c. Composing Section d. Press Room e. Cartoon, Advertising and Art Sections
5:30 P.M.	Banquet - Kungsholm (Swedish Smorgasbord)
7:00 P.M.	1. Address - To be announced.
8:00 P.M.	2. Kungsholm - Miniature Opera Presentation.

Sat. June 28th

8 - 9:45 A.M.	Open-House, Technical Drawing Dept., 4th and 5th floors, Main Bldg.
10 A.M.	General Session - Smith-Olson Hall, M.C. Bldg. W.E. Street Presiding. 1. Papers a. Gerardi, J.(U. of Detroit) - "Should Colleges teach Drafting Techniques? b. Bergen, J.H. (AMF) - "Simplified Drafting" e. Levens, A.S. (U. of Cal.) - "Introductory Nomography"
12 noon	Luncheon, Commons Bldg.
2 P.M.	Field Trip (Optional) 1. Museum of Science and Industry 2. Art Institute 3. China Town 4. Gray-Line Sight Seeing Tour

INDUSTRIAL NOMOGRAPHY

by
D.S. Davis
Virginia Polytechnic Institute

Industry makes generous use of many valuable techniques: instrumentation, engineering drawing, spectrographic analysis, statistics, patent law, thermodynamics, x-ray examination, and stoichiometry, to name but a few. Common to most industrial endeavor is the need for reliable and convenient methods of calculation so that manufacturing operations can be satisfactory, technical control can be dependable, and research can be sound.

Industrial work is characterized by enormous volumes of computations that must be made by operating men and technicians who have had little training and experience and who can be given only intermittent supervision. Under these conditions engineers and others in supervisory capacities supply their men with graphical aids especially designed for routine use, convenience, accuracy, and for significant saving in time. The best of such graphical aids, known as nomograms, alignment charts, or nomographs, meet these requirements admirably and find wide application in industry.

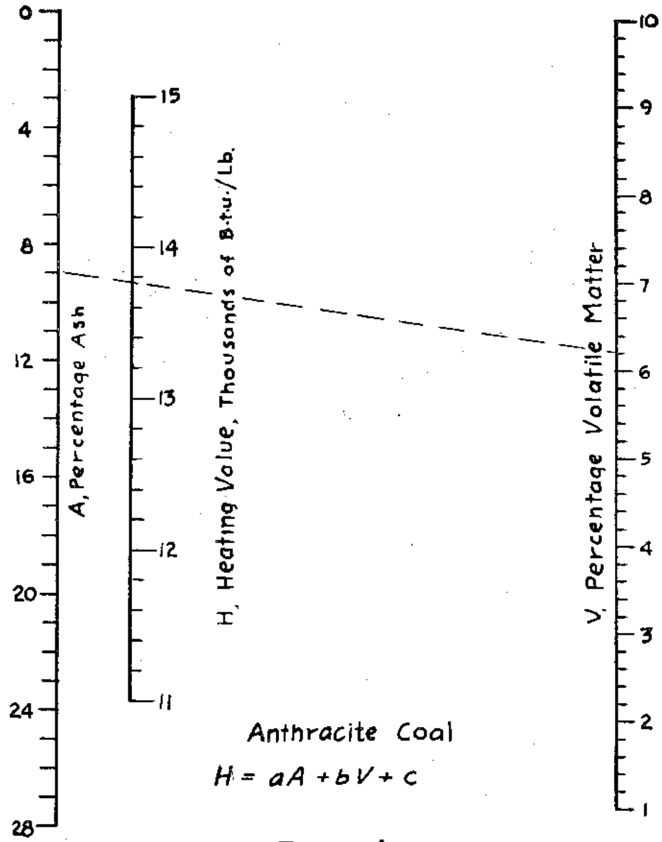
The simplest and most common form of nomograph is represented by three axes that are graduated and placed so that they can be intersected by a straight line in values that satisfy an equation in three variables, in accordance with elementary principles of plane geometry. The design and construction of a nomograph requires one (1) to know the relationship between the variables, (2), to know the ranges that these cover, (3) to identify the relationship in question with one of the standard type forms, and (4) to choose unit representations or moduli to be used in constructing the necessary scales.

