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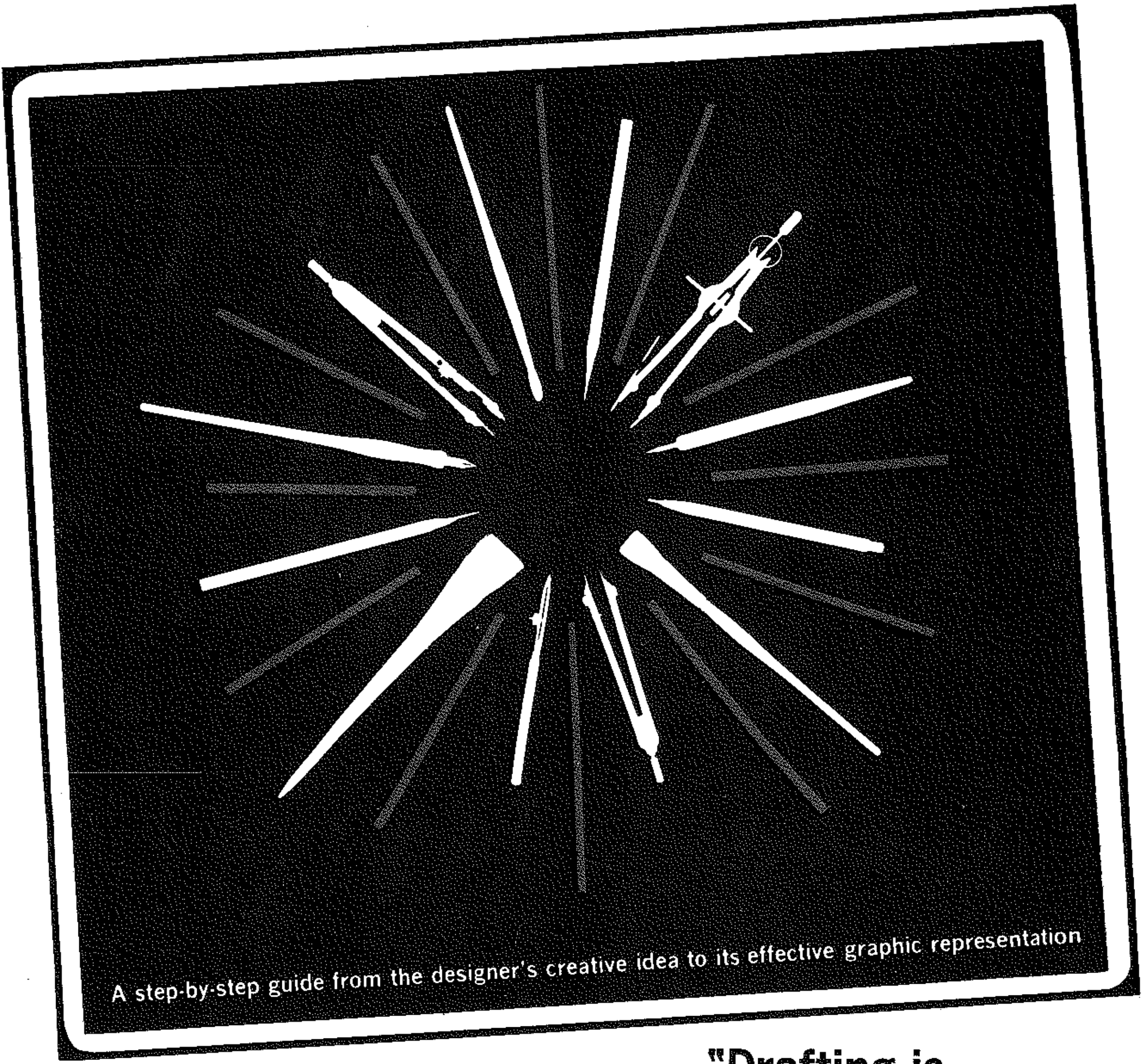

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"Drafting is the principal medium of expression for designers"-- By C. Leslie Martin

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Design Graphics

By C. Leslie Martin, *University of Cincinnati*

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Coming, spring 1962

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On the Twentieth Century Limited
Enroute to the Mid-winter meeting
at the University of Wisconsin.

These are years of change in engineering. So that we may take an active part in determining the direction of change we must maintain our lines of communication. This Journal has been one of the lines for many years. To maintain the Journal as the leader for reporting advances in the teaching, research and administration of Graphics in Engineering and Science on a college and university level all members are urged to be active in reporting their teaching or research activities or supporting the Journal by encouraging wide subscription.

Several years ago I was fortunate in being able to attend a Seminar at Columbia arranged by Professor Ferdinand Freudenstein on Space Kinematics. Professor Beyer, a distinguished internationally known kinematician had been invited to lecture. In presenting his lectures which were the outcome of a life devoted to geometry and mechanism, he fluently used the methods of plane geometry, solid and projective geometry, vector analysis, descriptive geometry (Mongean and first angle), calculus and his own inventions. He used models and gestures and complex notations to describe his problems and their solutions. He was a virtuoso, using many media to create and solve the problems of geometry in moving space linkages. This ability to use eclectic methods and novel approaches was founded on his thorough European education as a mathematician and engineer. It is this same thoroughness of background and high degree of competence which characterizes Professor Borecky, our Canadian member who has written us an invitation to study Projective Geometry in this issue. He feels that if Engineering Graphics teachers will study Projective Geometry and introduce some of its concepts in our classrooms we will increase the power and depth of our own and our students' insight. Our Oldtimer will remember that Professor Rule's "Lulu of a problem" was solved by projective geometry.

This week a publisher sent me a large and handsome new text on Basic Graphics. This title triggered a Shock Wave in me as I had just been pre-conditioned by reading an article by this title for this issue of the Journal. I urge you to read this article and send dissenting and concurring remarks to me for publication in the May Journal. (Deadline March 15.) As a note to Rex' article and a reminder to future authors of more texts on Basic Graphics we should remember that most people, that is, the public, think of Graphics as an art form with etching, engraving, woodblock and lithography techniques and involving fine arts and applications in visual design such as bookmaking and advertizing. In fact there are large and long established schools of Graphics to whom our (ASEE) concept of Graphics is completely foreign. We have only recently latched on to this word instead of Mechanical Drawing or Engineering Drawing and it may be useful in the long run. But in using this word, Graphics, we should use a suitably descriptive prefix so that at least we are aware of Sir Charles Snow's "Two Cultures" and two kinds of graphics. Otherwise we will be getting ourselves into the same kind of confusion which still embraces the word engineer.
To conclude I must report that a member of the Division whom I queried about the Journal, suggested we publish articles of interest in the Technical Institutes and High Schools. I urged him to submit an article and he promised to do so. Subsequently I tried pressuring him by mail. All to no avail, so that in lieu of the article I offer the following tale.
A group of practicing engineers from industry and a professor from a prominent Northeastern US Engineering School recently was sent by the State Department to a remote area in Africa to provide technical assistance and to assist in establishing a new technical university for the surrounding countries. Unfortunately the plane transporting the group developed engine trouble and made a forced landing in a forest which was inhabited by a fierce tribe of cannibals. Of course the engineers from industry and the professor were quickly captured and imprisoned and were fattened up for the annual feast. Although the prisoners eventually became resigned to their fate they were very curious about the rites which preceeded the cookout and particularly to learn that a menu was being prepared. On reading the menu the engineers from industry became very agitated and quickly formed a committee and petitioned the Old Tribal Chief. They told him, "We realize we are unfortunate victims of the situation and are resigned to our fate but why does the menu list engineers from industry at $2.00 a portion and the professor at $100.00 a portion? Why is the professor worth so much more than the engineers from industry?" The Old Tribal Chief looked tolerantly at the engineers from industry and answered with great patience. He described in detail the heat transfer problems, mass transfer, and the boundary layer conditions involved in their boilers and described the P,V,T and economic relations involved in the large modern pressure cookers used by the fierce tribe. The committee of engineers from industry was still dissatisfied and again asked, "If we are worth only $2.00 a portion, why is the professor worth $100.00 a portion?" The Chief then said pityingly, "Have you ever tried to put the pressure on a professor?"

