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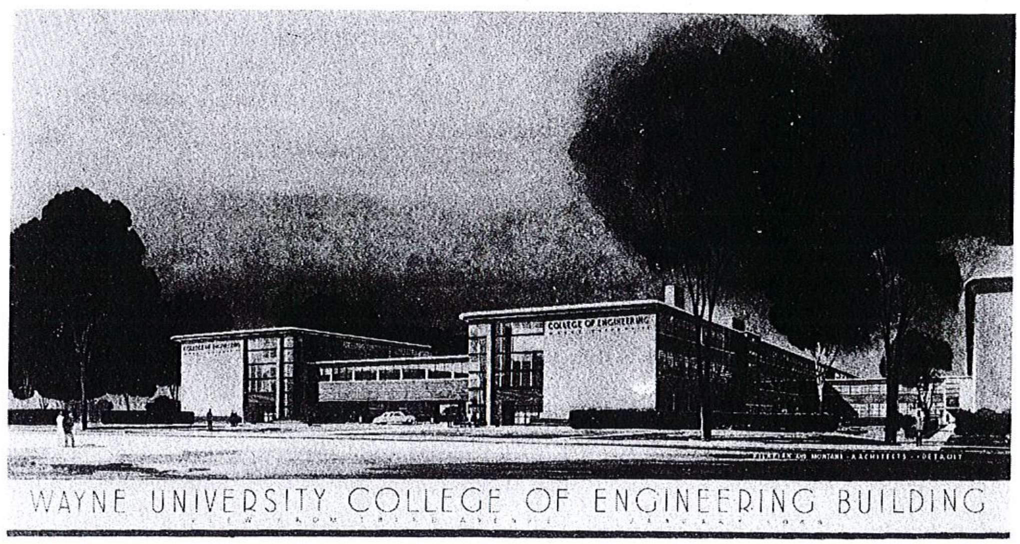

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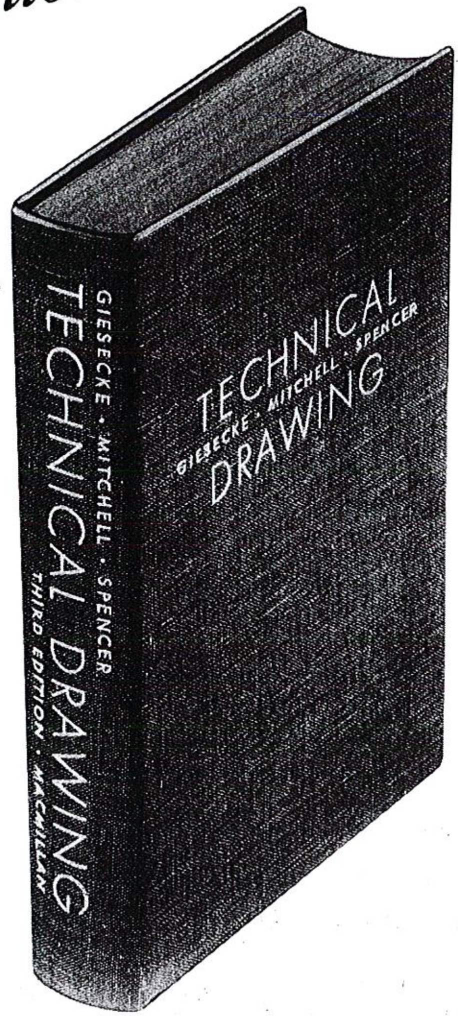

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by

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New Problems . . . All problem layouts have been changed to agree with the American Standard size of 11″ x 17″ or 8½″ x 11″. There are many new and better problems throughout with 50% more auxiliary view problems and almost twice as many new sectioning problems with emphasis on the more advanced type of problem.

New Material . . . Many new articles have been added on dimensioning, almost trebling this section. A completely new article on "Axonometric Projection by the Method of Intersections" has been added on the relatively new development in the field, presenting it from a new and simplified approach which makes trimetric drawing about as easy as isometric drawing. A wealth of information has been added in a new section on Shop Processes.

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JOURNAL OF ENGINEERING DRAWING

PUBLISHED IN THE INTEREST OF TEACHERS OF ENGINEERING DRAWING AND RELATED SUBJECTS

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CONTENTS

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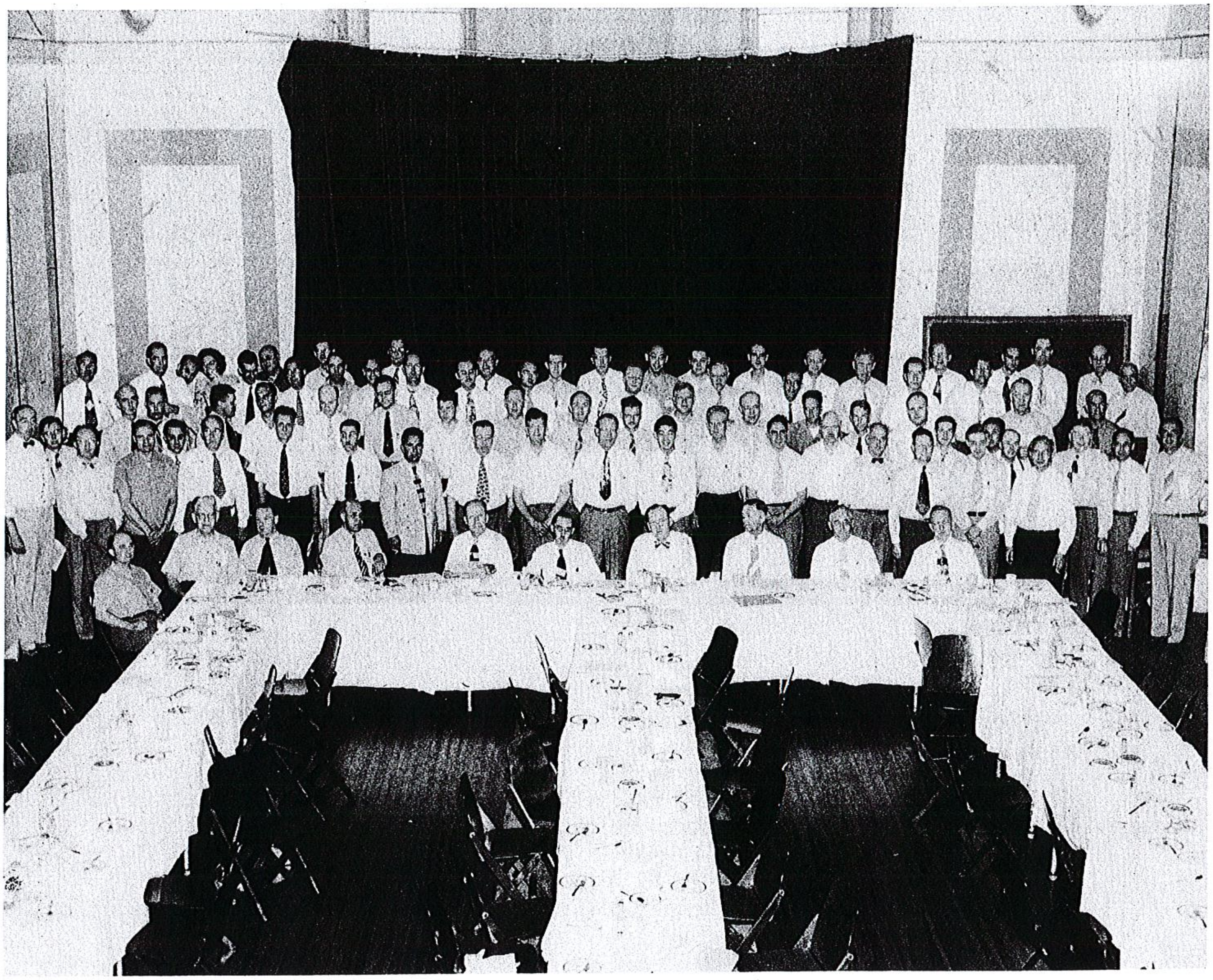
PUBLISHED IN FEBRUARY, MAY, AND NOVEMBER BY
THE DIVISION OF ENGINEERING DRAWING AND DESCRIPTIVE GEOMETRY OF THE
AMERICAN SOCIETY FOR ENGINEERING EDUCATION



DIVISION OF ENGINEERING DRAWING, ASEE
FIFTY-SEVENTH ANNUAL MEETING
RENSSELAER POLYTECHNIC INSTITUTE — TROY, NEW YORK
June 20-24, 1949

REPORT OF THE MEETING OF ENGINEERING DRAWING DIVISION

by

Professor O. W. Potter, Secretary
Renssealaer Polytechnic Institute, Troy, New York
June 20-24, 1949

This year our host was the Rensselaer Polytechnic Institute located at Troy, New York just across the river from Albany, the capital of empire state. Located in the hills above the city we found ourselves going up or down stairs most of the time. Take it easy was the by word. The first two days were hot as it seems to be at this time of the year. A good heavy shower early Wednesday morning cooled things off some and the balance of the time was quite comfortable.

A most interesting program was presented and for the benefit of those who were not able to attend it is listed below.

Monday 6/20. Afternoon Conference.

Papers.

1. Ellipse Guides
   J. G. McGuire, Texas A & M College
2. Foreign Drafting Practices
   T. C. Brown, North Carolina State College
3. S.A.E. Drafting Standards
   J. H. Hunt, General Motors Corporation
4. Z14 Progress Report
   R. P. Hoelscher, University of Illinois
5. General Discussion

Tuesday 6/21. 12:30. Luncheon and Annual business meeting.

Reports of Committees.

1. Constitution and By Laws - Justus Rising
2. Election Committee - O. W. Potter
3. Advanced Credit - R. S. Paffenbarger
4. Advance Graphics - F. A. Heacock
5. Bibliography - H. E. Grant
6. Exhibit - James Rising
7. Publishing Board - R. T. Northrup
8. T Square Page - W. J. Luzadder

Wednesday afternoon conference. 6/22/49.

Papers.

1. Visualization
   Mary Blade, The Cooper Union
2. Welding Symbols
   Allen C. Craig, General Electric Company
3. Logic of Multiview approach in Descriptive Geometry
   B. L. Wellman, Worcester Polytechnic Institute
4. General Discussion

The papers were well presented and were both interesting and instructive.

The Display Committee (James Rising, Chairman, H. G. Kinner, W. E. Street) presented a most interesting exhibit. This comprised a display of old drawing instruments obtained from the Metropolitan Museum of Art, New York City, and Theo Alteneder and Sons, new instruments from Germany by the Gramercy Import Company. Also displayed were a number of historic books on drawing from various sources. Professor T. C. Brown's collection of foreign drawings was most interesting. There were drawings from Brazil, China, Cuba, England, Estonia, Greece, India, Italy, Norway, Siam, South Africa, Sweden, Switzerland, and Turkey.

There was also a good display of students current work in Engineering Drawing from a number of Engineering Schools.

The entire exhibit was very good and the committee is to be complimented for their fine job.

In addition to the schedule program there were committee meetings, entertainment, etc.; there is something doing all the time. If you haven't attended these meetings you are missing something.

(Continued on page 34)

ENGINEERING DRAWING DIVISION, ASEE MID-WINTER MEETING

Host Institutions

University of Illinois, Chicago Branch
Illinois Institute of Technology
Northwestern University

TIME: January 19, 20, 21, 1950

Details of our program are not available at the time the copy must be submitted for this issue. The general plans contemplate a plant visitation Thursday afternoon, January 19.

Friday will be devoted to a visit to one or more schools in the area, and also to the Eugene Dietzgen Manufacturing Company. Dinner meeting and program Friday night.

Technical session Saturday morning, and a concluding luncheon meeting Saturday noon, January 21.

You are invited and urged to attend. If you wish specific details, write to Professor C. I. Carlson, University of Illinois, Navy Pier, Chicago, Illinois.

THE THEORY OF THE ELLIPSE GUIDE

by

J. G. McGuire, Texas A & M
American Society for Engineering Education Drawing Division
June 20, 1949

Drawing ellipses by the aid of the irregular curve has always been a source of irritation for most draftsmen. Accordingly, though this method is essential for desired results for some jobs, several devices have come into use that tend to lessen the drudgery in drawing an ellipse. The ellipse guide is one of the most important of such developments. The guides are a real time saver for the draftsman. They are of particular value in drawing axonometric projections that involve cylindrical details. Furthermore, the ellipse guides are of great value, when properly used, as aids to the student in learning some of the basic principles of projection as taught in Descriptive Geometry. To use the guides, however, without resorting to trial and error, the draftsman must have a good knowledge of projections.

The Lietz ellipse guide set is one of the most commonly used. The STANDARD set (small series) has ten templates with from 19 to 27 holes per template. The templates range from 15° to 60° with increments of 5°. The major diameters on the small series range from 1/8" to 2". Although, the set just described is sufficient to take care of most ellipses for the ordinary drafting room, there is available a large series of ten templates made to complement the small series. The large series has ellipses with major diameters ranging from 2-1/8" to 4".

Figure 1 shows the 60° template with ellipses that have major axes ranging from 1/8" to 2". The angle stamped on the ellipse guide indicates the angle of tilt of the line of sight to the plane of the circle that the ellipse guide represents. The numeral under each ellipse indicates the major axis of the ellipse or the diameter of the circle that the ellipse represents.

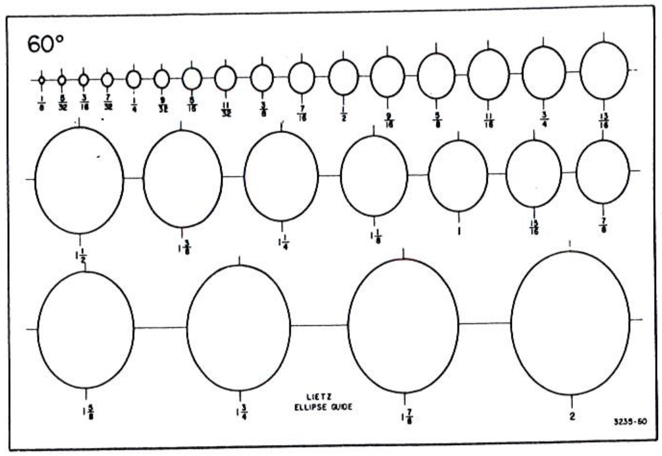


Fig. 1

In determining the proper ellipse guide to use for an ellipse it is best to consider the ellipse as being an oblique view of a circle. In Figure 2, the true and edge views of a 2" circle are shown. The line of sight makes 60° with the edge view of the circle; therefore, the 60° guide would be selected. Furthermore, the 2" hole would be used since the ellipse to be drawn represents a 2" circle. A simple rule, therefore, for determining the ellipse guide for a particular view of a circle is to determine the angle between the plane of the circle and the line of sight for that view. Figure 3 shows an application of this rule for drawing a dimetric projection. As indicated in Figure 3 the primary auxiliary view is drawn using the 45° guide. Since the plane of the circle shows as an edge in the top view and the line of sight shows the true length, the ellipse guide angle for the primary auxiliary view may be obtained directly from the top view. On the other hand, the determination of the ellipse guide for dimetric projection (secondary auxiliary view in this case) requires an additional step although the principle is

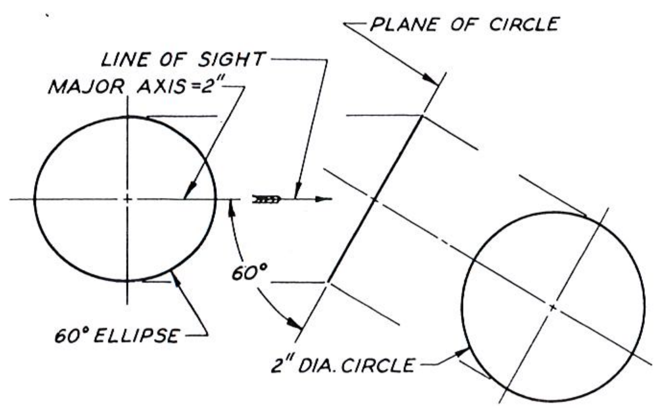


Fig. 2

the same. In this case the true angle between the line of sight for the projection and the plane of the circle is 31°; therefore, the 30° guide was selected.