Most industrial nomographs are based on relationships of the following forms:

Type	Form
A	$f(x) = F(y) + \phi(z)$
B	$f(x) = F(y)\ \phi(z)$
C	$f(x) = \psi(x)\ F(y) + \phi(z)$
D	$f(x) = F(y) / \phi(z)$
E	$\phi(z) = a + b\,F(y)$

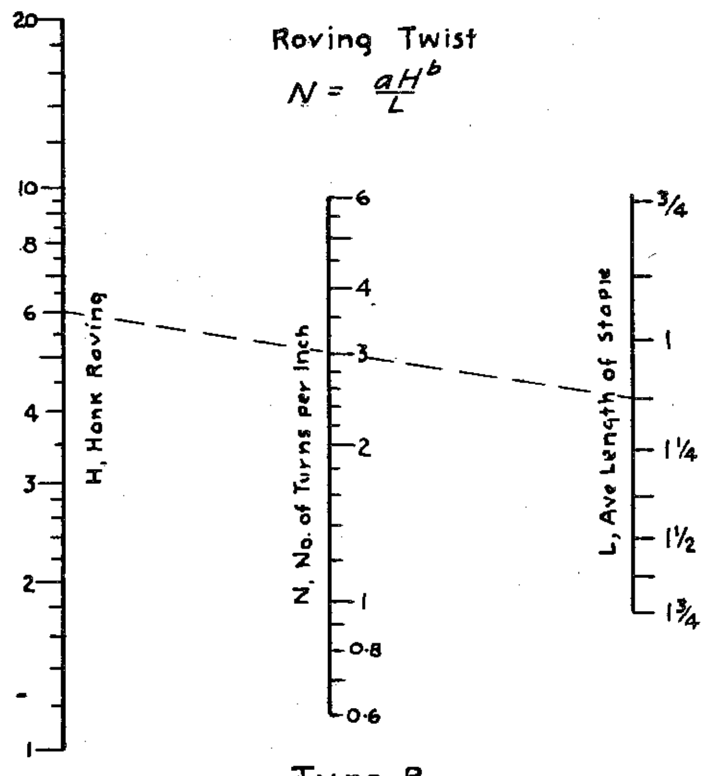
where f (x), F (y), and ø (z) represent any functions of the variables x, y, and z, and where a and h depend upon x but are defined by tabular date or curves rather than by a mathematical equation. These forms are closely related; the distinctions lie in the manner in which the nomographs are constructed.

Type A, addition or substraction, leads to parallel axes that are scaled uniformly or nonuniformly as required by the nature of the functions.



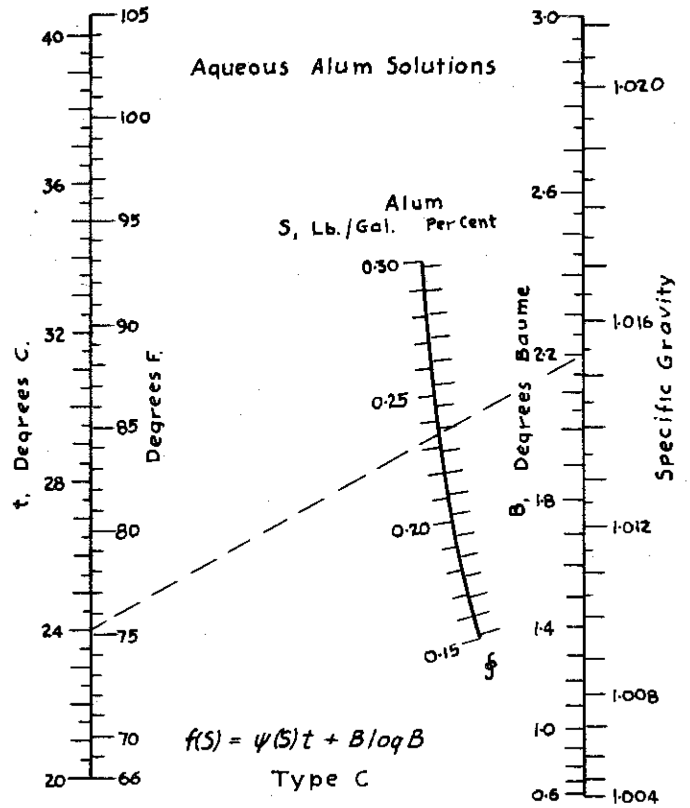
Type A

Type B, multiplication or division, when written in logarithmic form, results in parallel axes that are scaled logarithmically in the functions of the variables.

