THE JOURNAL OF

ENGINEERING DRAWING

CONTENTS

Frontispiece: Rice Institute Meeting, January 1957 12

Editorial Page 13

Advanced Principles in Dimensioning *P. G. Belitsos* 14

Movable Scale Nomographs *J. Norman Arnold* 23

Operational Symbolism for Graphical Processes *S. A. Coons* 27

Problem Solution: Tangent Circular Arcs *Andre Halasz* 40

Distinguished Service Award to Frank A. Heacock

Citation *Ralph T. Northrup* 43

Response *Frank A. Heacock* 45

On Ideas and the Engineer *John F. Gordon* 45

A Light Table *Howard C. Nelson* 47

General Motors Institute 48

Mid-Winter Meeting, January 1958 – Program 49

Officers and Committees, 1957-58 51

Bibliography Committee Report *Samuel E. Shapiro* 53

Candidates for Offices, 1958-59 – Tentative Slate 56

Analysis

Synthesis

Communication

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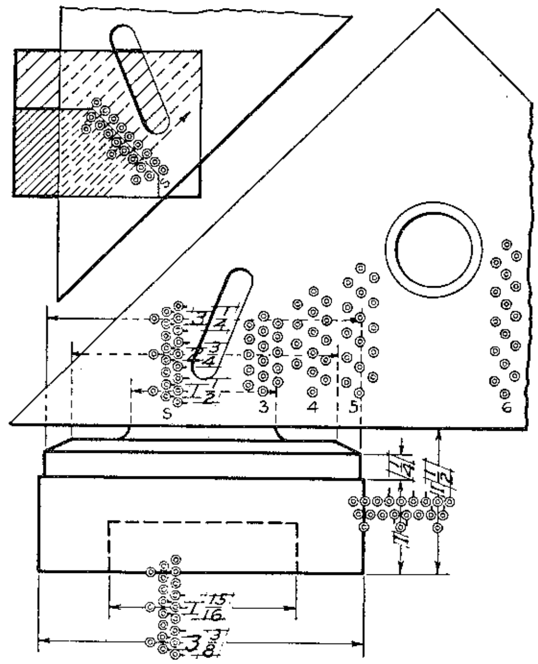

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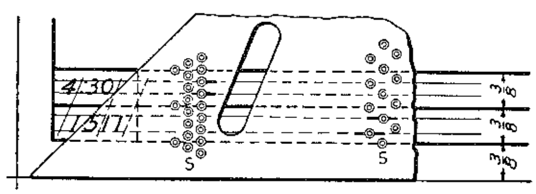

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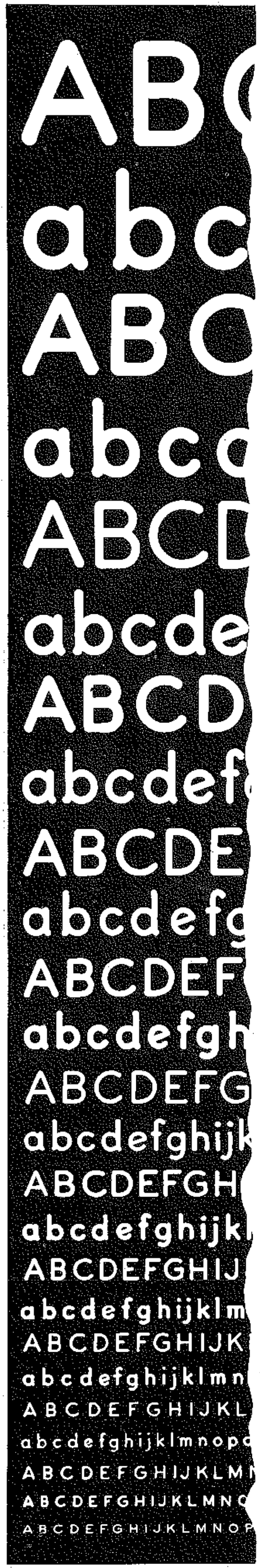

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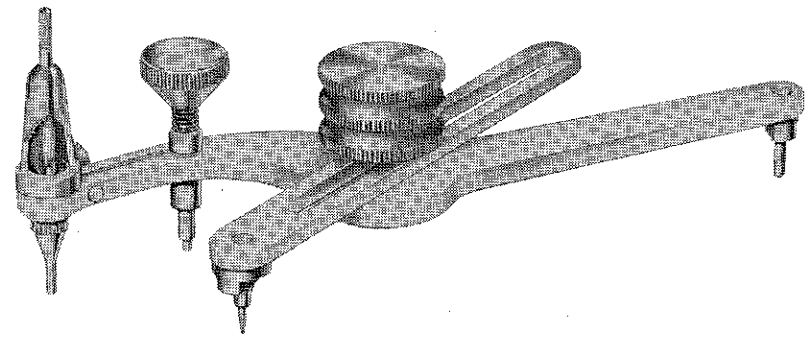

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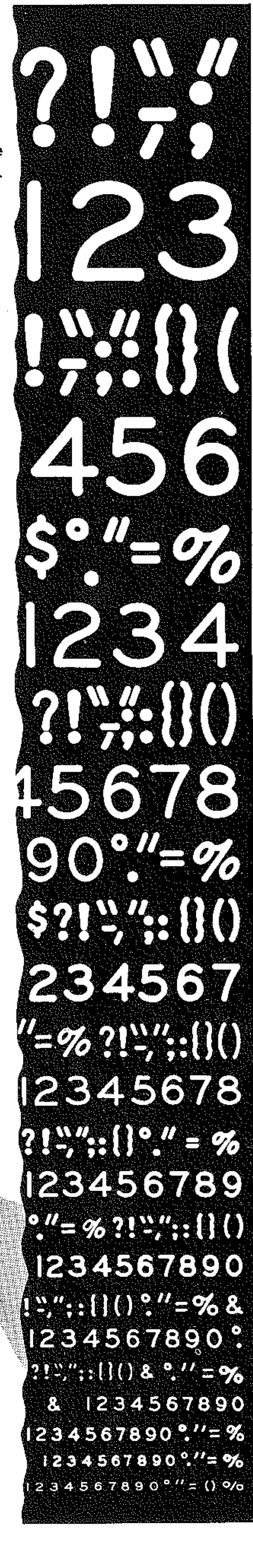

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This story is typical of the American engineer and the products of his creative genius. But where does this genius come from? History shows us it is *not* hereditary. Distinguished engineers both past and present in most cases came from average homes. As youths they didn't act or react any differently than the lads who crowd our classrooms today. This creative genius, the spark of achievement, slumbers in every lad. Whether this spark is fanned into a flame before it is smothered decides the student's future. Time and time again, instructors of mechanical drawing have witnessed the awakening of this inner genius. Here the student discards his boyish fancies for the practical and achievable. For the first time he learns the meaning of precision craftsmanship. He begins to think analytically and to use sound judgment. During these formative days, impressions are indelible . . . good and bad. For this reason the student's drawing instruments should be selected with exacting care. Drawing instruments are basic tools of every engineer, and inferior tools will never inspire skilled workmanship. Drawing instruments are a lifetime possession, and the only instruments worthy of consideration are the very best the student can afford. Precision inspires precision...perfection inspires perfection.

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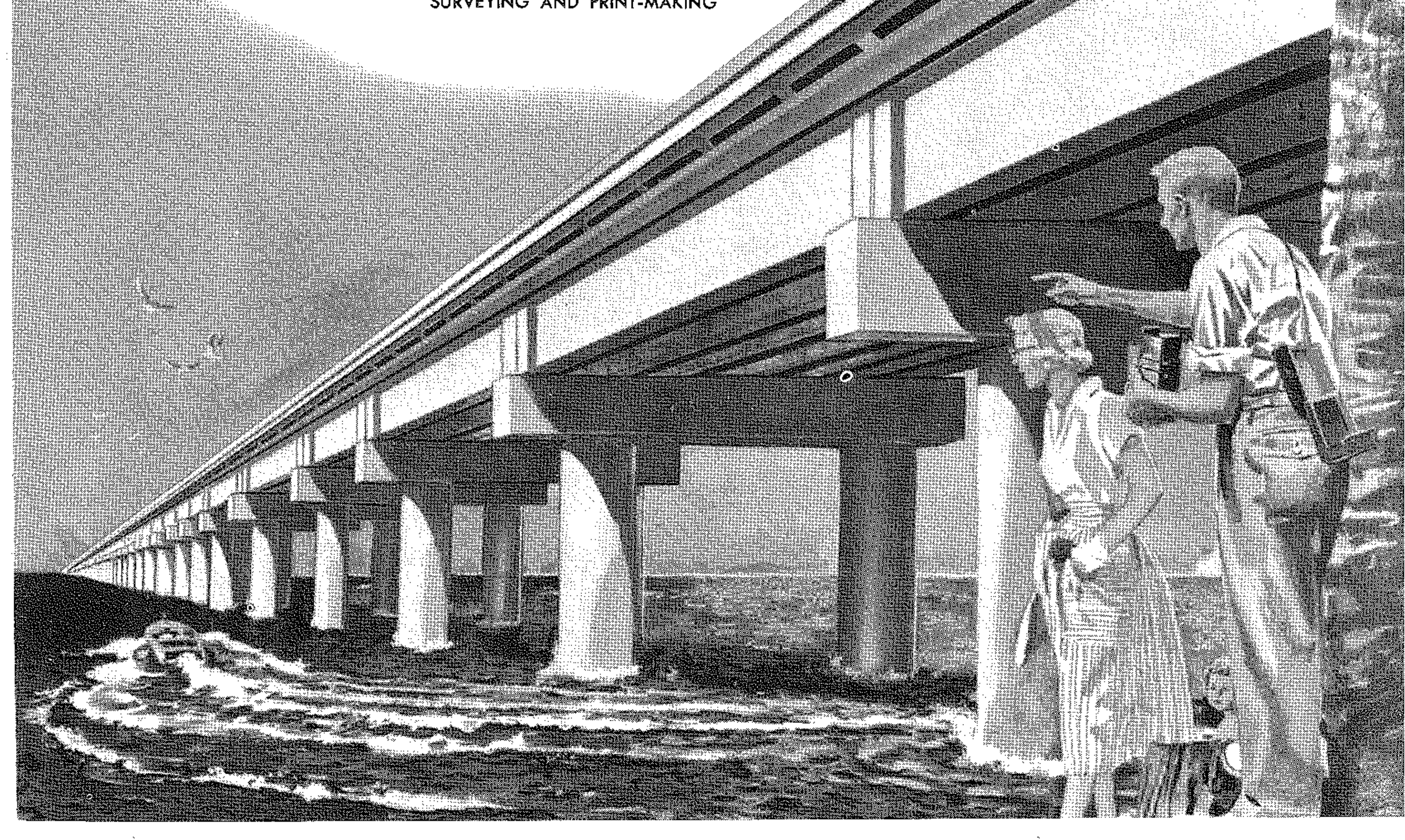


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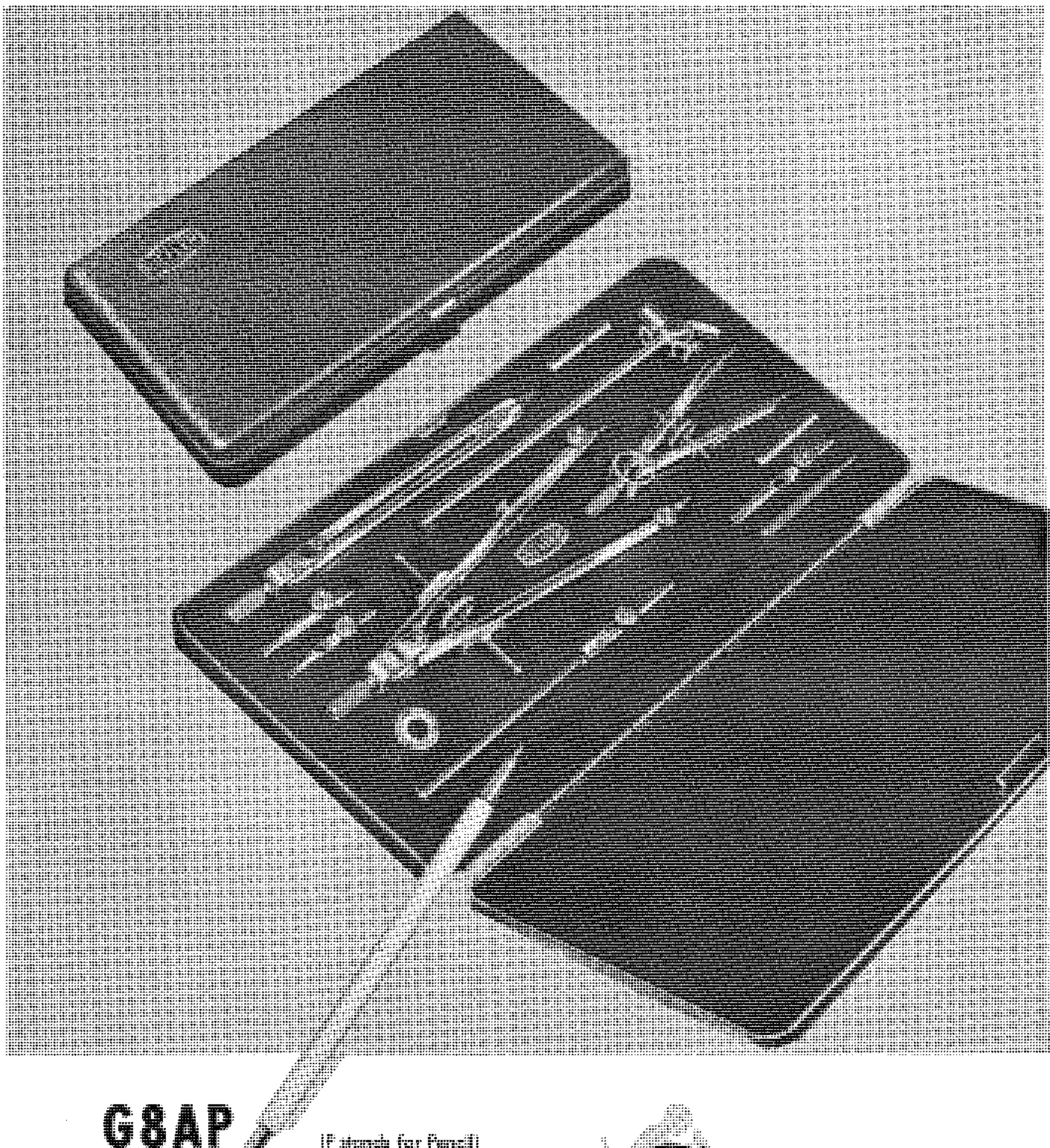

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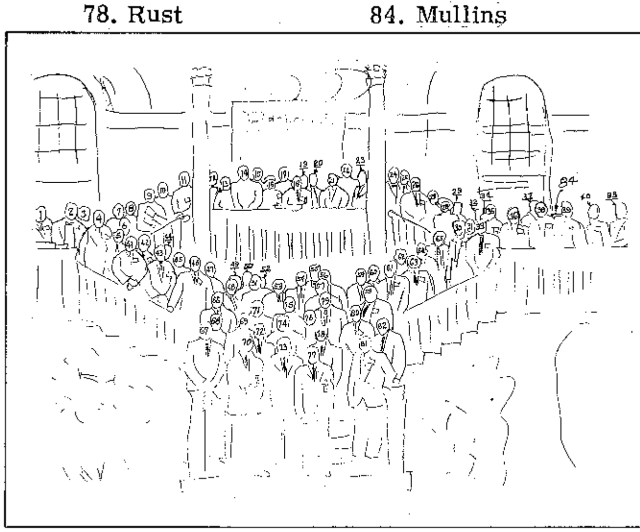

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INTEGRATION

If a course is not "integrated" does it mean that it is "disintegrated?"

In all seriousness, what is an integrated course? Is it a course in which descriptive geometry is disguised beyond recognition? Is it a course in which there are many problems whose solutions require two and sometimes (but not often) three auxiliary views, but no descriptive geometry? Or is it a course that carries orthographic projection both freehand and instrumental, a bit of descriptive geometry, a smattering of nomography, some charts and graphs, some empirical equations, graphical calculus, and perhaps a little graphic statics? In how many hours is all of this or part of this taught?

Is it possible to get specific answers to this vitally important question? The pages of this JOURNAL are open to anyone who has come to any conclusions about integration and how it should operate.

WE BID YOU WELCOME

More teachers in secondary schools, technical institutes, and industrial arts departments of colleges of education are now reading the JOURNAL OF ENGINEERING DRAWING than ever before and we are happy indeed to number them among our friends. Now that they have joined our company, we'd like them to stay with us.

At the same time that we express our pleasure in the anticipation of mutual profit that will accrue, the editor invities contributions of articles from our new subscribers. A paper on any topic that has to do with the education of young engineers will get a fair reading and a prompt acknowledgment.

ON THE SOLUTION OF PROBLEMS

On page 41 of the May, 1957 issue we carried a problem submitted by the University of Vermont triumvirate, V. H. Paquet, G. H. Dewey, and G. R. Charron. It looked easy, but when some of us attacked it almost disdainfully, it turned out to be quite a puzzler.

Although we had expected to get an avalanche of solutions, only three persons actually sent solutions to the editor. The first was sent in by Dean John Rule, of the Massachusetts Institute of Technology. The second solution, identical to the first, was air mailed in by Dr. Paulo Rodrigues Lima, professor at the Universidade do Brasil, Rio de Janeiro. The third person to submit solutions was Professor Andre Halasz, of The City College of New York. Professor Halasz must have been in a wholesale mood, for he sent in four solutions together with an amusing yet scholarly commentary. His number ber-2 solution was the same as that submitted by Professors Rule and Lima. In the interest of completeness, Professor Halasz' paper is the one selected for publication, even though it was not the first received.

Professor Paquet has informed us that one of his students has turned in to him a correct solution and we congratulate both Professor Paquet and his student for a profitable association.

But let's leave aside this particular problem and ask ourselves a basic, provocative question. The question is: What really is involved in the solution of problems? We all know that the "scientific method" involves setting up a hypothesis, gathering data, discarding irrelevant facts, drawing conclusions, and then testing the validity of the conclusions.

We can talk about scientific method but it will be meaningless to our students if they have not tried it out directly and deliberately to see whether it works. It is fatuous to claim that giving our students problems to solve teaches scientific method as an inevitable by-product. If this is the objective we want, it will never be an accidental outcome.

In other words, the way to make the problem solving method a key to education is to let the student in on the secret. The secret is that an answer to a specific problem is important only if solving that problem has taught him how to attack any problem.

Advanced Principles in Dimensioning of Engineering Drawings

By P. G. Belitsos

Jet Engine Department, General Electric Company

IMPORTANCE OF GOOD DIMENSIONING PRACTICES

There is no.company in industry today that is not faced with countless difficulties in the manufacture, inspection, or servicing of its products, many of which originate on the engineering drawing board. These difficulties and the action required to eliminate them are the concern of all types of engineering effort that go into the end product since they affect the function and serviceability of the product and the ability of the company to produce at a competitive price. They should also be of vital interest to you who teach the engineers the fundamentals and applications of engineering drawing and graphics.

A careful analysis of these difficulties reveals that they stem from two important causes:

1) Improper consideration is given to the basic principles that should be applied in establishing the dimensional requirements of the design; and
2) When the dimensional requirements of the design are finally determined, they are not adequately stated on the drawing in terms that can be clearly understood and uniformly interpreted.

As you know in the past five years the tempo at which dimensional practices have been studied by industry, national and international groups has increased sharply. There are many important principles and considerations in dimensioning for interchangeable manufacture that have been given much careful study. Many of these are new to most engineers and will require considerable educational effort both in industry and in the universities. A few of these are so new that they have not yet beengiven the serious study needed to standardize them and to properly integrate them into widespread industrial practice.

The following is an explanation of these principles with illustrations including the very latest experience from the front lines of industry.

COMPLETENESS OF DIMENSIONAL REQUIREMENTS

Probably the most important and fundamental principle is that only enough dimensions should be given to completely define the engineering requirements of the end product; and that these shall be expressed in such a manner as to allow the maximum latitude and flexibility to manufacturing and inspection operations. You will notice that I emphasized the complete definition of the engineering requirements of the end product.

When this principle is followed it results in engineering drawings that are most acceptable to multiple manufacturing sources:

1) That are widely separated in location from the design source; and
2) That have different methods and processes suited to their own equipment and experience to produce the engineering requirements of the end product.

Applying this principle also relieves the engineering department from getting involved unnecessarily in controversies that do not affect the engineering requirements but are merely centered around the relative merits of one method of manufacturing or inspecting the part as against another method. This reminds me of an amusing expression used by a British authority in a recent American-British-Canadian conference. When asked his opinion on this principle his quick reply was 'Why sir, it is the only protection the drawing office has against the endless cries from all sides to sack the bloke that made the drawing.' I assure you that expressions such as 'sack the bloke that made the drawing' are not uncommon in our American drafting departments.

Next, it is important that the precise shape, size and location and relationship of all surfaces and features must be clearly defined. Deviations that can be tolerated for every dimensional requirement should never be left to the imagination of the workshop. They must always be specifically stated. Just think of the countless engineering man-hours that are wasted when the engineer is called into the shop to settle a controversy on the meaning of a questionable dimensional requirement. To say nothing of the distress involved when a foreman working on a rush job on the third shift has to call the engineer at 3 A.M. to fill in on information which is inadequately stated.