Figure 4 shows a problem that was used in one of our freshman drawing classes at the A. & M. College of Texas. The students were given a picture with the necessary dimensions. They were asked to make a complete working drawing. Furthermore, the students were required to draw all views (with exception of end view) completely in order to further their training in the theory of projections and to demonstrate the value of the secondary auxiliary view as an aid to the visualization of the object. At "A" in the primary auxiliary view the 30° template was selected and the 7/16" hole was used. It can be seen that the line of sight for the primary auxiliary view shows true length in the top view. Also, the plane of the circles projects as an edge in the top view.

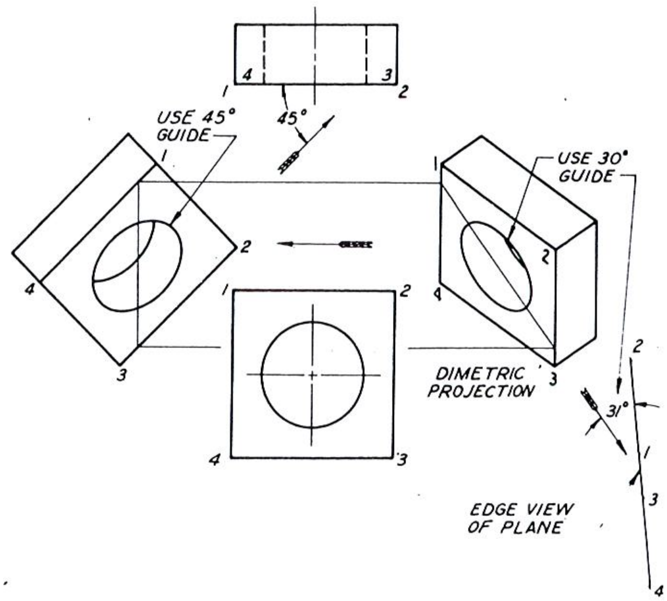


Fig. 3

At "B" in the primary auxiliary view the plane of the circles projects as an edge and the line of sight for the secondary auxiliary view shows true length which indicates the 45° template.

For the 7/16" holes at "C" on the secondary auxiliary view, it is necessary to draw another view in order to determine the angle between the line of

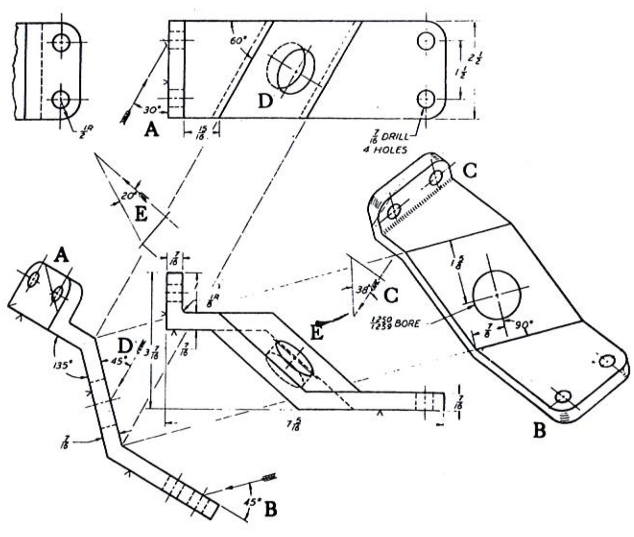


Fig. 4

sight and the plane of the circles. Although the angle at "C" measures 38°, the 40° template gives a very satisfactory representation of the 7/16" holes.

The $1\frac{1}{4}$" diameter hole at "D" in the top view may be drawn by using the 45° template as indicated at D in the primary auxiliary view. The 20° template for the front view at "E" was determined by drawing an auxiliary view in a manner like the method used at C.

This principle also can be used very readily on the conventional type of axonometric projection - where only one view is available. The three axes for trimetric projection may be assumed as vertical, 15° with horizontal and 45° with horizontal, respectively, as shown in Figure 5 (a). The plane of the circle is revolved to the true size position and then projected to appear as an edge. The line of sight makes 49° with the plane of the circle; therefore, the 50° guide was selected for the trimetric projection shown in Figure 5 (b). The draftsman can easily perform all the required construction on one view.

A better understanding of the method used in the previous example may be had by thinking of the object as a cube (Figure 6) that has been pushed part of the way through the frontal plane. Angles Θ and $\emptyset$ selected as indicated in Figure 6 will give isometric, dimetric or trimetric projection as desired. It can be seen that the lines of intersection between the faces of the cube and the frontal plane are true length. Figure 7 shows the three faces of the cube revolved about the true length lines into the frontal plane where they appear true size. Auxiliary views are then drawn so that the true length lines appear as points. These auxiliary views show the line of sight true length and the respective surfaces of the cube as edges. The angles shown in the auxiliary views (Figure 7) are the respective angles of ellipse guides to use for circles that may appear in the three faces of the cube. Figure 8 is an application of this method for determining ellipse guide angles for a trimetric projection.

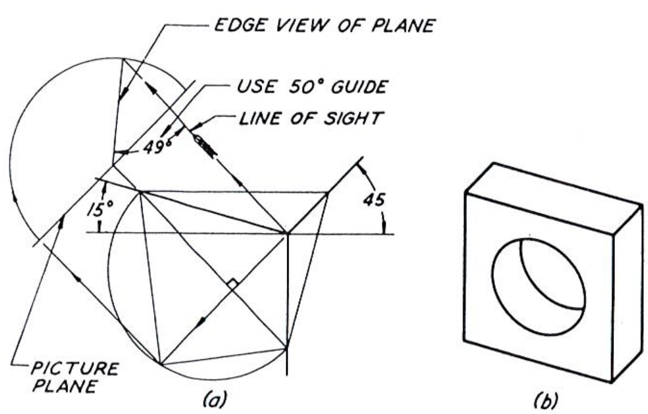


Fig. 5

(Continued on page 30)

VAN NOSTRAND FOR COLLEGE TEXTS

TECHNICAL DESCRIPTIVE GEOMETRY

By

PROFESSOR WILLIAM E. STREET

Head of the Engineering Drawing Department, Agricultural and Mechanical College of Texas

PREPARED for the regular descriptive geometry courses usually offered in the latter half of the freshman or sophomore year. *This* text provides a *new approach* to the subject and *develops the draftsman's method* of treatment in obtaining size, shape and position of every detail of structures and machines. Written in clear, concise, style employing use of problems and illustrations compounded by men close to engineering companies.

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CONTENTS: Projections; Primary Auxiliary Views, Successive Auxiliary Views; Revolutions; Developments; Intersections; Perspective; Shades and Shadows; Force Diagrams; Loaded Structures.

ILLUSTRATIONS, PROBLEMS are arranged in progressive order depending upon the method of solution. Material is also grouped for easy transition for the student who has one or more semesters of college drawing as follows: (1) illustrations using straight orthographic projection; (2) illustrations involving primary auxiliary projection and (3) illustrations using successive auxiliary projection.

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SOME RELATIONSHIPS BETWEEN DESCRIPTIVE GEOMETRY AND MECHANICS AND DESCRIPTIVE GEOMETRY AND MATHEMATICS

by
Prof. W. Harold Taylor

Introduction

For some time it has been apparent that many faculty members of our engineering colleges have not observed that Descriptive Geometry is a course closely related to several branches of engineering education.

It is the object of this paper to bring to the attention of teachers of Graphics, a few of the relationships which exist between Descriptive Geometry and Mechanics and Descriptive Geometry and Mathematics. It also introduces some ideas which it is hoped will stimulate research and study in the graphic solution of engineering problems.

Graphic solutions are recognized to be correct only to the degree of exactitude of the drawing. In at least one airplane plant the contours of an airplane fuselage are graphically solved to tolerances of one thousandth of an inch.[1] It is apparent, therefore, that graphic solutions may be employed to a considerable degree of accuracy. The accuracy of graphical solutions may be refined to limits well within the variation of physical strength factors of most of our materials and in many instances are closer to exact than is the theory on which much of our engineering design formulae depend.

Granted that graphics are very nearly exact and that our graphic solutions are at least good checking media for design let us consider some of the relationships with other fields of engineering curriculae, already mentioned.

Descriptive Geometry and Mechanics

Descriptive Geometry in general deals with points, lines, planes, surfaces and solids in space. Let us narrow our consideration for a short time to that of straight lines in space. Any straight line in space may be projected on three planes mutually at right angles. Any two of these projections will define the line generally. The angle which the line makes with the horizontal and vertical planes of projection and with the profile plane may be readily found. Conversely, if the magnitude of the line and the angles which it makes with the planes of projection are known, then the plan, elevation and profile projection of the line may be determined.

A method for using the foregoing principle for the graphical solution of non-coplanar forces is given by Warner.[2] This author states that, "in electrical engineering this method applies to the solution of electromagnetic or electro-static vectors. Combinations of velocities in mechanisms or space travel may be treated in this way. Likewise moments, rates and other quantities which may be represented by vectors not lying in the same plane may be determined; or if they are known their resultants may be determined by these methods."

Definitely Warner[3] opened, for some of us, a new chapter in graphics with the above statement. Bubb, Schumann and possibly others have taken cognizance of this problem in mechanics. It is doubtful if many of our faculty members in Mechanics, Electrical Engineering or in Mechanical Engineering have utilized to its full extent the graphical solutions in teaching the subject matter of their courses.

Students well trained in Descriptive Geometry have noted that many problems in statics are readily solved by Descriptive Geometry methods in considerably less time than analytic solutions and that quite frequently a combination of graphic and analytic methods yields a still quicker solution.

The solution of forces in a frame symmetrical about an axis such as in a circular or parabolic dome, the nose of a rigid dirigible airship or other frame of such nature is not readily solved analytically. When such structures are built it is not infrequent practise to approximate by using a series of relatively short straight chords with a group of four planes adjacent to any joint as is illustrated in Fig. 1.

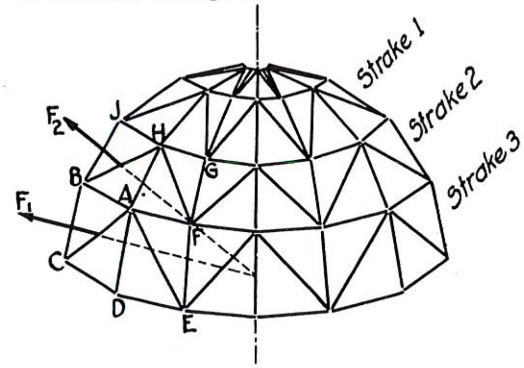


Fig. 1

A series of forces AB, CA, DA, EA, FA, HA are all contributory to the equilibrium of the point A. These forces may be reduced to equivalent forces in three planes mutually at right angles. However, the forces in AB, for example, are contributed from the areas ABJH and ABCD. These areas may each be represented by a vector through the centroid of each surface and normal thereto, as F_1 and F_2. It is evident that all the forces in the Strake 1 will pass through a common point in the central axis of the structure. Similarly all the forces in the normal surfaces of Strake 2 will pass through a common point. If the structure is spherical then will all the surface vectors pass through a common axial point. If it is some other curve such as a parapola or hyperbola then will all the normals not meet in a single point?

From these normal vectors may be obtained magnitudes which represent the resultant or equilibriant forces between adjacent planes. The idea of two shells forming such a dome may be utilized, one shell to carry the forces in line with the Strake and the other to carry the forces meridianally. When these are added together for any two surfaces they indicate the forces which must be transmitted by the member common to them. The whole structure then builds up a series of loads to be transmitted to the circumferential support structure at the base of the dome.

No attempt is made in this paper to follow through such a type solution. It is lengthy but solves the problem in much shorter time than the analytical solution. Problems of these types are mentioned here solely to stimulate thinking and research along these lines.

[1] S.A. Coons, "Graphical and Analytical Methods as Applied to Aircraft Design," Journal of Engineering Education, Vol. 37 (June, 1947), p. 858.
[2] Frank M. Warner, Applied Descriptive Geometry with Drafting Room Problems, 1st. Ed., 1934, Chapter V, pp. 73 et sub.
[3] The author does not have sufficient references to determine the originator of the application of descriptive geometry to the space force system. If Warner was not the originator, the author apologizes.

(continued from page 9)

Descriptive Geometry and Mathematics

In our definition of Descriptive Geometry we state that Descriptive Geometry is that branch of mathematics which deals with the representation of points, lines, planes, surfaces, and solids projected upon plane surfaces.[1] From its definition therefore we should expect a very close relationship to mathematics. Unfortunately, few text books, at least in this country, even mention this fact. The idea seems to have grown that Descriptive Geometry is a graphical method of resolving quantities in plans, elevations and profile or auxiliary projections with no connection whatever to mathematics.

Watts and Rule in their text are a notable exception to the statement above.[2] At the risk of being boring this paper will attempt to condense some of these relationships very briefly.

A basic equation of the straight line in analytic geometry with which every engineering student should be familiar is

$$\frac{X-X_o}{l} = \frac{Y-Y_o}{m} = \frac{Z-Z_o}{n} = r \quad \text{- - - - - - - - - - - - - (a)}$$

where X, Y, Z is any point on a straight line.

X_o, Y_o, Z_o are the coordinates of any known point on the line.

l, m, n, are direction cosines of the angles between the line and the X, Y, Z axes respectively.

and r is the length of line.

We consider a line segment AB, A with coordinates (X_o, Y_o, Z_o) and B with coordinates (X, Y, Z) and with r representing the length AB.

Then $X = rl + X_o$

$Y = rm + Y_o$ - - - - - - - - - - - - - - - - (b)

$Z = rn + Z_o$

It might be noted that for any line in which X_o, Y_o, Z_o and l, m, n, are fixed these equations are parametric with parameter r.

Also it is evident form Fig. 2 that

$[a^h b^h] = r \cos\alpha_H$

$[a^v b^v] = r \cos\alpha_v$ - - - - - - - - - - - - - - - (1)

$[a^p b^p] = r \cos\alpha_p$

Where $[a^h b^h]$, $[a^v b^v]$, $[a^p b^p]$ are the length of the profile, plan and elevation of the line AB respectively.

and α_H, α_v, α_p are angles made by the line AB with the profile, horizontal and vertical planes.

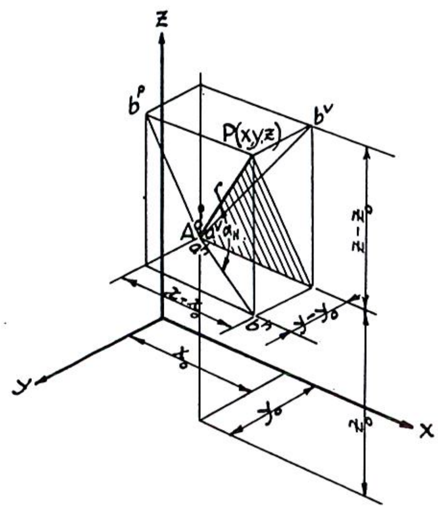


Fig. 2

From plane geometry

$(X-X_o)^2 + (Y-Y_o)^2 = [a^h b^h]^2$

$(Z-Z_o)^2 + (X-X_o)^2 = [a^v b^v]^2$ - - - - - - - - - (2)

$(Y-Y_o)^2 + (Z-Z_o)^2 = [a^p b^p]^2$

Then from Equation 1

$(Z-Z_o)^2 = r^2 - (r \cos\alpha_H)^2$

$= r^2 (1-\cos^2 \alpha_H)$

$= r^2 \sin^2 \alpha_H$

$Z-Z = r \sin \alpha_H$

$Z = Z_o + r \sin\alpha_H$

Similarly - - - - - - - - - - - (3)

$Y = Y_o + r \sin \alpha_v$

Further from Equation (a)

$(X-X_o)^2 + (Y-Y_o)^2 + (Z-Z_o)^2 = r^2$

and substituting values from Equation 3

$(X-X_o)^2 = r^2 - r^2\sin^2\alpha_v - r^2\sin^2\alpha_H$

$X-X_o = r\sqrt{1 - \sin^2\alpha_v - \sin^2 \alpha_H}$ - - - - - - (4)

From Fig. 3, it is evident that

$\frac{X-X_o}{r} = \cos \alpha_X$

$\frac{Y-Y_o}{r} = \cos \alpha_Y$ - - - - - - - - - - - - - - - (5)

$\frac{Z-Z_o}{r} = \cos \alpha_Z$

Where α_X, α_Y, α_Z are the angles between the line AB = r and

[1]Spherical triangles, spheres, surfaces and solids of double curved surface are not included in this paper. Spherical triangles may be solved by descriptive geometry as also may planes tangent to any sphere at any point. Reference to the following texts is invited.