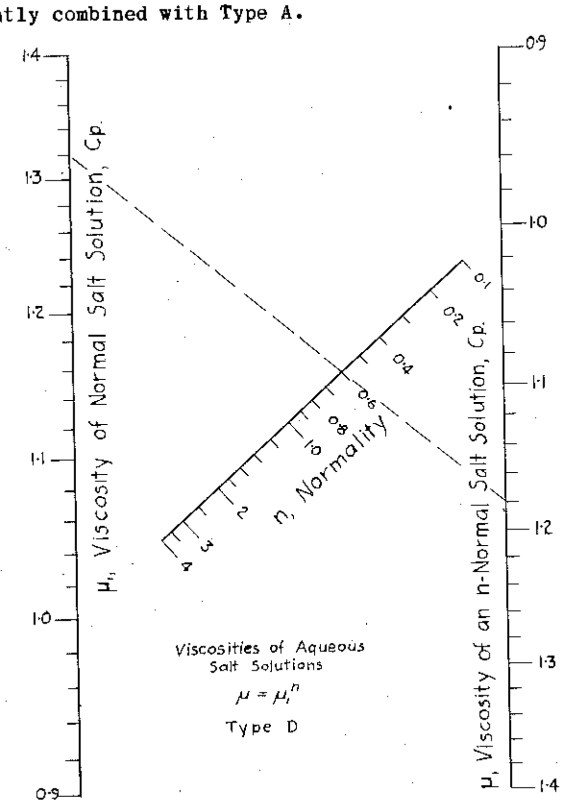


Type B

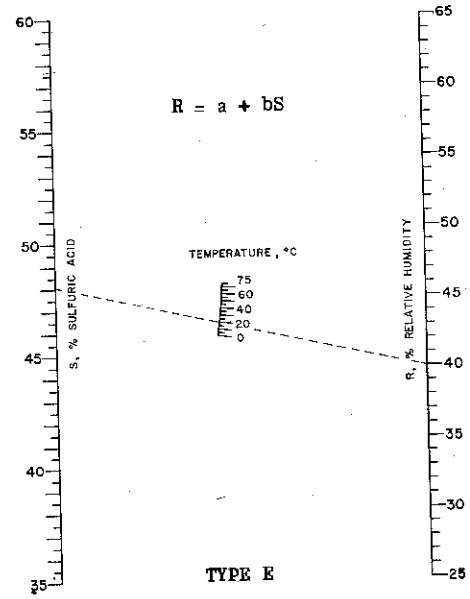
Type C, characterized by the recurrent variable x, leads to parallel y- and z-axes supplemented with an x-axis that is often curved.



Type D employs one diagonal axis and two parallel axes, enables multiplication and division to be performed without resort to logarithmic scales, and is frequently combined with Type A.



Type E, a form adapted to line coordinate methods, is really a variant of Type C. In many instances industry requires nomographs to handle four, five, and six-variable relationships so that combinations of the elementary three-variable forms are necessary.



TYPE E

Figure 1

Figure 1[1], illustrates a Type E nomograph that solves the equation R = a = bS, where R is the percentage relative humidity attained by air bubbled through sulfuric acid of a percentage concentration of S, and a and b depend upon the temperature.

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THE VALUE OF THE CIRCULAR NOMOGRAM TO AN INDUSTRIAL FIRM

by
Edward C. Varnum
Head, Operations Research
Barber-Colman Company, Rockford, Illinois

The primary purpose of a nomogram is to provide rapid numerical answers for problems of a special nature. To an industrial firm such as Barber-Colman Company which employs engineers engaged in development, production, inspection and sales activities, a nomogram has value because of its primary function in the solution of day-to-day problems.

In the case of the circular nomogram a secondary value appears because of its geometric appeal to readers of technical literature and to engineers in customers' plants. A circular nomogram is the most artistic of the various types of nomograms and therefore has an advertising value which transcends its original value as an aid in the easy solution of numerical problems governed by an underlying formula. An example of such a secondary advertising use is the high-quality celluloid Horsepower calculator issued by the Barber-Colman Aircraft Controls Division which solves specification problems for users of our linear and rotary actuators.