Sincerely,
Mary Blade

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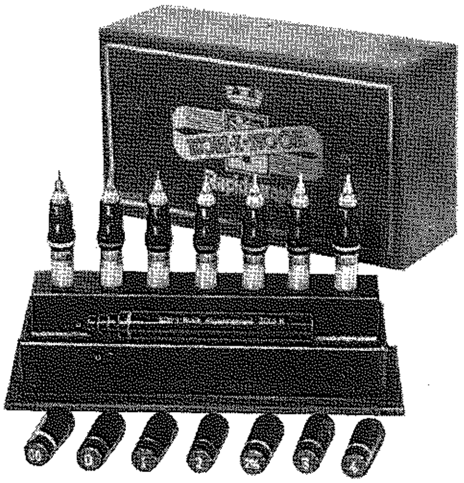

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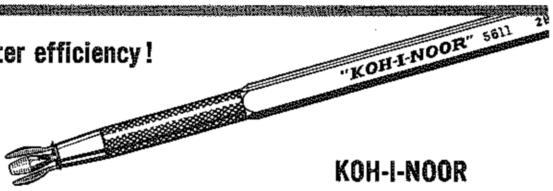

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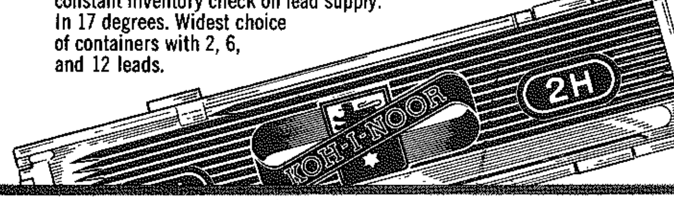

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WARREN J. LUZADDER has been teaching Engineering Graphics at Purdue University since 1930. As a successful writer of engineering books, he has authored the P-H texts, *Fundamentals of Engineering Drawing, 4th* and *Technical Drafting Essentials, 2nd.* Professor Luzadder is also co-author of Prentice-Hall's *Problems in Engineering Drawing, 4th* and *Problems for Engineering Graphics.*

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RELATIONSHIP BETWEEN PROJECTIVE AND DESCRIPTIVE GEOMETRY

By Professor V. P. Borecky, University of Toronto, Department of Civil Engineering,
Division of Engineering Drawing

EDITOR'S NOTE: This article is included in the Journal with the hope that interest in projective geometry may be revived or stimulated. Professor Borecky has submitted a number of articles of which the following is the first, giving some introductory notions. If readers will respond, further articles will follow.

Descriptive geometry has been defined as a special case of projective geometry. Descriptive geometry is an intuitive representation of plane figures and space objects in an arbitrary position in space in one plane (blackboard, paper) by means of orthographic, axonometric, or perspective projection. In descriptive geometry we advantageously use the methods of projective geometry treating those properties of a plane figure, or a spatial configuration which remain invariant (unchanged) in projection.

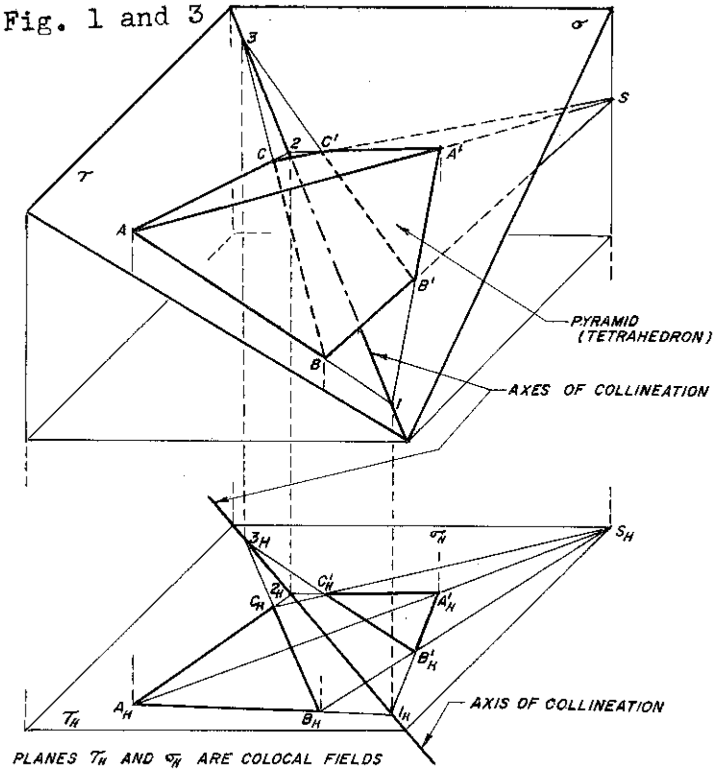
When dealing with a simple industrial (mechanical, electrical, structural, civil, or mining engineering) drawing, the methods of projective geometry are really not needed, but in a complicated and representative design (i.e. required when competing for the acceptance of a design for a modern and expensive project) involving: monoplanar projection, perspective projection, photogrammetry, relief perspective, shade and shadows of a complex architectural project, and especially warped surfaces up to the fourth degree. Projective geometry offers a series of elegant auxiliary means to the construction of solutions of the most complicated problems.

Projective geometry initiated from Euclidian axioms about parallel lines and ideal (vanishing) points (i.e. points at infinity of straight lines, projecting onto the ideal line located in the projection plane), enriched by geometri constructions of other Greek philosophers (i.e. Thales), extended by the propositions of French scientists and mathematicians as Desargues, Pascal, and Brianchon, and finally completed by French, Czech, Swiss, Italian, and German geometrographicians as Chasles, Pelz, Sobotka, Klima, Steiner, Cremona, Weyr, Mannheim, and others, is also called "geometry of position" because it pays attention to the mutual position of the object and its projections.

Projective geometry is based on central projection, i.e. the perspective projection is directly conjoint to and developed from perspective collineation. If we remove the centre of projection (the station point S) to infinity, we obtain perspective affinity, and both, perspective collineation and perspective affinity, are designated with a common name: homology. The so called Desargues' line is identified either as axis of collineation, or as axis of affinity depending on the position of the centre of projection (S).

Pictorial construction in Fig. 1 and 2 show the difference between perspective collineation and perspective affinity.

Fig. 1 and 3



PLANES τ_H AND σ_H ARE COLOCAL FIELDS

If the space configurations of Fig. 1 and 2 are projected on any arbitrary plane, the figure which represents Desargues' triangle results, since collineation and concurrency, or affinity and concurrency are preserved in the respective projections, as demonstrated in Fig. 3 and 4.

Note: the fields in Fig. 3 and 4 are called colocal i.e. resulting from the projections on the H-plane of τ & σ, and ν & π respectively.

Note. Fig. 4 shows affinity in colocal planes, but it is not directly related with Fig. 2(i.e. by perpendicular projectors as Fig. 1 & 3).

Since in descriptive geometry the biplanar projection is almost exclusively applied for the purposes of engineering drawing, it is useful to be acquainted with the concept of the plane of identity. Namely the projections of a plane figure lying in a plane in an oblique position with respect to the principal projection planes (i.e. H-plane and V-plane) are also related to each other by an invariant line (again a Desargues' line, or axis of homology) which is the intersecting line of the plane of the figure and the plane of identity. The plane of identity passes through the intersection of both principal projection planes (R.L., or ground line) and bisects the angle (90) between the projection planes, i.e. passing through the second and fourth quadrants. Thus the plane of identity is an excellent means for the control of accuracy of the lines in both projections, because any figure, or line lying on the plane of identity have their projections identical (H-projection = V- project. This concept is illustrated in Fig. 5.