Schreiber - Das Technische Zeichnen - Spizielle Darstellende Geometrie. Published by Otto Spamer, Leipsig, 1864. pp. 631 et sub.

Taylor - Elementary Descriptive Geometry - 2nd Edition. University of Alabama Press.

Watts and Rule - Descriptive Geometry - Prentiss-Hall.

[2]Watts and Rule, Op. cit.

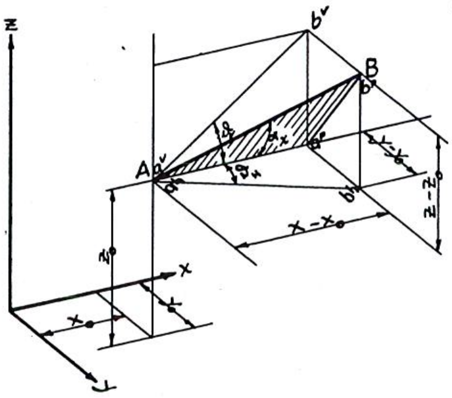


Fig. 3

From Fig. 3, and Equation 5 it is evident that $X - X_o = r^o \cos\alpha_X$ and $Y - Y_o = r^o \cos\alpha_Y$. This is only saying that the distance parallel to the X axis is $r^o \cos\alpha_X$ and parallel to the Y axis is $r^o \cos\alpha_Y$.

If we combine $r \cos\alpha_X$ and $r \cos\alpha_Y$ (Fig. 4) then is

$$\frac{rm}{rl} = \frac{r\cos\alpha_Y}{r\cos\alpha_X} = \tan I_H = \frac{Y-Y_o}{X-X_o}$$

$$= \tan I_V = \frac{Z-Z_o}{X-X_o} \quad \text{- - - - - - - (6)}$$

$$= \tan I_P = \frac{Z-Z_o}{Y-Y_o}$$

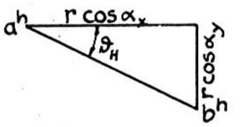


Fig. 4

Where I_H, I_V and I_P are the angles which the plan, elevation and profile projections make with the horizontal ground line.

In Descriptive Geometry we know the quantity $r \cos\alpha_X + r\cos\alpha_Y$ and call it the plan of AB. Similarly we can set up mathematical expressions for the elevation and profile projections.

Turning to the vector representation, consider the well known vector equation

$$A = A_X\hat{I} + A_Y\hat{J} + A_Z\hat{K}$$

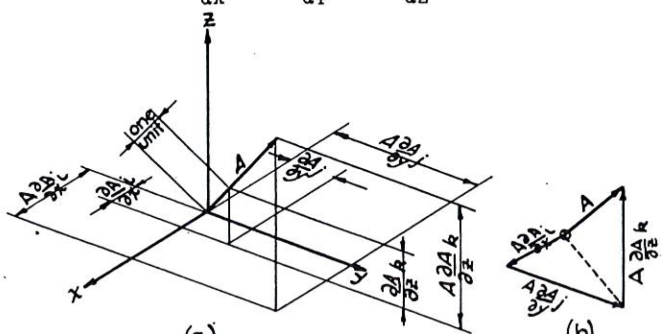
where $\hat{I}$, $\hat{J}$, $\hat{K}$ are unit vectors in the X,,Y, & Z directions and A_X, A_Y, A_Z are components in the directions X, Y, & Z respectively.

If A is a vector quantity associated with an arbitrary point (X, Y, Z) in space

A_X is then $A\,\frac{\alpha A}{\alpha X}$, A_Y is $A\,\frac{\alpha A}{\alpha Y}$ and A_Z is $A\,\frac{\alpha A}{\alpha Z}$

then

$$A = A\frac{\alpha A}{\alpha X}\hat{I} + A\frac{\alpha A}{\alpha Y}\hat{J} + A\frac{\alpha A}{\alpha Z}\hat{K}$$



(a) (b)

Fig. 5

Again we note that these three components may be represented graphically as shown in Fig. 5(a).

Graphical combination is shown in Fig. 5(b).

Now supposing that our origin is translated with respect to H, V, and P orthogonal planes so that O is now a point in space.

Fig. 6.

The vector sum of $A\frac{\alpha A}{\alpha X}\hat{I} + A\frac{\alpha A}{\alpha Z}\hat{K}$ is the elevation and

the vector sum of $A\frac{\alpha A}{\alpha X}\hat{J} + A\frac{\alpha A}{\alpha Y}\hat{J}$ is the plan and

the vector sum of $A\frac{\alpha A}{\alpha Z}\hat{K} + A\frac{\alpha A}{\alpha Y}\hat{J}$ is the profile

view of A.

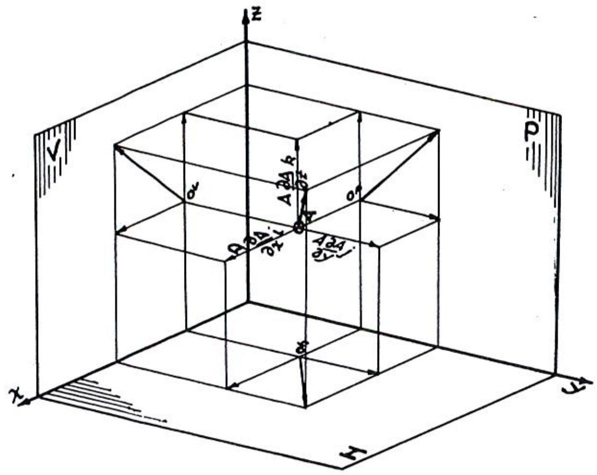


Fig. 6

This simply brings us back to another way of combining these components to plan, elevation and profile from which we can graphically define the vector or force A.

These two examples are but a few of the many connections with the field of mathematics. These, it is hoped, will form a basis for stimulating thought on how to extend our thinking in this field of endeavor.

Relationships with Other Fields of Endeavor

Smalley has shown in his master's thesis that Descriptive Geometry methods may be utilized in the field of Industrial Engineering. Smalley used a moving picture film on which he had first projected a grid system for reference, to study the motion of an object in terms of space movement, such as a person's hand. He shows that a sort of personal movement factor can be developed allowing for set tolerances or motion and arrives at an efficiency of operation based on these concepts. It is a pleasure to be able to announce that Smalley was connected for a time with the Author's department.

Conclusion

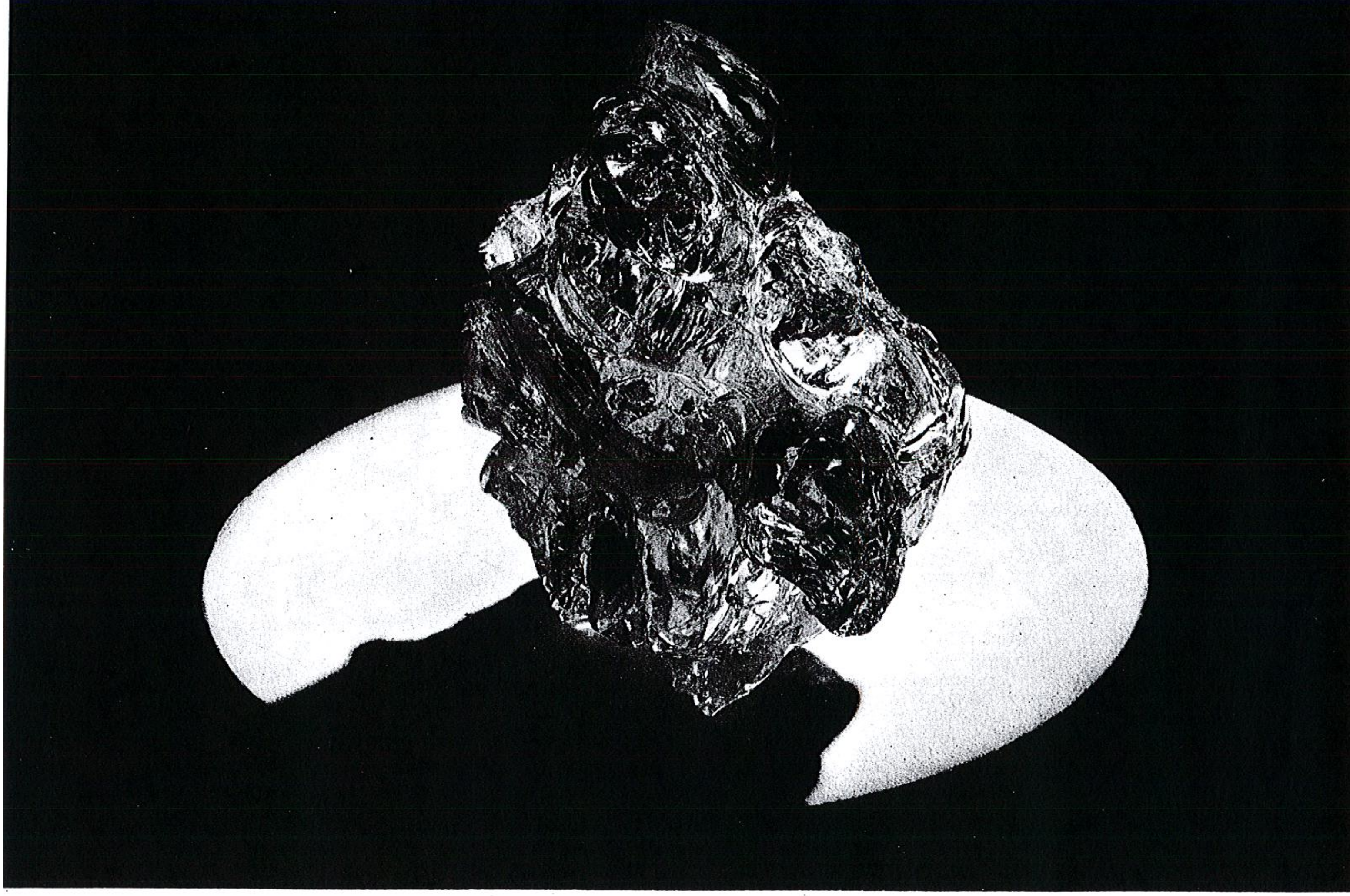
Graphical solutions of concurrent non-coplanar forces can be readily solved. Likewise other vector quantities may be similarly treated.

A method for the solution of framed shells of revolution has been indicated.

The significance of terms in our basic analytics and vector analysis has been presented.

From the above it is evident that in the teaching of Descriptive Geometry the usefulness of this course in other courses should be realized and emphasized. In return these other courses will utilize this material for ready solutions or as a checking medium. The accuracy of the check depending on the accuracy of the plot.

BALANCE DOES IT



(PHOTO COURTESY CORNING GLASS WORKS)

THEY are making glass perform feats it never performed before. They are making boats out of glass, fishing rods out of glass, fireproof fabrics out of glass. *Balance* does it. Glass technicians know that each ingredient of glass has a special property and by balancing the ingredients properly they are able to give the finished glass product the characteristics desired.

The formula that makes a desirable citizen in these United States is generally known: ambition, go-ahead, ability to get along with people, steadfast purpose, clear thinking, right judgment. It is also known that each embryonic citizen, the boy or girl in school, has each of these qualities in seed form. How successful a citizen the youngster becomes depends on how each of these ingredients is developed *in balance* with all the others. *Balance* does it.

The youngster who has only ambition may become ruthless and selfish, succeeding at the expense of his fellows. The youngster who possesses only ability to get along with others may become wishwashy, characterless, subject to all the evil influences let loose. The ideal, the *necessity* in fact, is to develop all the ingredients in balance. This is the chief responsibility of the educator and his opportunity lies only in the classrooms during the youngster's formative school years. Here, the educator *must* seize upon every opportunity and must make the most of that opportunity. No educator can escape his share of the responsibility, still less the instructor in mechanical drawing. His opportunity is in class, and his greatest opportunity is when the youngster first comes to class, is becoming acquainted with the tools he will use and the disciplines he will be subjected to in the years that follow. Therefore the tools of mechanical drawing *cannot* be disregarded, *must* be recognized in their importance, *must* be selected with the utmost care. The economy of a few pennies in selecting these tools of creation, these instruments of discipline, these influences in judgment, in ambition, in careful craftsmanship is an unwise economy, an extravagance in fact that may promote profligacy and waste of opportunity and human material all the rest of the youngster's life.

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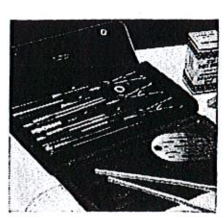

DIETZGEN

EVERYTHING FOR DRAFTING AND SURVEYING

REPORT OF THE COMMITTEE ON ADVANCED CREDITS DRAWING DIVISION, ASEE

Troy, New York, June 21, 1949

The Committee on Advanced Credits has completed sixteen Unit Tests in Engineering Drawing, and these are being distributed through the Educational Testing Service, 15 Amsterdam Avenue, New York 23, New York. These tests cover the following subjects:

1. Use of Instruments and Applied Geometry
2. Orthographic Projection I
3. Orthographic Projection II
4. Orthographic Projection III
5. Sections and Conventions
6. Auxiliary Views
7. Elementary Dimensioning
8. Screw Threads and Threaded Fastenings
9. Advanced Dimensioning
10. Working Drawings
11. Isometric Drawing
12. Oblique Drawing
13. Perspective Drawing
14. Charts, Graphs, and Diagrams
15. Intersections
16. Developed Surfaces

These tests were first prepared in experimental forms, and these forms were tried out in twelve representative institutions. The experimental groups ranged in size from N = 168 for DEVELOPED SURFACES, to N = 854 for ELEMENTARY DIMENSIONING. There was a further revision of the test materials by the Committee and by the staff of the Graduate Record Office in the light of the statistical analysis of the data provided by the experimental try-out, and a selection of items was made for the final forms of the tests, which are now available.

The tests may be used as teaching aids during the period of instruction on a unit; as examinations at the end of the unit, either for the purpose of assigning grades or as reviews; and in groups of units as mid-terms or final examinations. The tests may also be used for establishing credit for either entering or transfer students.

The tests are entirely objective; all the questions in the tests are of the multiple-choice type. The answers to the questions are recorded on a separate question sheet which accompanies each Unit Test in the series. Scoring is accomplished by use of a stencil and takes very little time.

Most of the questions are based on figures printed in separate folders, which may be used indefinitely.

These tests are to be made available to all colleges and universities of recognized standing as determined by the Educational Testing Service and the Committee on Advanced Credits. No prep schools or high schools will be allowed access to the tests. This will be rigidly controlled by the Educational Testing Service.

PRESERVATION OF THE TEST MATERIALS

If the tests are allowed to fall into the hands of unauthorized persons, they will shortly become useless. The Educational Testing Service recommends, therefore, that the following precautions be taken with regard to the protection of the tests:

1. The drawing folders should be serially numbered. A labeled space for the serial number is provided at the upper right-hand corner of the cover page of each drawing folder.

2. The drawing folders and question sheets should be kept under lock and key in a central place, preferably the departmental office.