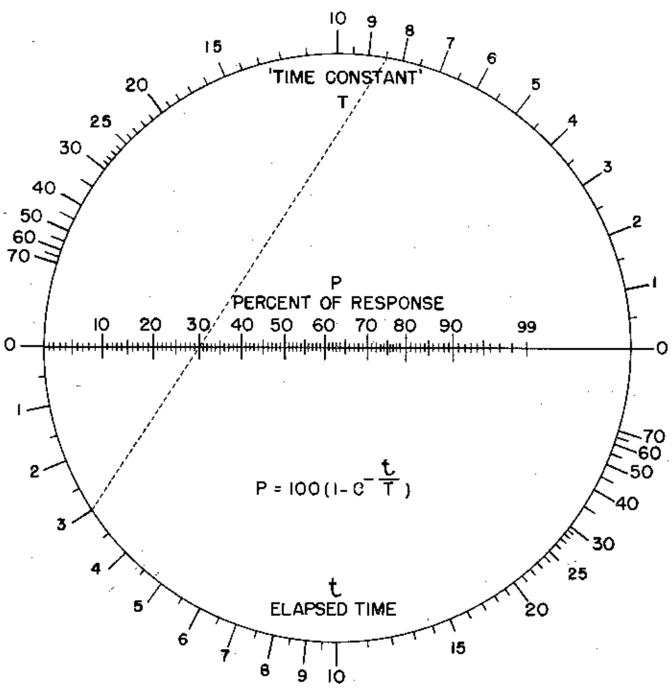

Fig. 1

Figure One is a Time Constant Nomogram which provides a quick check for temperature response tests in which the response system is essentially first order and the input is a step function. For a ramp function input the time constant is the steady-state time lag. This nomogram may also be applied to other situations in which the equation $P = 100\ (1-e^{\frac{t}{T}})$ is basic. In radioactive decay, for example, the concept of "half-life" is used rather than "time constant". By drawing a line through the 50 per cent response mark we see that a half-life is approximately seven tenths of a time constant. This nomogram is useful to Barber-Colman enginners conducting response-time tests for temperature sensitive elements and designing temperature control circuits. This nomogram may also be used to obtain the time constant from incomplete response data if two responses and their respective times are known by trial and error assumption of maximum responses until both sets of observed data yield the same time constant.

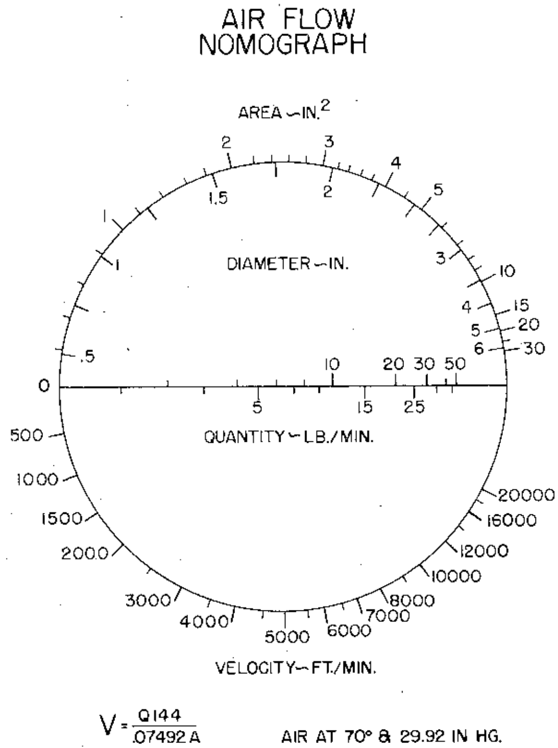

Fig. 2

Figure Two shows an Air Flow Nomograph prepared by Mr. Wayne A. Ringoof our Aircraft Controls Development Department for relating Diameter or Area of duct, Quantity of air, and Velocity of air. On the nomogram prepared for in-plant use the following notes are given: "When solving for Q and air is not at std. density, multiply Q by density factor. When solving for V and air is not at std. density, divide V by density factor. Density factor $= \frac{\text{density, lbs/ft}^3}{.07492}$." Mr.Ring has made other circular nomograms for use at Barber-Colman Company and has published several non-circular nomograms, References 3-5.

The two nomograms above are related to our Aircraft controls development and design. We also produce air distribution equipment for various types of rooms ranging from staterooms on the U.S.S. United States to White House rooms on Pennsylvania Avenue. To study these applications we construct full-scale room models in our large Air Distribution Laboratory which is 50 feet wide, 100 feet long and 15 feet high. In connection with an air distribution study for one of the local hospitals, Rockford Memorial, our acquaintance with Dr. Samuel

Natelson, their Chief Biochemist, lead to the preparation of two circular nomograms on medical subjects. Figure Three shows one of these nomograms which was published by Drs. Natelson and Barbour in Reference 6 and later adapted for a publication by Drs. Natelson, Crawford and