SUPPLEMENTARY ENGINEERING DATA

Every effort must be made to include as many of the detail engineering requirements on the face of the drawing as possible, and in a compact and concise form. The amount of supplementary technical data such as dimensional interpretations, material and finish specifications, heat treatment and other processing requirements which are referenced on the drawing, must be kept to the absolute minimum necessary to describe the engineering intent. It is not unusual for a purchasing department to send out a relatively small drawing with a substantially thick bundle of supplementary data. Engineers must have an intimate working knowledge of this supplementary data and whenever possible, condense it to such an extent that it can be specified on the face of the drawing. This is important because it is not unusual to have data which is not on the face of the drawing, overlooked in manufacture and inspection. In those cases where this is impractical, supplementary data call-outs must at least be easy to find. This will also facilitate the collection of data that is not to be sent out by purchasing for quotes from prospective suppliers.

SHOP RUN TOLERANCES

Before we get into the complex subject of geometric and positional tolerancing, let us first look at the extent to which we can rely on 'shop-run tolerances' that can be expected from ordinary established workshop practices. To maintain the accurate geometric and positional tolerance requirements of mechanical designs requires special equipment and involves time-consuming and expensive manufacturing and inspection operations. Tolerances of form and position should therefore, be specified only for those requirements affecting performance or interchangeability where these established workshop practices cannot be relied upon to produce the required standards of accuracy. Where drawings are used by a large number of sub-contractors, it has been found necessary by many companies to define these expected shop-run tolerances and other related details in a specification which is referenced on each engineering. A sufficient number of these have now been developed in industry so that they can serve as the basis for an industry standard. This standard can be used as part of the basic knowledge required by an engineer in understanding what can be expected from general purpose machines and common workshop practices. With this knowledge as a part of his training, the engineer can more intelligently assign precision tolerances of form, size, and location for interchangeable components.

TRUE POSITION DIMENSIONING

You have no doubt been following with considerable interest recent developments in geometric and positional dimensioning. In the last few years a vast amount of engineering effort in Britain, Canada and the United States has been concentrated on this subject. The following is the very latest information on the principles of dimensioning related to this subject being finalized in this country by a joint task force of the SAE Aeronautical and Automotive Drawing Standards Committee and the Dimensioning Committee of the American Standards Association.

Let us look at these principles and see how they first apply to true position dimensioning. In any group of cylindrical features that are designed to mate on an interchangeable basis, it is necessary to control the location of the features within certain design limits. To do this, it is first necessary to establish the theoretically true location of the features by the use of basic (untoleranced) dimensions. This can be done by any suitable form of dimensioning which may be used to locate points or lines in space. On drawings which use a block of general tolerances, it is necessary to insure that the general tolerances are not applied to these locating dimensions. This is done by adding a note to the drawing which specifies that the general tolerance does not apply to the the dimensions establishing the true position of the features.

Features which can be located by true position dimensioning may be cylindrical such as holes or bosses, or non-cylindrical such as slots and dovetails. In addition these features may be located in continuous or interrupted flat planes, cylindrical or conical surfaces, and they may be in equally spaced or scattered arrangements. In addition, the features may be all of one size or they may be of different sizes. One of the important advantages of the use of basic dimensions is that there is no accumulation of tolerances. This applies even if there is a chain of dimensions. Let us look at some figures that illustrate these points. See Figures 1 to 8 inclusive.*

APPLICATION TO CYLINDRICAL FEATURES

For purposes of illustration, we will confine this analysis to equally spaced holes which are cylindrical features commonly used in most designs. The allowable deviation of the holes from this true position is specified by using the phrase 'LOCATED WITHIN .005 OF TRUE POSITION'. The tolerance. of course, will vary to suit the requirements of the design. In fact, this system facilitates the use of different tolerance values for the location of any of the features in any group, if required by the design. The phrase 'LOCATED WITHIN .005 OF TRUE POSITION' has been used in the aircraft engine industry for about 15 years and specifies the radial deviation from the theoretically exact position. In order to eliminate any possibility to misunderstanding it has recently been agreed to add the designation 'R' (for radius) in order to pinpoint the fact that the specified positional tolerance is a radial value. The note would then read 'LOCATED WITHIN .005R OF TRUE POSITION'. For those that prefer to express this as a total tolerance, the phrase 'LOCATED AT TRUE POSITION WITHIN .010 DIA' is used. Both methods of expression mean the same thing. One specifies the radius of the tolerance zone and the other its diameter. See Figure 9.

Now, let us examine the meaning of this dimensional requirement. In terms of the axis of the hole, it means that the axis of each hole at all sections along its length must fall within the specified cylindrical tolerance zone whose center is located at true position. At this point, it is important to note that this tolerance zone also defines the limits within which variations in the squareness of the axis of the hole must be confined with respect to the surface. See Figure 10. If the design does not require the same positional tolerance for the full length of

* All the figures follow the text of this article.

the hole, a more liberal tolerance can be applied at the other end by the method shown in Figure 11. If there are several cylindrical features on one axis such as a counterbore, spotface, etc., it is necessary to carefully specify to which of the features the true position tolerance applies. This can be done as shown in Figure 12. If the design does not require the positional tolerance to apply to each of the features on a common axis and this fact is clearly stated it will eliminate many questions from manufacturing and inspection and at the same time keep the cost of tooling and gaging at a minimum consistent with the design requirement.

DESIGN CONTROL OF CONDITION OF SIZE

We now consider the next important dimensional principle. Since the hole itself has a size tolerance which provides the high and low limits of size, it is necessary for the designer to define clearly the condition of size to which the positional tolerance is applicable. In all but a few exceptional designs it is necessary to maintain the specified positional tolerance at the maximum material condition only. This fact is established by the use of the following general note on the drawing: 'TRUE POSITIONAL TOLERANCES SPECIFIED ARE FOR MAXIMUM MATERIAL CONDITION ONLY UNLESS OTHERWISE SPECIFIED'. The use of the term 'MAXIMUM MATERIAL CONDITION' is new and will require extensive usage and explanation to be understood by engineering personnel and the many users of the drawing. When used in a drawing note it means that the specified tolerance applies at that limit of size at which the part contains the maximum amount of material. This, of course, would be the maximum limit for an external feature such as the maximum diameter of a mating flange, or the minimum limit of an internal feature such as the minimum diameter of a hole. By controlling the maximum material condition of size of mating parts, the designer exercises the necessary control over the least favorable condition of assembly.

When the note as above specifies that the positional tolerance applies to the maximum material condition, it follows that where the actual size of the holes are other than at maximum metal size, the design permits an additional positional tolerance equal to one-half the difference between the actual measured size of the hole and its maximum material size. This is a somewhat difficult principle to grasp without a detailed explanation. This can best be done by demonstrating how the position of each hole is to be inspected. A fixed gaging pin with a diameter equal to the minimum diameter of the hole minus the total positional tolerance is located at true position. If by means of transparent overlays, a hole at minimum size is placed over this gage pin, it can move by the amount of the positional tolerance. If another transparent overlay is used with a hole at its maximum size, it is immediately obvious that this can move by the amount of the positional tolerance plus the value which represents one-half the difference between the maximum and minimum hole size. Figure 13 illustrates this principle pictorially.

One method for specifying the requirement that the positional tolerance applies only at the maximum metal condition of size is to add the abbreviation MMC to the tolerance note. This introduces another unknown expression on the drawing requiring additional educational effort. Those industries that have sucessfully used true position dimensioning for the longest time find this unnecessary.

Another controversial point has been to identify the basic untoleranced dimensions that establish the theoretically true position of the holes as 'TP' dimensions as shown in this same Figure. Here also is another unknown expression. It would not take long to drop these 'MMC' and 'TP' designations if they were used since it would become evident with experience that identifying individual dimensions with these would constitute carrying excess baggage on the drawing. See Figure 14.

In limited applications where the design demands it, the positional tolerance may be specified to apply regardless of whether the feature is at maximum metal size, minimum metal size or anywhere in between. Where this restricted positional control is required, the phrase 'REGARDLESS OF HOLE SIZE' is added to the true position note. The addition of this phrase establishes a design requirement which is more difficult to meet and also requires more complicated and expensive positional gaging since inspection must be based on a method which will locate the actual center of each hole. It is evident that this type of control will be used in very few design applications. Therefore, the use of this additional phrase emphasizes this special requirement in order that it will not be overlooked. See Figure 15.

APPLICATION TO NON-CYLINDRICAL FEATURES

The principles of true position dimensioning outlined up to this point for groups of cylindrical features are equally applicable to groups of non-cylindrical features such as slots, dovetails, serrations, tabs, etc. The differences are mainly in the geometry of the tolerance zone. For example, in terms of the axis of the slot shown in Figure 16, the note 'LOCATED WITHIN .005 EITHER SIDE OF TRUE POSITION' means that the axis of the slot must fall within a rectangular tolerance zone which is symmetrically disposed on either side of the true geometric position of the axis by the amount of the specified true position tolerance. The total width of the tolerance zone is therefore twice the true position tolerance.

Here again, for those that prefer to express the drawing note in terms of the total tolerance zone, the note would read 'LOCATED WITHIN .010 TOTAL ZONE WIDTH'.

TRUE POSITION IN RELATION TO DATUM SURFACES

We now come to a very important principle in true positioning dimensioning. Most designs for interchangeable assemblies require parts that have groups of cylindrical or non-cylindrical features that must be located in relation to an integral datum such as a pilot diameter. It is important that the true position tolerance is related to the required datum. If this is not done either of two things can happen:

1) Manufacturing and inspection may select the improper surface from which the location of the feature is controlled; or
2) They may assume that there is no requirement to control the location with respect to any datum which will result in maintaining the positional tolerance only in a hole-to-hole relationship.

In either case trouble may result; improper tools, and parts will be made, with resulting loss of time, money and effort. Figure 9 shows how the datum surface is specified. In this case the positional tolerance establishes the hole-to-hole relationship and also the datum surface to hole relationship. However, by virtue of the same principles explained previously the true position tolerance specified must be maintained to .005 only if both the datum surface and the holes are at their maximum material size. Any hole not at its maximum material limit is permitted an increase of positional tolerance to the extent previously described. Furthermore, if the datum is not at its maximum material condition, a further increase of positional tolerance is permissible for all holes in relation to the datum, but not in relation to each other. The success of designs that are to be produced for interchangeable manufacture depends to a great extent on the proper selection and use of datum surfaces which involves the application of another important principle of dimensioning. Here the designer can play a very big part in reducing production and inspection difficulties to a minimum by intelligent and economical designs. Positional accuracy should be restricted to the minimum number of features. All remaining positional features then become relatively unimportant, and as a rule, can be given large minimum clearances and correspondently large positional tolerances.

Before passing from the subject of true position dimensioning, I would like to point out that its use will eventually be extended to cover geometric tolerances for symmetry, and alignment and concentricity. See Figure 17. This is particularly true where allowable errors of squareness, angularity or parallelism must be included within the one tolerance zone.

GEOMETRIC TOLERANCING

In addition to positional dimensioning, a considerable amount of engineering effort has been concentrated by industry in standardizing the methods of establishing the geometric requirements of components. This is an area in dimensioning practice which bristles with complexities.

Most engineers have difficulty in expressing or interpreting the geometric requirements of designs that have relationships involving concentricity, squareness, roundess, alignment, parallelism, angularity, etc., that must be accurately maintained in order that the parts may assemble and function properly. It is not unusual for manufacturing or inspection to get conflicting interpretations for the same requirement from several engineers.

Considerable time should be spent with student engineers training them the fundamentals and applications of geometric tolerancing. This is becoming more and more important with the ever increasing requirements of mass production, interchangeability and performance, particulary with hi-speed rotating parts. In order to appreciate the problems involved it is only necessary to make a dimensional analysis of a compressor for a jet engine which rotates at 8000 RPM and has to maintain certain radial and axial clearances between the rotor and stator blades and vanes in order to function at maximum efficiency.

Time will permit only a brief review of some of the fundamental methods of expressing geometric requirements. You will note that the word 'WITHIN' is included in most tolerance notes. For example, STRAIGHT WITHIN .001, FLAT WITHIN .005, PARALLEL TO SURFACE A WITHIN .002. In each of these notes the requirement is that the dimensional value defines a total tolerance band within which the variation for the applicable surface must be held. This, of course, means the whole surface and not merely a point or a line on the surface.

To further clarify the tolerance expressions used for these geometric surface relationships, it has been decided by the dimensioning task force of SAE and ASA to add the word 'Total' or its equivalent to geometric tolerancing notes as in the following: 'FLAT WITHIN .003 TOTAL', 'SQUARE TO SURFACE A WITHIN .005 TOTAL', etc. In the case of concentricity the customary 'FIR.' (Full Indicator Reading) will be used instead of 'TOTAL'. See Figures 18, 19, and 20.

It has been pointed out that one of the shortcomings of present practices in industry is that some tolerance expressions specify a total tolerance and others specify a tolerance which is to be applied bilaterally or as a radial distance in any direction from the point of origin. Actually, however, the more important consideration is not how the tolerance is specified but rather that its intent be clear and unmistakable. Every effort has been concentrated in developing tolerance expressions, or methods of delineating allowable tolerance requirements that do not require any explanation by the engineer.

For example, Figure 21(a) illustrates a typical airfoil section for a turbine blade. The true shape of the section is described by a series of points which are located in their theoretically exact location by rectangular coordinates from two datum lines. The tolerance on the shape has often been defined by the note:

AIRFOIL CONTOUR MUST BE WITHIN .002 OF TRUE SHAPE EXCEPT LEADING AND TRAILING EDGES MUST BE WITHIN .003 OF TRUE SHAPE.

The first part of this note has been interpreted to mean either ±.002 or .002 total and the second part is questionable because it does not define the extent of the leading and trailing edges. To eliminate any mis-interpretation a much better method of tolerancing contours such as these has been developed. Looking at the new method there is no question of the designer's intent. See Figure 21(b).

To illustrate one further complication supposing we define a rigid metal tube having multiple bends in several planes by a series of straight lengths, bend angles and twist angles expressed as basic untoleranced dimensions. See Figure 22. As in the previous illustration this the true shape of the tube, and a contour tolerance specifies the allowable variation from true shape. However, in this case, the outside diameter of the tube has a size tolerance. A tool engineer designing a gage for the tube might well ask the following question. Does the contour tolerance apply to the maximum O.D., the Minimum O.D., or does it apply regardless of what size the O.D. acutally measures providing that it is within its specified size limits? This can be clarified by the addition of a simple phrase and the contour tolerance now reads: THIS TOLERANCE APPLIES AT ALL POINTS ON MAXIMUM EXTERNAL SURFACE OF TUBE CONTOUR.

The relationship between form tolerances and size tolerances must always be kept in mind. The requirements of most designs for interchangeable parts are that the specified geometric tolerance applies regardless of the feature size. Therefore, Where geometric tolerance notes are expressed without any qualifying phrase such as the one just shown for the rigid tube, they are to be observed regardless of the actual finished sizes of the features concerned. There are some designs where the specified geometric tolerance has to be held only at the maximum metal size of the feature. The method of indicating this on the drawing is by adding a qualifying phrase to the tolerance note which specifies this condition. For example, for external cylindrical surfaces the note "AT MAXIMUM DIAMETER" and for internal surfaces "AT MINIMUM DIAMETER" would be added.

The principles which have been covered up to this point are merely the simple fundamentals. Student engineers should understand these principles and should have an opportunity to apply them to design problems and also to study applications in actual components used in industry. For example, let us take the dimensioning of a compressor rotor blade for a turbo-jet engine with its complex airfoil contours, twist angles, precision geometric surface relationships and dovetail configurations. This challenges the engineer's basic training in drawing and graphics and stimulates his interest in one of the most vital steps in the process of creative engineering; that is, the committing of the design on paper.

SUMMARY OF OTHER ADVANCED PRACTICES

Time does not permit a detailed discussion of other important principles and considerations in the dimensioning of engineering drawings but I would like to give you a quick run-down of some items of particular interest.

SYMBOLIZED NOTES FOR GEOMETRIC SURFACE CONTROL

The use of symbols on a drawing is a time-saving device and at the same time eliminates repetitious details which results in a drawing that is easier to use. The geometric and positional dimensioning practices that we have discussed can be reduced, in time, to a series of symbols. However, before symbols can be introduced it is very necessary that the dimensioning principles involved are widely used and understood in the present detailed note form. I cannot pass from this subject without mentioning a symbolized method of geometric surface control which has considerable promise and is gaining increased usage on Aircraft engine drawings. It is not only simple but it eliminates a common dimensioning problem related to concentricity and out-of-roundness control for multiple surfaces. Figure 23 illustrates one typical application for this symbolized method. Note how this one note clearly specifies the tolerance for a large number of surfaces.

INTERPRETATION OF DIMENSIONAL LIMITS

With the increased use in industry of the complete decimal system of dimensioning one of the problems that has been raised is the interpretation of dimensional limits. If a dimension is expressed as a two-place decimal such as $\begin{matrix}.92\\.90\end{matrix}$, can parts which are inspected as $\begin{matrix}.924\\.896\end{matrix}$ be considered as meeting the dimensional requirement? You will note that although these limits can be rounded off to $\begin{matrix}.92\\.90\end{matrix}$ they exceed the absolute limits of $\begin{matrix}.92\\.90\end{matrix}$ and therefore are not acceptable. Student engineers must be taught this simple principle. Rounding-off may be utilized in the mathematical computations involved when establishing dimensional requirements, but once the dimensional limits are specified they are absolute limits; that is, to the extent of the accuracy possible with the measuring equipment used and the human factor involved in the measurement.

FREE STATE VARIATION

The increased size of such products as aircraft jet engines and guided missiles with the emphasis on high speed and reduced weight presents problems in the dimensional control of the shape of sheet metal components. Although large thin shapes can be maintained accurately in the machining position by fixtures, they become distorted when removed from the restraining forces used in the fixtures. This distortion may result because of the weight or flexibility of the part, or because of internal stresses released by the manufacturing processes. Thus in the free unrestrained state, the configuration of this type of component is other than that which it takes when properly assembled with other parts and consequently is also different than the one delineated on the drawing. This presents many problems in the inspection and acceptance of these parts. The restraints or external forces which can be allowed to bring the parts back to drawing configuration must be carefully defined on the engineering drawing to simulate actual assembly conditions. The allowable free state variations must also be specified. Figure 24 illustrates the complexity of this type of dimensional control.

AUTOMATION

Automation has reached the drafting room. For example, digi-verters and vari-plotters are being used in the layout of precision master contours. Industry is just beginning to scratch the vast possibilities in using data processing equipment in the preparation of engineering drawings and data lists. Watch for rapid developments in this area. For one thing automation should accelerate the pace at which fractional dimensioning will be replaced by the complete decimal dimensioning system.

REDUCED SIZE DRAWINGS

Developments in photography and reproduction techniques are affecting the preparation of drawings. No longer will the engineer be required to pore over prints that are 10 to 20 feet in length as he hikes from one end of the drawing to the other obtaining dimensional information. Drawings are being reduced successfully in size by 50%. In order to maintain legibility at reduced size, new techniques are being used in the preparation of drawings affecting the size of letters, spacing, sectioning, thickness of lines, dimension lines, placement of dimensions, etc.

NATIONAL DIMENSIONING STANDARDS

By the end of the year we will probably have an approved American Dimensioning Standard which will be ready for coordination with England and Canada. This will provide material for a very active educational effort in the next few years in which all of you will participate. Your text-books should devote more chapters to these advanced dimensioning practices, your student engineers should spend more class time applying them to design, and you should participate in research studies in improving the dimensional analysis of engineering designs. All of this activity will assist in eliminating those problems in industry that originate on the drawing board.

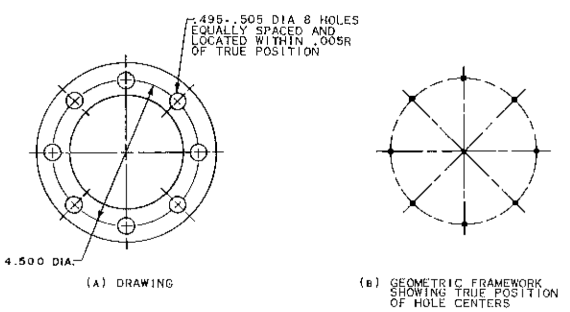


Fig. 1 - In this case, the true position of each hole is determined from the basic bolt diameter and the basic angular relationship established by the drawing note.

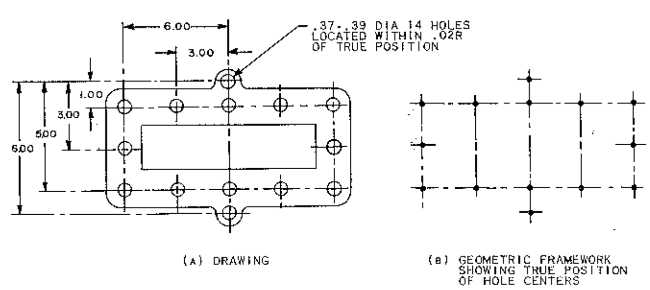


Fig. 2 - Here the true position of each hole is determined by the use of basic rectangular coordinate dimensions.

(Continued)

BARBER-COLMAN COMPANY NOMOGRAPHY PRIZE

Competition for the $100 nomography prize announced in the February, 1957 issue will close January 1, 1958. Any nomograph appearing in a regular periodical before that date will be eligible for consideration. The nomography Committee would appreciate having called to their attention any unusual nomographs. Names of the committee members are listed elsewhere in this issue.

The prize money is donated by the Barber-Colman Company, Rockford, Illinois.