3. When the materials are checked out to instructors, a record should be kept of the serial numbers of the drawing folders and number of question sheets checked out. Instructors should be responsible for the safekeeping of these materials while the materials are in their possession.

4. Students should not be allowed to keep their question sheets indefinitely. After the students have had the corrected question sheets for as long a time as may be necessary for the instructor to review them, the students should be required to turn them in to the instructors, who will return them to the departmental office for filing or destruction.

5. The office should see to it that the number of question sheets returned by an instructor is the same as the number checked out to him and that the serial numbers of the returned drawing folders are the same as the serial numbers of those checked out.

RECOMMENDATIONS

Recognizing that the granting of college credit is usually a matter of institutional policy, nevertheless the Committee recommends that no college credit be allowed by engineering drawing departments for work done elsewhere except for credit earned in E.C.P.D. accredited Colleges and in Junior Colleges accredited by the institution involved. In exceptional cases, however, when proficiency is proven by submitted work and the passing of appropriate examination, students may be granted credit or excused from taking specified courses, according to the policy of the institution.

The Committee recommends the use of these tests in accordance with the way they were planned; that is, they may be combined in any order to meet the needs for any particular basic course by selecting the proper units to be included in accordance with the time allotment available. They may be used singly for quizzes, or in combination for finals or proficiency tests, and with performance type tests when that portion of the work is to be tested. The Committee believes that with these units designed as they have been, much flexibility is provided for their usage; and because of the wide variance in the units covered in the basic courses in different colleges and universities throughout the country, this is deemed a very worthwhile feature.

The work of the Committee has been concluded. The distribution of these tests will be in the hands of the Educational Testing Service. We, therefore, recommend that the Committee be discharged.

Respectfully submitted

Webster M. Christman
Maurice Graney
Randolph P. Hoelscher
John M. Russ
Ralph S. Paffenbarger, Chm.

NEWS ITEMS

The Gramercy Import Company of New York, whose advertisement appears in this issue, has given the Drawing Division a check for one hundred dollars to be applied on the expenses of Professor T. C. Brown's work on foreign drawings. This is most appropriate and generous. We acknowledge this gift with thanks. It will serve a useful purpose in the study for co-ordination of our work in engineering drawing.

Our chairman, Professor O. W. Potter, University of Minnesota, is anxious to line up some good papers to be presented at our next annual meeting. Anyone interested in writing a paper should communicate with him at once.

Professor R. P. Hoelscher has evidently given up his job of Director at the Chicago division of the University of Illinois, at Navy Pier. He now is the head of the Department of Engineering Drawing at the University of Illinois at Urbana.

Professor Griswold, of Cooper Union, New York City, sent the editor some very interesting pictures taken at the picnic at Lake George. I am sure that anyone attending that picnic who wishes copies of these pictures, can obtain them by writing to him.

Send your new and renewal subscriptions to the Journal to Professor Ralph Northrup, Wayne University, Detroit, Michigan. The subscription price is only $1.25 per year.

ATTENTION !!!

DEPARTMENTS OF ENGINEERING DRAWING

At the national convention of the ASEE at Rensselaer Polytechnic Institute, Professor T. C. Brown, of North Carolina State College, Raleigh, North Carolina, had a very interesting and comprehensive display of drawings from the principal foreign countries of the world. This exhibit created a great deal of interest. Professor Brown is now planning a trip to have these drawings shipped around the country from institution to institution for the purpose of allowing each school the opportunity of displaying them. If you care to have such a display routed to your institution, please send your request to:

Professor T. C. Brown
North Carolina State College
Raleigh, North Carolina

A GEOMETRIC APPROACH TO LITERATURE

by

C. H. Gray
Renssaelaer Polytechnic Institute
June, 1949

I have never been noted for sticking to my last; but I can't remember when I have ever been quite so bold as I have been in accepting your invitation to speak to you. Nobody in the history of the world, probably, ever knew less than I do about engineering drawing. I am noted in my family for never being able to measure anything accurately. I could never draw a straight line. The only angles I know intimately are those long-dead Angles who migrated to the British Isles about 1400 years ago and whose language I am able, like a comparatively few other people, to read. I can appreciate, by the way, therefore, the answer the Scotsman made to the man who asked what was the difference between a Scot and an Englishman. The answer was that when the Angles came to Britain the acute angles went to Scotland and the obtuse angles to England. (Before the evening is over, I hope to deal with the "geometry" of that joke.) Maybe the fact that my grandfather came from the borderland between England and Scotland should give me confidence that my hereitage is that of an angle of 90°. Maybe I'm destined to be right, after all. Or maybe I'm just fooling you into forgetting that I am really apologetic about using geometrical terms at all. My head, as the fourth grade boy once wrote, is full of ignorance. Yet "ignorance", said Giordano Bruno, ""is the most delightful science; it is got without labor and without pain, and keeps the mind from melancholy."

As I have become involved in the discussions of engineering education, I find that many of you are concerned over the artificial barriers that have been set up between fields of study. The watchword now is coming to be "integration" or "correlation". After a long history of the gradual separation of sciences from each other - and arts as well - the trend is towards joining together again what man has put asunder. Perhaps then I may make my small effort tonight to explore some similarities and dissimilarities between your discipline and mine.

I suppose that the central purpose of education is to give people power to make something out of this chaotic world we live in. It is not only to the child that, as William James has been often quoted as saying, the world appears as a "big, blooming, buzzing confusion". To make anything out of the confusion we all have to learn to use our senses in a conscious as well as unconscious way. We have to learn to bring these sensations into some orderly and significant pattern for contemplation and for the basis of further exploration. We have to learn to weigh with our feelings of pleasure and pain, with our moral sense (whether innate or the product of experience), and with our imaginations (whatever they may be) the values in one kind of order and another, one kind of happening or another, one kind of emotion or vision and another.

I should guess that much of your work is in the training of the eye both to see and not to see. You have to teach people to abstract from what the eye sees those aspects which are significant for some purpose other than to be seen. The eye has to see, so to speak, through steel and concrete. But it will then cease to be the eye which records an image of the rose and the moon; it will be the eye of the mind, a mathematical eye. That mathematical eye will record the unseen as though it were seen; from some previous use of the sense-organ and then from some rational ordering of the data a new way of seeing has been developed. The power to see in that way is one of the objectives of your work.

How closely allied with the power to see with a new eye is the power to represent what is seen, only you can tell me. Probably in one sense the thing has not been seen until it has been represented. As in the work of a writer the idea and the words cannot exist without each other, so your vision and your graphic representation of it cannot be separated; until the representation is complete the vision cannot be said to exist. I can assure you that until this paper is finished I cannot be sure that I have anything to say. I am trying to see something; and as I write, the vision will, I hope, become clear. It will not do to take refuge in some defence that I know what I want to say but cannot put it into words. If the words do not make a reasonably clear and consistent image of the idea (within the limits of the verbal techniques), the sad truth will stare me in the face that there never was any clear or consistent idea there. So, a second objective of education is the power to represent the things seen through the new power of seeing.

The purposes to which such powers are put are, of course, primarily "practical". However much some of you enjoy the designs of your drawings and the "beauty", as you may even call it, of a solution of a problem, you know that mostly such enjoyment is beside the point. If the drawing cannot be used by some one else for something he wants to go on to do, you know that the first purpose has been muffed. Of course you have a right to demand of the user that he can read your language. Even if many of your students will be users rather than makers of such drawings in their future careers, you must train these users both to see and to represent - for the latter is the best way of making sure that the language will be understood. Once a design drawing is readable, however, it becomes a practical tool for something else.

Before I get off this abstract plane to something more concrete about literature, let me point out something else that you are doing in your work.

(Continued on page 16)

(Who are you, anyhow, to ask for the concrete? Your whole business is with abstractions, airy, fanciful, bodiless abstractions. My profession is concerned with the concreteness which you have renounced - indeed the whole "world, the flesh and the devil").) You have the audacity to represent, usually, a three-dimensional object by a two-dimensional drawing. Nobody would dare to say to you: "But that's not a nut-and-bolt; that's only a lot of lines on a flat piece of paper. I can't pick it up as I could a nut-and-bolt. It hasn't any roundness or thickness; you only make it look as though it had. You're a fraud. That's only the way you see a nut-and-bolt." In discussions of literature, on the contrary, we have to face such attacks every day. You have taken a step, in your work, towards symbolizing one plane of experience in terms of another plane of experience. When your drawings are used for their practical ends, the user simply moves from one plane to the other, and, because he has found it profitable to do so, he also finds it possible. (I hope you have begun to see through the allegory I am writing. I have really not written a word about engineering drawing. It's all about literature. My "party line" has become two-dimensional. And let's make it three-dimensional by talking about another art.)

When you go home next week, I hope you will look at the pictures on your walls and ask yourselves why you have them there. I am sure they are nice pictures. I am almost equally sure that in most cases they show not the slightest relationship between your "taste" (if I may call it such) in engineering drawing and your taste in art. In how many instances have you chosen pictures in which the artist is trying to reproduce what you and he can see with that "naked eye" which in your profession you renounce as you would renounce in society any other nakedness? In how many of your pictures can you find the artist, on the contrary, searching to give in the most economical terms some selective vision of reality, even if it leads to abstraction, distortion, elimination and other violences to nature which you have trained yourselves to in your profession? Have you perhaps mistaken the purpose of art as I would mistake your purposes if I complained that your two-dimensional nut-and-bolt had no thickness and roundness? Anybody can see with the "naked eye"; nobody need go to art for what he can see himself. Art is always, when it is good, abstract in the same way that your science is abstract. For "meaning" is an abstraction or tends towards an abstraction. "Abstraction" is a "process of leaving out of consideration one or more qualities of a complex object so as to attend to others."

Turning back to literature, then, I think I may assume that you and I are agreed on certain principles. We both value highly the ability to see and to represent what is seen. We both are willing to leave out of consideration one or more qualities of a complex object so as to attend to others. We both accept the possibility of representing an object that exists in a certain number of dimensions by another object existing in fewer dimensions. We both accept, that is, the process of symbolizing, of letting one thing stand for another. We make these assumptions and accept these methods in the name of some purposes. One purpose on which we both agree is to arrive at a more accurate grasp of the object. We may differ in the emphasis we put upon certain aspects of the total "grasp" of an object and we may differ in the purposes to which the grasp shall later be put. Furthermore, of those who read engineering drawings and the works of literature we both demand a discipline of the senses and of the mind, a discipline which leads to an understanding of the principles of seeing, of selecting from what we see, of the purposes to which the visions we represent are to be put.

One of the chief difficulties we teachers of literature meet is our students' resistance to seeing things in unaccustomed ways. They are like the Victorian lady who stood with James McNeill Whistler before his painting of Battersea Bridge in London. "Mr. Whistler," she said, "I have lived in London all my life and I have never seen Battersea Bridge look like that." "My dear madam," answered Whistler, "don't you wish you could?" Whistler was not a very gracious teacher and was willing to leave his pictures to more adventurous spectators than the Victorian lady. We teachers are interested in the development of our students and must therefore give more persuasive explanations than his. The difficulty lies in the relations between seeing and believing. We all use our seeing powers and trust them. We base our sense of truth on what we see. Having come to conclusions about "truth", we then are inclined to trust more in that secondary conclusion than in the seeing. In painting, for example, there were centuries during which the trunks of trees were painted brown, because that was the way some painter had seen them. When some later painters insisted on testing this conclusion by looking freshly at trees, they saw that a purple was nearer to the "truth". Uproar ensued, for men had become so enamored of their "idea" of the truth that they trusted that idea more than their senses. In literature, American writers who had seen some of the sweeter aspects of village life perpetuated for decades the view that life was idyllic in "the deep-tangled wildwood". When a new generation of writers turned their eyes freshly upon village life and found some of the less lovely aspects, the discovery led to a new and rather shocking vision of American life. Again an uproar followed, for readers trained to see only certain aspects were asked to look again, and resented the disturbance to their accustomed ways of seeing and believing.

A vivid example of this trait came into my life recently in a class which was discussing Sinclair Lewis's Babbitt. The example, however, leads to a principle more fundamental than the one I have been discussing here. The class had been enjoying the comic aspects of Babbitt's character; nearly all had chipped in with examples of the discrepancy between his pretension to idealism and his actual ignorance and unideal performance. I noticed one young man with a glum face who seemed to resent our apparently unanimous condemnation of not only Babbitt but "the American business man". Near the end of the hour he raised his hand to protest that American men did not talk in this pretentious strain; that he had never

(Continued on page 25)

A RATING SCALE FOR GRADING ENGINEERING DRAWINGS

Presented at Engineering Drawing Conference
ASEE Convention
Austin, Texas, June 16, 1948

by

E. G. Kirkpatrick
Purdue University

Over the last several years experimentation in grading student drawings has been carried on by the drawing staff at Purdue University. I should like to present the results obtained and the nature of the grading process which has developed. As a preliminary some examination of the general problem of measuring drawing achievement seems appropriate.

In discussing this problem, we are led initially to a consideration of the nature of the achievement. Can the achievement be expressed verbally or symbolically and hence be measured by an objective type test? Or, is it a highly organized type of behavior requiring tests of a problem or a project nature? Unfortunately, for testing purposes, at least, we cannot place engineering drawing achievement exclusively in either one or the other category. We must recognize at the outset that there are some phases of drawing achievement which are verbal and which may be isolated and most economically and reliably measured by means of objective type tests. Then, too, we must keep in mind that there is an area of highly organized student activity in which his achievement is best expressed by means of a "product" - something that is a direct indication of his application of information, skill, and understanding. Whether or not the student can handle drawing instruments and meaningfully manipulate the graphic language is better indicated by the "product" that he produces with his drawing tools than by any verbal test we know of covering this behavior. The "product" is, of course, the completed engineering drawing.

The first step in the evaluation of either of these two general phases of drawing achievement is a clearly defined statement of those specific objectives which are to be considered as factors of this achievement. To meet this initial requirement, we in the Drawing Department at Purdue University have prepared an Instructor's Manual of Course Objectives. I have here several copies of the Manual. Some of you may care to examine the Manual after the discussion. Just a few words in this connection: the Manual does not operate to direct or restrict the approach of the individual instructor to the teaching of his own class; no regimentation is implied or understood. The Manual merely integrates and organizes, in writing, the instructional objectives of our department. The instructional objectives are formulated in terms of:
(1) General Objectives, day-to-day purposes irrespective of Group or Lesson; (2) Group Objectives, which refer to specific segments of the course. Both General and Group Objectives are sub-divided in terms of: (1) Knowledge, (2) Relationships, (3) Habits, (4) Skills, and (5) Attitudes. The function of the Manual, as we see it, is to encourage a psychological and job analysis point of view in "what we are attempting to do in the classroom" and hence "what constitutes student achievement" or, in other words, "what specifically do we expect to measure."

The second step in our evaluation program was the selection of devices for measuring the specific objectives. Two distinct measuring instruments are now employed: (1) an objectively scored quiz, and (2) a performance drawing test. The objectively scored quiz is designed to evaluate objectives of a factual nature and objectives involving the application of drawing principles to specific situations, e.g., completion type problems requiring specific operations or solutions. Our objectively scored quizzes are quite similar in general content and form to the Unit Tests in Engineering Drawing recently prepared by the A.S.E.E. Committee on Advanced Credits. We make use of standard answer blanks and an International Test Scoring Machine located in our Department of Educational Reference. The scoring is objective, reliable, and economical. Individual test items may be easily and quickly validated by means of a machine tabulation and a nomographic application of the Kelley Upper and Lower Quarter Technique. The performance drawing test is designed to measure objectives which are largely organizational and expressive in nature, that is, they require a demonstration of skill in handling drawing instruments, and a perception, analysis, and application of graphic relationships and drawing symbolisms. The scoring is subjective, unreliable, and exceedingly laborious; these are the undesirables which have given rise to the use of the Rating Scale technique.