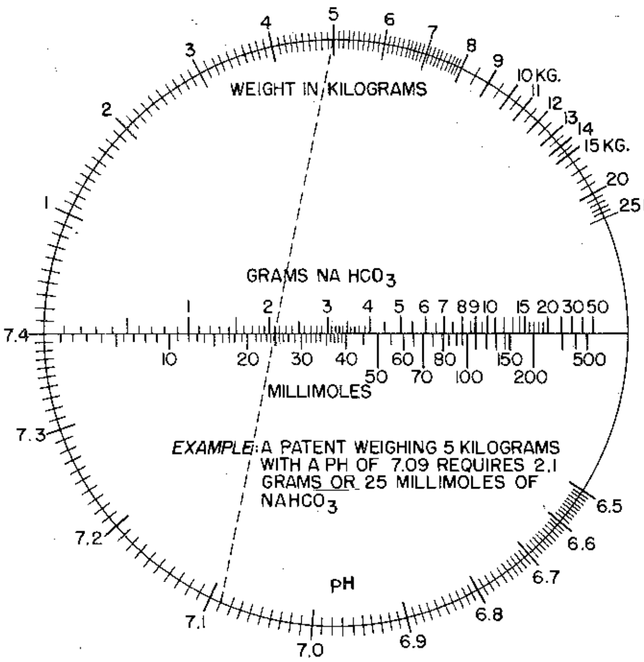

Fig. 3

Munsey on premature babies, Reference 7. The value of circular nomograms is unique for publicity purposes, especially when designed for interests of customers. The medical nomogram deals with a topic far removed from Barber-Colman's primary products but serves to illustrate the universal applicability of nomography. Reference 9 also demonstrates this wide usefullness of nomograms.

We are currently drawing a circular nomogram for finding the length of a downward blown jet of heated air. The basic formula was developed from research work at Kansas State College in Manhattan, Kansas under the direction of Professor Linn Helander and sponsored by the American Society of Heating and Air Conditioning Engineers. One of our preliminary nomograms had four scales on the upper semicircle and two scales on the lower. Recent simplifications and approximations have reduced the number of scales to two on each semicircle with only two drawn chords necessary to evaluate the required jet length.

For those interested in the geometrical theory of circular nomograms and in the detailed method of making them, reprints of Reference 1 are available from the author upon request. We recommend Reference 2 for a complete description of circular nomograms in Chapter XVII. Professor Adams, who is sharing this session with us, is a co-author of References 2 and 8 and has also published Reference 9 which is a comprehensive survey of nomography. As a tribute to the excellence of the Review of Scientific Instruments article we mention that our interest and use of circular nomograms arose from reading the article on May 10, 1949. Few articles in the literature have such far-reaching effects.

References 10, 11 and 12 indicate circular nomograms published in the literature dealing with the Gaussian distribution curve, statistical control charts for fraction defective, and the t-test for significance of the difference of means, respectively. Reference 13 describes straight-line, curvilinear and Lo-Ho nomograms as well as circular nomograms designed at Barber-Colman Company.

Conclusion: We have shown severel uses of circular nomograms for inplant and advertising uses at Barber-Colman Company. In contrast to other types of nomograms, the circular variety has an artistic appearance particulary suitable for publicity purposes. Like all unique features, this value will diminish when other firms also publicize this type of nomogram under this Company name. The abiding value in this event will be our reputation as a leader and pioneer in new fields.

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HAVE YOU SEEN THE ANNOUNCEMENT OF THE NOMOGRAPHY PRIZE ON PAGE 31? Articles on any topic received by December 15 will be considered for the February issue of the JOURNAL.

See page 39 for the Editor's address.

REQUIREMENTS OF A TOLERANCING SYSTEM

By

Earl D. Black

General Motors Institute

It is the principal function of the designer or draftsman to express engineering ideas by way of engineering drawings that are precise instruction to ultimate manufacture of interchangeable parts. These parts must be presented to the customer at a cost--and with satisfactory service--that will encourage a continuous market for the product.

Limits and tolerance dimensioning is the controlling factor in ultimate manufacturing of a product.

There are no absolute rules or formulas in use today for establishing limits and tolerances for all phases of engineering. However, drawings are widely used and exchanged between industrial firms. The frequent exchange of engineering personnel also creates the perpetual problem of coordinating the thinking that is involved between the designer, draftsman, toolmaker, and production, inspection and service departments of one industry with those of others.