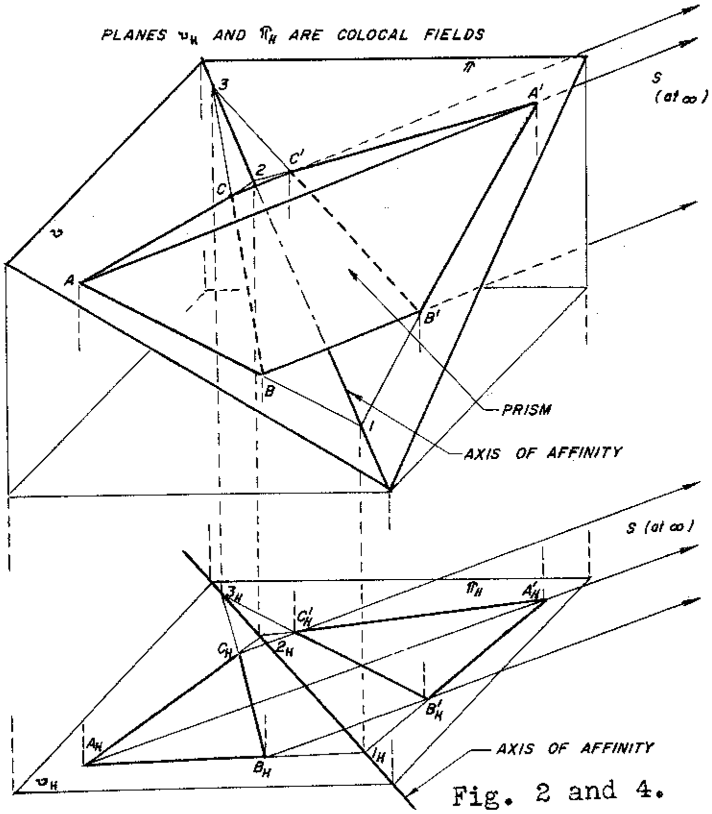
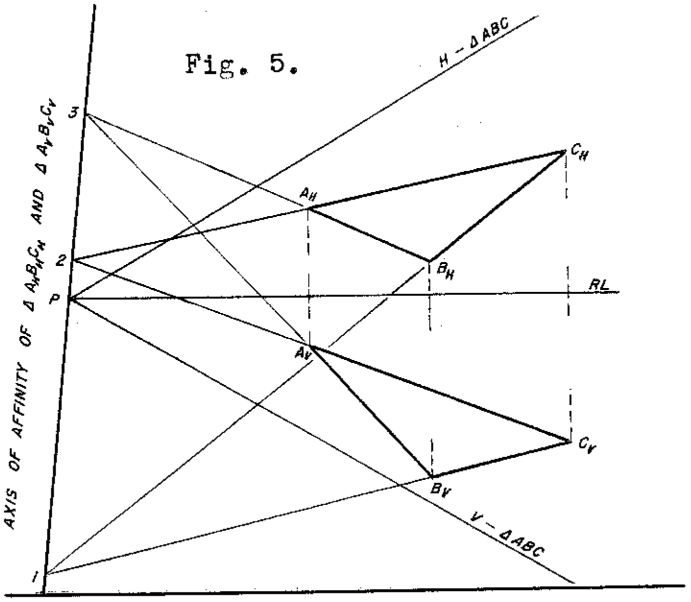


Fig. 2 and 4.

Fig. 5.



The two fields shown in Fig. 1 and 2 have been projected onto one plane as in Fig. 3 and 4. Observing Fig. 3 and 4, we conclude: two fields in which the plane figures are related to each other by means of either concurrent, or parallel projectors, and by an additional line on which the points belonging to both fields are identical, are perspectively collinear or affin to each other.

Observing the Fig. 1 and 2, we also conclude that the corners of the figure in the oblique plane (i.e. in space) and those of its projection on the projection plane (i.e. H-plane) are connected by projectors which may be regarded as lateral edges of a

(i) pyramid (tetrahedron)
(ii) triangular prism

so that the two triangles lie in two cutting planes. The intersecting line of the cutting planes is the axis of

(i) collineation (ii) affinity

the centre of projection being the vertex of the tetrahedron (i), removed to an infinite distance (ii).

The real value of the devices supplied by projective geometry can be demonstrated by means of Desargues, Pascal, and Brianchon theorems applied on conic sections and their projections possessing the common property of being collinear, or affin to each other and that in plane as well as in space.

To be able to appreciate fully the value of these propositions, it is necessary to take recourse to some basic concepts of the plane, and analytic geometry, i.e.

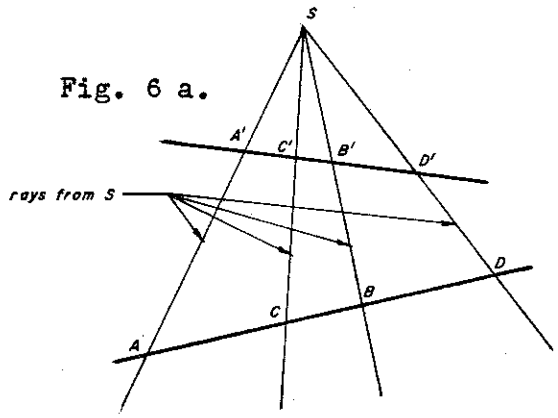
(a) harmonic cross ratio
(b) involution, self-involutory points, radical axis, mean proportional
(c) pole and polar to a conic section, conjugate, or reciprocal poles and polars
(d) polar triangle common to two conic sections collinear to each other, circular points.

A thorough treatment of these concepts would require a lengthy treatise. A short clarification and description of concepts (a), (b), and (c) follows: (a) harmonic cross ratio

The cross ratio of the segments on two straight lines intersecting four rays issuing from the centre of projection, S, remains invariant, i.e. (see Fig. 6 a) $\delta = \frac{AC}{BC} : \frac{AD}{BD} = \frac{A'C'}{B'C'} : \frac{A'D'}{B'D'}$

If $\delta = -1$, the cross ratio is called "harmonic" cross ratio.

Fig. 6 a.



This relationship is also true for a pencil of rays, or a bundle of planes, where the cross ratio of the same trigonometric functions of the angles between the rays (planes) remains unchanged.

If one point M = M' belongs to both sets of points, i.e. (ABCM) and (A'B'C'M') then the sets are in perspective relationship to each other, if they are intersected by the same pencil of rays as shown in Fig. 6 b.

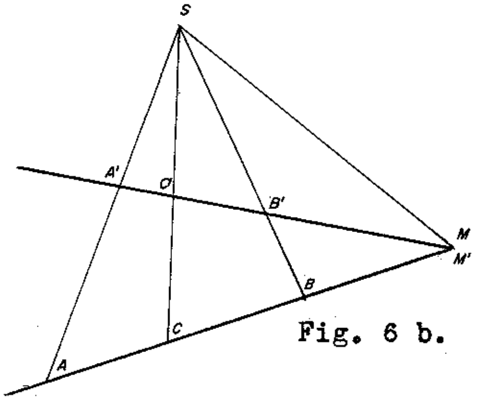
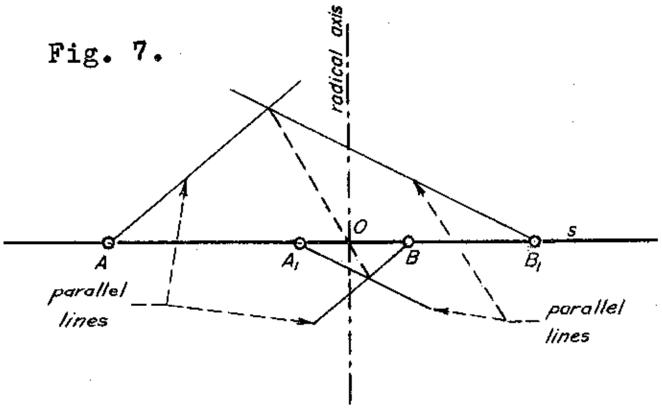


Fig. 6 b.

(b) <u>involution</u>

Let us have two sets of pairs of points: $A\ A_1$ and $B\ B_1$ on a straight line, s, and construct the centre of involution, C, as shown in Fig. 7.

Fig. 7.



The <u>point involution</u> is characterized by the relation:

$$AO \cdot A_1O = BO \cdot B_1O = \text{const.}$$

The constant is called potency of involution.

The centre of involution, O, can be constructed by two other methods (based on the same principle), as shown in Fig. 8 a, and 8 b. The "radical axis" is perpendicular to the line s.

Fig. 8.a.