The Rating Scale has long been used as an effective tool in psychophysical measurement techniques in psychological and educational research. It has more recently been adapted to personnel and vocational problems of an evaluative character. The Rating Scale has appeared in various forms and in connection with many distinct problems of measurement.

Basically, however, it is a simple technique which merely improves the reliability of judgments or estimates in connection with "product or procedure evaluation." Its function is to systematize and organize judgments concerning the separate features or phases of the "product" - in our case, the engineering drawing.

To illustrate the mechanics of the Rating Scale scoring technique, let us refer to the Sample Rating Scale that has been distributed to you. The Items of the Scale - Views, Dimensions, Sectioning, etc. - represent the important general features of this particular performance drawing test. The non-consecutive numbers refer to paragraphs in the Manual which give specific instructions regarding what is to be graded under each Item. We have some 30 odd such Item descriptions in the Manual and merely select them by number to fit new performance drawing tests. The first column represents the relative weighting of the Items in accordance with their relative importance on this particular test. The weighting is a tailor made proposition for each new test. The second column represents Raw Score evaluations for each Item. The particular Raw Score evaluation scale employed at Purdue University is a four point scale. The third column represents the product - <u>Weight</u> times <u>Raw Score</u> - for each Item. The manual skill Items - Execution and Lettering - are negatively weighted. This will be illustrated in the following example.*

The reasons for the negative weighting of the manual skills factors - Execution and Lettering - may be of interest to you. We encountered an arithmetical problem in connection with the weighting factors. We tried initially to use positive weights for all Items of the Scale and soon had to admit the possibility of two undesirable extreme conditions:
(1) a student might score very low on analysis of the problem, yet the positive weighting of the Execution and Lettering Items could in the case of a very good job of Execution and Lettering be sufficient to give the student a passing grade; or, (2) a student might score very low on Execution and Lettering, yet a very high score on analysis of the problem would pull him to a passing grade. In neither case did we consider the results justifiable. The arithmetic problem of preserving the correct balance between weightings of analysis versus technique proved to be a pre-determined job for each test, and not a satisfactory job at that. We turned then to negative weighting which simply amounted to this: no positive reward for an expected achievement of linework, lettering, and neatness, but a rather marked penalty for failure to reach the expected levels of achievement. This eliminated the extreme conditions that we have just referred to. An incidental educational return from the negative weighting was an immediate improvement in student attitude towards Execution and Lettering, hitherto, quite an attitudinal problem in view of the fact that we do not grade laboratory drawings in our department.

The discussion thus far has been concerned with: (1) the field of measurement in connection with engineering drawing; (2) the need for a Performance Drawing Test; (3) the setting of objectives; and (4) the mechanics of the Rating Scale. We may now conclude with a few remarks directed at the philosophy behind the Rating Scale technique.

Basically, a grade for a Performance Drawing may be considered to be a function of two variables: (1) the estimated quality of each phase of the drawing; and (2) the relative importance attributed to each phase of the drawing. The problem of improving the reliability of scoring is a problem of controlling as best as possible under the subjective circumstances these two variable factors.

The latter variable, relative importance of each phase of the drawing, is numerically controlled by the weighting factors of the Rating Scale. The weighting is entirely independent of the grader. The remaining variable - estimated quality of each phase of the drawing - is not controllable under conditions of subjective grading. The reliability of separate estimates of quality for given phases of the drawing

(Continued on page 34)

* Refer here to "Sample Rating Scale."

EXPERIMENT IN VISUALIZATION

by

Mary F. Blade
The Cooper Union School of Engineering

A hundred years ago Galton gave us the first scientific picture of mental imagery. Today we believe that man's primary mental abilities or traits involve six or more factors. One of these can be described as spatial visualization, a faculty which is well developed in engineers and related scientific workers. In this paper we discuss the growth of this faculty and the possibility of deliberately extending it.

We found that visualization, or a person's ability to think in three dimensions, can be improved through training and practice. Visualization is developed only through experience in relating what an individual sees to what he feels with his sense muscles. It is visual and tactile-kinesthetic. He sees with his fingers, he feels with a look. Therefore he must have intimate experience with physical objects themselves before he can become proficient at manipulating them in the space-pictures of his imagination.

These conclusions are based on questionnaires and spatial achievement tests given to freshmen students at The Cooper Union School of Engineering before and after their first year of engineering studies.

NOTES ON VISUALIZATION

What is visualization? We often hear this word in the descriptive geometry classroom as well as in engineering work, but what does it really mean? We cannot ask this question without also thinking of a number of others. Is the ability to visualize subject to training or is it something unchangeable, like the length of your arm? What relation exists between this ability and a course in descriptive geometry or other engineering subjects? Finally, we want to know how to measure visualizing ability, in order to determine its growth and to understand better its relation to the work of the practicing engineer. We need to know the answers to these questions if our students are to get the greatest possible benefit from their study of descriptive geometry and engineering drawing.

Webster says to visualize is to form a mental image of something not before the eye; to picture mentally. To engineers the word means not only to form a mental picture but also to manipulate these pictures mentally. Therefore visualization means a dynamic as well as a static mental procedure.

Engineers especially need to visualize because they must solve problems regarding things which they do not have actually before them or in their hands. Professor Rule (15) has said that what is important to the creative scientist (including the engineer) is the ability to follow through a dynamic situation -- that is, the ability to operate on visual images according to his creative notions, and to maintain his visualization through the resultant alterations.

In order to solve their problems, engineers must produce and interpret abstract symbols. For it is not enough for engineers to simply visualize their problems. They must be able to communicate their solutions and to understand the solutions of others. The means of communication is the language of graphic symbols, that is, drawing. The requirements of these drawings, however, are different from those of the artist in that they must be more quickly made, and most important, capable of only one interpretation.

Thus engineers must visualize, (must form mental pictures) must draw pictures of objects in space according to a conventional system they learn, and must be able to understand the pictures of other engineers in this conventional language. Our purpose, as teachers, is first of all to teach the engineering student how to solve problems by creative analysis, and as a necessary part of this, to assist him in the visualizing which is so important to solving problems, as I have just pointed out.

But can a student be taught to visualize? To answer this question we must examine the mental equipment of the engineering student -- that is, his ability in dealing mentally with space problems and his previous experience with them at different age levels. In fact, it is necessary to go back to the days when this student was only a baby!

His experience in space sense began very early. When he was a month old he could follow an object with his eyes but he couldn't reach out and grasp it. At four months, he could focus on a hand and shift his eyes through 180°; though his hands were uncurling, he could reach out only with his eyes. When seven months old, he began to touch and manipulate everything he could lay his hands on. By the time he was a year old he had enough experience relating his feel of things with his view of things so that he could perceive visually without touching the object. But not until he was about eight years old did he not touch what he was looking at as often as formerly. However, even today he may have the experience, as every one of us does occasionally, of seeing something and saying, "Let me take a look at that!" and he doesn't just use his eyes; he takes the object in his hands and "feels a look."

This story of visual development describes the dual nature of our concept of space...what our eyes see, and what our sense muscles tell us about a thing. That is, the optical and the tactile kinesthetic represent the conflict between what we see and what the object really is. That a conflict in fact exists will be evident when we examine the pictures made by children and the pictures of early peoples.

A child first draws pictures of an object without regard to its distance from him. He thinks only of the object itself without reference to other objects, its position on the paper, or even sometimes without reference to the whole object of which it is a part. Each object and its parts are known separately and may be drawn separately, of its in combination, not in their true related position. For example (illustration), when a young child draws, he combines his knowledge of the object from the feeling of how he touched it, and his visual impression. He draws things in their most characteristic position; the result is a sort of combination two-view orthographic projection. Such a picture does not represent what he sees at a given moment, but is an effort to express the real form rather than the apparent form. However, by the time a child is nine, he can arrange features within an outline in true spatial relation; he is a keen observer and is beginning to draw in perspective. But, if he is not given special opportunities, his ability to draw in perspective may lag far behind his ability to interpret perspective pictures.

From the history of the child's early experiences in seeing we have seen there is a dual nature to his concept of space. When we examine the drawings of our ancestors, we find the same child-like concept of space. During the stone age, the cavemen in the Pyrenees drew animals combining several points of view in the same drawing. Much later, about three or four thousand years ago, the ancient Egyptians made combination views of objects. In fact, they could be considered as combination orthographic projections on parallel vertical planes. Human figures are combinations of frontal and profile representations in the same drawing. Although overlapping figures give an impression of depth, all figures in the same group stand on the same horizontal plane. Several stone and papyrus drawings by ancient engineers in Egypt are combination plan and elevation views. It is an interesting speculation whether orthographic projection drawings are more natural or basic, culturally and experientially, than perspective drawings which represent objects from one optical point of view.

Perspective drawing is generally considered to be the most convincing illustion of space. It was not until about 500 B.C. that some unifying organization of pictures developed. (But no Greek or Roman picture has been found which illustrated a completely unified construction based on a single vanishing point (3).) It was not until about 1400 years later than geometers and artists formulated the studies of perspective. And from that time until today, a period of about 500 years, perspective has been synonymous with the representation of space.

By the time a student enters college, he has had at least 16 years' experience in translating perspective drawings into mental images of three dimensional objects. This continual experience interpreting perspective drawings has been ever present everywhere, from fairy story illustrations to the mass of visual material from which no person can escape, even as he rides along the country road.

But what about the student's experience in visualizing from orthographic projections? It is practically none. Ever since Gaspard Monge invented descriptive geometry, 160 years ago, space problems have been solved by this method. But though descriptive geometry and engineering drawing techniques are widespread today, the student does not usually encounter them until college or, at the earliest, in high school. Some students have experienced orthographic projections only in seeing house plans, in a slice of bread, in unfolded paper boxes, and other homely illustrations.

The student therefore comes to college with the childhood experience of relating his feel of things with his view of things plus many years experience interpreting perspective drawings, and usually very limited experience making perspective drawings.

I have reviewed the student's background in visualization and drawing because I believe it is important to have it well in mind before trying to answer the question: "Can we teach students to visualize? All the problems of seeing, when the student was young, were based on the physical experience of handling, manipulating and relating objects, as well as "optically" seeing objects. In a similar manner, when a student begins to study descriptive geometry, we should teach him how to relate real objects to their symbolic representations, which are nothing but points, lines, and curves on a piece of paper without this relation. To make vivid and real the mental manipulation of conventional symbols, the student should make and handle simple objects which contain the spatial elements represented on the piece of paper. By manipulating the objects, relating them to the procedures of drawing space problem solutions, the student must necessarily gain experience in manipulating objects in his imagination. In this manner, he can be given specific and intensive training and experience on which to base his visualizations of similar problems, or new problems combining elements of old problems. This type of training should come early in the curriculum and should gradually taper off, as its need becomes less.

The ability to picture an object mentally, from an engineering drawing in orthographic projections, depends on the understanding of certain specific clues. When we look at an object we have numerous clues or hints to help us understand its real spatial qualities. When we look at artists' pictures, there are many clues, the pale blue of the farther hills, for instance, as well as the perspectives. But in orthographic projection we have no such crutches. The clues to understanding orthographic projection are abstract.

Altogether I have been able to think of at least twenty-four types of clues which we use for perceiving space relations, but only the following nine are present in visualizing an object from its orthographic projection:

1. Knowledge of what the object is (for example, as given by the title).
2. Silhouette (outer contour) and intersections.
3. Overlapping contours.
4. Symbols for hidden lines and surfaces.
5. Two or more coordinated views.
6. Sections.
7. Symbol for materials.
8. Notes and dimensions.
9. Other abstract symbols and conventions which have standardized meanings.

The principal clues to depth and space relations which are not ordinarily used in orthographic projection are:

1. The various factors of perspective.
2. Color.
3. Shades and shadows.
4. Factors of binocular vision.
5. Tactile-kinesthetic perception.

From these lists, it appears strikingly evident that descriptive geometry and engineering drawing convey their message chiefly through symbolic abstractions. We can say, then, that the making, manipulating, and interpreting of abstract symbols must be included in the engineering student's problem of visualizing, "forming mental images of objects not before the eye." Since space visualization depends on this type of mental manipulation, it is reasonable to state that training in descriptive geometry can improve the students' ability to visualize.

To discover the true relationship between visualizing ability on the one hand, and success at descriptive geometry on the other, we should start by defining the measure of spatial ability.* Attempts were made as long ago as 150 years, to test spatial ability. From small beginnings, the scope and number of spatial tests have increased steadily. At present there are probably over a hundred in use, some being of the "paper and pencil" type, while others require actual manipulation of two or three-dimensional objects. The paper and pencil tests are the most readily adaptable to group testing. Estes (8) concluded from a limited study that the paper and pencil tests might have equal validity with the physically manipulative type.

Although thirty years ago spatial ability was thought to be measurable by descriptive verbal tests, meant to conjure up a mental picture or space image (14), the modern tests contain little verbal material.

In the spatial ability test used in the Pre-engineering Inventory, taken by some engineering freshmen, the candidate matches surface planes and other elements on pictorial drawings of objects, some of them shaded. The test contains work samples taken from descriptive geometry and engineering drawing, which subjects the student will soon be taking.

In the Minnesota Paper Form-Board Test the candidate selects from a multiple choice, the pattern which represents the sum of given geometrical areas.

The spatial relations test of the College Entrance Examination Board is another paper and pencil test, comprising three sections: block counting, intersections of pictured three-dimensional objects by planes, and rotation of solid forms. Shading is used in the first two sections.

We teachers in engineering schools are interested in the measurement of a student's visualizing ability, but even more important, we should like to know how this ability correlates with his chances of becoming a successful engineer. A review of present-day test results indicates that as yet we do not have all of the answers. While spatial test scores of individual students applying for admission correlates well with these students' later achievement in descriptive geometry and engineering drawing, very little has been learned regarding the relation of these scores to other subjects, except that there is a closer correlation with success in mathematics than with success in verbal subjects. Several investigators believe there is a relation between mental qualities measured by the tests and abstract symbolic thinking.

When the results of spatial tests are taken as a whole, a difference appears between the scores for boys and girls. The higher scores attained by the boys' group may be due to the radical difference between the games, hobbies, outlook, and training of the boys as distinguished from the girls. The difference is significant because it may indicate that through training, spatial ability can be organized and developed.

Engineering schools at the present time usually admit a candidate who receives a low score on spatial tests, provided this deficiency is compensated by his general ability at mathematics. These students have difficulty with descriptive geometry and engineering drawing, and it becomes the problem of the teacher, either to train the students to use whatever ability they may have, or to help them gain the experience background which will increase that ability. In other words, we face the question, "Do the tests measure the visual experience of the candidate or his potential ability?

One way of attacking this problem would be to determine whether a student's score on spatial tests improves or not after he has had a course in descriptive geometry and

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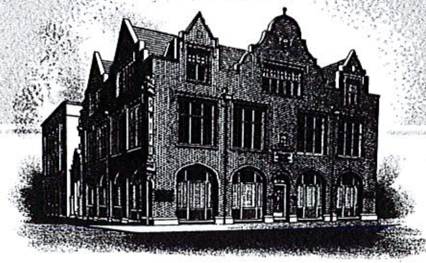
* Spatial ability is used here to mean spatial visualizing ability.



PROGRESS REPORT ON REVISION OF A.S.A. Z14 STANDARDS FOR DRAWINGS AND DRAFTING PRACTICE

by

R. P. Hoelscher, Head
Department of General Engineering Drawing
University of Illinois

Active work on the reorganization of Sectional Committee A.S.A. Z14, sponsored jointly by the A.S.M.E. and A.S.E.E., got under way at a meeting of the Sectional Committee with forty-four (44) representatives of colleges and industries on March 30, 1948. At the meeting the sponsors appointed a Steering Committee consisting of R. F. V. Stanton, Chairman; R. P. Hoelscher, Vice Chairman; R. S. Paffenbarger, W. A. Bischoff, H. L. Keller, C. L. Miller, and W. A. Siler.

A policy of coordinating other standards with an aim of bringing them under a revision of the present standards Z14 was approved. The scope of the work of the reorganized Sectional Committee was to include unification of the standard to be developed with the British, Canadian, and other International groups.