Dimensioning engineering drawings for satisfactory control of fabrication and interchangeability depends on at least four major considerations. The omission of any one of these considerations in any system of controlled dimensioning will result in undesirable inaccuracies under critical conditions.

First, the function of the part is the first consideration. A number of the questions regarding material quality and shape may be answered readily when the function of the part is thoroughly explored. Is the part for stationary use? Is the part to be permanently fixed or disassembled? Is the part to slide against another part of similar or contrasting material? Or perhaps the part is to roll under assembled operating conditions. If the part must slide in operation, what is the effect of heat and expansion due to friction under dry or properly lubricated conditions? What is the age expectancy of the part? Is the part to remain in assembled position by pure friction or some other fastening device? Perhaps the part is to be assembled with other parts in a combination of conditions.

What is the general appearance desired in the part? What is the strength required? What of operating clearance? How about special finishes? And above all, how about replacement and servicing of related parts?

Second, the size or mass, shape, and material conditions must be considered. Is the blank for the part to be fabricated from material that is small or massive, thick or thin, rigid or pliable? Is the blank spherical, cylindrical, prismatic, or what is the ultimate shape of the part? Is the material soft or hard, elastic or brittle, ductile or resilient, porous or fine grained? What internal strains exist in the part as a result of previous manufacturing processes necessary to achieving the blank size and shape? Does the material retain its original condition or does it change with age and atmospheric or climatic conditions? What is the effect of heat expansion on the material?

Third, fabricating processes have their special limitations. How is the part to be made, by a single process or a multiple series of processes, and if multiple what of accumulative tolerances? Is it to be cast? If so, is it by sand mold, plaster mold, die mold, semi-permanent mold or by centrifugal forces?

Is the part to be forged? Is it made by drop forging, pressing, rolling, up-setting, or by extruding?

Is the part a stamping? Is it made by bending, drawing, blanking, punching, or trimming? How many of these operations are involved and what is the effect of one manufacturing process upon the others?

What are the machining operations performed upon the part? Is it to be a snagging operation, a saw cut, a torch cut, or is it to be a finer finish as by turning, shaping, milling, boring, drilling, reaming, grinding? Perhaps the desired final condition may require a hone finish or a special polishing operation to give a super finish. Just how is the part to be checked for accuracy, and what of the variables in the checking device?

Fourth, what are the dimensions on the drawing that must give specifications for securing the answers to considerations one, two and three?

There are three classifications of methods of dimension control for positional tolerances: (1) dimensioning for use; (2) dimensioning for manufacture; (3) dimensioning for inspection.

Dimensioning for use more nearly suits the designer. It is his objective to design a part or assembly of parts that may be produced at a cost that will encourage public use. Any other objective is incidental and subordinate; otherwise his job as a designer will cease to exist.

Positional tolerances are given for assembly and operational conditions. The degree of accuracy which is essential to the functional requirements of each detail part must be carefully analyzed. The more permissible limits or tolerances, the lower the costs to produce the part as this permits diverse methods of manufacturing. Metal scrap, expense for tools, and labor costs may be reduced.

Dimensioning for manufacture is used by the layout man man or tool maker who has the first responsibility of producing the tools with which the part is to be made. All dimensions for his use must be within the limitations of his current manufacturing processes.

Any system for limits and tolerances, to be practical, must be based on current successful manufacturing practices. Possible variation in parts may cause interference or undesirable conditions. Accumulation of these variations may be greatly controlled by intelligent dimensioning of mating parts.

Dimensioning for inspection must be keyed into the inspection equipment with with inspection is to be performed/ The cost of a super-accurate instrument used to check the parts must be taken into account. Where a part may be simplified to arrive at a satisfactory result and avoid expensive inspection equipment, it is the duty of the designer and his staff to make these changes.

CONCLUSION

Any successfuly tolerancing system must answer the numerous questions arising from considerations regarding (1) function of the part or parts being manufactured, (2) material quality, mass and shape, (3) fabricating processes and finish results desired, and (4) positional tolerances that normally result in limit accumulations. Satisfactory solutions must be recorded on the detail or asembly drawing through notes and specifications. Any other procedure is reverting backward to the "trial and error" method of manufacturing which engineering drawing is supposed to prevent.