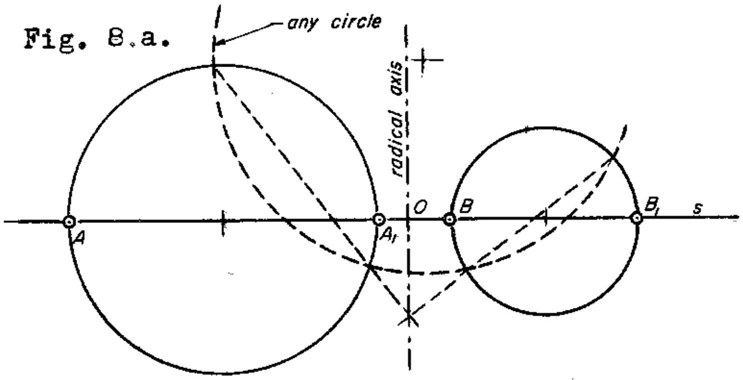
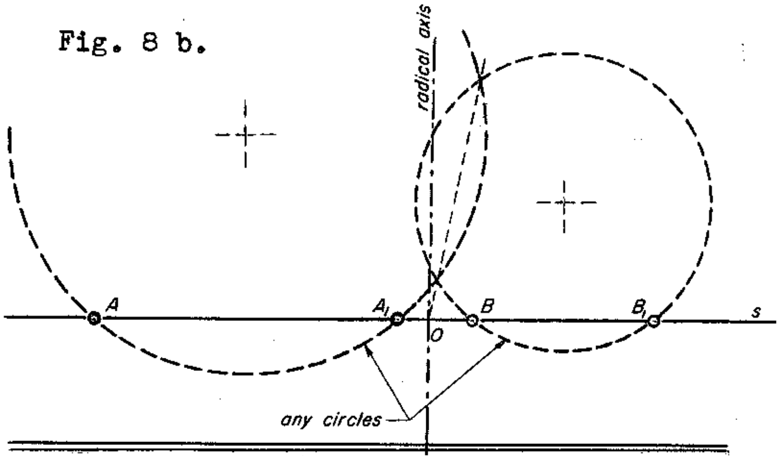


Fig. 8 b.



The involution is:

elliptic)
hyperbolic)→ if the pairs $A\ A_1$, $B\ B_1$ are)→
parabolic)

separated by)
on the same side of)→ centre of involution O.
$A_1 \equiv B_1$; $AA_1 \lessgtr BB_1$)

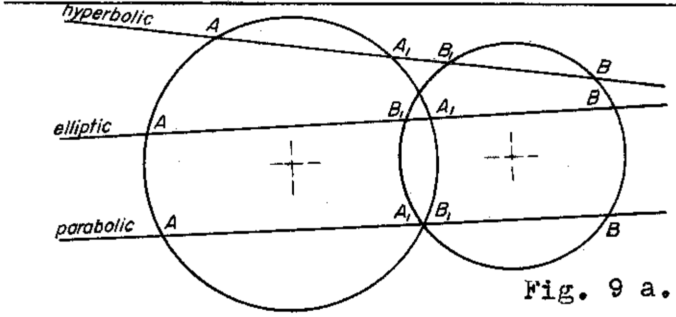
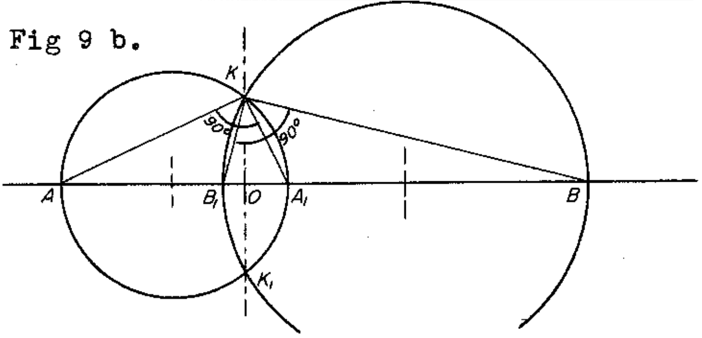


Fig. 9 a.

as per Fig. 9 a. In the elliptic involution there are two points K, K_1, from which the involution projects under right (90) angles. See Fig. 9 b.

Fig 9 b.



The selfconjugate (dual, selfinvolutory) points of involution are found by means of the "mean proportional", constructed as in Fig. 10.

The mean proportional is characterized by the relation:

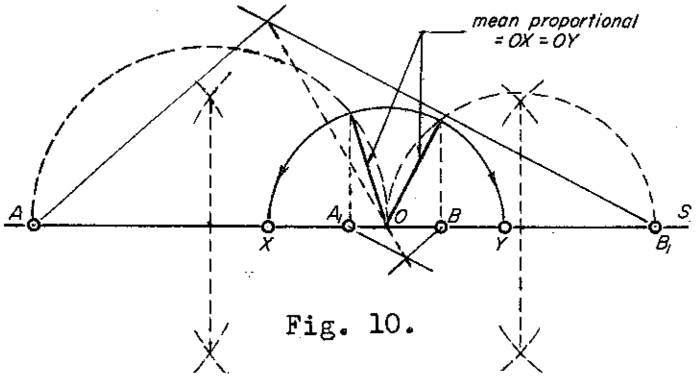


Fig. 10.

$$OX = -OY = \sqrt{OA \cdot OA_1} = \sqrt{OB \cdot OB_1}$$

X and Y are selfinvolutory points.

(c) pole and polar of a conic section

Note that the conic section is represented without any ambiguity by a circle in Figs. 11 and 12.

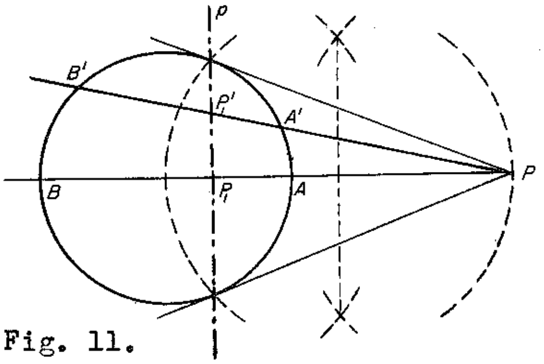


Fig. 11.

The pole and the polar of a conic section are point P and line p, so related to two points on the conic (on the same straight line through P and P_1), such as A and B, that the distances

$$AP : BP = AP_1 : BP_1 = -1,$$

form a harmonic cross ratio. See Fig. 11.

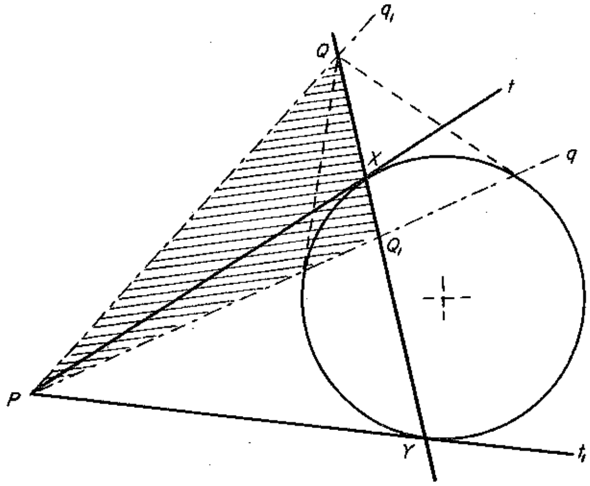


Fig. 12.

The pairs of conjugate (reciprocal) poles to a conic section, such as Q and Q_1, on an arbitrary straight line, p, form point involution for which the selfinvolutory points, X and Y, are the intersections of the line p with the conic, as illustrated in Fig. 12.

The concept of "ray involution" can be deducted in a similar manner as the "point involution", i.e. observing Fig. 12, we conclude:

The conjugate polars, q and q_1, passing through an arbitrary point, P, form a pair of ray involution for which the selfconjugate rays, t and t_1, are the tangent lines from point P to the conic. The triangle PQQ_1 has the property that the sides opposite to its corners are the polars, and therefore the triangle PQQ_1 is called the polar triangle of the conic.

References: "Descriptive Geometry" by Watts and Rule, Prentice-Hall, N.Y., 1946
"Graphics" by Rule and Coons, McGraw-Hill, N.Y., 1961

A NEW ENGINEERING DISCIPLINE - TECHNICAL ANALYSIS AND DEFINITION

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The purpose of an engineering drawing is first to provide a record of the decisions, agreements and compromises accepted by the Engineering, Manufacturing, Verification and related groups throughout the development and life of a design. Its secondary purpose is as a communication medium.