The Steering Committee met on February 9, 1949, to set up a permanent organization. The word "room" was eliminated from the title of the standard leaving it as indicated at the head of this report. The scope of the Z14 Sectional Committees responsibility was accepted as previously defined. It was agreed that this was not to cover such items as standardization of filing cabinets, width of rolls of paper and cloth, sizes of drafting equipment, and the like.

The Steering Committee considered and authorized the extension of invitations to join the Sectional Committee to a number of industries and National Societies not presently represented.

It was decided to form an Executive Committee to coordinate and review sub-committee work prior to submission to the Sectional Committee. This Committee was assigned the task of naming the sub-committees and of selecting the chairman for each sub-committee and approving the membership of each sub-committee.

The following persons were named on the Executive Committee:

NAME	REPRESENTING
R. F. B. Stanton, Vice Pres. American Machine & Foundry Co.	Member-at-large
R. P. Hoelscher, Head of Department General Engineering Drawing University of Illinois	American Society for Engineering Education
R. S. Paffenbarger, Prof. Chairman, Dept. of Engr. Drawing Ohio State University	American Society for Engineering Education
J. M. Barnes, Engr.-in-charge Drafting Division Philadelphia Electric Co.	Member-at-large
W. A. Bischoff Drafting Standards Engineer Bell Telephone Laboratories, Inc.	ASA Telephone Group
W. A. Siler Delco-Remy Division General Motors Corp.	Society of Automotive Engineers
H. L. Keller, Mgr. Com'l Engr. Ohio Crank Shaft Co.	American Society of Mechanical Engineers
C. A. Ward, Jr. Senior Naval Architect Gibs & Cox, Inc.	Society of Naval Architects Marine Engineers

The following officers of the Executive Committee were elected:

R. F. V. Stanton, Chairman
R. P. Hoelscher, Vice Chairman
R. S. Paffenbarger, Secretary

The Executive Committee met again on March 10, 1949 and set up the following sub-committees:

I - Size and Format
II - Line Conventions, Lettering and Sectioning
III - Projections
IV - Pictorial Presentation
V - Dimensioning and Placing Tolerances on Drawings
VI - Screw Threads
VII - Gears, Splines and Serrations
VIII - Castings
IX - Forgings
X - Metal Stampings
XI - Plastics
XII - Die Casting
XIII - Springs-Round and Flat
XIV - Structural Drafting
XV - Air Frames Standard
XVI - Tool and Gage Drawing
XVII - Notes

Work was also begun on the selection of chairmen of these committees and suggestions were made as to membership on them.

The general policy was set up of limiting sub-committee membership to the range between five and ten active members, with corresponding members selected by the chairmen as desired. Corresponding members are to receive material; communicate their opinions; free to, but not expected to attend sub-committee meetings; and to have no vote.

Some additions were made to the Sectional Committee which is not as yet complete. The general policy of publishing the standard in Sections as they are completed and accepted was adopted.

Another meeting of the Executive Committee is scheduled for September 29, 1949. At the meeting sub-committee chairmen now appointed will report on the organization of their sub-committees and their general plans.

A few sub-committees have not as yet been organized.

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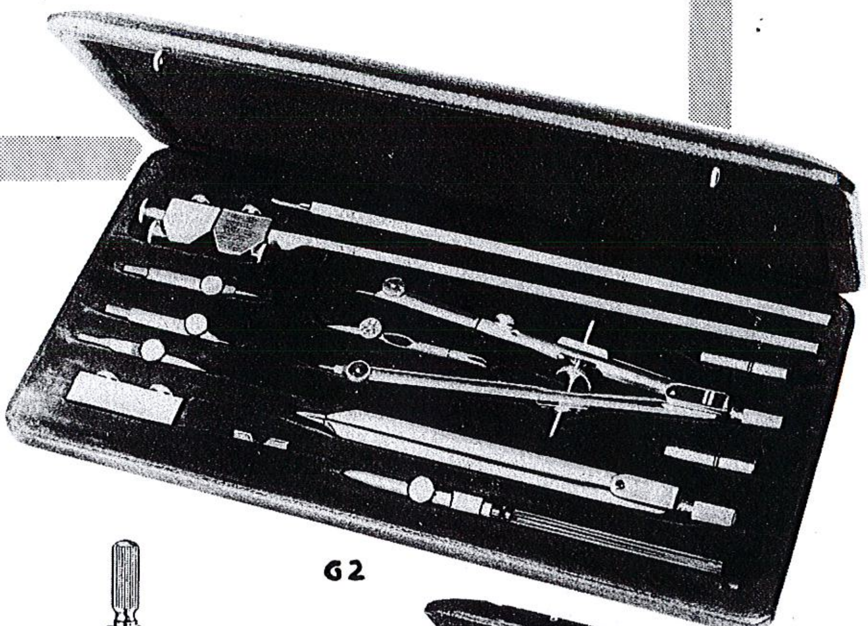

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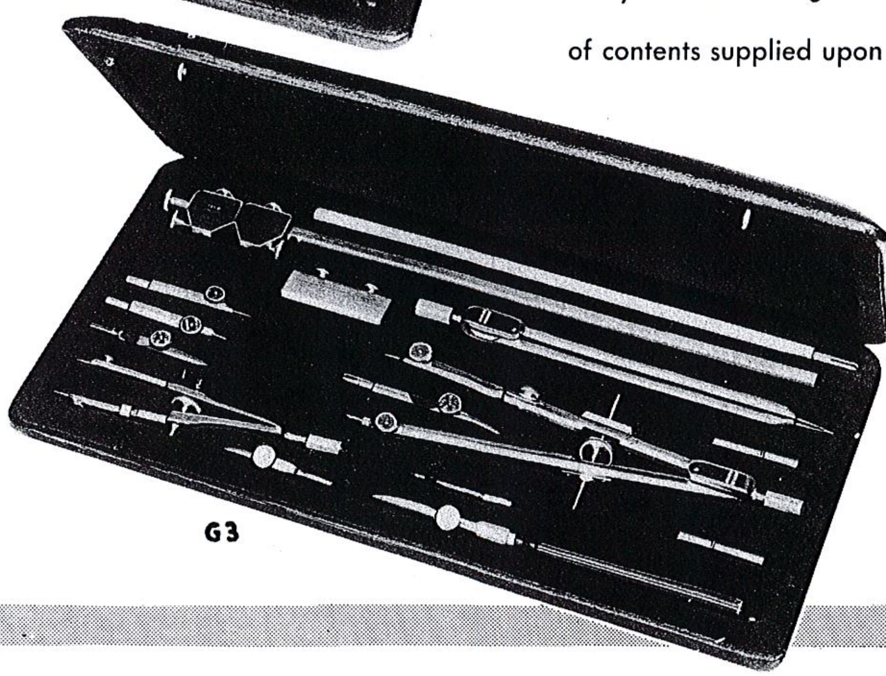

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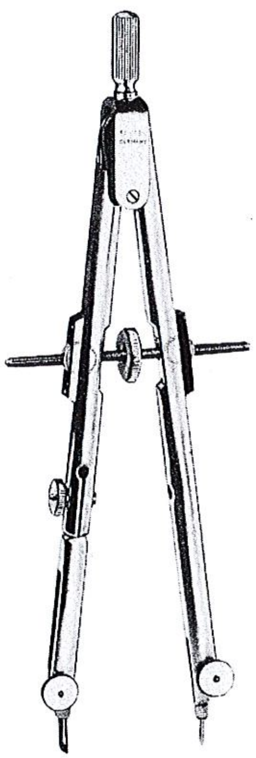

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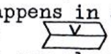
heard men in locker-rooms talking the way Babbitt talked. I had Whistler's old lady before me, but I respected her. As there was not time in that hour to pursue the question, I waited until the next hour which happened to come after a week-end. When the class re-assembled, I raised at once the question of the relation between literature and life, or the relation between one man's vision and another's. I then turned to the young protester with the question, "Mr. L., how many Babbitts do you think there are?" He replied with a good deal of enthusiasm, "I met one during the week-end." The class and I burst into a roar of laughter. But the question was by no means answered. He was now inclined to believe in the "truth" of Lewis's vision because he had himself met a "Babbitt". While it helped him to see Lewis's point, it also helped me to make clear that the value in literature did not depend upon one's being able always to match a fictitious character with some living person. You, for instance, could never convey to a student the idea of a perfect triangle if you had to depend upon being able to show him a perfect triangle in nature or even to draw one which would stand the test of exact measurement. You have to ask him to take representations which to the sight approximate the idea, though of course you use tendencies in nature that can be seen. You are more concerned with the idea, an intellectual concept, than with the perceptible fact. Your use of the concept is proved, not by the test of sight, but by the consistency of the idea and the uses to which it can be put. What light, you are justified in asking does this idea throw upon the visible objects?

The process of literature is somewhat as follows: look at human life until you are familiar with as many of its aspects as possible; see the facts as they actually look to you; note their qualities and relationships; from these observations draw inferences that may be true for whole sets of facts; represent your segment of human life so that it conveys both the truth of visible fact and the truth of whatever inferences you have been able to make. As engineering draughtsmen see through steel and concrete to a formal, structural truth, the literary artist sees through the facts of life to a formal, structural truth.

We are all familiar with the phrase, "the eternal triangle". It has become so common that we may have forgotten that it is a figure from geometry. What it represents in human relations is a simple pattern, though with the usual infinite variations in proportions. While some variations represent the emphasis on husband, wife, or lover, still more subtle variations can be achieved by taking varying points of view, by moving round the plane and noting the way the figure looks from different angles. Out of the infinite variations no one can tell what new meanings may be extracted. Although the artist may play with his kaleidoscope, in the end the pattern he selects to set down in his words must have more consistency and rightness than any kaleidoscopic pattern has. You too must make your selection from the infinite variations open to you. There may be more than one "right" way. When the purpose is that of utility for manufacturing, you may find many solutions that will do. But I am sure you have criteria of economy, of ease in reading, of grace. In literature we hesitate to use the word "utility", lest we limit the meaning to one dimension. Yet there is no doubt in my mind that the principle of utility is at the base of all judgment of art. The object that is to be made is a life. In the chants, the riddles, the dances and the carvings of primitive folk we know that a magic utility was assumed. When men began to imagine that they made all these things merely for the purpose of embellishing their surroundings, for "beauty", for their leisure hours, they were well on the way to losing the instinct for great art itself. Fortunately, just as the religious instinct persists in saints and mystics during even the most materialistic eras, the instinct for art has had a way of persisting through all the degrading distractions of other useful pursuits. It does so because it is a means of seeing, of realizing, of getting that "grasp" of what life is which is the most useful thing a human being can get.

When I first thought, however, of speaking on the "geometric approach", I had in mind a particular kind of literature. For a number of years I have been interested in the problems of laughter and comedy. To most people there are no "problems" in laughter; you either laugh or you don't. To me that simple answer is like saying to an electrical engineer: a current either passes or it doesn't; who cares to find out any more about it? In my studies I have come to a point where a geometrical analogy can convey the idea of the comic most vividly. Let me return to my introductory joke about the Angles. "The acute Angles went to Scotland; the obtuse Angles to England." What happens in a joke like this? We are living on one plane of meaning: "Angles" with a capital A means a tribe of Teutonic folk who migrated to the British Isles. At a point in the tale we suddenly find ourselves on another plane: "angles" with a small "a" - and the differentiating adjectives that belong with them. The moment we say, "The acute Angles went to Scotland," the word "acute" also has two planes; or the word "acute" brings the two together. You may plot the joke as a fall or a sudden shift from one plane to the other. You will find such a shift, I believe, in all forms of humor. With this diagram you may then "explain" the point of your joke that has fallen flat, or may explain the differences between French and British humor, or make interesting studies of your own laughter and what it reveals of your most habitual beliefs and ideals.

The most recent study of laughter has beaten my theory into print, and has carried the geometrical figure a step further. Arthur Koestler represents what happens in a comic experience by two contiguous planes:  The mind, travelling serenely through one plane, suddenly strikes the second plane: at that point an explosion occurs. In order to understand a joke, a humorous character or saying or a comic situation, we have to get several points and planes into proper relationship. In simple puns these relationships are easy to grasp, as they are in mother-in-law jokes or bad-boy jokes or other such conventional patterns. In our pun on "angles" the relationships have become more complicated; the joke

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bears thinking about and does not lose by analysis. We have moved from the plane of Angles = people, to that of angles = geometrical figures; we have been brought over through the word "acute" = (1) less than 90° and (2) sharp, shrewd, smart. When we come to the word "obtuse" we have a logical antithesis which drives home the jest against the Englishman: both "acute" and "obtuse" have been taken over by way of metaphor into the plane of qualities of human intellegance. The geometrical analogy works out on both sides of the figure.

All the while we have been on the plane of the Scot who is answering a seemingly innocent question. Suddenly, again, we realize that an age-old antagonism between the two parts of the island of Britain has been at the base of this joke. We took "Scot" to mean "man"; we were on the plane of "a man's" reasoning, and suddenly found ourselves on the plane of "a Scot's" reasoning. Once more we shifted planes; we were caught once more in an error; the joke was on us as well as on the Englishman. But in another sense it was on the Scot too. One of the commonest forms of humor is that of automatism, repetition. There is something, for example, comic about twins, or about racial or national traits. When, therefore, we realize that the Scot is acting not as a "man", but according to the conventional idea of the Scot (i.e. in his patriotic antagonism to the English), we laugh at the automatism. No diagram that I can construct will get all these various planes into the relations that obtain between them in the swiftly passing moment of one innocent joke. I am convinced, however, that it is from these formal relations that the humor springs. When we tell a joke we have to make sure that we tell its parts in such order that we don't confuse the planes before we get to the "point". Perhaps nothing could more convincingly demonstrate the purely formal structure of a joke than the unhappy experience of a joke that fizzles. If the humor lay in some inherent quality of the people or incidents themselves we would laugh, in whatever order our words might be spoken.

From this unhumorous analysis of the geometrical structure of a joke, you will be relieved to have me turn to another kind of literature. There is something precious about our humor; each man clings to his own and few will thank you for looking too closely at it. The geometric approach has proved its usefulness to me, however. I believe strongly that you can tell what a man is from what he laughs at, and to get at that you must in the last analysis find the planes and their angles of relationship. Of all the many philosphers before Koestler who have tried to discover the basis of laughter, Schopenhauer is the one who came nearest to the geometric formulation - and he even uses a geometrical "joke" for his example. If time permitted I would quote it for you; the geometry is better than the joke.

Instead I must turn to another form of literature to see whether this geometric approach can be pushed further.

I recently read in the T-Square Page a recommendation of sketching as preparation for the final drawing. I think I know what was meant, for I have watched poets doing the same thing - at least in a few interesting cases their sketches have come down to us. What I am going to discuss will illustrate the inseparable relation between "idea" and its representation. I will illustrate also the way in which the poet's eye moves about an object to find that angle from which the object can best be looked at to bring out its meaning. It will also show the craftsman playing, so to speak, with his materials until by experimenting he not only finds how best to use them but even stumbles upon the very meaning itself.

We live on the earth. We have studied the earth and its relations with the sun, the stars, and the other planets. Out of mathematical inferences we have constructed an astronomical system. We are intellectually convinced that the earth is a planet moving in an orbit about the sun, and turning meanwhile each day a full revolution on its axis. Any sunny day we can get a verification of the earth turning on its axis by seeing, as we say, "the sun come up in the morning and go down in the evening." Since we know that the same experience of watching the sun come up and go down taught men in earlier ages that the sun moved about the earth or crossed the sky above the flat earth, we realize that it is not the experience but the inference which has corrected our interpretation. That inference transformed man's early notions of the meaning of his life. It was revolutionary once, but is now taken for granted. The point I wish to make is that the turning of the earth on its axis is something we know only through inference, and yet the conception, when it is grasped, inspires man's awe. The recent total eclipse of the moon was viewed by people with many varying reactions. Such a sight is taken in by us visually and then translated into terms conforming with our concepts of astronomical science. We saw a shadow cross the moon; we know that the moon moved into the shadow of the earth. The turning of the earth explains how we see the sun come up and go down. But we have never felt nor seen nor heard the actual turning of the earth. Because we are a part of it we can never feel nor see this majestic rolling of the great ball. We don't even stop to think about it. We couldn't use such thoughts unless we were astronomers carrying the inferences farther and developing corollaries to it that would be useful in our science or other sciences.