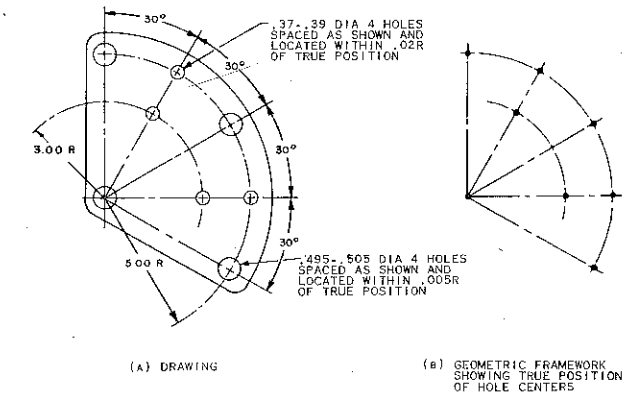


Fig. 3 - In this case, the true position of each hole is determined by basic angles and radii. Note that this part contains holes of different diameters and holes located within different positional tolerances.

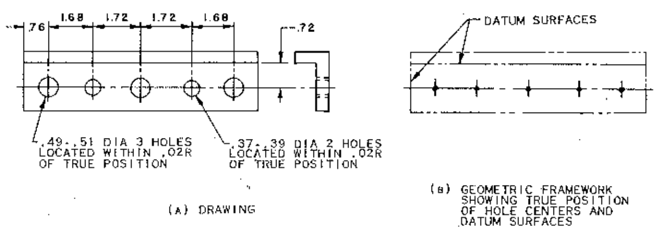


Fig. 4 - here all the holes are located on a straight center line and the linear position of each hole is specified by basic dimensions. Note that chain dimensions can be used because true position tolerances are not cumulative.

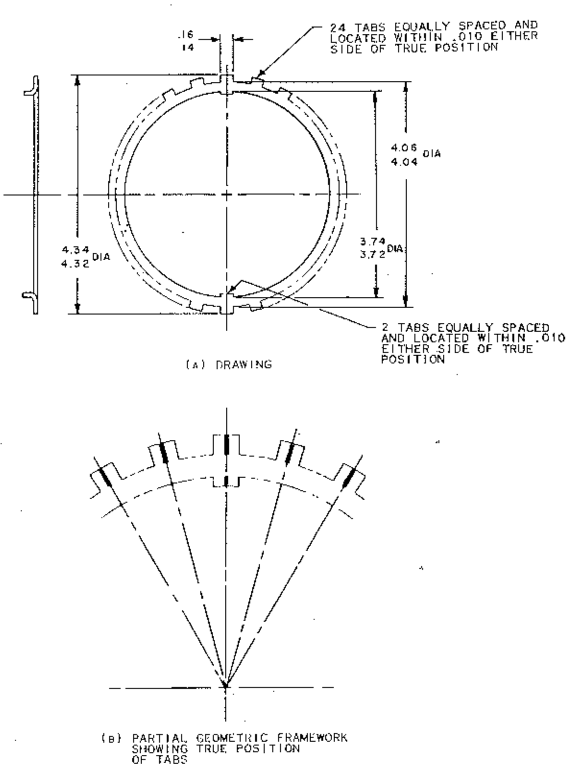


Fig. 5 - This illustrates the application of true position dimensioning to locate and tolerance a pattern of tabs.

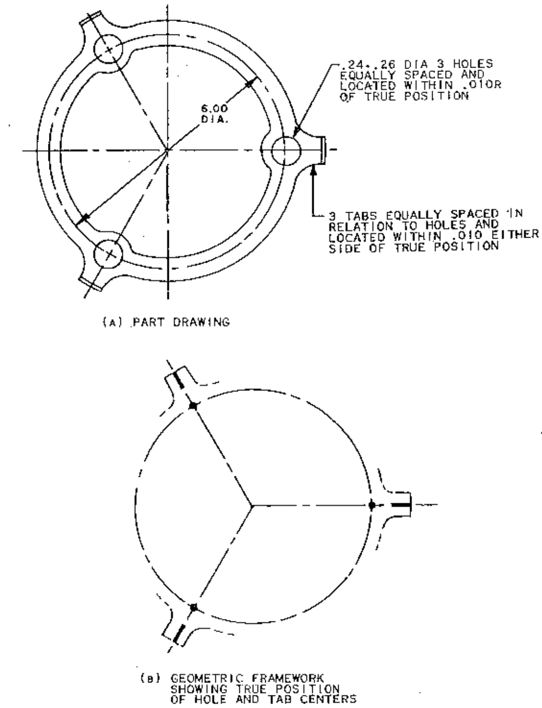


Fig. 6 - In this case holes and tabs are located within a true position tolerance and in relation to each other within the same tolerance.

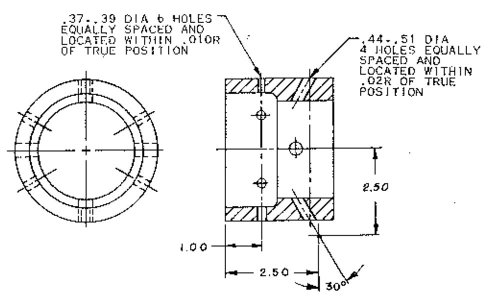


Fig. 7 - In this case true position dimensioning is used for holes which are normal and at an angle to the axis of a cylindrical component.

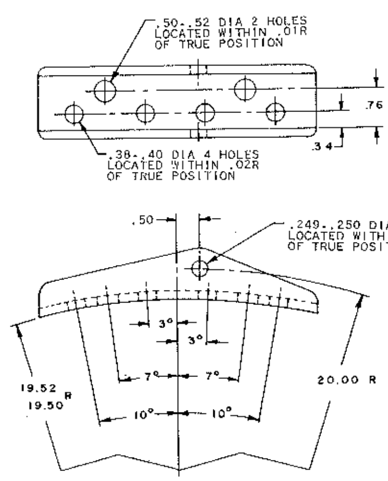


Fig. 8 - This illustrates that true position dimensions can be used to locate different patterns of holes on the same part with a combination of angular and linear dimensions.

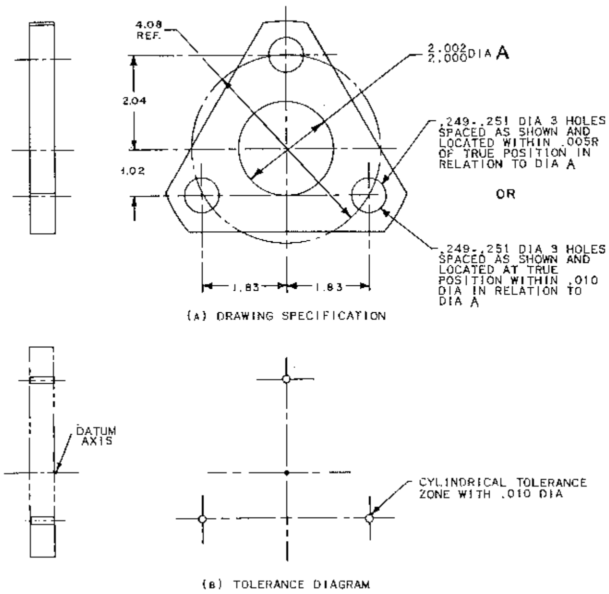


Fig. 9 - Two equivalent methods of specifying the positional tolerance

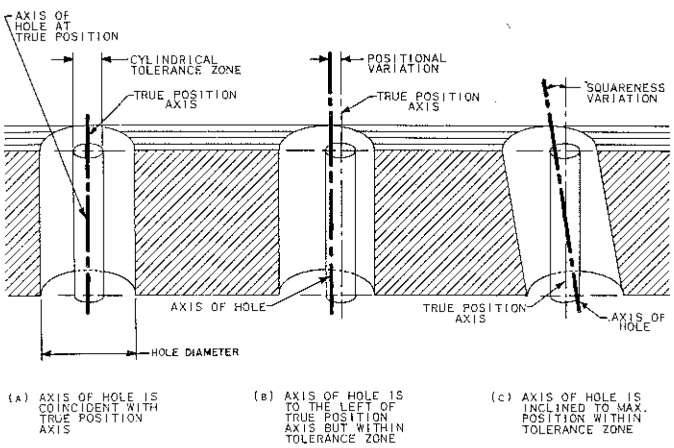


Fig. 10 - This shows relationship of axis of hole and true position tolerance zone

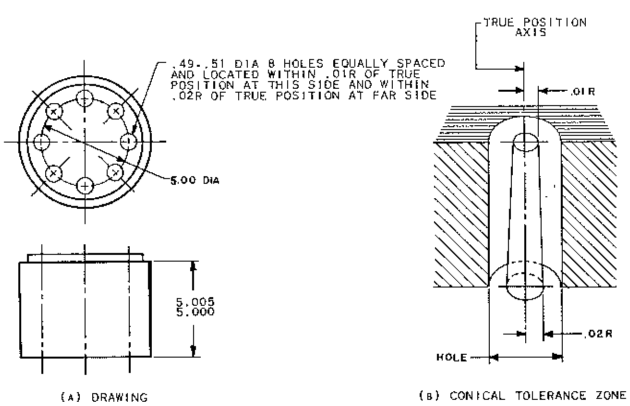


Fig. 11 - In this case it is impracticable to maintain both ends of the long hole to a close true position tolerane. The far end has a larger positional tolerance than the near end.

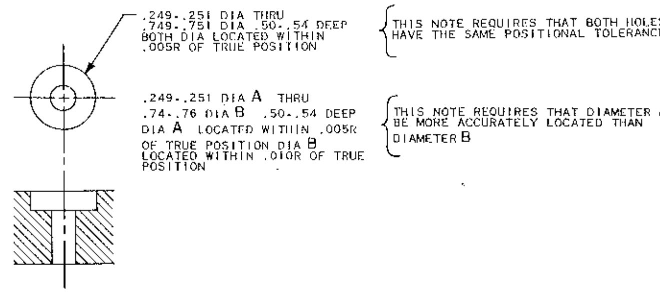


Fig. 12 - In this case, where there are several cylindrical features on one axis, it is necessary to specify to which of the features the true position tolerance applies.

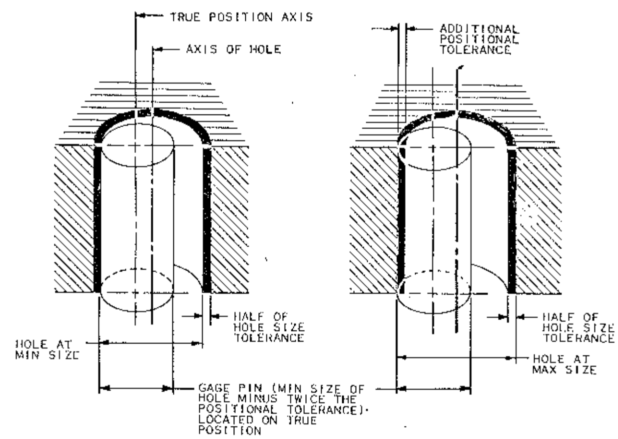


Fig. 13 - This illustrates the additional positional tolerance permissible at minimum material condition when positional tolerances apply at maximum material condition.

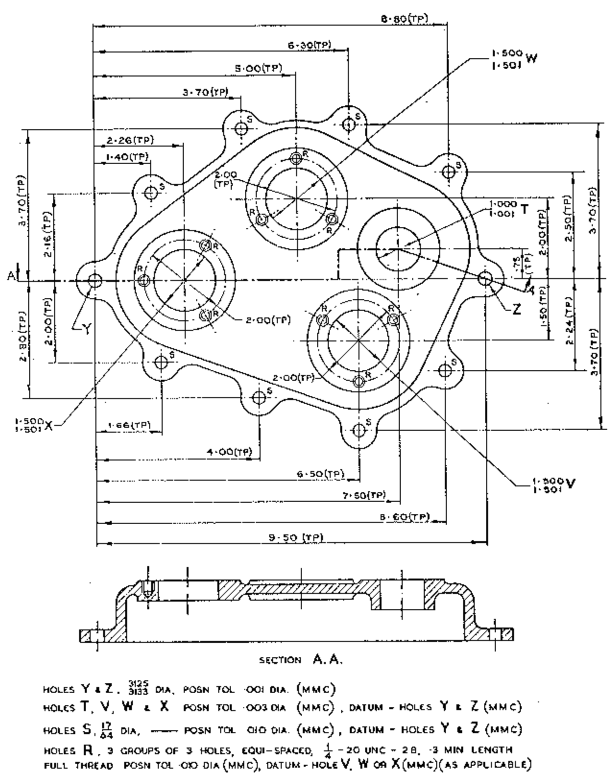


Fig. 14 - This figure from British Standard BS308 (1953) shows extensive use of the MMC and TP designations.

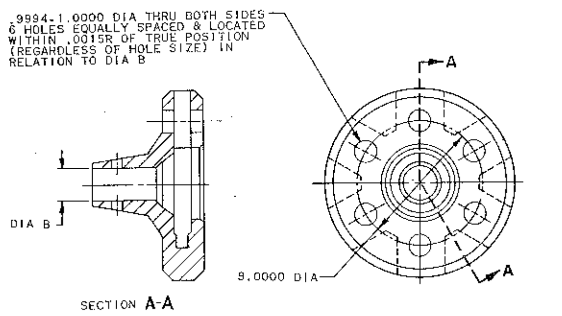


Fig. 15 - In the case of this planetary pinion cage, each hole location has to be held within the specified positional tolerance, regardless of hole size.

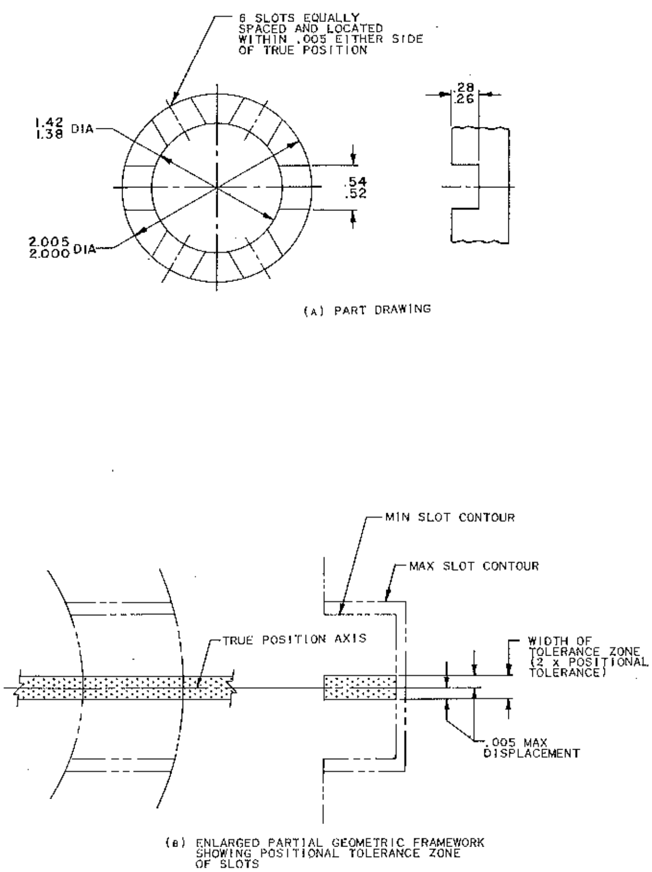


Fig. 16 - Here, the true position of each slot is determined by the basic angular relationship established by the drawing note.

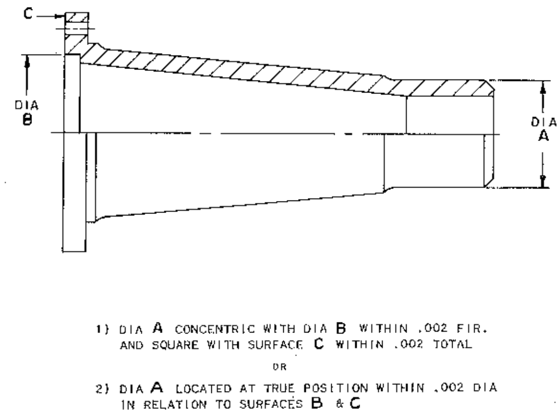


Fig. 17 - This illustrates the application of true position dimensioning to control concentricity and squareness.

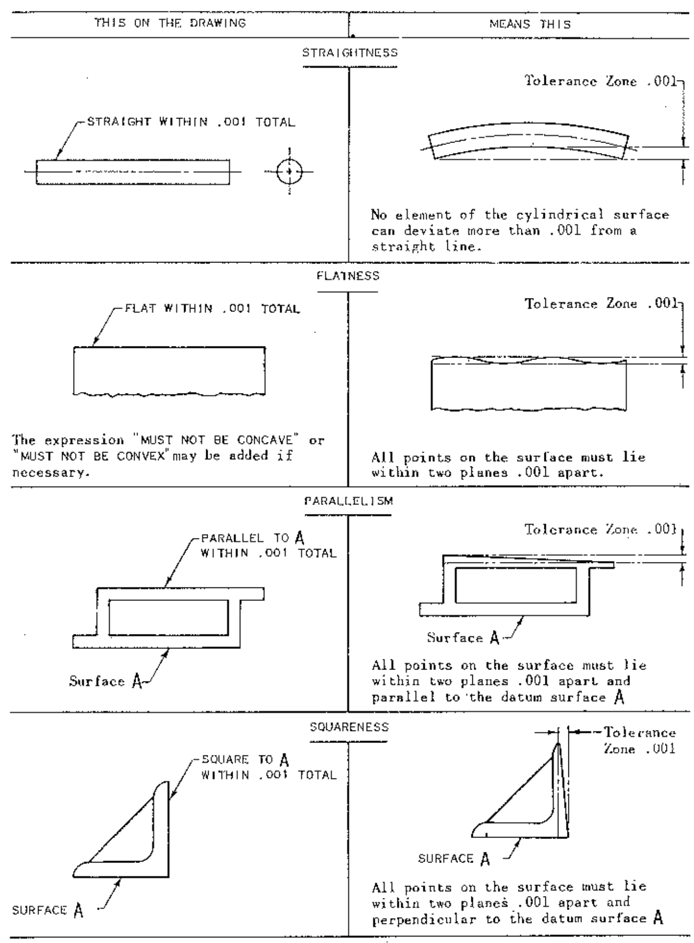


Fig. 18 - Geometric Tolerances

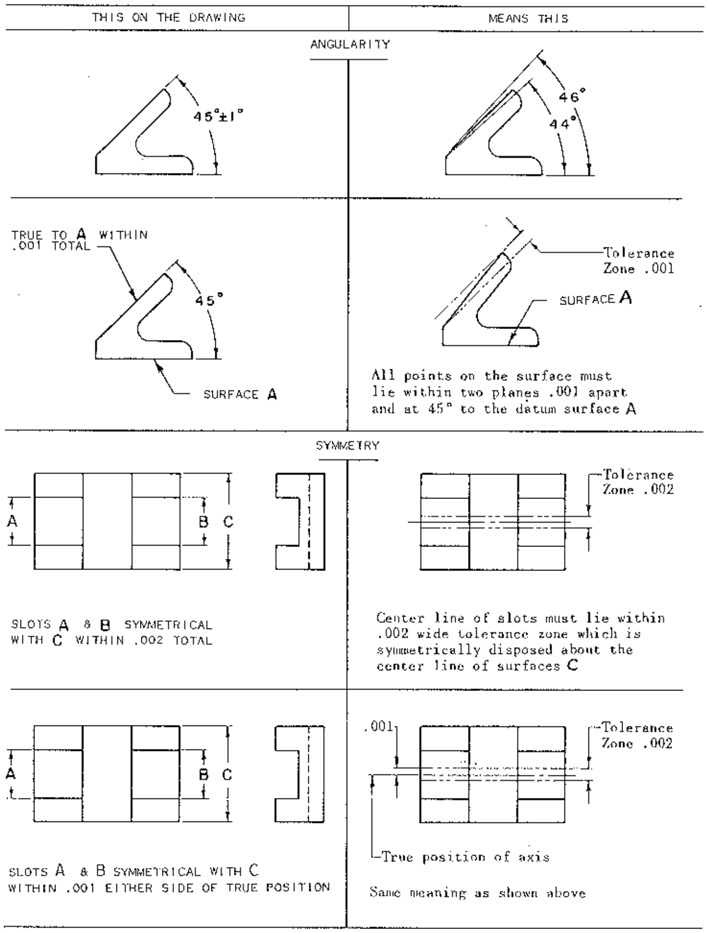


Fig. 19 - Geometric Tolerances

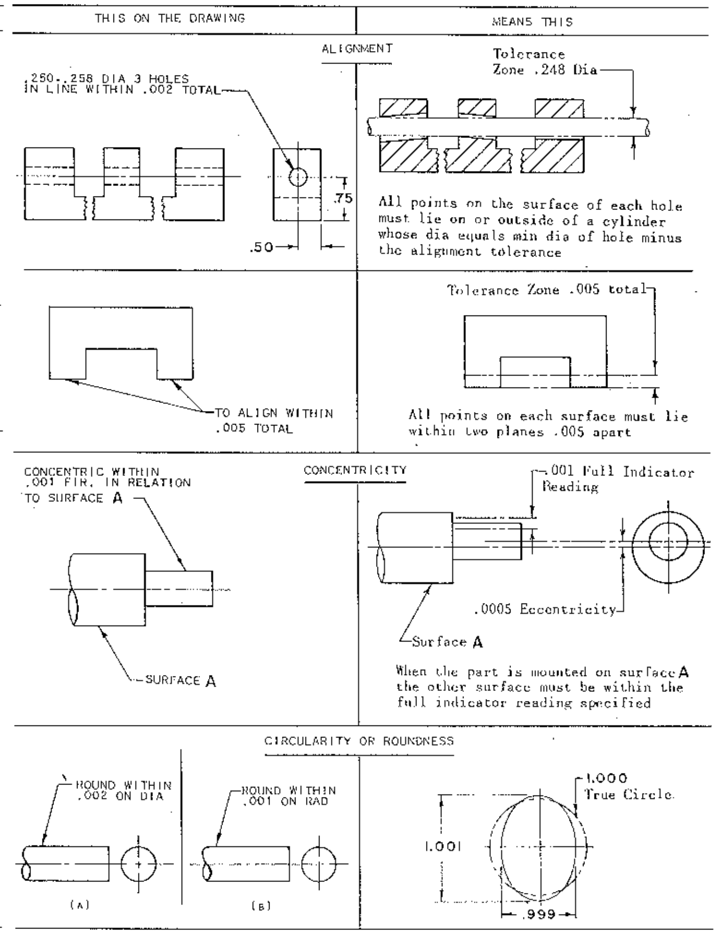


Fig. 20 - Geometric Tolerances

Movable Scale Nomographs

By J. Norman Arnold
Purdue University

INTRODUCTION

In a brief discussion of movable scale nomographs, one of the difficult decisions to make concerns the relative emphasis to place upon the several factors of general theory, practical application, and the use of simple examples. Very simple examples, excellent from some points of view, are often of little or no practical value, and consequently may give a poor impression of the usefulness of the device, and except to the experienced practitioner will not reveal the broader implications of general theory.