CHANCES ARE 100 to 1
That You have Some Answers:

- —— How do you challenge the interest of exceptionally good students?
- —— Why do you Boost - or Blast - "Simplified Drafting?"
- —— How do you feel about nomography in your courses?
- —— Should we concern ourselves with "the needs of industry" or with "the needs of the student" or are they one and the same?
- —— Why teach descriptive geometry?
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- —— Should high school drawing be required of entering freshmen engineers?
- —— If so, how do we judge the quality of the high school work?

The editor of the JOURNAL OF ENGINEERING DRAWING is eager to read your answers and your thoughts on these questions. Put your ideas down on paper and mail them in without delay.

The supply of material worthy of publication in the next issue is low. Get on the ball point pen, goose quill, or typewriter and flail away. You will be writing not for money but for posterity.

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The JOURNAL OF ENGINEERING DRAWING is constantly on the prowl for material suitable for publication. If you have any reservations about the suitibility of your ideas for JOURNAL readers, put your ideas into writing and send them along for the editorial board to judge. Every communication will be acknowledged promptly with appropriate comments.

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

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WOULD YOU CARE TO MAKE A STATEMENT

Do you teach engineering drawing? Do you teach descriptive geometry? Do you teach engineering graphics? If so, the chances are good that you have something you'd like to say to teachers of other engineering subjects about the relationship of your subjects to theirs in the education of engineers.

The "T-Square Page" of the JOURNAL OF ENGINEERING EDUCATION is devoted to the interest of the Division of Engineering Drawing. The T-Square Page is an excellent medium, especially since the articles are written by teachers of drawing and descriptive geometry for a captive audience of our colleagues in other subject-matter fields. We have them where we want them!

If you have anything to say that you consider suitable for the T-Square Page, put it in writing and send it to Professor Albert Jorgensen, University of Pennsylvania, Philadelphia, Pa. The topic will be suitable if it's something that teachers of other engineering subjects ought to know-- anything that will further the interests of our Division. Your contribution should be about 550 or 600 words in length. If you can't possibly condense it to a single page, sometimes the editor has given us more than a page when something important comes up. But generally keep it short.

Would you care to make a statement? Make it on paper and send it to Professor Jorgensen.

HAVE YOU RENEWED YOUR SUBSCRIPTION ?

INDEX TO 1955, VOLUME 19

Compiled by

Irwin Wladaver
New York University

GUIDE TO THE INDEX:

Each entry is accompanied by a notation such as "N 55,14." This means that the item is in the November 1955, issue and that it begins on Page 14. F = February, M = May, and N = November.

SUBJECT INDEX:

In certain cases, changes in titles have been made where original titles were not sufficiently indicative of the content. Articles dealing substantially with several topics appear under several headings.

AUTHOR INDEX:

With few exceptions, titles in the Author Index are entered the way they appeared in the Journal.

SUBJECT INDEX

AUTHOR INDEX

BRADDOCK LETTERING ANGLES

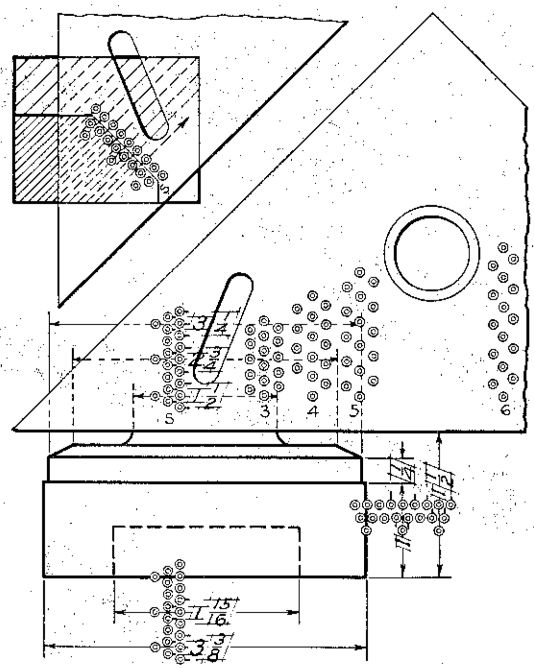
VERSATILE LETTERING TRIANGLES FOR

SYSTEMATIC DIMENSIONING

UNIFORM LETTERING

ACCURATE SPACING

PRECISE DRAWING



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6"-60
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8"-60
9"-60
4"-45
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7"-45
8"45

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9"-60
4"-45
5"-45
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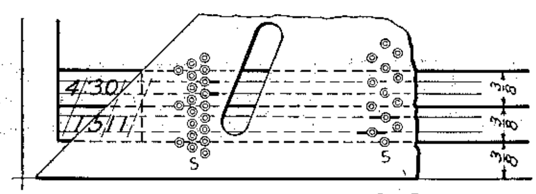