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* The poet William Wordsworth once had an experience which made him for a moment know the turning of the earth through his senses, not through mere inference. In his long autobiographical poem, The Prelude, he wrote about a boyhood experience while skating on the ice:

and oftentimes
When we had given our bodies to the wind,
And all the shadowy banks, on either side,
Came sweeping through the darkness, spinning still
The rapid line of motion; then, at once,
Have I, reclining back upon my heels,
Stopp'd short, yet still the solitary cliffs
Wheeled by me, even as if the earth had roll'd
With visible motion her diurnal round.

What happened to the boy was, of course, an optical and psychological phenomenon. Even Wordsworth admits that it was "as if the earth had rolled." Yet to the imaginative boy it seemed as though he had actually seen the earth turning. There was added to the truth of intellectual inference the more vivid and compelling evidence of his senses. His "drawing" so to speak, of the object was not complete and usable until the intellectually grasped idea had been fused with a sensuous experience.

But his "drawing" was of course not really complete until he had found the symbols by which to communicate his visualization to others. I must add, also, that the total idea (or object) must include the emotions which were simultaneous with the visualization. So, the words must give the idea (the turning of the earth), the sensation of the turning, and the meaning (which in literature is essentially idea felt rather than idea inferred). The meaning comes out in the full-toned words at the end of the passage:

yet still the solitary cliffs
Wheeled by me, even as if the earth had rolled
With visible motion her diurnal round."

The "truth" which the poet was trying to convey was not the astronomical concept of a sphere turning on its axis, but the awe which one would feel if one could actually see the earth spinning. Incidentally, what other sense of human insignificance and religious reverence comes through is part of the total effect. The culminating words have the resonance of organ tones, the abstraction of a scientific hypothesis, and, through the choice of the old Latinate word "diurnal" for "daily", a touch of the ecclesiastical or at least Biblical phrase.

These words were favorite words of the poet. "Earth" - "rolled" - "motion" - "diurnal". It is fascinating to watch him sketching with them. The passage I have read indeed turns out to have been but a sketch for something weighted with more meaning. A poem written about the same time uses the same words and also puts the turning of the earth into a relationship with death and love in a way that gives the poem universality. The poet is writing of the death of a beloved woman:

A slumber did my spirit seal;
I had no human fears;
She seemed a thing that could not feel
The touch of earthly years.

No motion has she now, no force;
She neither hears nor sees,
Rolled round in earth's diurnal course
With rocks and stones and trees.

Once more the central physical fact is the turning of the earth. At the climax of the man's grief and his attempt to grasp what death means, the bleak realization comes to the return of dust to dust, of the return of the warm, sentient body to the rocks and stones, to be part of this turning globe. This time we are not asked to imagine that we actually see or feel the earth turn. The astronomical hypothesis is taken for granted, but the grandeur and the bleakness and desolation of any image we can get of that hypothesis are related to two simple human experiences. There is a reciprocal action between the two sides of the figure: the majestic turning of the rough-textured planet is humanized, and the human experience of the death of one beloved is given a bleak and not too comforting cosmic setting. As in the analysis of humor, one must lay emphasis upon the formal, intellectual relationships between the parts. "Point of view" - a phrase which is used so glibly by us all in daily speech - must be taken by readers of literature with the more significant and literal meaning which it has with professionals in your field. When we get the point of view more accurately fixed and have related all the other points and planes to it, we have a formal structure from which all the meaning and subsidiary emotional effects derive.

In spite of the danger of carrying you on too long, I wish to follow this last remark further. It would be natural to say to oneself that the little eight-line poem means that "the death of the woman came as a grievous shock and can only be felt as the desolating final return of her body to the earth which turns its daily round by impersonal physical law". Such a phrase, however, or any other phrase, would fail to give the whole meaning. It would fail, not solely because when it comes to words the poet has the best ones, but because also there is a geometrical form, made up of the points and planes, which can only be seen as form and which is so basic to the meaning that as form it must be seen. You in your work must often be forced to say, "If I could tell you in words, I wouldn't have to draw it". I know that dancers say the same thing about their compositions: "You ask me what the dance means; if I could tell you in any other way than by dancing it, I wouldn't dance." That aspect of the art of poetry which is beyond words is the design, the relation of points and planes in space. That is why a geometrical approach is not only possible but essential.

C. H. Gray

R.P.I. June 22, 1949

* It is the literary draughtsman's business to represent such experiences, intellectual and sensuous, in forms that make them useful, useful in the making of a life.

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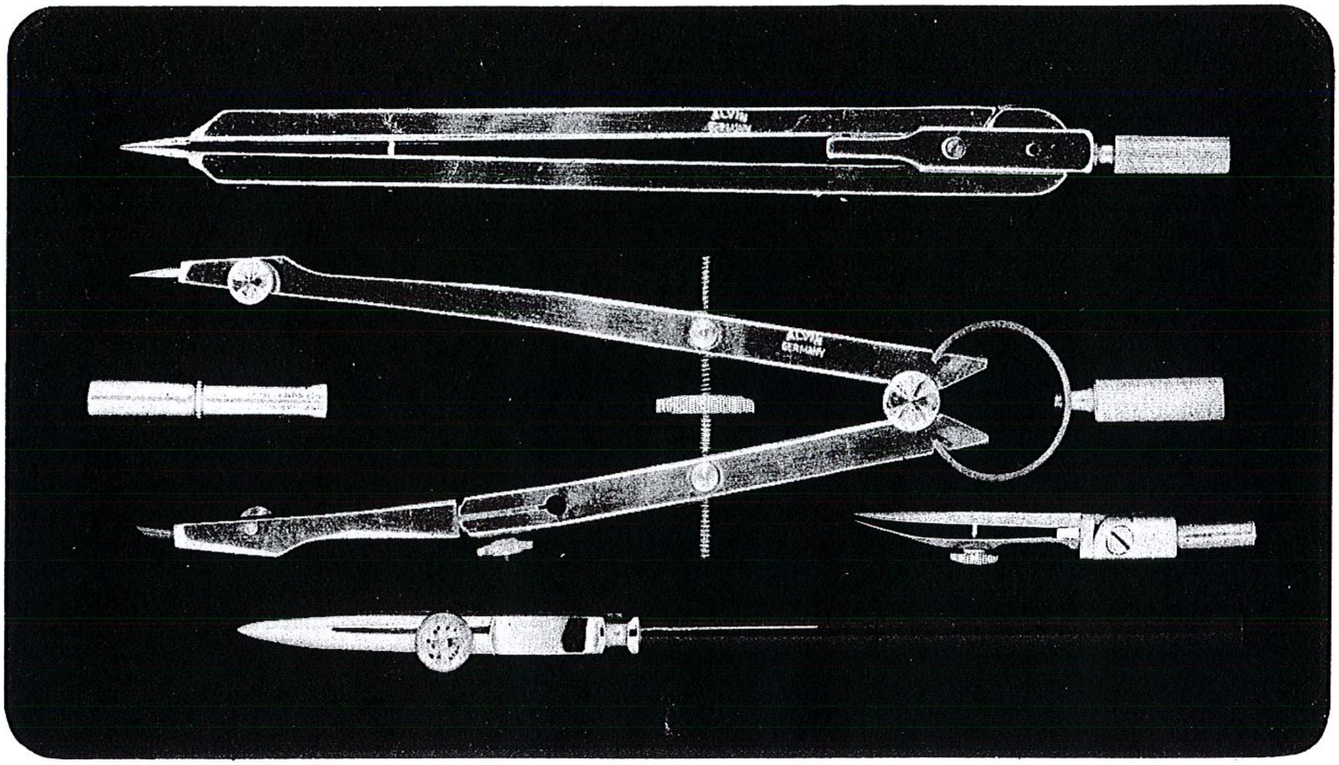

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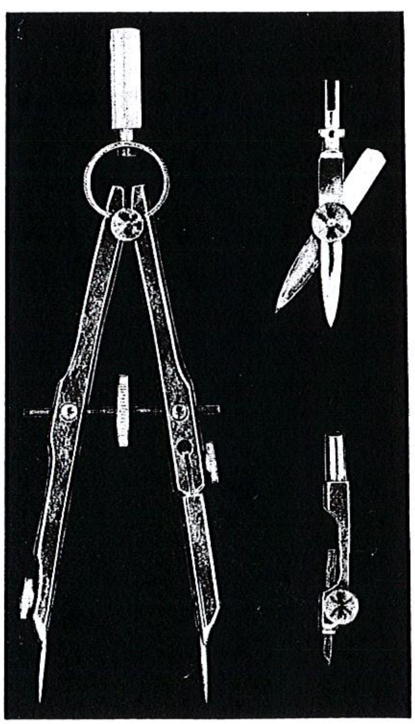

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(continued from page 21)

engineering drawing. I have searched the literature for such an investigation, but have found none. At Cooper Union we are making a study of students' spatial ability before and after a course in descriptive geometry. (Discussion of results of testing.)

Conclusions:

One picture, the Chinese, say, is worth ten thousand words. We might go even further, to say that one object is worth quite a collection of pictures -- let us say a hundred, to be conservative. In my opinion, a student must have intimate experience with objects themselves if he is to become the most proficient at manipulating them in the space pictured in his imagination. We should hark back to his fundamental early training in which the view of things was related directly with the feel of things. In a few hours of classwork we cannot hope to provide a student with the visual experience with things mechanical which his better-prepared classmates have been accumulating since boyhood, but by planning and intensive teaching, we may considerably help him.

In the new approach to teaching a young child the word "orange," he is actually handed an orange; he turns it around in his hand; he is shown a picture of an orange; he repeats the word "orange"; and he sees the letters forming the word. Thus, he attains a concept which goes with the word before any attempt is made to teach him to read the word.

In a similar way, the symbols of descriptive geometry can become related to the realities that they represent. If the student can handle the elements of the things he draws, his appreciation of them is likely to increase. If it can be accomplished without too great an expenditure of time, students should be encouraged to make simple models of some of the problems. A powerful aid to visualization is to have students set up an analogy between the reference planes of their problem and some large-scale structure about them, such as the walls of the room, then to picture the problem in actual space. Another teaching aid which does not seem to have received adequate prominence in the literature, is the use of gestures. The whole class may be asked to "draw" in the space before them the points, lines, and planes of their problem. As their hands describe each part of the imaginative figure, they receive a corresponding kinesthetic impression. They can be taught, in the same way, to "feel" imaginary geometric solids.

We should not omit from consideration the purely physical aspects of the visualization problem. Paul Schilder (16) has pointed out that the perception of straight lines and angles, as well as the sense of the vertical, depend on the inner ear (vestibular apparatus, in the terminology of the psychologist). There are also eye defects which cause poor depth perception. In view of these facts, the difficulty some students have with descriptive geometry may be due in part to eye or ear defects. In such cases, physical examinations would have diagnostic value.

Another suggestion for help comes from several psychologists who have been studying the actual movements of the eyes as a person solves problems. The patterns of movement as well as the times of each eye fixation are recorded. A relation between success in certain problem-solving and the various patterns of eye movements has been found. Teachers could make good use of some of the results of these studies in descriptive geometry and other problem solving courses (2).

A most potent means of developing spatial ability is undoubtedly the stimulation of the student's interest and enthusiasm, by calling to his attention the practical usefulness of the various geometrical constructions for solving common engineering problems with a minimum of effort. The economic value of the subject to a person adept in it should not be hard to demonstrate. On the other hand, as the student gains facility, his increasing capacity to visualize should be like an opening door to his curiosity and interest.

Summary

1. Visualization is the formation of a mental image of something which is not before the yeye. It must be particularly exercised in the study of descriptive geometry, where space problems have to be solved by manipulation of symbols.

2. Complex spatial problems may occur in every phase of engineering work. These problems demand for their solution, the ability to operate mentally on visual images.

3. Not a great deal is known about the mental process of visualization, but we know that the child, learning to visualize, repeatedly amplifies his visual impressions by touching and handling things. Psychologists call the latter, "tactile-kinesthetic experience."

4. The tests of spatial visualization, of which there are many, appear to measure a distinct ability, that involving the mental manipulation of spatial elements. Test scores correlate with achievement in descriptive geometry and engineering drawing, and perhaps in subjects requiring abstract thinking.

5. The fact that boys consistently do better than girls on spatial tests may be due to differences in the total experience in spatial visualization of the two groups. If this is so, it indicates that visualizing ability may be "trainable," and it may be practicable to give students intensive training in relating actual objects to the conventional representations of the same objects in order to develop latent ability. This training would involve personal manipulation by the student of solid geometrical and mechanically important objects. Descriptive gestures representing the points, lines and planes of descriptive geometry problems, especially when used by the students themselves, are a practical aid to visualization.

Acknowledgement

I thank Professor C. Higbie Young for his interest, encouragement, and assistance. Because of the teaching methods we have at Cooper Union, by which less experienced teachers work with more experienced teachers in the drawing laboratories, I have had no opportunity to "catch" some of the earnest enthusiasm and interest with which Professor Young stimulates his classes.

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When the lengths of both axes of an ellipse are known, the ellipse guide angle may be determined on the desired view as shown in Figure 9 (b). In this case the ellipse is thought of as a view of a circle that has been rotated about a diameter until the minor axis is the length shown. Figure 9 (a) shows

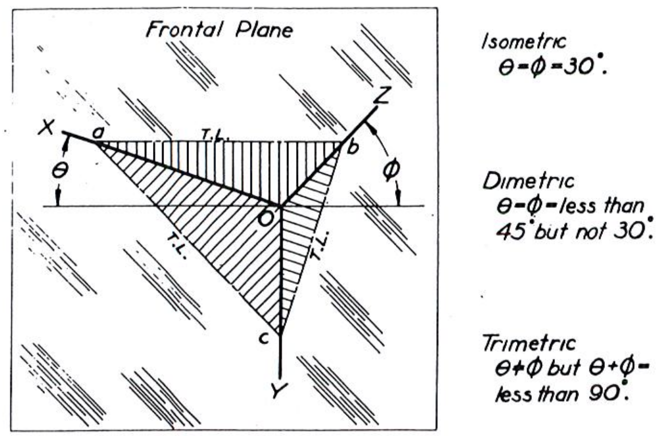

Fig. 6

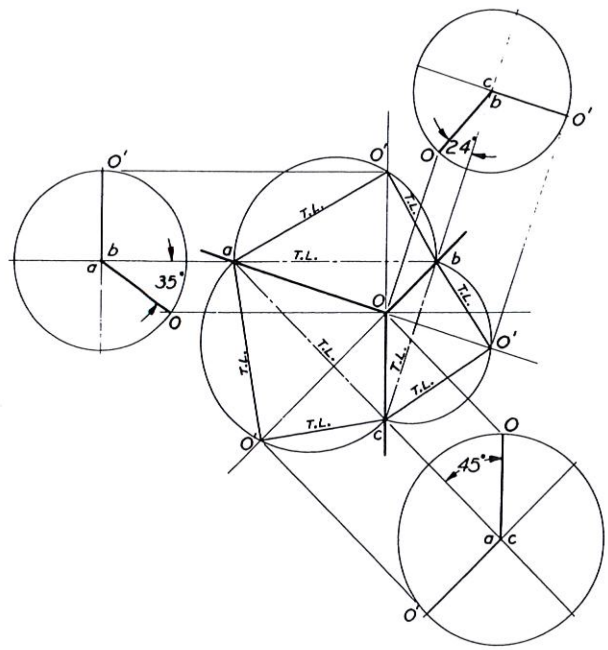

Fig. 7

the circle in its revolved position. As previously, the ellipse guide angle is determined by measuring the angle between the line of sight and the plane of the circle. In Figure 9 (b), the entire operation is performed on one view.