It is intended to compromise on these points by presenting some very elementary forms of movable scale devices which the reader can easily check and verify. Also, variations of these forms, which are likely to be more useful, are indicated. And a certain degree of generalization is suggested, without complete proof.

TYPE OF MOTION

Complex motions of nomographic elements are conceivable, but we shall limit discussion here to simple motions confined to a plane, such as:

(a) rotation,
(b) translation along a straight line
(c) motion along a curve and parallel to a straight line
(d) motion parallel to one straight line, then parallel to a second straight line.

The element which is moved may be an ungraduated line or curve, a graduated line or curve, or a coordinate grid. Again, it is conceivable to have several elements in one chart which move, but we shall devote most of our attention to devices which include a single movable element.

METHOD OF OPERATION

To some persons, the word "nomograph" means a computing device operated only by laying a straight edge across graduated scales, i.e., an alignment chart. To others, the term nomograph also includes the coordinate grid device, or network chart, as well as devices operated by drawing a line tangent to a curve.

On problems for which an alignment chart is possible, this type is probably less confusing to use, more accurate to read if interpolation is necessary, and less work to prepare. But the design of an alignment chart is more difficult than the corresponding network chart.

Another difference is particularly pertinent to our present purpose. The mathematical effect of making certain elements of a network chart movable seems to be more easily grasped than is the similar motion of an alignment chart element. Therefore, to begin with, several common network charts are analyzed and the effect of making an element movable is studied.

NETWORK CHART—INTERSECTING LINE

From analytic geometry, the general equation of a straight line coordinate graph is

$$Y = ax + b \qquad (1)$$

A set of such straight lines through a point on the ordinate axis is shown in Fig. 1, for which the equation is

$$W = 20 + UV \qquad (2)$$

The set of lines in Fig. 2 meet on the U-axis, and the equation is

$$W = 2.5V[U - (-4)]\text{, or } W = 2.5V\,(U + 4) \qquad (3)$$

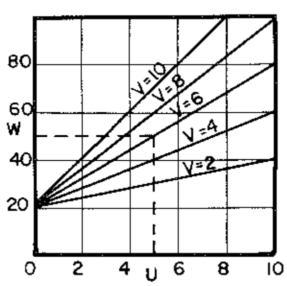


Fig. 1.

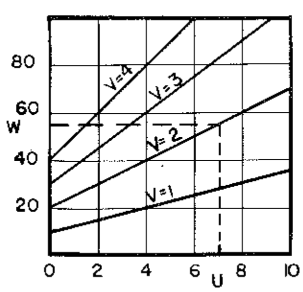


Fig. 2.

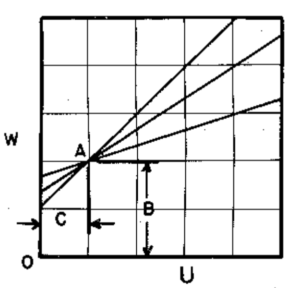


Fig. 3 shows in outline form that for a set of lines through the point A, the equation is

$$W - b_0 = KV\,(U - c_0) \qquad (4)$$

If in place of a uniform ruled grid the grid scale is proportional to square root, or square, or logarithm, then the corresponding function in Eq. 4 is similarly modified.

The V-lines in Fig. 1 can be made movable by having a transparent overlay bearing the line and point of intersection. The base includes the grid and a scale for V which, in operation, is matched with the line on the overlay, Fig. 4.

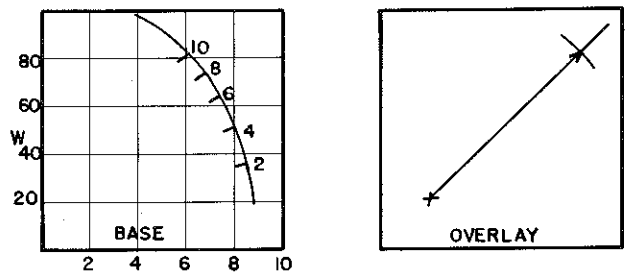


Fig. 4. Movable Scale Chart

If the point of intersection of the V-lines is out of convenient range then matching of circle arcs, C, as indicated in Fig. 5 can be used.

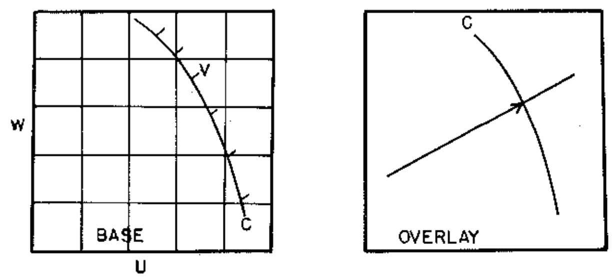


Fig. 5. Movable Scale Chart
Match circle arcs in base and overlay

NETWORK CHART —PARALLEL LINE

A network chart on which all V-lines are parallel, or the circle arc has infinite radius, is shown in Fig 6. The equation is

$$W = 2U + 4V \qquad (5)$$

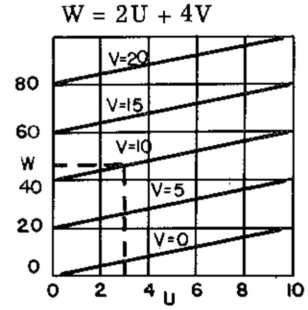


Fig. 6
Network Chart
Eq: W = 2U + 4V

Fig. 7 (following page) shows the movable scale device for this chart.

Scales for U and W need not be uniform; they may be logarithmic or proportional to any other single-valued function. Fig. 8 shows an example which is logarithmically ruled. The equation represented is

$$\log W = 0.5 \log U + \log V + \log 2$$

or

$$W = 2V\sqrt{U}$$

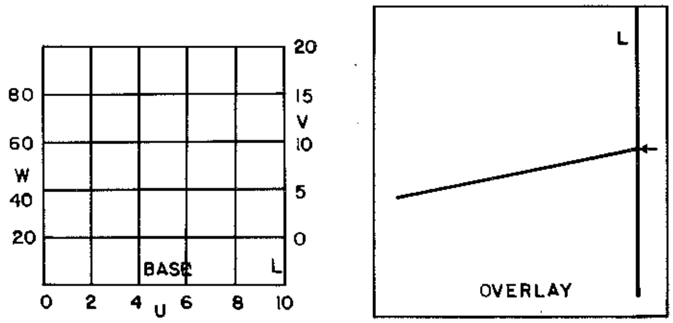


Fig. 7. Movable Scale Chart
Match lines L on base and overlay

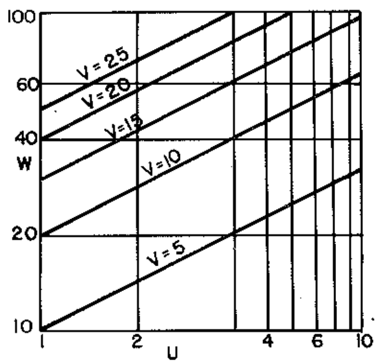


Fig. 8. Network Chart

An equivalent movable scale device is shown in Fig. 9. The arrow on the overlay is made to match values of V and the line L on the overlay is made coincident with the line L on the base.

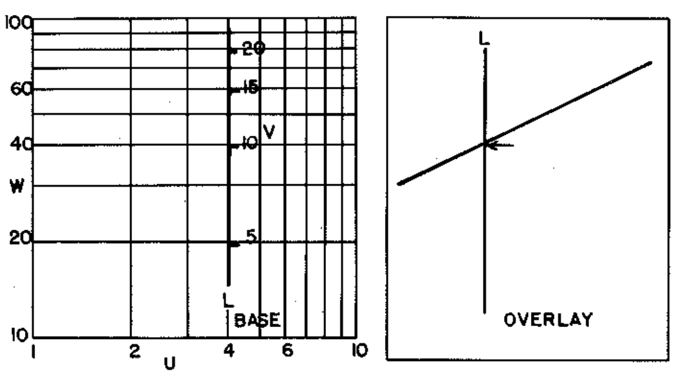


Fig. 9. Movable Scale Chart
Match lines L; match arrow with V

Some functions which cannot be easily expressed in an equation, may be incorporated in a movable scale chart, Figs. 10 and 11. A transformation of U-scale can be made which would straighten the curve on the overlay.

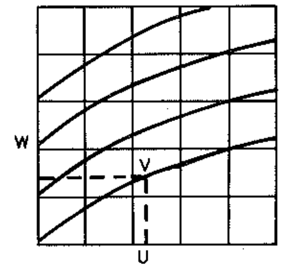


Fig. 10. Curved line chart

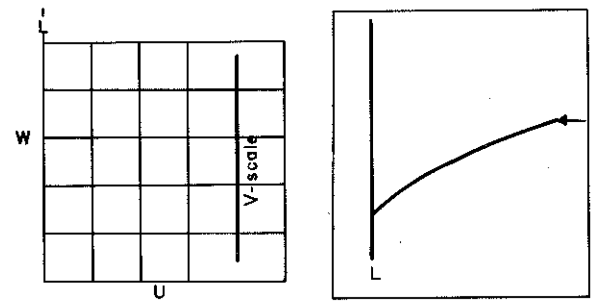


Fig. 11. Skeleton Movable Scale Chart
Match lines L; match arrow with V

NETWORK CHART—MORE THAN THREE VARIABLES

A diagram of a four-variable chart is shown in Fig. 12. Essentially, it is two 3-variable charts in contact along the line MN. Of course, each rotating line for V and for W can be made a movable transparent. It is also possible to have one or both halves of a 4-variable chart operate by linear motion of a transparent rather than by rotation.

Mechanically, two movable elements become more difficult to manipulate and control than a single movable element.

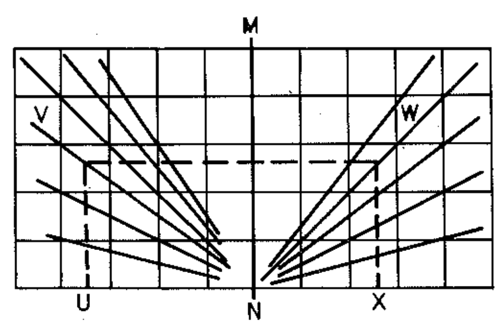


Fig. 12. Skeleton Four-variable Network Chart

ALIGNMENT CHART—PARALLEL LINE

The alignment chart, Fig. 13 solves the equation

$$r + t = s \tag{8}$$

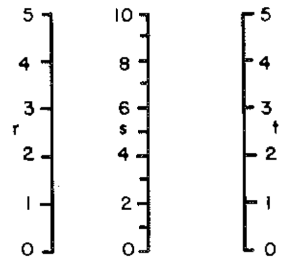


Fig. 13. Alignment Chart
Eq: $r + t = s$

If the t-scale is movable along its axis an additional variable can be added or subtracted. A method for doing this is shown in Fig. 14. The value of u on the overlay is matched with the arrow on the base, and alignment of the points on r, s, and t scales solves

$$r - s + t - u = 0 \qquad (9)$$

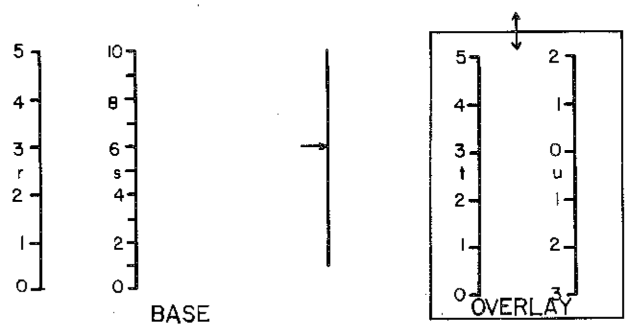


Fig. 14. Movable Scale Alignment Chart
Match arrow with u; align r, s, t.
Eq: $r - s + t = u$

Obviously, instead of uniform scales for r, s, t, and u, they may be logarithmic, proportional to square root, or other type of function.

If values of u are matched with values of v on a parallel scale on the base, Fig. 15, then

$$r - s + t - u + v = 0 \qquad (10)$$

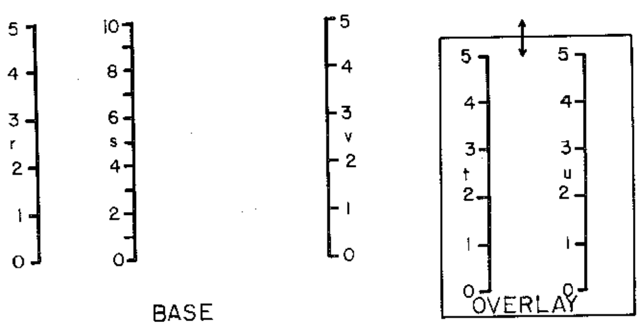


Fig. 15. Movable Scale Alignment Chart
Match u with v; align r, s, t.

Addition and subtraction of functional lengths by a translation parallel to the scales of Figs. 14 and 15 operates much the same as a straight slide rule. Consequently, the determination of this equation is readily reasoned out.

Equations associated with a translation perpendicular to the parallel scales, or translation of N-chart scales, or translation of other intersecting scale devices are more readily developed from determinant expressions.*

ALIGNMENT CHART—DOUBLE TRANSLATION

More complex motions than the simple linear movement of the several preceding examples obviously can be used. For example, the S-scale may move with the zero following along a parabola, but maintained parallel to an axis, as shown by Fig. 16, for which the determinant is

$$\begin{vmatrix} -1 & r & 1 \\ u^2 & u+s & 1 \\ 1 & t & 1 \end{vmatrix} = 0$$

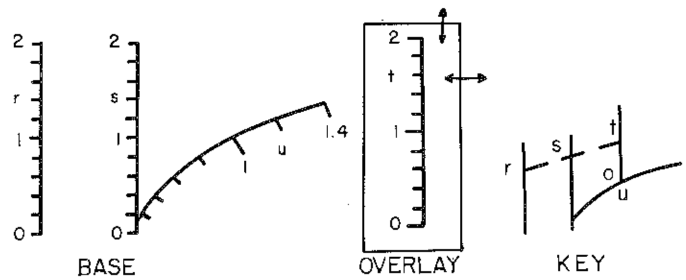


Fig. 16. Movable Scale Chart
Match 0 on overlay with u;
align r, s, t (t scale parallel to r, s)
Eq; $(u^2 + 1)\, t - (u^2 - 1)\, r = 2\,(u + s)$

The determinant reduces to

$$(u^2 + 1)\, t - (u^2 - 1)\, r = 2\,(u + s) \qquad (11)$$

The scales for r, s, and t are linear and uniformly ruled here, but any function of these quantities could be used.

If the u-scale is some shape other than parabolic, the equation solved by the nomograph also is modified.

As a more useful double translation example, the damping equation typical of some electrical and radioactive phenomena is

$$I = I_0 E^{-bt} \qquad (12)$$

or using an intermediate quantity, Q,

$$\ln I_0 - \ln I = Q = bt$$

*See Chapter 7, Graphic Aids in Engineering Computation, by Hoelscher, Arnold and Pierce. McGraw-Hill, 1952.

$$\log b + \log t = \log Q$$

which is the form in which it is solved in Fig. 17.

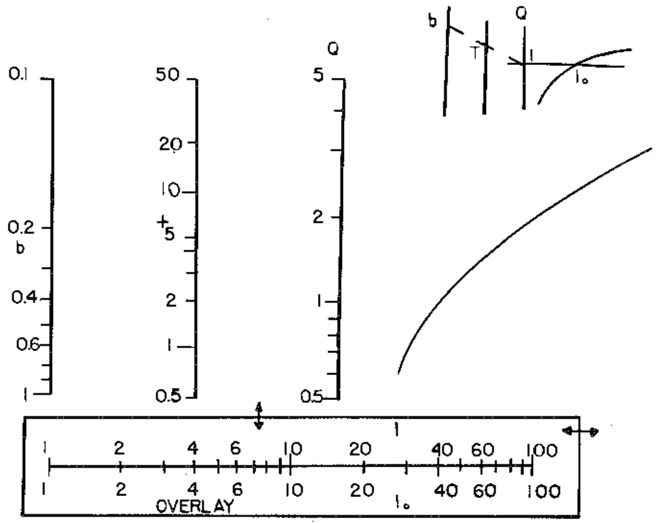


Fig. 17. Movable Scale Chart. Align b, t, and Q; match I with Q and I_0 with curve.

The subtraction of logarithms is accomplished in this example by matching I with the vertical line and I_0 with the curve, keeping the scale on the overlay always perpendicular to the vertical line.

CONCLUSIONS

The continuous variation of some quantities which is possible on movable scale nomographs is advantageous and convenient. Fewer lines mean less complex appearance and less labor of preparation than for other forms of computing charts.

Movable scale nomographs are not readily published in usable form. This is true of special slide rules also, but it does not interfere with the use of special slide rules for advertising novelties.

These several examples hint at the computational possibilities of movable scale nomographs.

More widespread acquaintance with the topic is necessary if its full potentialities are to be realized.

Operational Symbolism for Graphical Processes*

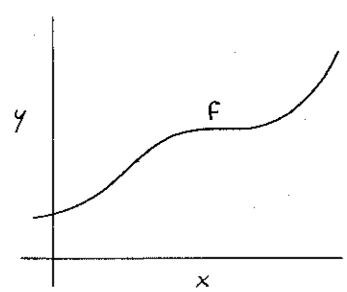
By Steven A. Coons

Massachusetts Institute of Technology

The following paper sets forth a symbolism and associated algebra for describing the manipulation of graphs. In some aspects it is quite general, and the author thinks it may be of some interest because of this rather general nature. As a typical example of one class of inherently graphical relationships which can be dealt with, one could cite problems dealing with magnetic circuit networks. These are roughly analogous to electrical networks, except that in place of Ohm's law, one has to deal with non-linear magnetization curves of empirical nature.

We shall give attention to three-variable graphs which may be considered as special arithmetical tables, and in which the ordinary operations of addition and multiplication are only special cases of a much larger group of operations. It is from this viewpoint that the following methods derive.

A graph is, of course, a representation or record of a relationship between two varying quantities. It serves to establish a correspondence between the coordinates:-



Where we have been in the habit of writing $y = f(x)$, we shall abbreviate the notation to read $y = fx$. (This does not mean that x is multiplied by f in the ordinary sense.) Our reason for introducing this abbreviation comes from the following considerations:

Suppose, in ordinary notation, that

$$y = f(x)$$

but also $z = g(y)$

and again $w = h(z)$

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

Then, performing the successive substitutions,

$$w = h\{[g\ f(x)]\}$$

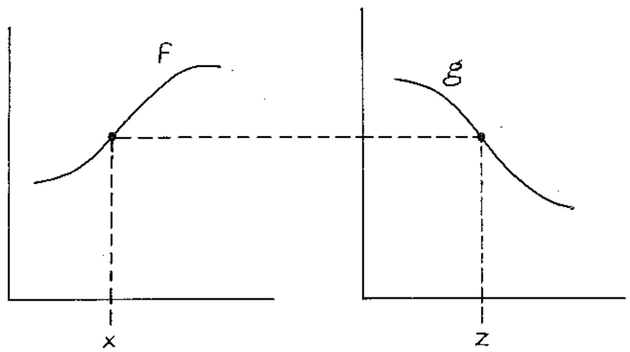
which is very awkward. We would prefer to write more simply:

$$w = hgfx.$$

Consider now the expression

$$z = gfx$$

This symbolizes the graph f which relates x to another unmentioned quantity, and the graph g which in turn relates the unnamed quantity to z.



Evidently we can combine these graphs, so that

$$z = cx.$$

We could do this by recording the resultant z quantity from the two original graphs, for each value of the input x. Then we could write

$$z = gfx \equiv cx$$

or

$$gf \equiv c.$$

(We must remember that this does not mean a "constant, c, multiplied by x" but "the c function of x".) This says that the result of applying the two graphs successively, first f, then g, is identical to the result of applying the graph c. We can think of c as the "product" of f and g in a certain sense. The commutative property rarely holds: thus, usually,

$$fg \not\equiv gf.$$

If $y = fx$, we can read out values of y for input values of x. But alternatively, we can as easily read out values of x for input values of y. We use the symbolic expression

$$x = f'y$$

to indicate this inverse situation. The f' graph and the f graph are mirror images of one another by reflection in the line $y = x$.