In order for it to fulfill these objectives, the drawing must reflect the combined knowledge of two separate but interrelated fields:

1. Graphic presentation (pictorial, orthographic, etc.)
2. Technical analysis and definition (elements, magnitudes, relationships, etc.)

The art of graphic presentation is well formulated and adequately taught in engineering schools and technical institutes, but no effort has been made to formulate technical analysis and definition as a field of study.

It is primarily because no such field of study exists that today's technical drawings are filled with faults: the information in them is ambiguous and incomplete; their dimensioning and tolerancing are poorly planned, and, perhaps most harmful of all, they are not universally interpretable.

To cure these deficiencies, we propose a two-pronged attack on the ills of engineering drawing by:

1. Establishment of a curriculum in engineering schools which teaches technical analysis and definition. We feel that we have a sound basis for such a field of study in our "axioms" and "implements," some of which are presented in this article;
2. Acceptance throughout industry of the major precepts of the philosophy presented in this article.

The first purpose of the combined fields of study would be to educate engineers. At present, few if any schools instruct engineers in anything but theory, leaving the hard lessons of practical application to be learned in the student's first job. It must be drilled into the engineering student -- and demonstrated in practical terms in the classroom -- that while he will deal primarily in concepts, the producers of his design must deal in specific dimensions. If the engineer cannot bridge this gap by transmitting his design concept in terms understood by the producer, the product will suffer and indeed may never reach the consumer. Engineers should recognize that fabricators, proceeding by habit and tradition, will unintentionally impose intolerable compromises upon a design as it passes through their hands. The engineer must know enough about the limitations of production equipment and personnel - and must state his purpose in a language sufficiently clear and precise -- so that the fabricator is not thrown back upon tradition for guidance.

The term "design concept" means that the engineer has a mental image of a finished product. He can transmit this image to producers by expressing himself verbally, by preparing an article, or by making up a technical drawing.

In the first two cases, where words alone are used, no engineer would permit the use of the material in his name until he had examined and understood each word. The technical drawing is equally important as a transmission medium, yet engineers will routinely sign and release drawings containing symbols and expressions which they admit they do not understand.

The reason for this is not any lack of formal education on the part of the engineers; it is simply that there is no common language in the engineering business. There never has been.

The second purpose of the curriculum would be to train a type of specialist who does not now exist: the Drafting Technologist. There are many factors acting to bring technical drawings to their present low level of efficiency, but one of the most evident is that in far too many instances throughout industry, the most important part of a technical definition is entrusted to a detailer, who is normally a young draftsman with minimal background and experience. The person in this position is somewhat like an interpreter between the conceiver of a design and its executors. Without detracting in any way from the authority or prestige of the engineer, he should be a technically strong support on whom the engineer can rely.

A technologist to fill this need can be produced by the joint curriculum we have suggested. He would be thoroughly familiar with the capabilities and limitations of fabricators and inspectors, and would make knowledgeable allowances for these on his drawings, at the same time compromising design intent as little as possible. Furthermore, he and the engineer, trained in similar curricula, would be in a position to disseminate a truly standard engineering language throughout industry.

"Technical Analysis," in general terms, means simply an evaluation of the limitations under which an item can be produced without adversely affecting design objectives. "Definition" means the delineation on paper of dimensions and tolerances which make allowances for these limitations and will still permit production of standard parts. The two principles are brought into use together whenever a drawing is made or revised.

Similarly, the field of technical analysis and definition is inseparably interrelated with that of graphics. A design concept can only be clearly and unmistakably expressed when technical analysis and definition are effectively applied to a graphic presentation.

When initiating a set of technical drawings, the Design Engineer and the Drafting Technologist must analyze the design on the basis of at least five important points:

1. What is the designer's intent?
2. What is the most feasible manufacturing process?
3. What is the best method of verification for each part?
4. Is everything expressed so that it can be commonly understood?
5. Is information complete?

Each of these questions must be answered in the manner best suited to the occasion. When the engineering, manufacturing and inspection functions are physically close to one another, a rough sketch and close liaison will suffice; however, items to be produced at diverse locations by shops having varied equipment and experience require drawings containing the most explicit information.

It is in the latter circumstance, where liaison is limited, difficult and expensive, that the acceptance and use of certain statements which we call "axioms" would be of inestimable value. We also consider them to be essential in the founding of the new curriculum.

For example: "All measurements originate in the manufacturing and verification equipment, and not in the actual part."

If this axiom were adopted as a national standard, the confusion caused by assuming origins of measurement such as centerlines, bench marks, stations, datum planes, etc. would be eliminated.

Of a list of 42 axioms which we consider basic, we can present only a representative sample here:

1. A desired end product is always the result of compromises.
2. Technical drawings do not dictate design, process or verification methods, but are recorded facts, decisions and results of intelligent compromises.
3. Graphic design definition should be resolved into two basic elements: the straight line and the curved line.
4. Each element in a design has magnitude and relationship.
5. Dimensions separated from tolerances define perfection.
6. Tolerances denote permissible deviation from perfection.
7. Two methods of inspection predominate: read-out and no read-out.
8. The read-out inspection method requires that specific features of a part have a fixed relationship to the origin and orientation established in the verification equipment.
9. The no read-out method does not require that specific features of a part have a fixed relationship to the origin and orientation established in the verification equipment.
10. Design objectives must be considered in determination of whether the method of inspection should be read-out, no read-out or both.

All of these axioms, plus others, should be considered for every drawing.

Technical definitions are expressed on drawings through the aid of what we call "implements," some of which are: Dimensions; Arrowheads; Arrowhead substitutes; Tolerances; Positional tolerance Fixed relationship; Variable relationship; Contour; tolerance; Positional limit; Projected tolerance; Datum; Datum translation; Element translation; Line of orientation; True position dimension; Radial True position dimension; Maximum material condition; Verification criteria.

These implements should be selected carefully, and only those which apply should be used.

After technical drawings have been initiated and distributed, they are further developed from contributions made by the engineering, manufacturing and verification groups. Because no common engineering language is available, these groups currently are forced to operate by so-called "standard" practices, which too often are composed simply of each individual's experience, habits and prejudices, modified by the traditional procedures of his particular company.

Needless to say, such diversified backgrounds and opinions give rise to misunderstandings, which in turn lead to errors at every step in the concept-to-use sequence. Is it any wonder that functional parts are rejected and sometimes scrapped, while non-functional parts are accepted, with the natural consequence of rising costs in time, money and improper utilization of personnel?

It is basic in our philosophy that there must be a constant, intelligent exchange of information between Engineering, Manufacturing and Inspection -- and the results of this interchange must be recorded. This is the first purpose of technical drawings.

The engineer must assure that the compromises necessary to produce an item are reasoned, rather than inadvertent or undesired. The results of such compromises must also be recorded on the drawing.

Other things which must be recorded may be determined in part by considering the need for:

1. Allowable deviations from perfection compensate for errors inherent in manufacturing and verification equipment and processes.
2. A graphical representation of a design in perfection (i.e., ideal) to be used as a guide for assembly, disassembly, retrofit, maintenance, shipping, storing, training and final evaluation.
3. Processing and verification as agreed on.
4. Dimensional definition in perfection.
5. Material selection as agreed on.
6. Environmental protection
7. Quality control.

8. Future reference and surveillance.

In early phases of development, these recordings will perhaps be far from the intended end result. But as initial decisions are compromised, discussed, coordinated and revised, more complete and reasonable technical definition can be established.

Several times in this article we have used the term "language" as a collective for the conventions, symbols and "shorthand" expressions used on technical drawings. It will be instructive to examine some detailed examples of what we mean when we say that there is no common engineering language at present.

There are at least three "standard" methods of dimensioning drawings. One is to dimension from centerlines. <u>But the actual part does not have centerlines</u>.

Another method of dimensioning is from theoretical points, lines, or planes, such as stations, water lines, bench marks or the axes of complete assemblies. However, <u>these are not physical features</u> to which the machinist or inspector can relate set-ups and measurements.

A third method is from the "straight" edges of a part. By the use of drafting machines and scales, the edges may be shown as straight lines on a drawing, <u>but they are not straight on the actual part</u>; design may not even require that they be straight. The actual edges may have high and low points, peaks and valleys. If holes are located from these edges and a drill jig is used, the jig may only reflect the high points as the origin of its measurements. But for the same part, inspectors may use a gage containing flush pins which can pick up the valleys instead of the peaks. The result will be one set of readings obtained during processing and a different set during inspection.