If the major axis and one additional point on the ellipse are know, the ellipse guide angle may be

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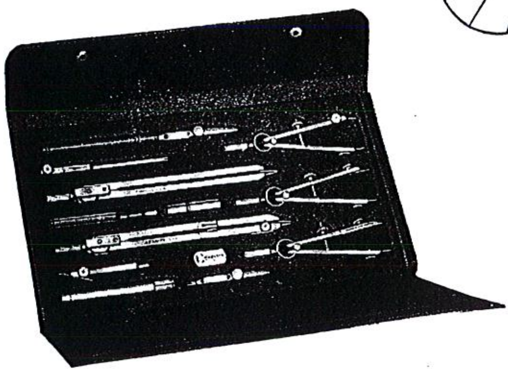

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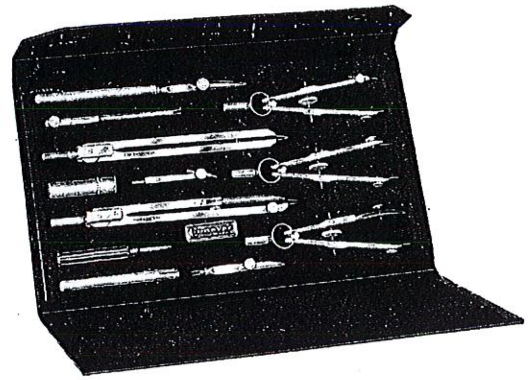

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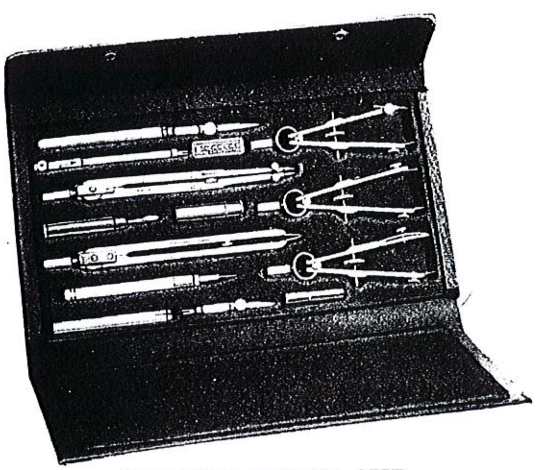

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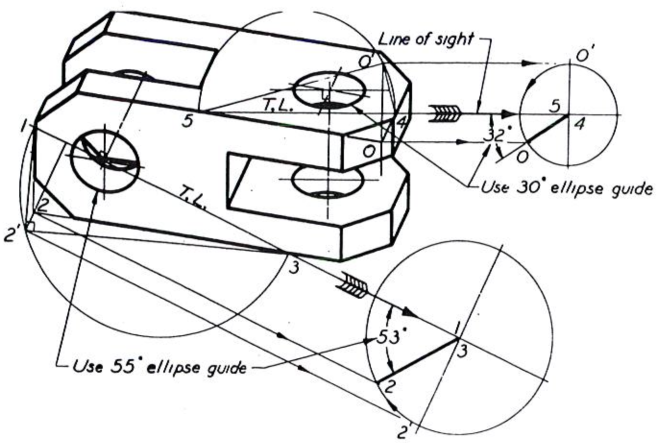

Fig. 8

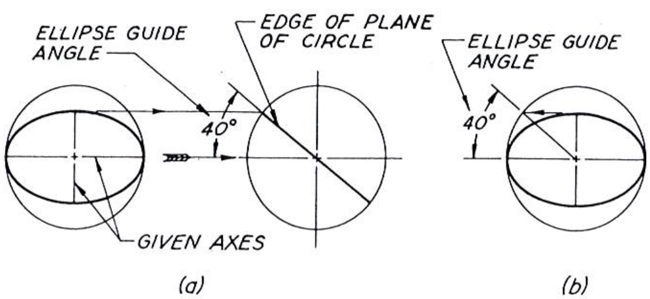

Fig. 9

determined as shown in Figure 10. A point view of the axis is obtained and rotated as indicated. To understand this construction it is necessary, as in the previous examples, to think of an ellipse as being an oblique projection of a circle. In the left view of Figure 10 point "C" has been revolved about axis a-b to the position it would have in the true view of the circle. It is then projected to the right view and then counterrevolved as shown by the several

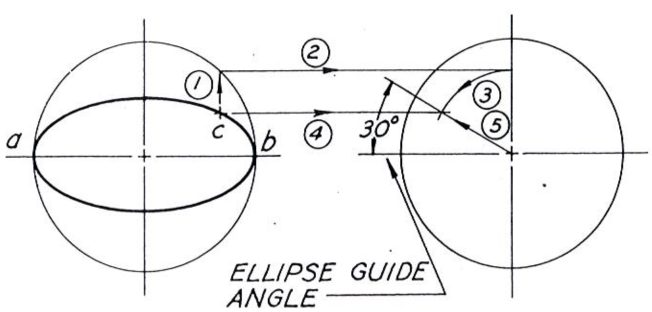

Fig. 10

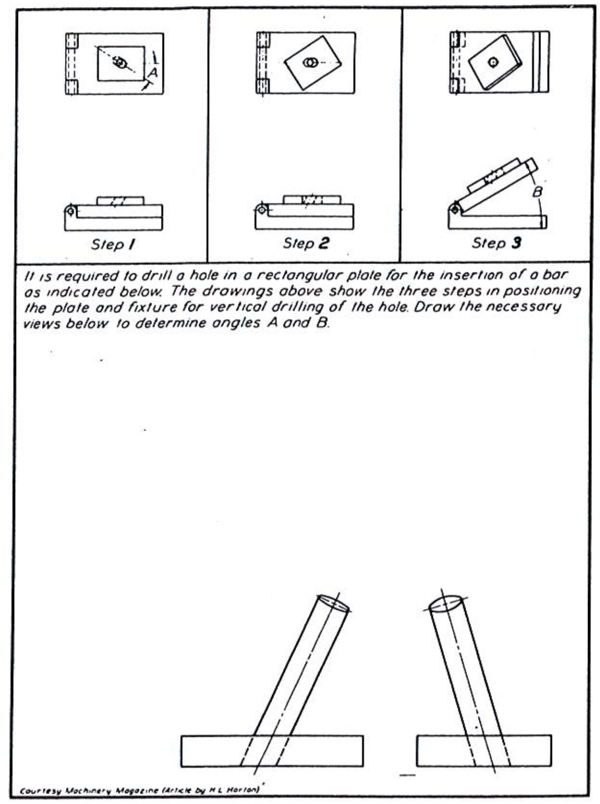

Fig. 11

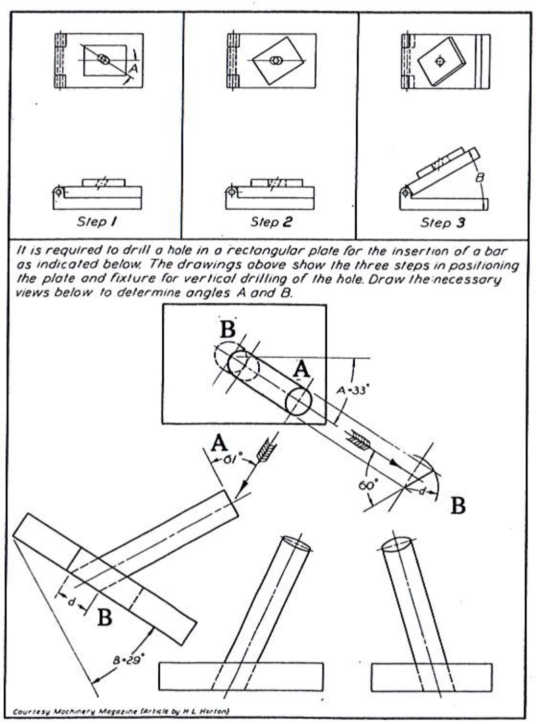

Fig. 12

(Continued on page 34)

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steps. This construction may be accomplished in one view if desired. If the angle should be 31° or 32° the draftsman would of necessity use the 30° guide. Likewide, if the angle is between 33° and 37° inclusive, the 35 guide would be required.

Figure 11 is another problem that was used in our descriptive geometry classes at the A. & M. College of Texas. The diagrams at the top of the drawing show the position that the part and fixture must be in for vertical drilling. The student is asked to draw views that will determine the angles necessary for positioning the part and fixture. With ellipse guides available it is a simple job for the student to draw all views completely (Figure 12). The construction for the ellipse at "A" is the same as used in Figure 4. However, the construction of the ellipse at "B" offers difficulty for some students. Even though the ellipse at "B" in the top view is not a projection of a circle in the true sense, the same reasoning may be used. An auxiliary view projected as that the major axis appears as a point will show the amount of tilt of a circle with a diameter equal to the major axis of the ellipse. The angle that the line of sight makes with the edge views of the circle will indicate the proper template for this case.

In summary and conclusion, the methods of determining the ellipse guide angle for several conditions have been given. It is the conviction of the speaker that all graphics students should have the opportunity to use the ellipse guides and, furthermore, that the student should be given, as a regular part of his instruction, the theory behind the proper use of these guides.

(continued from page 5)

You will be interested to know who the new officers are. They are as follows:

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The high light of the meeting was the annual dinner. Everyone was out in their best "Bib and Tucker." There were beautiful women and flowers, and good food. Business was all completed, officers elected, technical sessions over, and everyone relaxed. After the dinner we listened to an inspiring address by Professor C. H. Gray of Rensselaer on the subject, "A Geometric Approach to Literature."

On Thursday afternoon there was an inspection trip through the Watervliet Arsenal. With this our session ended.

Professor H. B. Howe and his local committee were most gracious hosts. Another annual meeting is over and we look forward to our mid-year meeting in January in Chicago and the next annual meeting at the University of Washington at Seattle, Washington. Plan to be with us at these meetings.

(continued from page 17)

may, however, be reasonably improved by: (1) separating, in the grader's thinking the two distinct and unrelated factors - analysis and execution. An aid to this kind of thinking is the provision for the separate Execution Item on the Rating Scale. It encourages the grader to analyze student errors from a job analysis point of view in terms of the manual and mental operations involved; (2) separating, in the grader's thinking, the "rating" and "weighting" operations. To attempt to perform both operations simultaneously is to divide one's attention such that discrimination on a purely qualitative basis is impossible. The Rating Scale provides for automatic weighting, thereby freeing the grader's attentive powers for the discriminative task of estimating quality; (3) employing a common scale, 4-3-2-1, for the evaluation of each phase of the drawing. Under schemes of absolute scoring, e.g., 24 points for views, 16 points for dimensions, etc., the grader must continually shift his numerical standards or proportionate scale. The Rating Scale separates the "weighting" from the "rating" and thereby provides for a common scale.

I might add that, from the single point of view of measurement and evaluation only, and disregarding the incidental educational advantages which might accrue, the Rating Scale is worthwhile because it does improve the reliability of scoring and does lighten the labor of doing a good job of scoring. Our experiments and experiments of others in the fields of education and psychology indicate a very low reliability coefficient for scoring "products" as single units, e.g., placing some red marks on a drawing and estimating a grade for the drawing as a whole. Attempts that we have made in the direction of absolute scoring, that is, assigning numerical values for specific lines, dimensions, etc., have not been satisfactory. The "product" nature of the performance drawing test does not lend itself to a breakdown into a number of specifics. Alternative methods of graphical and dimensional expression further add to the difficulty of setting up a rigid scale of points for specifics. Finally, the labor of scoring on an absolute-points basis is prohibitive, and the added precision implied is never really attained. An exception to these remarks is the completion-type problem in which the student completes a specific projection, a required dimension, etc. Absolute scoring schemes are applicable to this type of problem, but so also are the more desirable objective type scoring methods. This type of problem should be allocated to the objectively scored quizzes.

In introducing the Rating Scale technique into a large department we naturally had to overcome a certain inertia - an understandable reluctance on the part of some instructors to abandon their own familiar individual schemes of scoring, and a certain natural opposition to something new and seemingly complex. However, the plan has now been in operation for six semesters and is proving to be highly satisfactory. Familiarity with the Rating Scale technique has really lightened the burden of scoring a new test, especially for those instructors who, in the past, did conscientiously devise their own schemes for scoring each test. Acceptance of the technique by students and staff is now commonplace. Each staff member grading independently of other staff members now has some assurance of being in line and on common ground with his colleagues in the matter of departmental standards for grading. The students feel that they are being treated on the same impartial basis regardless of whose section they may be assigned to. It is no secret that they like to know how their Performance Drawing grades are determined. Finally, the Rating Scale tends to focus their attention upon specific areas of their drawing work requiring additional review and study. This factor of attitude is perhaps the really valuable educational outcome of this whole approach.

SAMPLE RATING SCALE
for
GRADING ENGINEERING DRAWINGS

Presented at Engineering Drawing Conference,
ASEE Convention
Austin, Texas
June 16, 1948

by

E. G. Kirkpatrick
Purdue University

GE 11 - PERFORMANCE DRAWING 3			
	Wt.	Raw Score	W. RS
1. Views.	7	3	21
3. Dimensions.	9	4	36
5. Notes and Titles	4	2	8
6. Execution -		4	- 0
linework,		3	- 6
measurement,		2	-12
& neatness.		1	-18
9. Lettering -		4	- 0
form, 65		3	- 4
weight, 16		2	- 8
& uniformity.		1	-12
Raw Score: 49	Grade: 5.1		
Name..................	File No.........		

Procedure:

1. Raw Score Scale: 4, 3, 2, 1 points.

2. Weight x Raw Score equals Weighted Raw Score for a single item

   (in the example, Item #1 Views, Weight of 7 x Raw Score of 3 equals the Weighted Raw Score of 21, ... etc.)

3. For Execution and Lettering Items, encircle both the Raw Score and the Weighted Raw Score, and the reason for the deduction.

4. Sum of the Weighted Raw Scores equals total Raw Score for test.

   (in the example, 21 36 8 - 12 - 4 equals 49)

5. A frequency distribution of Raw Scores is employed to convert individual Raw Scores to Grades.

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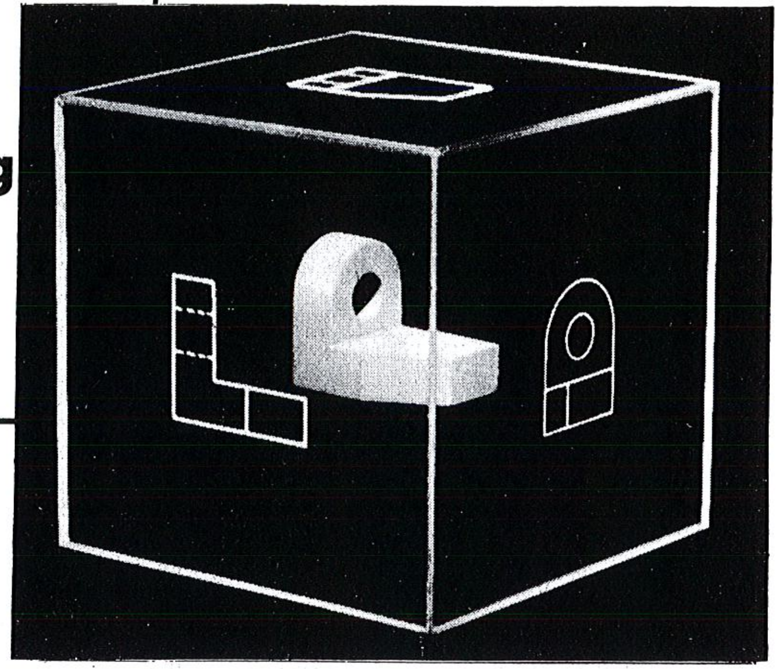

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