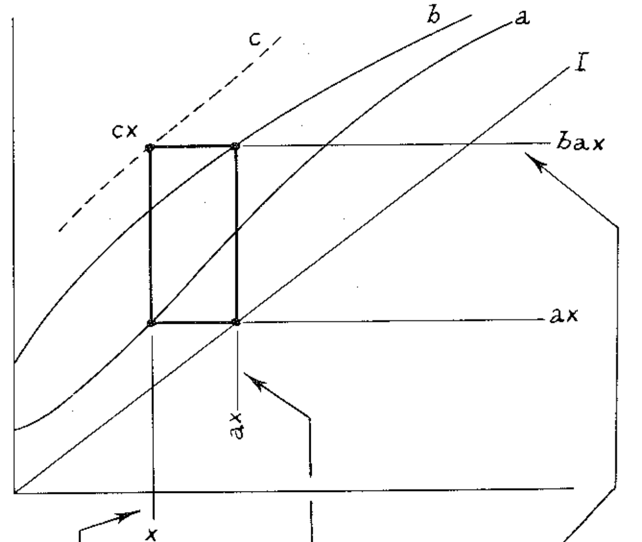
If $y = fx$ and $x = f'y$,

$$\text{then } x \equiv f'fx$$

$$y \equiv ff'y$$

$$\text{and } x \equiv ff'x$$

We define $f'f \equiv ff' \equiv I$ as the identity relationship. Now that we have established the identity graph, we are prepared to devise a simple construction for the product of two graphs.



The first input; an arbitrary x.

The first output; this becomes a new input, and goes here.

The second output; but by hypothesis, this is equal to cx. This then establishes a point on c.

We wish to construct

$$y = bax \equiv cx$$

$$\text{or} \quad ba \equiv c.$$

With a, b, and I drawn, we construct ax for some arbitrary x. This appears first as an ordinate, but we convert the ordinate immediately to a new abscissa by means of I and obtain next the new quantity b(ax) which now appears as a new ordinate. But $bax = cx$ by hypothesis, and this yields a point on the graph for c, on the original x coordinate. We repeat for other x, to obtain the curve. The important part of the construction is the moving rectangle with corners on curve a, line I, curve b, and curve c respectively.

Consider a problem. Two graphs, a and b, are known. Graph Θ is to be found, so as to satisfy the identity: $\Theta ax + \Theta x \equiv bx$.

Since this is an identity, we can suppress the variable x, so our equation reads

$$\Theta + \Theta x \equiv b.$$

(Continued on page 36)

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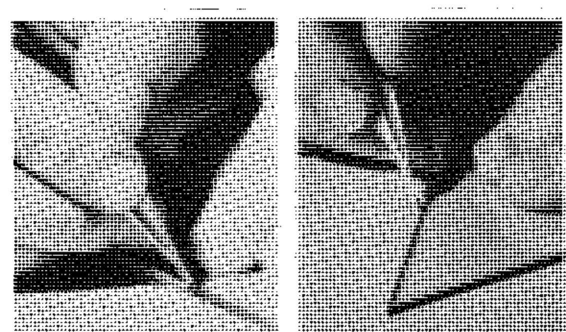

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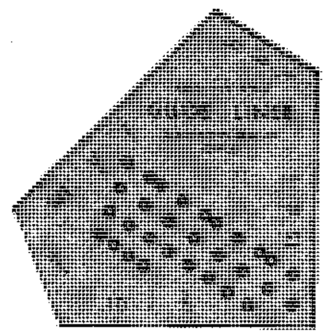

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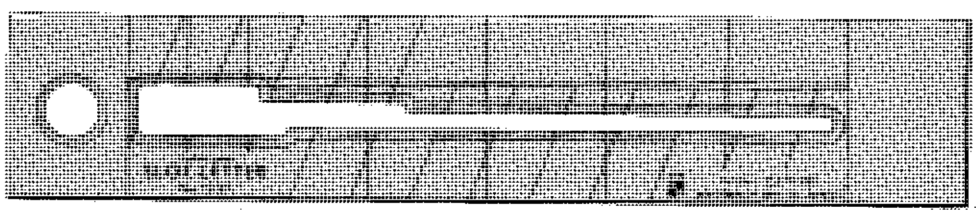

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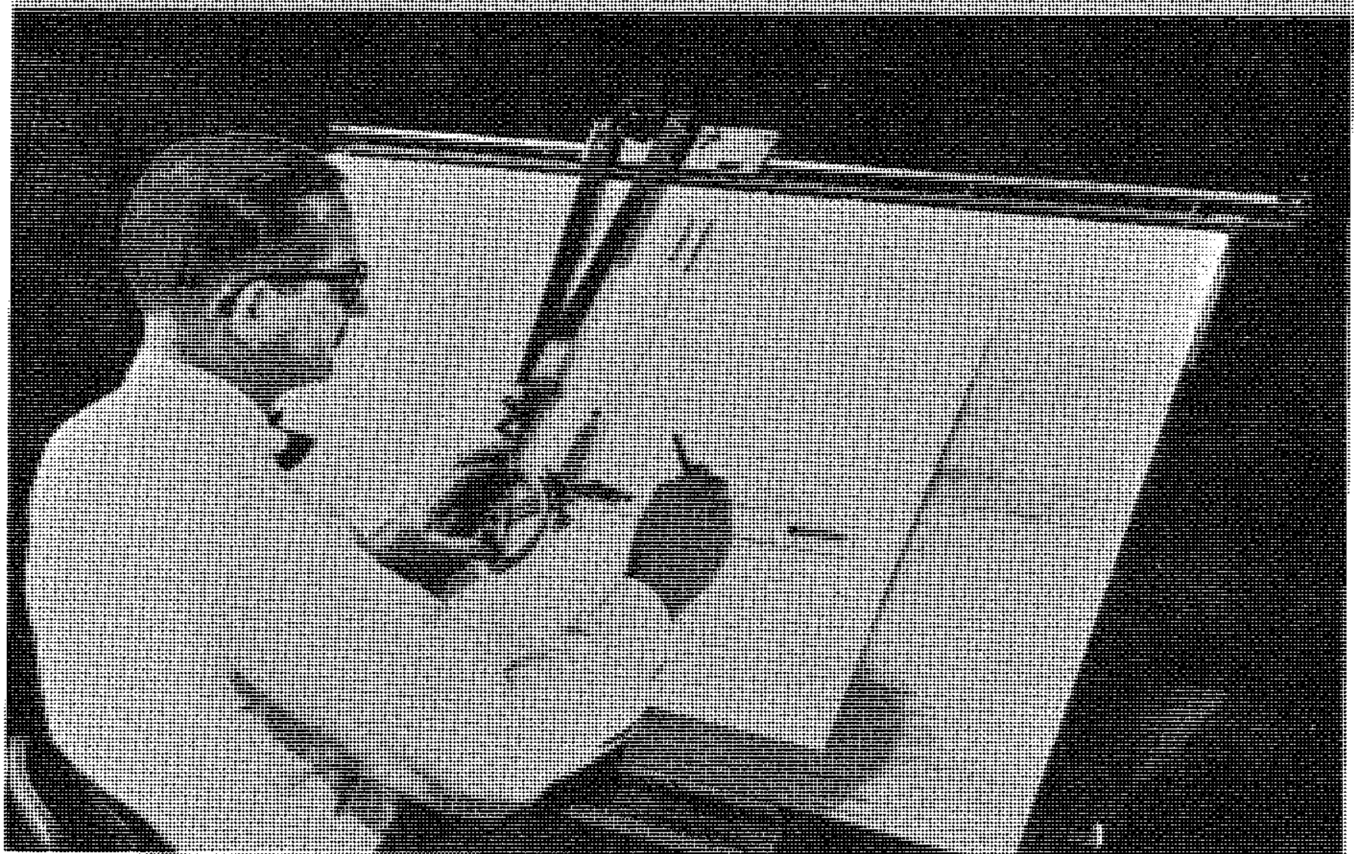

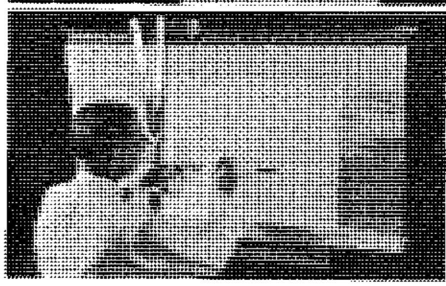

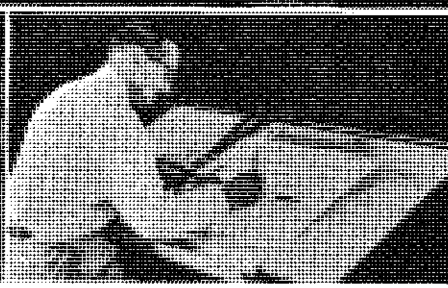

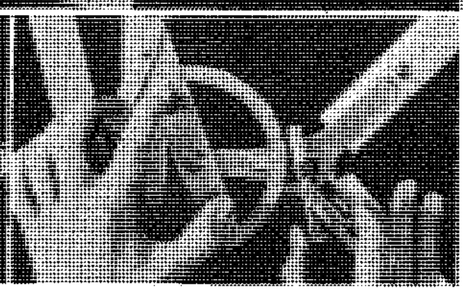

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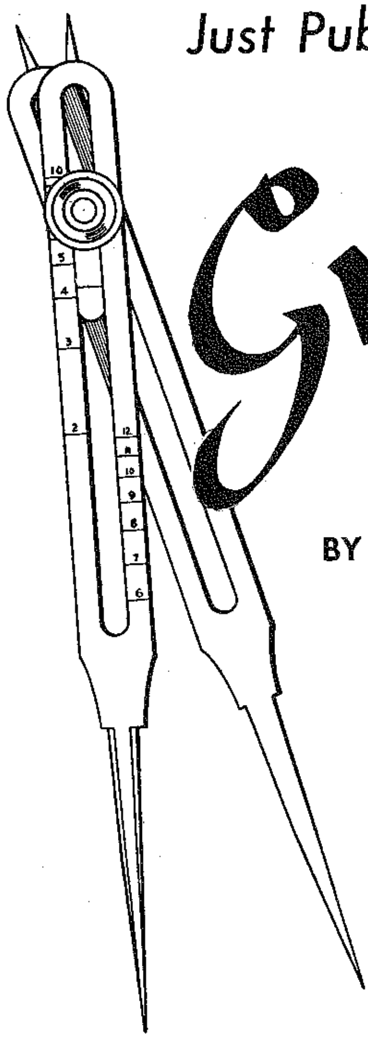
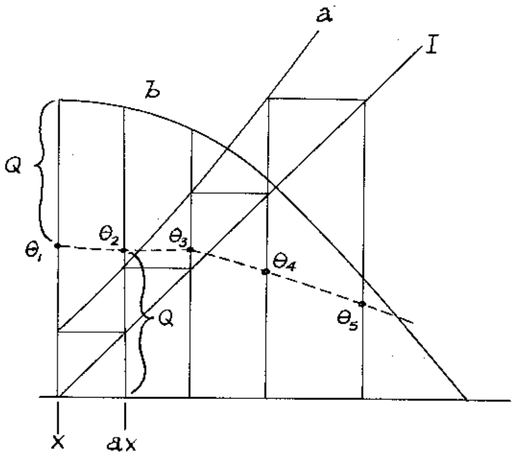


(Continued from page 28)

Remembering that Θa is not an arithmetical product, we have no right to factor, as one might be inclined to do. That is to say, $\Theta a + \Theta \not\equiv \Theta(a+I)$.



[Distance Q taken from the x coordinate line, where it first appears, and moved downward to the right onto the ax coordinate.]

The known graphs a and b together with the identity graph, I, might appear as shown. We require any graph Θ which will fulfill the conditions set forth in the identity. For any x, we assume a point for Θ_1. Then our original statement, rearranged, reads;

$$\Theta a \equiv b - \Theta$$

and yields another point on the Θ curve, point Θ_2.

The equation is iterative: for greater clarity we might introduce subscripts,

$$\Theta_{n+1} a = b - \Theta_n$$

and we may proceed to establish a series of points on Θ based on the original assumed point. Indeed any arbitrary curve segment, continuous or not, may be drawn between Θ_1 and Θ_2, and then all the rest of Θ is defined. The arbitrary nature of the solution is not a novelty; partial differential equations also exhibit this arbitrariness in their solutions.

In passing, the identity, in ordinary notation:

$$\Theta(x + a) \equiv \Theta(x)$$

is a special case of the identity just examined. It is

$$\Theta a \equiv \Theta$$

where ax means x + a, and where $bx \equiv 0$ for all x. The solution is evidently any periodic function with period a. Compare the non-uniform periodicity of the previous more general case with the uniform periodicity here.

If we have the identity

$$abx \equiv cx \quad \text{for all } x,$$

then $abc'x \equiv x$

is also true. We arrive at this conclusion by the temporary substitution

$$u = cx$$

whence by definition $x = c'u$.

Then $abx = abc'u = cc'u = u$

or $abc'u \equiv u$.

But this is an identity for all u, and we may replace the symbol u wherever it occurs by the original symbol, x, or any other symbol we choose. Thus $abc'x = x$, as was asserted. This might be called "right hand multiplication."

On the other hand, suppose we have the equation (not the identity)

$$ax = bx.$$

This equation is satisfied by a particular x. We multiply both sides of this equation by b', on the left hand;

$$b'ax = b'bx$$

$$b'ax = x$$

and this is a justifiable result. But it would be quite false to write

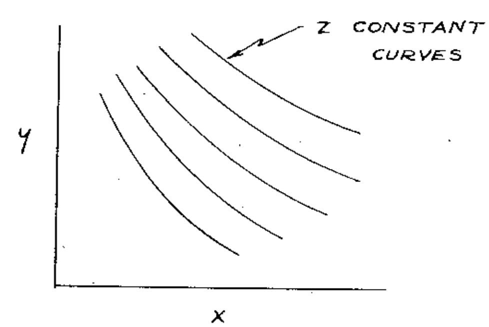
$ab'x = x$ (the result of right hand multiplication)

because usually $b'a \neq ab'$. Left hand multiplication can always be performed, but right hand multiplication is valid only for identities.

Now we are ready to consider the three variable function

$$\phi(x,y,z) = 0.$$

A typical graph of such a function is familiar:



We symbolize the graph:

$$y = \underset{z}{a}x .$$

This is merely an extension of our notation, and means that the "a" graph consists of not one, but a multiplicity of curves, each corresponding to a particular value of z. The composite symbol $\underset{z}{a}$ replaces the single symbol, a. As before,

$$x = \underset{z}{a'}y$$

and

$$I \equiv \underset{z}{a}\underset{z}{a'} \equiv \underset{z}{a'}\underset{z}{a}$$

There are six distinct relationships implied by the original statement:

$$y = \underset{z}{a}x \qquad x = \underset{y}{d}z$$

$$y = \underset{x}{b}z \qquad z = \underset{x}{c}y$$

$$x = \underset{z}{c}y \qquad z = \underset{y}{f}x$$

We have already identified the relationship $x = \underset{z}{c}y$ since we know that

$$x = \underset{z}{a'}y$$

so that

$$\underset{z}{c} \equiv \underset{z}{a'}$$

We now define

$$y = \underset{x}{b}z \equiv \underset{x}{\bar{a}}z$$

From the two operators, ' and -, we are able to construct all these relationships in terms of the original graph.

Thus, beginning with $y = \underset{z}{a}x$, we can write $y = \underset{x}{\bar{a}}z$, Then the prime operator applied to this result yields:

$$z = \underset{x}{\overset{'}{\bar{a}}}y$$

The bar operator next yields

$$z = \underset{y}{\overline{\overset{'}{\bar{a}}}}x$$

We could next apply the prime operator, but instead, let us return to $y = \underset{z}{a}x$ and apply the prime operator to obtain

$$x = \underset{z}{a'}y$$

Then the bar:

$$x = \underset{y}{\overline{\overset{'}{a}}}z$$

Then the prime:

$$z = \underset{y}{\overset{'}{\overline{\overset{'}{a}}}}x .$$

We observe that this last result is the same as the one obtained earlier;

$$z = \underset{y}{\overline{\overset{'}{\bar{a}}}}x \equiv \underset{y}{\overset{'}{\overline{\overset{'}{a}}}}x$$

or, as a theorem,

$$\overline{\overset{'}{\bar{a}}} = \overset{'}{\overline{\overset{'}{a}}} .$$

There are thus six graphs, related by the operators ' and - :

$$a, \overset{'}{a}, \bar{a}, \overline{\overset{'}{a}}, \overset{'}{\bar{a}}, \text{ and } \overset{'}{\overline{\overset{'}{a}}} \equiv \overline{\overset{'}{\bar{a}}}$$

Any further operations by prime or bar merely return us to some member of the set. Thus, for example, the prime operator applied to

$$\overline{\overset{'}{\bar{a}}} \text{ yields } \overset{'}{\overline{\overset{'}{\bar{a}}}} ,$$

but

$$\overline{\overset{'}{\bar{a}}} \equiv \overset{'}{\overline{\overset{'}{a}}}$$

and the prime operator applied to this last graph evdently yields $\overline{\overset{'}{a}}$.

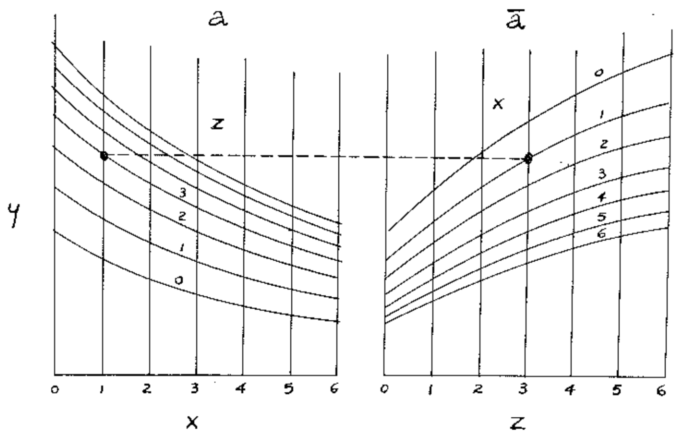
Hence

$$\overset{'}{\overline{\overset{'}{\bar{a}}}} = \overline{\overset{'}{a}} .$$

Indeed we may state that two successive operations by either prime or bar invariably cancel one another, as follows directly from their definition.

We already know that the prime operator implies rotating or reflecting the graph about the I line. The new bar operator also has a simple graphical significance. If $y = \underset{z}{a}x$ and $y = \underset{x}{\bar{a}}z$ are the two graphs in question, the "ā" graph is obtained by "profile section" of the "a" graph (to employ a descriptive geometry notion.) Thus:

(Continued)



The prime and bar operators, together with their associated algebra, enable us to symbolize certain graphical manipulations, in terms of two fundamental graphical constructions.

For example, the equations

$$y = \underset{u}{ax}$$

$$y = \underset{w}{bx}$$

define a transformation of xy coordinates into uw coordinates in a fairly general sense.

The inverse transformation:

$$w = \underset{x}{cu}$$

$$w = \underset{y}{du}$$

certainly represents no difficulty from a practical point of view - one simply plots x constant and y constant curves in a uniform uw system. But can the graphs c and d be derived from the original graphs a and b by means of the fundamental constructions? This question perhaps has some theoretical interest.

We begin with the pair of equations

$$y = \underset{u}{ax}$$

$$y = \underset{w}{bx}$$

and eliminate y:

$$\underset{u}{a}x = \underset{w}{b}x$$

This establishes the relationship of u to w along an x constant coordinate.

$$\underset{x}{\bar{a}u} = \underset{x}{\bar{b}w},$$

from which we obtain

$$w = \underset{x\ x}{\overset{\perp}{b}\,\bar{a}}\,u\,.$$

But the indicated multiplication

$$\underset{x\ x}{\overset{\perp}{b}\,\bar{a}}$$

may be performed, yielding

$$w = \underset{x}{\overset{\perp}{b}\bar{a}}\,u\,.$$

This is the first of the two desired expressions, with $c = \overset{\perp}{b}\,\bar{a}$. Again, we may write, from the original equations,

$$x = \underset{u}{\overset{\prime}{a}y}$$

$$x = \underset{w}{\overset{\prime}{b}y}$$

Eliminating x,

$$\underset{u}{\overset{\prime}{a}y} = \underset{w}{\overset{\prime}{b}y}$$

$$\underset{y}{\overset{\top}{a}}\,u = \underset{y}{\overset{\top}{b}}\,w$$

$$w = \underset{y\ y}{\overset{\prime}{\overset{\top}{b}}\,\overset{\top}{a}}\,u \equiv \underset{y}{\overset{\prime}{\overset{\top}{b}}\overset{\top}{a}}\,u\,.$$

This is the second desired expression, with the hypothetical d graph given by

$$d \equiv \overset{\prime}{\overset{\top}{b}}\,\overset{\top}{a}\,.$$

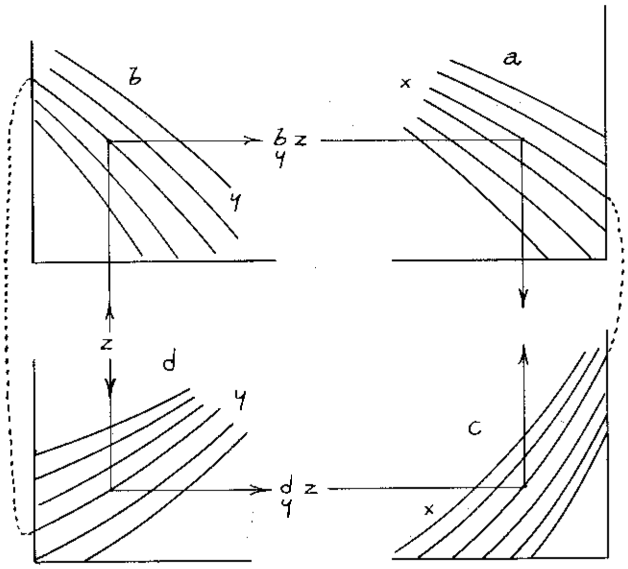
The foregoing certainly makes hard work out of a very simple matter; but another example will not be quite so easy. Suppose that three unknown quantities, x, y, and z, are defined by the set of three simultaneous equations

$$\underset{x\,y}{abz} = \underset{x\,y}{cdz}$$

$$= \underset{x\,y}{efz}$$

$$= \underset{x\,y}{ghz}$$

Each equation is a description of a relationship of three variables. We might draw a diagram of the first of these relationships:



If we choose any pair of the three quantities, such as x and y, then z will presumably have some dependent value, so that the rectangle may be drawn. (It is, of course, entirely possible that for such a choice of x and y, no z exists.) But it is manifestly not simple to carry out this construction, except by a tedious trail and error process. And there are many pairs of values of x and y to consider, and two other equations to deal with all simultaneously. We appeal to our algebraic manipulations.