The variety of interpretations that can be put upon these three dimensioning methods demonstrates the ambiguity of the origin of measurements. How, then, are the machinist and inspector to obtain their measurements? Will their measurements be based upon a common set-up, and will the measurements be the same? If they are not, a production line may have to be shut down. In such a case, who is wrong? If a referee is needed to settle differences of interpretation, upon what may he base his decision?

The problem becomes more acute when an attempt is made to specify relative position (<u>to</u> where) as well as origin (<u>from</u> where). The difficulty is illustrated by considering a simple rectangle conventionally dimensioned with arrowheads as 2.00 ± .02 on the short side, and 4.00 ± .02 on the long side.

From this information, at least three interpretations are possible:

1. That the full tolerance applies on one side;
2. That the tolerance is equally distributed on all sides;
3. That the tolerance can be applied in any amount on either side, as long as the total does not exceed the maximum specified.

During manufacture and inspection, the question naturally arises: "Which interpretation did the engineer have in mind?" The answer is not important; the question should be "How can such ambiguities be avoided?"

If this simple example presents a problem, what can be expected of a drawing for a semi-complex part?

The most desirable -- and the rarest -- commodities in industry today are critical interchangeability of parts, standard verification criteria, and a language understood by everyone in the concept-to-use sequence. Steps toward these goals have been taken by the military services, technical societies, standards associations and industrial firms, but the results have been only partial solutions or on-the-spot cures for specific ills.

The deficiencies have always existed, but since World War II, with the rise of industrial diversification and increasing placement of multiple contracts for a single product, their effects have become magnified. The problems of liaison between multi-source contractor suppliers become greater and more expensive every year; the cost of errors resulting from inadequate transmission of ideas is incalculable.

Over the decades, industry has tried one theory after another to cure these deficiencies. For example, dimensions and tolerances have been cited as being at the root of the trouble. New symbols and terms such as True Position (TP), Positional Tolerance (Posn Tol) and Maximum Material Condition (MMC) have been introduced for use on drawings.

These theories have some merit, and they do furnish a partial answer to some problems, but the terms themselves frequently become the subjects of confusion and controversy. The reason is that such concepts have only specific applications. The basic problem cannot be solved by this type of approach.

The situation is analogous to that of a town with a high annual fire incidence. Some superb fire-extinguishing techniques may be developed to control the trouble, but as the town grows, the number of fires will still increase, because nothing is being done to remove the causes of the fires. Our objective here is not to solve specific problems in engineering drawings, but to <u>eliminate the reasons for the problems</u> by going to the root of the matter; by establishing a field of study which will furnish an ever-increasing number of engineers and technologists commonly trained and "speaking" a common engineering language.

If these steps are taken, industry will begin for the first time to see engineering drawings which are unmistakably clear, on which tolerances are sensibly set forth, and which use accepted symbols and expressions. By the time they are to be used for final inspection of a product, such recordings will furnish a complete and universally understandable delineation of the designer's intent. Industry has no other purpose than this.

A more comprehensive study of the presented philosophy can be found in the Sandia Corporations SCR 303, an AEC publication available from the Division of Technical Information, Oak Ridge, Tenn.

We do not, of course, consider the philosophy a final answer, but we are certain that it can form a more solid basis for the development of an engineering language than has ever existed before.

GRAPHICS SHOCK-WAVE

By Rex W. Waymack

Member of Future of Graphics Committee, Director of Technical Drafting
at Modesto Junior College in California

The classified section of a Los Angeles paper recently carried the following advertisement: "Wanted: one hundred draftsmen for immediate employment." This was only one employer's ad. The ads of companies wanting draftsmen in this one issue of one paper totalled several hundred. While it is probably exceptional that one company would normally be seeking one hundred draftsmen at one time, it is nevertheless true that there is a drastic shortage of draftsmen in the west coast industries. Practically every major company is sending recruiting teams to all parts of the continent seeking designers and draftsmen. In spite of this, a shortage still exists. Several major industrial concerns -- with which I have personal contact -- abound in engineers who must be used in many instances for tasks that any competent college drafting technology graduate could do more efficiently because he has had competent training in that area of work.

The conclusions drawn from this type of condition may be as varied as they are faulty. In order to make any rational attempt at a diagnosis, we must first trace the sequence of events that have led to this unnecessary waste of training and talent in the engineering profession, which in turn has concurrently caused a completely unwarranted shortage of draftsmen.

The climax of the Graphics movement occurred at the annual meeting in Berkley a few years ago when a one vote majority carried a motion to change the official name of the division to Graphics. Yet this change in title is actually no more than window dressing. The content is the all important item -- of major concern to educators and employers alike. If Graphics proponents believe that the new style engineer, who has been trained in Graphics, is that answer to the modern employer's prayer and more valuable than the old standard engineer, who was comparatively short-changed regarding Graphics techniques, then it would be well for them to consult employers on this subject. A little time spent in research might uncover some startling facts.

Since the advent of the Graphics movement, practically every accredited school has converted in one form or another to Graphics. In many cases only the title has changed while the content remained the same. But in most institutions the content has been drastically changed to a legitimate Graphics curriculum. This transition has occurred in most California junior colleges offering lower division engineering transfer curricula, as well as in the established four year institutions. Thus far, the end product of this transition has been considerably less than gratifying. It is becoming more and more apparent that only the superior student is capable of grasping even the bare minimum of basic fundamentals in a streamlined Graphics course.

The two remaining categories must necessarily be the average and inferior. Four year institutions, at least in California, seem to favor the philosophy that only the superior should attend the University, that the average should attend the State College, and the inferior should be disposed to the Junior College or Technical Institute. Most representatives of these four year institutions would violently deny this accusation, but we have only to point to the sage who once said: "Your actions speak so loudly I can't hear what you're saying." We could argue this philosophy indefinitely. How can any tax-supported educational institution legally or morally justify a program geared only to the superior student? That, however, is another topic long past due for a thorough debate; I mention it because it is pertinent to the present engineering educational hierarchy.

Industry has for many years been guilty of stock-piling engineering graduates far in excess of their actual needs, merely in hopes of utilizing them at a later date. In the meantime, the surplus engineers have been assigned busy work such as drafting, liaison men, etc. These assignments are totally unsatisfactory to both employer and employee, especially to the employee. The engineer is assigned a task which he feels is completely below his dignity. Yet in reality this same task demands knowledge and skill within an area about which the engineer is practically inept -- and certainly untrained -- despite the apparent professionalism often attributed to his degree. This situation is not mere fiction. It can be verified by anyone with enough honesty and fortitude to face the issues squarely as they exist in most of the major industrial establishments.

Is it logical to presume that there is no longer a legitimate engineering position for an average engineer? Indeed, is this creature of circumstances even an engineer? If not, should he be awarded a bona fide engineering degree? What then is the fate of this average individual with an average engineering education?

I spent this past summer with a large industrial concern which designs and packages warheads for several types of missiles. The organization, with two laboratories in different states, is an integral arm of the A. E. C. complex. This corporation has established a policy of inviting a limited number of educators to spend a minimum of two or three summers with them (on salary), primarily to observe and learn major problems involved in the designing and packaging of warheads. The administrative set-up of this corporation is probably superior to those of corporations in comparable industries, yet in spite of this, there was seldom a day during which a major problem did not arise. These problems inevitably involved two or more engineers, the project director and a minimum of two design draftsmen. Each problem was unique because invaribly there were no precedents to guide nor standards to fit the occasion. The A. S. A. standards, S. A. E. standards and Mil standards all had a common denominator -- inadequacy.

An analysis of the problem areas effects two or three major categories. By far the most prevalent problems dealt with what most of us would categorize as dimensioning methods. Yet they were fundamental, usually involving the inability of engineers to diagnose the functional requirements of the entire component. This was exemplified time and again by a complete lack of understanding by the engineers of such items as: (1) the advantages in some instances of True Position dimensioning as opposed to Bilateral Dimensioning; (2) the analysis of a shift of hole patterns using either method with respect to fabrication, verification, etc.; (3) a shift in the center of gravity of a component with respect to tolerancing build-up of dimensions; (4) the tolerance acceptable on a given contour without hindering function. And these are only a few of the problems!