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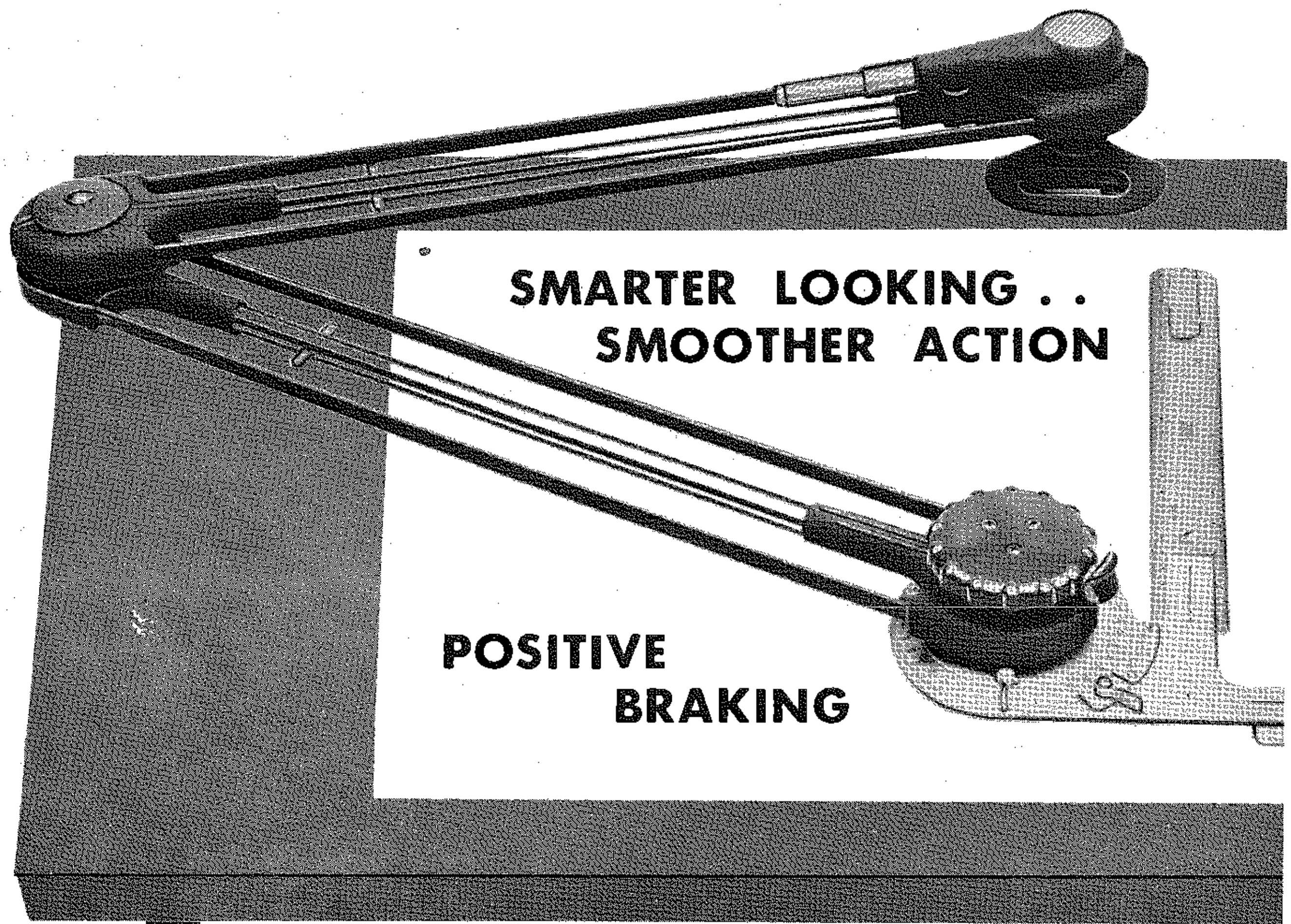

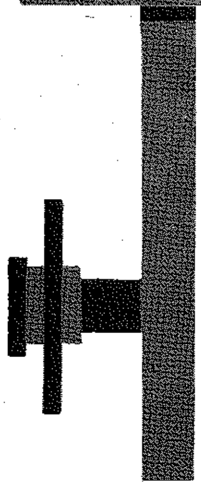

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