Make the substitution of a new unknown u:

$$u = b_y z$$

Then

$$z = b'_y u \, .$$

This yields, from the first equation by substitution for z,

$$a_x u = c_x d_y b'_y u = c_x d_y b' u = c_x \overline{d_u b'}\, y$$

$$\overset{\backslash}{\overline{d_u b'}}\; c'_x\, a_x\; u = y.$$

or

$$y = \overset{\backslash}{\overline{d_u b'}}\; c'_x\, a\; u = \overset{\backslash}{\overline{d_u b'}}\; \overline{c'_u a}\; x = \overset{\backslash}{\overline{d\, b'}}_u \overline{c'\, a}\; x.$$

But from the other two equations we obtain the similar expressions

$$y = \overset{\backslash}{\overline{f\, b'}}_u \overline{e'\, a}\; x$$

and

$$y = \overset{\backslash}{\overline{h\, b'}}_u \overline{g' a}\; x.$$

We can equate these, to obtain two equations in two unknowns, of the form:

$$A_u x = B_u x$$

$$= C_u x$$

where we use the new symbols A, B, C to represent the constructed graphs.

$$B'_u A_u\, x = x = B'_u A = \overline{B'A}_x\, u$$

$$\overset{\backslash}{\overline{B'A}}_x\, x = u.$$

But we can easily show that $\overset{\backslash}{\overline{B'A}}_x\, x = Fx$, so that we obtain the two very simple expressions:

$$Fx = u \qquad Gx = u$$

Fx = Gx represents the intersection of two curves, and yields the value of x. We now retrace our steps, finding u, and then y, and finally the third unknown z.

OUR NEW ADVERTISING MANAGER

Professor A. P. McDonald, the genial Texan who has no given names—only given initials—is our new advertising manager, elected by the members of the Division for the three year term beginning with this issue. Mac is well known to the other members of the Publication Committee and they have lost no time in making him welcome by dropping plenty of work into his capacious lap.

Professor McDonald has a well deserved reputation for his most remarkable sense of appropriate good humor and for his resourcefulness and vigor in carrying out any assignment. All of these qualities will be called on in the execution of his new duties as advertising manager, a job that we are happy to have entrusted to him.

If any member of the Division of Engineering Drawing and Descriptive Geometry knows of a manufacturer or a publisher who would benefit by advertising in this periodical, he should pass the word along to Professor McDonald and then let nature take its inexorable course.

Concerning the Problem on Page 41 of May, 1957 Issue:

"Construct Arcs (!) Tangent to a Line at a Given Point and to a Given Circle"

By Andre Halasz

The City College, New York, N. Y.

Among the problems in geometric constructions pertaining to tangent circles, those in which the radius of the unknown circle is given are comparatively simple, whereas those in which the radius of the unknown circle is itself unknown are considerably more difficult. They range from comparatively simple cases, such as the one here discussed, to the granddaddy of them all: Apollonius' problem (to find the circle tangent to three given circles); and Apollonius gave solutions to all of them some 15 centuries ago; and Malfatti's problem whose graphical solution was not worked out until the last century.

For many years, the problem here discussed was given at City College as an intermediate step in one of the regular descript problems. We used to throw it at the students with just a word of warning that it was quite a stopper; and at the next class when none had a solution, we would show them. Gradually we discovered that the high schools no longer teach geometric constructions and so we stopped expecting students to know them. But more of that on some other occasion.

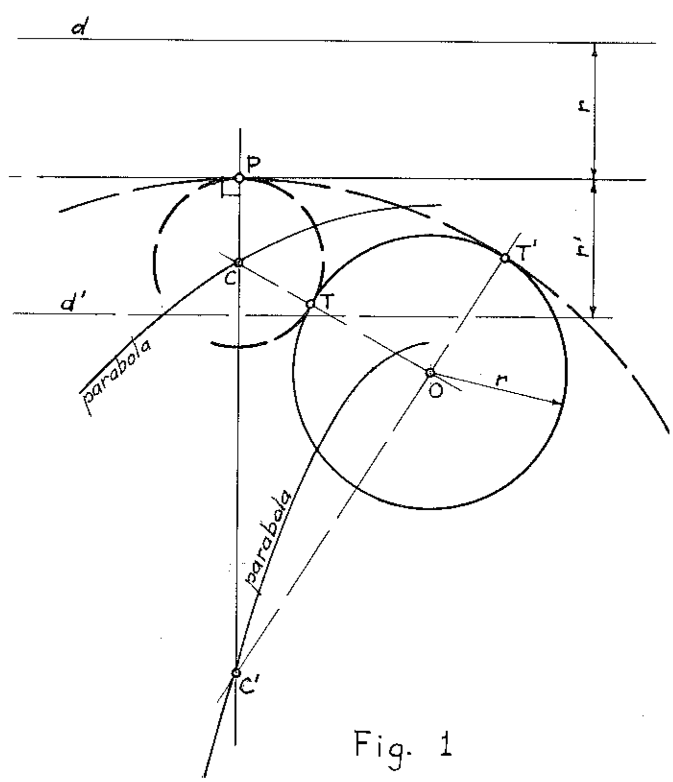


Fig. 1

Fig. 1 shows the construction based on straight LOCUS reasoning. One locus is obviously the perpendicular to the given line at point P; the other locus is the parabola whose focus is the center of the given circle and whose directrix is as far from the given line as the radius of the given circle. Since r can be laid off on either side of the given line, two such parabolae can be plotted, and their intersections with the first locus will give the two centers: c and c'.

It will be objected, of course, that the intersection of a plotted curve with a straight line is not "legitimate" construction, whatever that may man. Fortunately, as soon as it is recognized that the second locus is a parabola, it also becomes obvious that it need not be drawn at all. All we need do (Fig. 2) is to mark off points D and D' on the first locus, and draw the perpendicular bisectors of DO and D'O; their intersections with the first locus give the required centers. (What a horrible mouthful, this "per-pen-di-cu-lar bi-sec-tor"! Why doesn't somebody propose that we contract it to "per-bis" or "per-bise"? All right, I herewith so propose.)

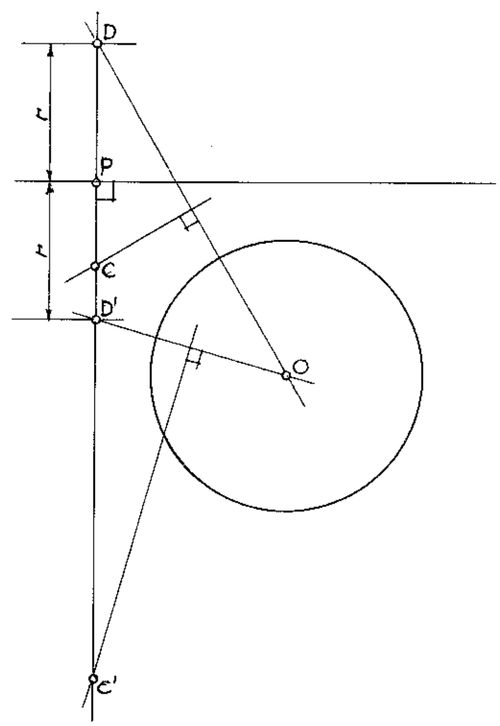


Fig. 2

In all my years of teaching, the only independent solution ever brought in by a student was the one shown on Fig. 3. She (for it was a she!) simply drew a diameter of the given circle at right angles to the given line, and joined its ends A and B to the point P. These lines mark the tangency points T and T', from which the centers C and C' are easily found. For proof: simply consider that O A T and C P T are similar triangles, hence, since one is isosceles, the other must also be.

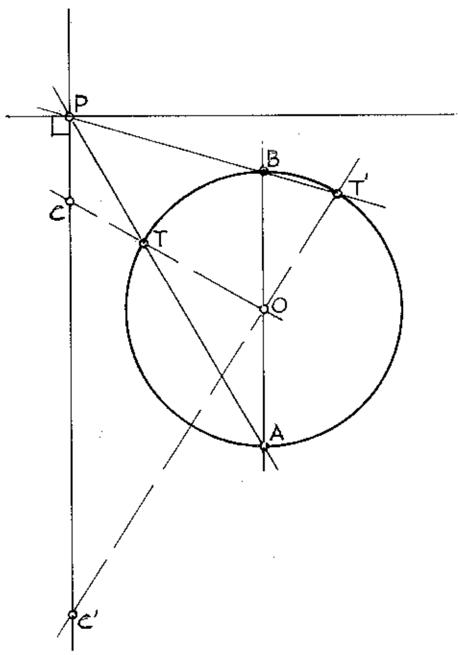


Fig. 3

My favorite solution, because prettiest, is shown in Fig. 4. It is based on "theorem of three circles", which, in simplified form, says that when three circles intersect, their common chords must meet in one point.* Therefore, draw any circle which is tangent to the given line at P; draw its common chord with the given circle; from where the common chord intersects the line at M, draw tangents to the given circle; the tangency points of these tangents are the tangency points required; t and t'.

Just for the sake of completeness, here are some variants which might be considered additional solutions.

In Fig. 1, we said: "One locus is obviously the perpendicular. ." This is true, but this locus need not necessarily be used. There are three given conditions of restraint (cleverly disguised in the wording as two); namely: 1. the circle must be tangent to the given line; 2. the circle must pass through the given point P; 3. the circle must be tangent to the given circle. The perpendicular locus represents conditions 1. and 2; the parabolic locus represents conditions 1. and 3.

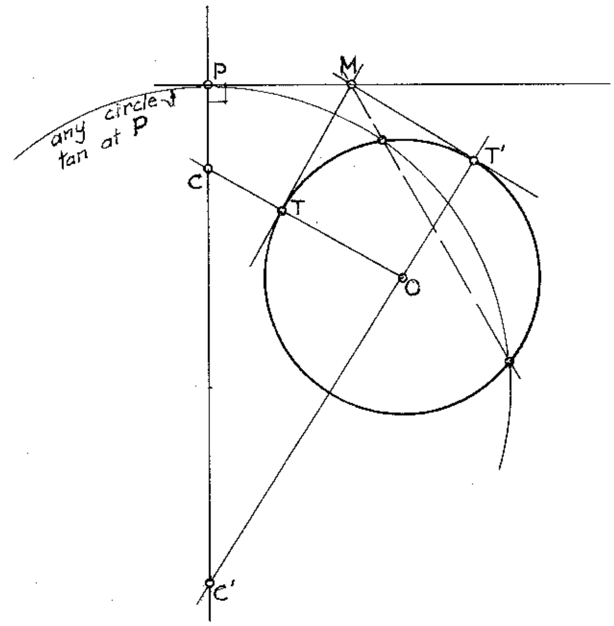


Fig. 4

There must be a third locus, representing conditions 2. and 3. And sure enough, a hyperbola whose foci are P and O, and whose major axis is the radius r, is such a locus. (This follows from the definition of the hyperbola: locus of points whose distances from two fixed foci have a constant difference.)

We could add this hyperbola to Fig. 1, and omit either the parabola or the perpendicular line, and still obtain the centers C and C'; these might be counted as two more solutions. And to carry this game of variants to the extreme, we could also, in Figs. 2, 3, and 4, substitute either the parabola or the hyperbola for the perpendicular line. Thus, counting all the trivial variations, we have here twelve different solutions to the problem.

Any other solutions?

I cannot forego the opportunity to call attention to what I consider a very insidious error and an important one. The statement of the problem says: "CONSTRUCT ARCS TANGENT. ." Arcs of what, pray? Arcs of ellipses? of Cassian ovals? of catenaries? An ARC is defined as " a portion of a curved line; as, an arc of a circle or of an ellipse. . ." (Webster Unabridged). It should be remembered that many curved lines are such that nothing but arcs of them can ever be drawn or seen—parabolae for example. To say ARC when one means CIRCLE is not merely loose language; it is part of that horrible high-schoolese with which the minds of boys and girls are being poisoned against an understanding of graphics.

* The full statement of the theorem is: "Given any three circles, the radical axes of any two taken at a time must meet in one point." This follows from the definition of the radical axis: it is the locus of points from which the tangents to two given circles are of equal length. Common chords of intersecting circles and the common tangent of tangent circles are special cases of the radical axis.

DIVISION OF ENGINEERING DRAWING

OF THE

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

RESOLVED:

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

Frank A Heacock

1957

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

ASEE

Chairman of the Division

Secretary of the Division

DISTINGUISHED SERVICE AWARD

Recipients of Engineering Drawing Distinguished Service Awards

1950 - Frederic G. Higbee
1951 - Frederick E. Giesecke
1952 - George J. Hood
1953 - Carl L. Svensen
1954 - Randolph P. Hoelscher
1955 - Justus Rising
1956 - Ralph S. Paffenbarger
1957 - Frank A. Heacock

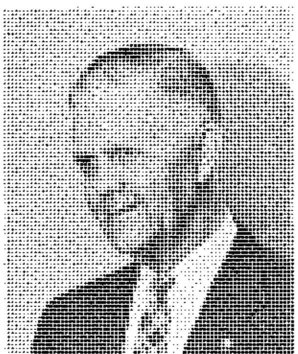
The A.S.E.E. Drawing Division Distinguished Service Award*

to

Frank A. Heacock

1957

Purpose of the award



Frank A. Heacock

According to the Articles of Procedure of the Drawing Division of the American Society for Engineering Education, the purpose of the Annual Service Award is to recognize and encourage outstanding contributions in the form of graphic research, improvement of the teaching art, and scholarly publications as they relate to the field of engineering drawing, descriptive geometry and other graphic work.

Nature of the award

The Distinguished Service Award consists of a certificate containing the candidate's name appropriately hand lettered or engraved thereon, and is presented to the elected recipient in June, at the annual dinner of the Drawing Division.

Eligibility requirements

Eligibility for consideration for the award as set forth in the Articles of Procedure and published in the Journal of Engineering Drawing, Volume 16, No. 2, May 1952, is based upon the following contributions:

1. An outstanding contribution to the art and science of teaching courses in a recognized field of graphics.
2. Success as a teacher both as to competency in the subject matter and leadership ability to inspire students to high achievement as indicated by friends and colleagues in the field of engineering graphics.
3. A recognized contribution in the form of the improvement of the tools and conditions of teaching as manifested through the publication of text books, laboratory manuals, design and construction of models, teaching aids, visual aids, publication or research finding, etc., as they relate to the field of graphics.
4. Improvement of the teaching art, through various activities such as the development and guidance of young teachers, development of testing and guidance programs, development of cooperative programs with other educational agencies or with industry.
5. Scholarly contributions to graphic literature, recognized fellowships, siguificant honors as granted by recognized organizations or agencies.
6. This rule of service according to the Articles of Procedure, is a definite requirement, and must be considered at all times in the selection of a candidate for the service award.

   "Service of the Division of Engineering Drawing by attendance at its various meetings, active participation in its programs, service on its committees, or as an officer of the Division with a record of definite achievement, and contributions to its publications or summer school programs."

Award committee

The Award Committee consists of the last three immediate past chairmen of the Drawing Division with the first retired member acting as its chairman.

Your committee for the year 1957, consisted of Professor Ralph T. Northrup, Wayne State University, Chairman; Professor Theodore T. Aakhus, University of Nebraska; and Professor William E. Street, Texas A & M College. Your committee acted in accordance with the stated rules in the selection of the candidate to receive the award for the year 1957.

Nominations for award and procedure

Nominations for the award may be made by any member or group of members of the Division, except members of the Award Committee.

Your committee sent out some two hundred nomination forms to the various departmental chairmen as indicated in the 1956 yearbook published by the American Society for Engineering Education; or to known members in a given school where the Engineering Drawing Department was not sufficiently identified as a separate unit. The returns from the survey indicated approximately 25 per cent.

Many names were submitted to the committee by the Division members. The final selection of the candidate to be honored this evening was not an easy task, for several of the candidates named by the members of the Division presented quite similar patterns of

*This citation was delivered by Professor Ralph T. Northrup, June 18, 1957, at Cornell University, Ithaca, N. Y.

achievement. After evaluating all the factors and taking into consideration the rule pertaining to service to the Division, your committee selected the candidate to be honored this evening. For the record, I should like also to state, this candidate was named by a larger number of persons and schools than any other.

Biography of recipient

Our honored recipient comes from that state in the Union where cotton and tobacco are king, and great statesmen from the past were born. He was born in Richmond, Virginia in 1893 and graduated from the Richmond Public Schools. He typifies the perfect Southern gentleman with the warm hand shake, pleasant smile, and soft spoken voice. He has gone collegiate, however, for the familiar Southern black brimmed hat is missing from his partially bald head.

He graduated with highest honors from the Virginia Polytechnic Institute in 1915 with a Bachelor of Science degree in Civil Engineering. His beloved Alma Mater awarded him a Civil Engineering degree in 1916. He also received a Civil Engineering degree from Rensselaer Polytechnic Institute in 1917. He was in charge of a survey for the hydro-electric development work at Goshen Pass, Rockbridge County, Virginia. Because of his outstanding scholastic achievements, Virginia Polytechnic Institute employed him as a part-time instructor in graphics three years before his graduation. He also worked as a junior engineer for DuPont.

In 1917 he served as assistant engineer on surveys and layout for U.S. Army Camp Wheeler at Macon, Georgia. He attended officers candidate school at Fort Myer, Virginia and was commissioned at second lieutenant in the 314th Field Artillery. He served overseas in France with the combat troops from 1918 to 1919.

Following his military service, he worked in New York as an inspector on construction of a laboratory building for Rensselaer Polytechnic Institute, and as a structural draftsman in the Department of Public Works at Richmond, Virginia.

He was appointed Assistant Professor of Engineering Drawing at Virginia Polytechnic Institute in 1921 and two years later became Assistant Professor of Graphics and Chairman of the Department at Princeton University. Through dedication to his work and untiring efforts he was promoted to the rank of Professor in 1950.

Our honored recipient was awarded the Brooks Fellowship in 1926 to carry out a study of water supply, sanitation, and hydro-electric plants in the United States. He worked as a bridge designer for the New Jersey State Highway Department for seven summers, 1924 to 1931. In 1936 he conducted a research project on fatigue in structural steel members. He was Director of the Engineering, Science, and Management War Training Program at Princeton University from 1941 to 1945. For ten years from 1945 to 1955 he was Director of Extension Courses at Princeton, as well as directing the Department of Graphics.

He has the honor of having attended all five of the Engineering Drawing Division Summer Schools as follows: Carnegie Tech 1930, Wisconsin 1936, Washington University at St. Louis 1946, Michigan State 1951, and Iowa State 1956.

He married Grace MacKay Calhoun in 1922 and their family consists of two sons and five grandchildren.

He has served the Engineering Drawing Division well during his association over the years. In 1936 he was editor of the T-Square page in the Journal of Engineering Education. He was selected as associate editor of the Journal of Engineering Drawing in 1938. He served as a member of the Executive Committee from 1941 to 1956 and was elected as chairman of the Engineering Drawing Division of ASEE in 1947. During his term of office, advanced graphics and research in graphics received emphasis and recognition. He later acted as chairman of the Advanced Graphic Committee. At the present time he is our representative member on the General Council of ASEE.

He has presented many papers at both the Engineering Drawing Division Summer Schools and at the annual meetings of the Division.

He has written extensively on the subject of graphics and its rightful place in Engineering Education. From his pen have come such papers as:

"History of Engineering Graphics," 1930
"Study of Graphics as a Means of Research," 1930
"Graphic Aids in Three-Dimensional Thinking," 1936
"Granting College Credit for Previous Drafting Experience," 1946
"Applications of Advanced Graphics," 1951
"The Role of Graphics in Engineering Education," 1953
"Teaching Engineering Graphics Effectively for Today and Tomorrow," 1954
"The Graphic Approach to Engineering Education." 1956

He is also the author of the monograph "Graphic Methods for solving Problems," 1952.

He is a member of the Princeton Engineering Association, the American Society of Civil Engineers, the American Society for Engineering Education, Sigma Xi, Tau Beta Pi, Phi Kappa Phi, and is a licensed professional civil engineer in the state of New Jersey.