Who is to solve these problems? The engineer? Certainly he is responsible for the development of the project according to specific functional requirements. Yet he lacks training in the necessary fundamental technical analysis and definition because they are not included in Graphics courses for the engineer. How about the draftsman? Is it his responsibility? No. He lacks the training for a technical analysis of the problems involved to insure proper functioning of the device that is being designed. This responsibility is clearly that of the engineer. Can it be that industry is oblivious to this paradox, as well as engineering educators? Is everyone expecting the impossible? Or are we merely copying the escapism of the ostrich?

This paradox is far too real to be tolerated any longer. The chasm separating today's engineer and the draftsman is too large to step over. It requires a deep fill or a bridge. The Sandia Corporation at Livermore, California, and others are now attempting to bridge this gap by encouraging faculty members to study their problems and offer suggestions.

Present day Graphics instruction has created not one, but several enigmas. The one described above is probably the major one, but certainly the effects of shifting from engineering drawing to Graphis is a close second. This shift has created a tremendous shortage of draftsmen and/or designers. An engineering drawing student could, in most cases, do an acceptable job of drafting and designing. At least he had training in the basic fundamentals and considerable practice in their application. This is not true of the Graphics student. The student knows. The employer knows . Apparently everyone is aware of this shortcoming except the professor who teaches it. As a result, a large majority of the California junior colleges have created one or more new curricula to meet the needs of industry. These curricula have largely been initiated within the past three years with the encouragement of industry. Practically all curricula are developed with the assistance of an advisory committee made up largely of industrial representatives. The titles of curricula vary somewhat, but by and large, they are Drafting Technology or Design Technology. Practically all are -- or will be -- E. C. P. D. accredited. Yet in spite of this surge of newly developed curricula -- with a total student participation that exceeds the number of engineering transfer students by a three to one ratio -- our school has received requests for thirty draftsmen during the past two weeks.

Do the answers to these paradoxical situations lie wholly within technical institutes and junior colleges, or do some of our senior sister institutions have some of the answers?

Continued from Page 21

This, very briefly, is how I visualize my responsibility as head not only of the Mechanical Engineering Department but the Mechanical Engineering Department including the Graphics Division. Only time will tell whether my solutions are as good as I hope they are; the question will be -- can we maintain a strong staff department under the circumstances as I have outlined them. Will the staff pick up enthusiasm for working with the younger students and lastly, whether we can develop a graphics course which is well suited to a strong, meaningful, basic engineering program. to the use of the tools in plotting data and fitting curves to the data. This to be tied, to a limited extent, to the mathematics of curve plotting. Finally, the course will wind up with the development of scales and graphical mathematics. This is certainly a reduced program over what had been done previously. Some desirable aspects have been left out through necessity. This is what we feel at the present to be the best we can do in the allotted time. The interested student will be encouraged through a form on honors program to work in greater depth than I have outlined.

TEACHING CASE STUDY NO. 3

ENCOURAGING CREATIVE ACTIVITY THROUGH ENGINEERING GRAPHICS

By James R. Burnett, Assistant Professor, Engineering Graphics Section,
College of Engineering, Michigan State University

One of the great advantages of graphical methods is its assistance in problem visualization. It permits an engineer to discuss with himself the problem to be solved and the method of solution. A favorite chemical engineering professor taught his classes that the first step in solving problems was to "draw a line." We have all observed that even in rather abstract mathematical lectures, problems are often first considered on the basis of a sketch. Hence, one pursues creative activity not only in solving a problem, but also in preparing it for solution.

There is a great challenge for us in graphics to present such methods to the neophyte engineer in order to get him started in a rewarding career. It seems that too many of us take the easier road of requiring the solutions to dull, preformulated problems where there is little left for the student to do but the mechanics of carrying out a standard solution. In fact, some published problems are very frustrating because only one of several equally good solutions can be used or the solver finds himself working off the paper, onto the drawing board and then into space.

At Michigan State University we believe we are having considerable success in presenting more and more problems by written descriptions (but not the type where the student must laboriously plot a descriptive geometry problem on a sheet of graph paper.) We encourage the student to make a rough freehand sketch of the problem and its solution and then a more carefully made sketch or drawing, depending on the nature of the problem. By using problems of this type, we hope we are helping our students to use and develop their ingenuity and imagination.

Like most of our present generation of so-called "integrated" text books, our course, given under a single course number, has essentially been comprised of three areas -- machine sketching, descriptive geometry and graphical computation. We are looking forward to making our problems require more analysis and creative activity by making them truly integrated. We hope the text book authors are also interested in going in this direction and that a beginning will be seen in the second generation editions that are now or soon will be coming out. We also hope these authors will present more rigorous discussions of many of the topics in what has been their latter chapters. For example, the idea, used in graphical differentiation, that a chord is parallel to a line tangent to a parabola at a point defined by a line from the center of the chord and parallel to the axis of the parabola, is a fine example of the law of the mean, and yet no one seems to present this. And, while working on such integrated problems, we are wondering if, for example, in discussing the graphical aspect of vectors, would it be a sin to mention dot and cross products; or, after discussing the graphical methods for finding the true size of a dihedral angle, would it be in order to consider numerical procedures that may be equally adaptable. We have tried some of these non-graphical methods in experimental sections and believe they are worthwhile.

For some time we have had our students solve empirical equation and calculus problems by both graphical and symbolic methods. This last fall we offered, purely as a voluntary activity, the opportunity of solving some of the problems by computer. The attendance at these sessions was very good. As our staff gets better acquainted with the analog computer and the compiler that is now being introduced for our digital computer, we hope to offer our students even more computer opportunities.

True, these activities are not strictly graphics, but we believe the relatively small amount of class time they require is worthwhile in getting our freshman students started in their engineering program. They have also helped to remove the reputation that graphics courses have built up over the years, that of being a boring course and one of the evils that is to be tolerated in the first year of engineering study. Such work, incorporated into the standard course, has created student interest, stirred their curiosity, made them more receptive to the other parts of the course, and has, we believe, encouraged and stimulated them to think analytically and creatively at the beginning of an education and career that will require much of such activity.

Whether creativity can be taught is questionable. However, we must encourage its use whenever possible. As Professor C. Richard Soderberg said at the 1960 Conference on Engineering Design Education: "No amount of formal education can take the place of inspired imagination and our system of engineering will surely atrophy unless we attend to this issue."

TEACHING CASE STUDY NO. 2- TEACHING TO DEVELOP IMAGINATION AND INVENTIVENESS

By Professor Kenneth E. Lofgren, The Cooper Union

As a second example of a challenging design problem for freshmen in our Graphics course, I submit the illustration on the opposite page. This also is an enlargement of a problem in Luzadder.

The students were asked to consider themselves designers for a company which had been manufacturing geared speed reducers, as illustrated in the textbook, but now was seeking to broaden its line of products. The specific need is a unit in which the output shaft is vertical and the input shaft horizontal. The worm and gear aspect is to be retained. The new unit is also to be somewhat better in grade. The instructor assumed the role of chief designer and as much as possible kept his instruction and assistance at this level. No calculations of loads or stresses were attempted; the job being essentially one of creating and fitting together new and more complex parts.

Lubrication of the moving members was given prominent attention however, and the designers were advised not to immerse the gear teeth and anti-friction bearings in lubricant except in cases where the action is relatively slow. The use of oil slinging discs was recommended.