Division of Engineering Drawing of the American Society for Engineering Education, Resolved: That, with the presentation of this award, the Engineering Drawing Division of the American Society for Engineering Education by this token acknowledges the many distinguished services rendered by

FRANK HEACOCK

The Society expresses its deep appreciation for those services, and the great personal pleasure of the individual members in having his friendship.

Frank A. Heacock, teacher, scholar and leader, it is a distinct honor and pleasure to be able to present to you this evening, this Distinguished Service Award which you have through your untiring efforts on behlaf of the Division of Engineering Drawing so rightfully earned. May you continue to serve in the future as you have in the past. Congratulations and God bless you for a job well done.

Response to the Award Citation

By Frank A. Heacock

Mr. Chairman, Ladies and Gentlemen:

This is indeed a very happy moment in my life. To receive the Special Award of the Drawing Division gives me a feeling of humility as well as gratitude and pride. Even in my dreams I never expected that I would be deemed worthy of this high honor. So I am deeply grateful to Professor Northrup for his kind words about me and to the Committee for their generous consideration. At the same time I am proud to be a member of the Division and to count as personal friends so many loyal teachers of engineering drawing and graphics.

When I joined the Society in 1926, I attended my first Annual Meeting at the State University of Iowa. There I met Professors Fred Higbee and Tom French, outstanding leaders in our profession. In 1930 I attended the first Drawing Division Summer School at the Carnegie Institute of Technology where Professor Harry McCully conducted a fine program that was of lasting benefit to many drawing teachers. It has been my privilege to attend all five of the Division Summer Schools. I have always enjoyed working with members of the Drawing Division, and I look forward to each midwinter and annual meeting to take part in the group activities.

Looking back over 36 years of teaching, it has been a rewarding experience to start the engineering education of so many students by teaching them the best way to sketch, to draw, and to solve problems by graphic analysis. I have gladly accepted the challenge to develop graphic insight that enables students to learn quickly, to understand correctly, and to apply their talents to creative engineering. It has been a real satisfaction to me when former students return after twenty years out of college and tell me that the graphics courses made a valuable contribution to their engineering education.

Mr. Chairman, this Special Award is one of the nicest things that ever happened to me. With all my heart I thank you.

On Ideas and the Engineer*

By John F. Gordon

Vice-President and Group Executive, General Motors Corporation

At his desk, drafting board, laboratory, or wherever he may be in industry, the engineer has the job of producing ideas.

To be sure, his mind has been well trained for many other tasks. He has been taught, for example, to solve problems according to a definite pattern. Simply stated, the pattern consists of defining the problem, assembling the facts, appraising the facts, and making a decision based on the appraisal. The engineer's training also equips him to apply the fundamentals of physics and other sciences, since most of the problems he sees require this kind of solution. He is accustomed to analyzing in terms of facts and material things.

But this kind of thinking is routine for him. When, on the other hand, he can produce ideas of his own for the solution of a problem, this is the real key to the engulfing satisfaction in his task and, indeed, is one of the reasons his employer values him. The engineer becomes, then, an "idea man"—one who can be creative.

The problems that come before him range from the workaday tasks in completing a design or a process to the "problem" of providing a new or improved product which the public wants. For example, the public's taste in automobiles changes rapidly. In years past, the motorist began to demand the elimination of manual gear shifting. The engineer's problem there was to meet that demand with the design of a satisfactory automatic transmission which could be built in production quantities. Working independently, General Motors engineers supplied a great many ideas to solve this problem. The answer came in three basic designs for automatic transmissions which were produced and put into service. The problem was solved and today's GM cars and trucks continue to use the same fundamental types in improved versions—the result of still more ideas along the way.

... As [the engineer] changes from college student to employe, the amount of direction he receives grows less and less. Thus, as he progresses, he becomes not a routine worker but one who sees in every task an opportunity to make use of his own creativity. Initiative and responsibility are now expected of him.

The engineer's experience teaches him that many of his ideas are not accepted, many have been thought of before, many will be modified in the process of discussion with others on his working team. However, a certain number of his ideas are used and therein lies the value of his work and the sense of personal satisfaction he derives from it.

Doing an engineer's job requires a number of important qualities. One of these is the ability to produce an idea. That is where progress makes its start.

---

* Excerpted from Editorial appearing in November-December, 1955 General Motors ENGINEERING JOURNAL, by special permission.


I HOPE THAT THIS WILL ARRIVE SOON ENOUGH FOR ME TO RECEIVE THE NEXT ISSUE!
Prof. E.M. Griswold
Journal of Eng. Drawing
The Cooper Union
Cooper Square
New York 3, N.Y.
US MAIL
DICK CARPENTER
Purdue

A Light Table

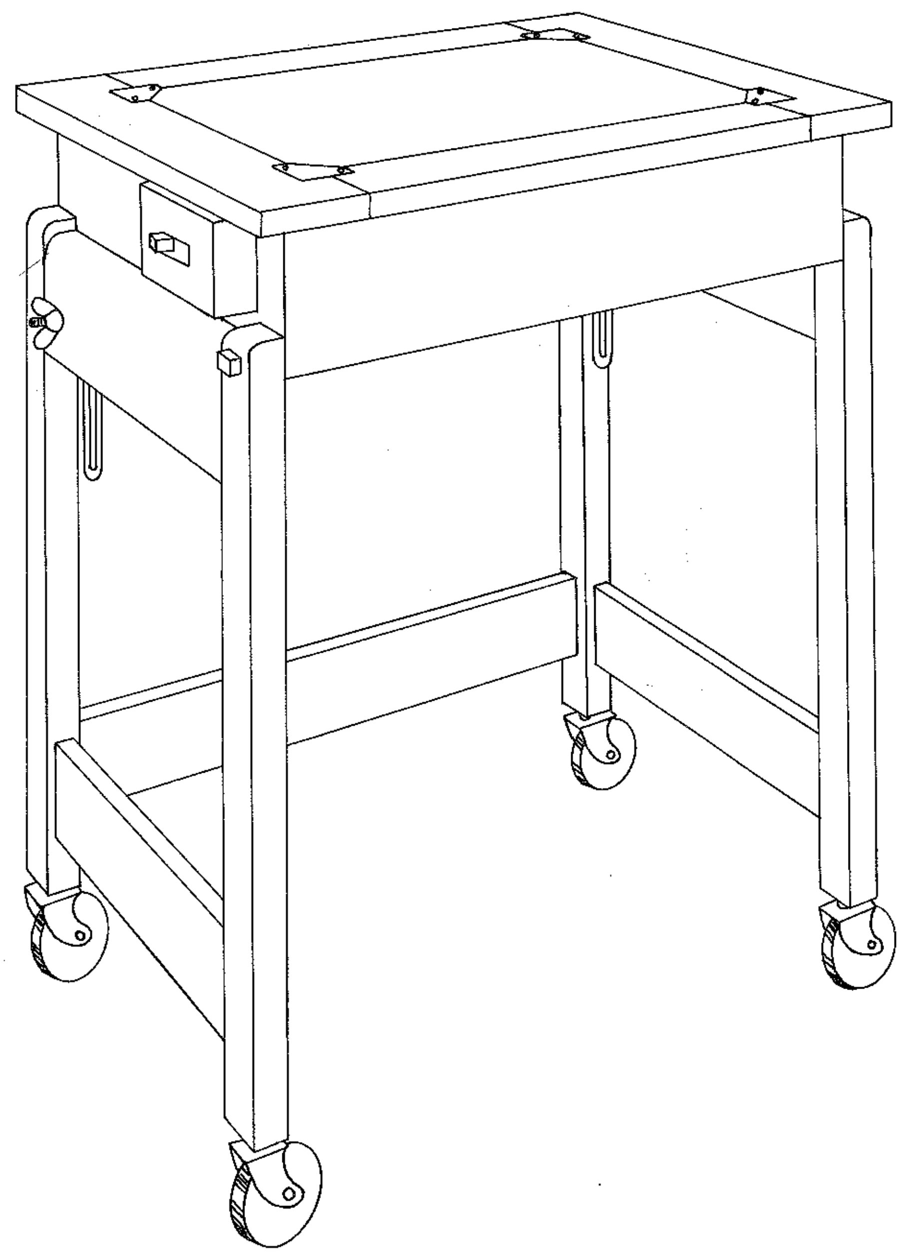
By Howard C. Nelson
University of Illinois, Urbana

Light tables such as the one shown in the accompanying illustration have proven to be very useful and continually in demand in the offices of the engineering drawing instructors at the University of Illinois. These tables make it possible to do more work easily and rapidly.

The accuracy of a student's work may be readily determined by placing a correct drawing on the table and placing a student's drawing upon it. Any discrepancy in the student's work can then be easily found.

Lines can be readily seen through heavy drawing paper which has been placed over another drawing on the light table. It is thus possible to trace drawings upon any type of paper. Drawings on mimeograph stencils can also be made on the light table. Blue prints may be printed by placing the tracing and blue print paper on the table and placing a drawing board over them.

This table is 30 inches high; the top is 17" x 24" with a 12" x 18" frosted glass. Four 15-watt fluorescent light tubes are mounted in the box below the frosted glass. The top of the table may be tilted at any desired angle. Hospital casters are attached to the legs so that the table can be easily moved. The tables were built in the University physical plant wood shop from detailed drawings prepared in the engineering drawing department.



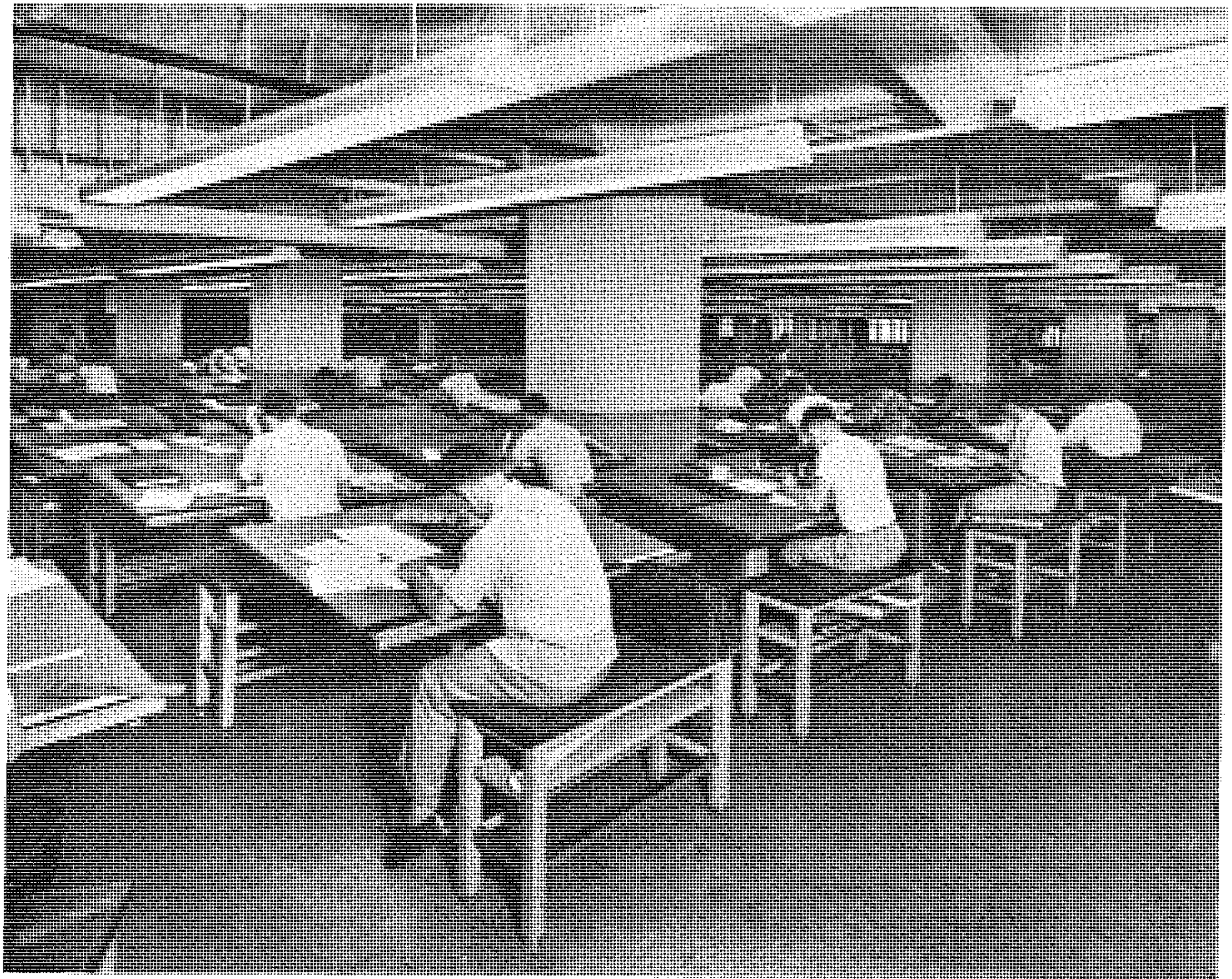
ITEMS, LETTERS, MISC.

Suggestions on how to make the JOURNAL more readable, more useful, and more informative are always in order.

One suggestion has been to include news items about members of the Division, particularly changes in affiliation. Persons involved are urged to send such information and other newsworthy items to the editor as soon as the information is official.

In addition, letters to the editor will be published if they appear to be of general interest. Letters commenting on articles, whether in agreement or not, are eagerly sought.

A suggestion has been made that the JOURNAL carry miscellaneous bits of advice and hints about devices and procedures that have been tried out successfully in classroom situations. The suggestion is good. Contributions to a column of miscellany will be acknowledged and credited.

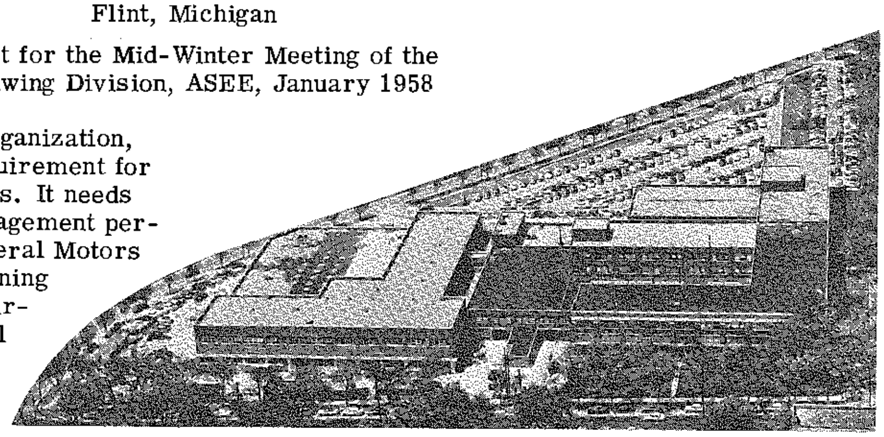


GENERAL MOTORS INSTITUTE: One-third of an acre in one room devoted to basic drafting courses in designing, process engineering, and automotive body drafting.

General Motors Institute

Flint, Michigan

Host for the Mid-Winter Meeting of the Drawing Division, ASEE, January 1958



As a manufacturing and distribution organization, General Motors has a never-ceasing requirement for many types of capable, trained individuals. It needs engineers, business executives, and management personel. To help furnish these people, General Motors Institute, the central educational and training service for General Motors, conducts four-year cooperative programs in mechanical engineering and industrial engineering.

Institute graduates thus supplement the manpower General Motors receives through close working relationships with other universities and colleges.

Every student in the cooperative programs spends half his training time at General Motors Institute and half at his cooperating unit. He goes from one training ground to the other every eight weeks (every four weeks if his cooperating sponsor happens to be located in Michigan, close to the Institute). In this way students continue this periodic transition between theory and practice for four full years and write reports coordinating their training at both places. This earns the students a diploma. Then they spend a full year in their respective sponsoring plants working on the solution of an assigned problem. Upon completion of a comprehensive report on the solution of their problem, they are awarded bachelor's degrees.

In the current semester, approximately 2,500 men are enrolled in the engineering programs, Since the first graduation class of 1928, about 5,000 have been graduated, of whom 69 per cent are still with plants and divisions of the Corporation--many in high administrative or technical positions.

General Motors Overseas Operations Division has sponsored more than 200 students from 16 countries under the overseas scholarship plan.

Incidentally, the cooperative system pays financial as well as well as educational dividends to the students. During their periods of work experience, students are paid as employes of General Motors. This enables many to earn their way through School, in full or in part.

The Institute has the further purpose of preparing, through education and training, established General Motors employes for improved effectiveness on their present positions and for future advancement. This is approached through continuous programs in the areas of management, distribution, and specialized technical subjects. These programs are conducted at the Institute, in the plants, and in convenient locations in the field. Instruction of this type was given to more than 34,000 last year. General Motors Institute also serves many educational needs of the community in which it is situated--offering to residents of the Flint area a diversified Spare Time Training Program of adult classes. It was in this way that General Motors Institute began--as an evening school co-sponsored by an organization of Flint factory employes and Flint manufacturers, back in October, 1919. Since then, the Institute had steadily increased in size and importance. The full-time faculty now numbers 290.

Since the original unit of the present structure was built in 1927, there have been seven major expansions. The most recent, completed in 1955, along with the modernization and remodeling of the older portions of the building, added 40 per cent to the floor space, bringing it to a total of 286,700 square feet.

With emphasis on the experimental approach in engineering education, particular attention was given to laboratory arrangement. These broad unobstructed areas, complete with the most modern equipment, allow for maximum flexibility required by any necessary changes in courses or curriculum.

Typical of the laboratories is that for drawing and design. It was laid out and developed to meet the instructional requirements of engineering drawing, kinematics, engineering design, tool design, die design, gage design, internal combustion engine design, automotive chassis and transmission design, and automotive body engineering. These instructional requirements resulted in standardizing on three drafting tables sizes of 44 by 60 inches; five by eight feet; and five by sixteen feet. There are a total of 280 tables in this non-partitioned area.

Mid-Winter Meeting

Engineering Drawing Division, A.S.E.E.
January 15 - 17, 1958
At General Motors Institute, Flint, Michigan

Tentative Program

WEDNESDAY NIGHT, JANUARY 15

6:30 - 7:30	Dinner Meeting - Executive Committee
7:30 - 9:00	Business Meeting - Executive Committee

THURSDAY MORNING, JANUARY 16

8:30 - 9:45	Registration - General Motors Institute
8:45 - 10:00	Coffee and Doughnuts (Ladies Invited)
9:00 - 10:15	Open House at General Motors Institute (Guided Tour - Ladies Invited)
10:30 - 12:00	General Session
Place:	G M I Auditorium, Room 3-110
Presiding:	James S. Rising, Vice-Chairman Engineering Drawing Division - ASEE
Welcome:	Guy R. Cowing - President - General Motors Institute
Remarks:	C. A. Brown, Vice President ASEE in charge of Instruction Division Activities
Response:	Warren J. Luzadder, Chairman Engineering Drawing Division - ASEE
Speaker:	Roy P. Trowbridge, Director of GM Engineering Standards

Section - "Drawing Could Be The Proving Ground Of The Engineer"

THURSDAY AFTERNOON, JANUARY 16

12:15 - 1:30 Luncheon and Business Meeting
Presiding: Warren J. Luzadder
1:45 - 4:00 Workshop

Subject: Engineering Drawing and its Relation to Designing
Place: Room 2-712
Chairman: Frank H. Smith (University of Michigan)
Analyst: Albert Jorgensen (University of Pennsylvania)
Recorder: Theodore Aakhus (University of Nebraska)

Subject: Better Methods of Instruction in Engineering and Technical Drawing
Place: Room 2-225
Chairman: J. Howard Porsch (Purdue University)
Analyst: Harold P. Skamser (Michigan State University)
Recorder: Irwin Wladavèr (New York University)

Subject: Problems in Graphical Analysis of Mechanisms
Place: Room 4-309
Chairman: Ralph T. Northrup (Wayne State University)
Analyst: Douglas P. Adams, (Massachusetts Institute of Technology)
Recorder: Frank A. Heacock (Princeton University)

Subject: Course Development in Relation to an Engineering Curriculum and Future Needs of the Young Engineer
Place: Room 3-110
Chairman: Carson P. Buck (Syracuse University)
Analyst: Ivan L. Hill (Illinois Institute of Technology)
Recorder: A. P. McDonald (Rice Institute)

THURSDAY EVENING, JANUARY 16

6:30 Dinner Meeting (Ladies Invited)
Place: Durant Hotel Ballroom
Toastmaster: Earl D. Black, Head of Engineering Drawing and Kinematics - General Motors Institute
Presiding: Warren J. Luzadder (Purdue University)
7:30 Address: Dr. Kenneth McFarland, Educational Consultant for General Motors Corporation
(Subject to be announced)
8:30 Entertainment

FRIDAY MORNING, JANUARY 17

8:15 - 8:45 Coffee and Doughnuts (Ladies Invited)
8:15 - 8:45 Visitation and Open House
8:45 - 8:55 Group Photograph (Chevrolet and Third Avenue Entrance)
9:00 - 11:45 Plant Trips
Place: AC Spark Plug Division
Place: Buick Motor Division
Place: Chevrolet and Fisher Body Assembly Division

FRIDAY AFTERNOON, JANUARY 17

1:30 - 3:00 General Session
Place: GMI Auditorium, Room 3-110
Presiding: Warren J. Luzadder
Technical Talks:

1. Quality Control Specifications and Their Effect on Drawings
Marvin Fuller, General Supervisor of Inspection Methods Research, International Harvester Company
2. Development and Use of Graphic Illustrations in the Manufacturing Industry
Frederick Jantz, Senior Design Group Leader, Product Engineering Department, Oldsmobile Division of General Motors Corporation
3. On The Job Training in Drafting
Tracy B. Nabers, Director of Drafting and Design Training - Chrysler Corporation Institute of Engineering, Detroit, Michigan

3:15 - 4:00 Panel Discussion
Panel Members:
Jasper Gerardi (University of Detroit)
Ralph S. Paffenbarger (The Ohio State University)
Henry C. Spencer (Illinois Institute of Technology)
Clifford H. Springer (University of Illinois)
William E. Street (Texas A & M College)
B. Leighton Wellman (Worcester Polytechnic Institute)

4:00 Adjournment

Ladies' Tentative Program

WEDNESDAY NIGHT, JANUARY 15

6:30 Dinner Meeting and Entertainment

THURSDAY MORNING, JANUARY 16

8:30 - 9:45 Registration
9:00 - 10:15 Open House at GMI (See Men's Program)

10:30 - 12:00	To GM Building - Detroit
12:15 - 1:30	Luncheon
1:45 - 3:00	Tour of model kitchen and passenger car exhibits.
3:00 - 5:00	Return to Flint

THURSDAY NIGHT, JANUARY 16, 1958

6:30 Dinner Meeting (See Men's Program)

FRIDAY MORNING, JANUARY 16, 1958

8:15 - 8:45	Coffee & Tea Hour
9:00 - 11:45	Tour of Flint Community College
12:15 - 1:15	Luncheon
1:30 - 3:00	Tea & Card Party

Officers and Committees - 1957-58

Division of Engineering Drawing and Descriptive Geometry, ASEE

OFFICERS:
- Chairman: W. J. Luzadder, Purdue University, West Lafayette, Indiana.
- Vice-Chairman: J. S. Rising, Iowa State University, Ames, Iowa
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- J. H. Porsch, Purdue University, West Lafayette, Indiana. (3 years)
- M. McNeary, University of Maine, Orono, Maine. (4 years)
- B. L. Wellman, Worcester Polytechnic Institute, Worcester, Mass. (5 years)
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- E. G. Paré, Washington State College, Pullman, Washington. (1 year)

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B. L. Wellman, Worcester Polytechnic Institute, Worcester, Mass.
H. P. Ackert, University of Notre Dame, Notre Dame, Indiana.
M. J. Wolff, University of Wisconsin, Milwaukee, Wis.

Nominations Committee for 1958:
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W. E. Street, Texas A & M College, College Station, Texas.
W. B. Rogers, U. S. Military Academy, West Point, N. Y.
R. D. LaRue, Colorado State College, Fort Collins, Colo.

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- R. H. Hammond, U. S. Military Academy, West Point, N.Y.
- F. A. Heacock, Princeton University, Princeton, N.J.
- A. Jorgensen, University of Pennsylvania, Philadelphia, Pa.
- R. A. Kliphardt, Northwestern University, Evanston, Illinois.
- J. S. Rising, Iowa State College, Ames, Iowa.
- B. L. Wellman, Worcester Polytechnic Institute, Worcester, Mass.

Report of the Bibliography Committee*

By S.E. Shapiro, Chairman
University of Illinois, Chicago

Books Published 1951 to 1957

AUTHORS	TITLE	PUBLISHER	ED.	YEAR	PAGES	PRICE
B. Allsopp	A General History of Architecture	Pitman	1	1956	233	7.50
M. W. Almfeldt & K. E. Haughton	Engineering Graphics Problem Book I	Wm. C. Brown	1	1955	80	2.75
	Engineering Graphics Problem Book II	Wm. C. Brown	1	1955	88	3.00
C. C. Bishop	Electrical & Electronic Drafting	McGraw-Hill	1	1952	272	4.50
S. L. Coover	Drawing, Sketching & Blueprint Reading	McGraw-Hill	1	1954	377	3.96
H. T. Davey & R. J. Wilkins	Engineering Drawing	MacDonald & Co.	1	1952	392	8.50
T. E. French & C. J. Vierck	Manual of Engineering Drawing for Students and Draftsman (Text Edition)	McGraw-Hill	8	1953	715	6.50
H. R. Goppert, C. I. Carlson, G. E. Cramer & E. J. Caldario	Problems in Engineering Geometry, Series 3	Stipes Pub. Co.	1	1956	88	2.75
H. E. Grant	Practical Descriptive Geometry (Reg. Edition Without Problems)	McGraw-Hill	1	1952	253.	4.75
H. E. Grant	Practical Descriptive Geometry (Alternate Edition With Problems)	McGraw-Hill	1	1956	403	5.25
S. G. Hall, L. D. Walker, E. D. Ebert & A. G. Frederich	Problems in Engineering Drawing, Series B	Stipes Pub. Co.	2	1957	62	3.00
R. P. Hoelscher, J. N. Arnold & S. H. Pierce	Graphic Aids in Engineering Computation	McGraw-Hill	1	1952	197	5.00
R. P. Hoelscher & C. H. Springer	Engineering Drawing & Geometry	John Wiley & Sons	1	1956	520	8.00
R. P Hoelscher, C. H. Springer, B. O. Larson & J. E. Pearson	Problems in Engineering Drawing, Series A	Stipes Pub. Co.	2	1956	58	3.00

*The Bibliography Committee requests readers to send in additions or corrections to this listing for the next report. Committee members are named elsewhere in this issue.

AUTHORS	TITLE	PUBLISHER	ED.	YEAR	PAGES	PRICE
R. P Hoelscher C. H. Springer B. O Larson & J. E. Pearson	Problems in Engineering Geometry, Series 1	Stipes Pub. Co.	2	1956	84	2.75
R. P Hoelscher C. H. Springer B. O. Larson & J. E. Pearson	Problems in Engineering Geometry, Series 2	Stipes Pub. Co.	2	1957	84	2.75
G. J. Hood	Geometry of Engineering Drawing	McGraw-Hill	4	1957	380	5.50
F. C. Horstmann	Technical Freehand Drawing	Pitman	1	1952		1.90
P. S. Houghton	Engineering Drawing & Drawing Office Practice	Lockwood				
H. B. Howe	Descriptive Geometry	Ronald Press	1	1951	332	4.25
H. B. Howe	Problems for Descriptive Geometry	Ronald Press	1	1953	77	3.50
C. A. Kulmann	Nomograph Charts	McGraw-Hill	1	1951	244	7.00
L. H. Johnson	Nomography & Empirical Equations	John Wiley & Sons	1	1952	150	4.00
L. O. Johnson & I. Wladaver	Elements of Descriptive Geometry, Part I, Text	Prentice-Hall	1	1953	73	1.95
	Elements of Descriptive Geometry, Part II, Problems	Prentice-Hall	1	1953	76	3.50
L. O. Johnson & I. Wladaver	Engineering Drawing Problems	Prentice-Hall	1	1956	66	5.00
A. S. Levens	Graphics in Engineering & Science	John Wiley & Sons	1	1954	696	7.00
A. S. Levens	Workbook to Accompany Graphics in Engineering & Science; Series I, Book I	John Wiley & Sons	1	1954	74	4.00
A. S. Levens & A. E. Edstrom	Workbook to Accompany Graphics in Engineering & Science; Series I, Book 2	John Wiley & Sons	1	1954	76	4.00
A. S. Levens & A. E. Edstrom	Problems in Engineering Drawing, Series IV	McGraw-Hill	1	1953	155	4.00
W. J. Luzadder	Fundamentals of Engineering Drawing	Prentice-Hall	3	1952	721	6.50
W. J. Luzadder	Graphics for Engineers	Prentice-Hall	1	1957	608	6.50
M. McNeary E. R. Weidhaas & E. A. Kelso	Creative Problems for Basic Engineering Drawing	McGraw-Hill	1	1957	48	3.75
C. L. Martin	Architectural Graphics	Macmillan	1	1952	213	4.35
Morehead & Morehead	A Handbook of Perspective Drawing	Van Nostrand	1	1952	178	6.00
H. D. Orth R. R. Worsencroft & H. B. Doke	Theory and Practice of Engineering Drawing	Wm. C. Brown Co.	1	1953	464	4.00
H. C. Orth R. R. Worsencroft & H. B. Doke	Problems in Engineering Drawing	Wm. C. Brown Co.	2	1953	118	2.65
E. G. Paré F. M. Hrachovsky & E. F. Tozer	Graphic Representation	Macmillan	1	1954	40	3.60

AUTHORS	TITLE	PUBLISHER	ED.	YEAR	PAGES	PRICE
E. G. Paré R. O. Loving & I. L. Hill	Descriptive Geometry	Macmillan	1	1952	309	4.25
E. G Paré R. O. Loving & I. L. Hill	Descriptive Geometry Worksheets, Series B	Macmillan	1	1954	75	3.25
	Descriptive Geometry Worksheets, Series C	Macmillan	1	1957	152	3.25
E. G. Paré & E. F. Tozer	Engineering Drawing Problems, Series N	Van Nostrand	1	1953	126	4.85
J. S. Rising & M. W. Almfeldt	Engineering Graphics	Wm. C. Brown Co.	1	1953	402	6.00
J. S. Rising & D. D. Glower	Engineering Graphics Problem Book III	Wm. C. Brown Co.	1	1957		3.75
C. E. Rowe & J. D. McFarland	Engineering Descriptive Geometry	Van Nostrand	1	1953	352	4.50
C. E. Rowe & J. D. McFarland	Problem Series C	Van Nostrand	1	1952	110	3.50
J. T. Rule & E. F. Watts	Engineering Graphics	McGraw-Hill	1	1951	396	5.00
J. T. Rule & E. F. Watts	Engineering Graphics Workbook		1			4.00
J. M. Russ	Quiz Questions to Accompany Engineering Drawing Textbook of French & Vierck	McGraw-Hill	8	1953	65	1.00
S. E. Shapiro D. M. Holladay G. Wilson & W. L. Shick	Problems in Geometry for Architects, Series A, Part I	Stipes Pub. Co.	1	1956	61	2.75
	Problems in Geometry for Architects, Series A, Part II	Stipes Pub. Co.	1	1956	56	2.75
H. W. Shupe & P. E. Machovina	Engineering Geometry and Graphics	McGraw-Hill	1	1956	347	5.25
H. C. Spencer	Basic Technical Drawing	Macmillan	1	1956	370	4.32
W. W. Turner	Integrated Problems in Engineering Drawing & Desc. Geometry	Ronald Press	1	1953		4.00
W. W. Turner	Shades & Shadows	Ronald Press	1	1952	122	3.25
C. J. Vierck C. D. Cooper & P. E. Machovina	Engineering Drawing Basic Problems, Series A	McGraw-Hill	1	1953	72	3.50
C. J. Vierck C. D. Cooper & P. E. Machovina	Engineering Drawing Problems, Series II	McGraw-Hill	1	1953	122	4.50
E. F. Waller	Technical Sketching	Pitman	1	1951		1.65
H. D. Walraven C. I. Carlson & E. J. Mysiak	Problems in Engineering Drawing, Series C	Stipes Pub. Co.	2	1956	64	3.00
F. M. Warner	Applied Descriptive Geometry	McGraw-Hill	4	1954	247	4.50
F. M. Warner & C. E. Douglass	Problem Book	McGraw-Hill	2	1955	63	3.75
B. L. Wellman	Technical Descriptive Geometry	McGraw-Hill	2	1957	628	5.75

AUTHORS	TITLE	PUBLISHER	ED.	YEAR	PAGES	PRICE
B. L. Wellman	Problem Layouts for Technical Descriptive Geometry, 2nd Edition	McGraw-Hill	1	1957	120	3.95
W. N. Wright	A Simple Guide to Blueprint Reading	McGraw-Hill	1	1956	120	5.00
F. Zozzora	Engineering Drawing	McGraw-Hill	1	1953	369	5.50
F. Zozzora	Engineering Drawing Problems	McGraw-Hill	1	1954	72	3.75
ADDENDA:						
J. N. Arnold	Introductory Graphics	McGraw-Hill	1	1958		
French & Vierck	Graphic Science (Eng. Dwg., Geom.&Gr.)	McGraw-Hill	Alt.	1958		
Giesecke, Mitchell & Spencer	Technical Drawing	Macmillan	4	1958		
E. G. Paré	Engineering Drawing	Dryden	1	1958		
F. Zozzora	Engineering Drawing	McGraw-Hill	2	1958		

Tentative Slate of Candidates for Offices of the Division, 1958-59

In accordance with the Rules of the Division, the Nominating Committee, R. T. Northrup, Chairman, presents a list of candidates for offices for the 1958-59 term. Additional candidates may be nominated by petition. A petition should be signed by ten members of the Division, identified by their schools and their signatures. The candidate named must have expressed his willingness to accept the office specified, if elected. Such petitions should reach Professor Northrup, Wayne State University, Detroit, Michigan, before the conclusion of the Mid-Winter Meeting, January, 1958.

The tentative slate is as follows:

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Albert Jorgensen, University of Pennsylvania

SECRETARY TREASURER:
Eugene G. Paré, Washington State College
Irwin Wladaver, New York University

EDITOR OF GRAPHIC SCIENCE PAGE:
Leon M. Sahag, Alabama Polytechnic Institute
Floyd A. Smutz, Kansas State College

EDITOR OF JOURNAL OF ENGINEERING DRAWING:
Carson P. Buck, Syracuse University
Wayne L. Shick, University of Illinois, Urbana

MEMBER OF EXECUTIVE COMMITTEE:
Mary F. Blade, The Cooper Union
Earl D. Black, General Motors Institute

REPRESENTATIVE TO GENERAL COUNCIL:
Jasper Gerardi, University of Detroit
Alexander S. Levens, University of California, Berkeley

Nominating Committee
R.T. Northrup, Chairman

DISTINGUISHED SERVICE AWARD

To members of the Drawing Division:

The committee on Distinguished Service Awards is soliciting your nominations for this Service Award. This committee consisting of the three immediate past chairmen of the Division gets together at the Mid-winter Meeting of the Division to determine the recipient of the award, so it will be necessary to have your nominations mailed to the undersigned not later than January 8, 1958.

To be eligible for the award a candidate must have made a clearly discernible contribution to teaching the art and science of graphics; contributed to the literature in this field; and rendered a distinct service to the Division of Engineering Drawing. For the full statement of requirements for the Distinguished Service Award, refer to the May, 1952 issue, page 27, of the Journal of Engineering Drawing. Send your nominations to me singly or in groups. I solicit your cooperation.

For the Awards Committee

T. T. Aakhus, Chairman
University of Nebraska
Lincoln 8, Nebraska

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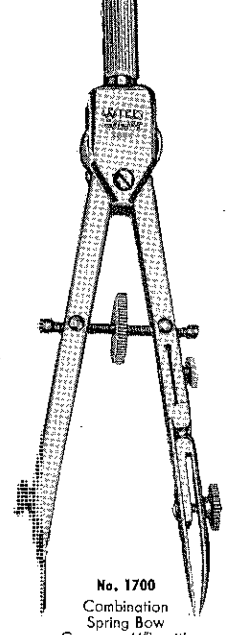
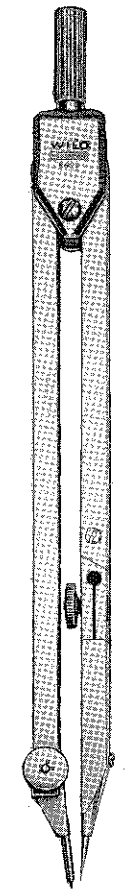
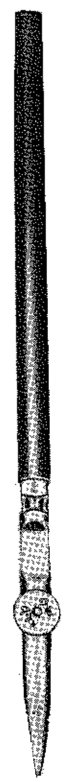


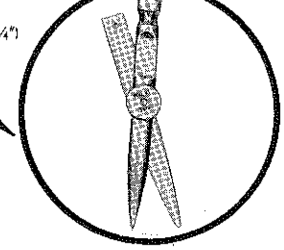
No. 1700
Combination Spring Bow Compass (4") with interchangeable divider point, pen, and pencil



No. 1784
Compass (6") with interchangeable dividers, pen, and pencil



No. 1593
Ruling Pen (5¼")



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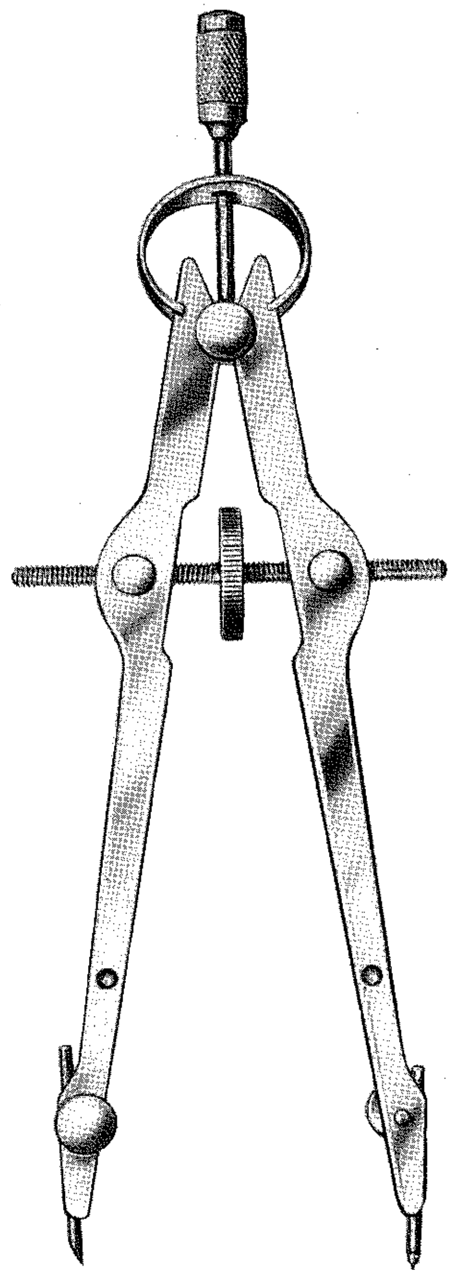

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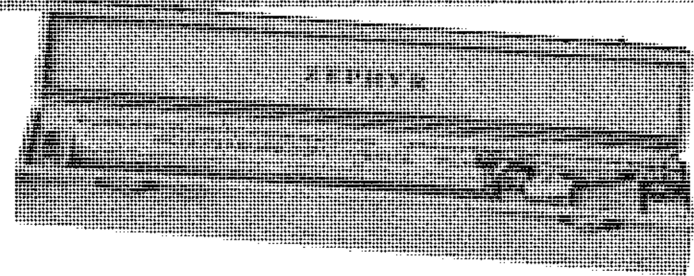
THE ZEPHYR LETTERING SET



The ZEPHYR Lettering Set is the response of the manufacturer of WRICO Lettering Guides to an insistent demand for a PRACTICAL inexpensive lettering set providing the sizes of lettering most commonly used.

Into every part of this set have gone more than thirty-five years of skill and experience by the world's foremost manufacturer of lettering instruments.

Lettering with a ZEPHYR set is simplicity itself. As the characters on the lettering guide are followed with the tracer point of the scriber the tail pin slides smoothly in the groove of the guide holder and the lettering point forms perfect uniform vertical lettering in either pencil or ink.

ACTUAL SIZE SAMPLES OF LETTERING

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ &

ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234

ABCDEFGHIJKLMNOPQRSTUVWXYZ & $¢ 12345678

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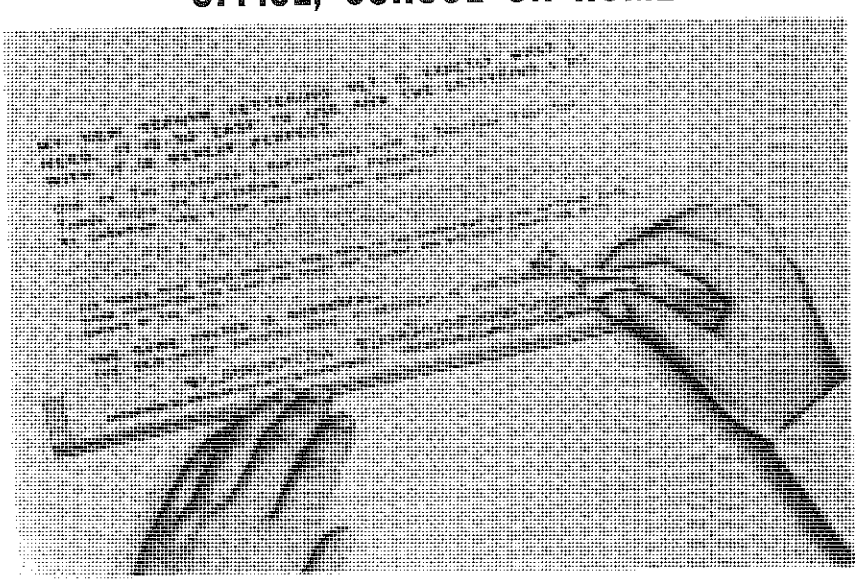
INDISPENSABLE IN DRAFTING ROOM, OFFICE, SCHOOL OR HOME



The ZEPHYR lettering guide has three sizes of lettering — Size 240 (.240 in. high), Size 175 (.175 in. high) and Size 140 (.140 in. high). The first two may be used with either the heavy line point or the fine line point. Each size has a complete set of capitals, numerals, and symbols.

The ZEPHYR Lettering Set is supplied in a handsome cabinet of selected, kiln dried, basswood with satin lacquer finish.

For complete information, send for Catalog #54.

THE
WOOD-REGAN INSTRUMENT COMPANY
INCORPORATED
FACTORY & GENERAL OFFICES
NUTLEY, NEW JERSEY