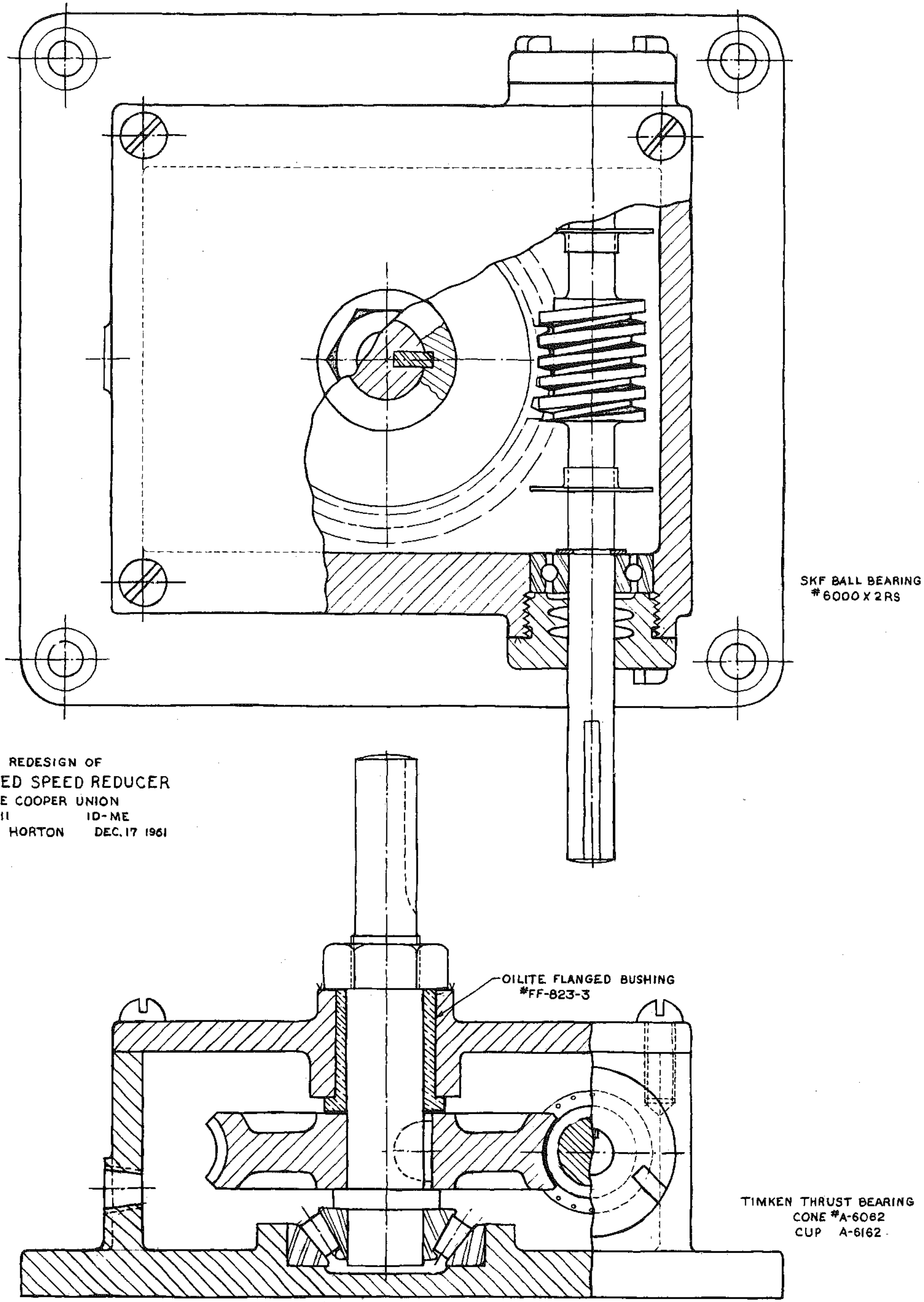
While all worked on the same project, each designer was encouraged to submit a unique design. He himself made the selection of gears and bearings, and mounted them in accordance with his own ideas. He could elect to make the worm integral with the shaft or could call for an assembly of worm and shaft. The economic aspects of such decisions were discussed. Throughout the project the chief designer (the instructor) chatted with the designers about machining problems, foundry practice, pattern-making, forging, benchwork and many other aspects of production manufacturing. These chats were usually at the table of the designer whose problem of the moment warranted such a discussion. Quite naturally, the other students gathered around to listen and to ask questions. A three hour session of this type of instruction, with eighteen or nineteen eager and inquisitive students, is a real workout for an instructor -- but it's fun !

In the main, these selected students (as implied in the previous article) knew little or nothing about shopwork. Magazine articles, written for the masses, have pictured fantastically precise machining as being commonplace, and as a result, students have no qualms whatever about calling for a machine accuracy to a tenth of a thousandth of an inch on a unit which should have a cost of only a few cents. On the reverse side, they see nothing amiss in calling for press fits where the dimensions are given to the nearest sixteenth.

Our students are not going to be draftsmen. Many of them will become top-level scientists. In my classes are several who can, quite properly, be labelled "geniuses." I cannot imagine that these men, on their way to the top in science and engineering, are going to be so daintily shielded from vulgar hardware that it's unnecessary for them even to know that it exists. I insist that they will be confronted, at one time or another, with the need for devices, experimental setups, and control units of awesome complexity. Perhaps it won't be their job to design these components, but to claim that they don't have to know anything about their design, is to me just sad nonsense. We feel that by giving our students this tiny introduction to the world of creating devices, they will bring a more sophisticated attitude towards their scientific problems.

OPPOSITE PAGE - STUDENT'S DRAWING

The student whose design is shown is a product of an excellent high school in New York City. His previous experience consisted of one semester of mechanical drawing and another in shop work. He is a mechanical engineering student with us and enjoys designing and tinkering with devices. At home, as a hobby, he is designing a small runabout car which has several interesting features.



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PROBLEMS IN ADMINISTERING ENGINEERING GRAPHICS AS A PART OF MECHANICAL ENGINEERING

BY John H. Hernandez, Head, Mechanical Engineering Dept., Manhattan College N.Y.

Combining the college graphics responsibility with that of another engineering department, in our case, Mechanical Engineering, is not necessarily the best solution to a proper and adequate handling of graphics. However, there are some distinct advantages to be gained by such an arrangement. The success of such a merger is the responsibility of the department head. The merger should be considered in the light of the graphics requirements of his own and the other engineering departments and the people involved in teaching graphics.

Some of the difficulties accompanying the acquisition of graphics by one of the engineering departments is the problem of staff. More will be said later, but at present suffice to mention that when a prospective faculty member is presented with the possibility of teaching graphics, many desirable candidates begin to have some misgivings. Another difficulty not at all unique to graphics but one that is a problem for anyone hoping to do a meaningful job of preparing a student in any field of engineering is the lack of sufficient time. Although this is true of most fields, it is particularly true with respect to graphics. Graphics, for reasons to be discussed later, is high on the list of subjects whittled down to make room in the engineering program for new courses or for a reduced program load. Obtaining sufficient time and holding it against all unreasonable approaches is rather a vexing challenge to anyone.

Many of the problems in Engineering Graphics stem from its past. The graphics area has been staffed on many occasions by professors who were too colloquial, their horizons too narrow and their position detached from the engineering school as a whole. Is it any wonder, then, that a portion of the engineering faculty look questionably at the graphics professor's achievements? Graphics is a necessary and important basic engineering science. You might well ask why has graphics settled to the position in which it is now found. As mentioned before, graphics faculties have a tendency to overspecialize in their own area and are trying to empire-build at a time when the whole curriculum is being shaken from its foundation, in an attempt to accelerate the teaching of traditional material and to include new material. Add to this the fact that most of the graphics faculty are a dedicated lot, willing to be overworked, overworked to the point where there is no longer time for scholarly endeavors. Research and progress in other than the more efficient teaching of traditional graphics has been neglected. Coupled with this is the fact that some of today's graphics faculty are people who have been assigned to graphics because they were not progressing in another engineering department in the manner that was expected (research and writing). These people showed a degree of mental stagnation and were eased out of other engineering departments and into graphics. A misfit or poor performer is going to do no better in the graphics department than he has elsewhere. This just compounds the problem and transfers it to another department. As a result, of these activities, more graphics professors than we would like to believe are looked on as glorified high school teachers, about whom responsible members of the other engineering departments say, "surely he has not come up to all our expectations but we only ask him to teach graphics." This is an alarming commentary and unfortunately there is some truth to it in many instances. Before graphics can gain proper recognition and begin to do the job that it must in the modern era, these conditions must be changed.

As the head of a mechanical engineering department with a responsibility for graphics, one might well ask of me: what are your opinions in these matters and what would you suggest as a solution? Are you trying to avoid the aforementioned difficulty? First, I believe that a college owes to the young freshman and sophomore some of its best teachers. These are the formative years when the student must adjust from high school, get off to a good start in college and learn the ways of the scholar. This the student will never learn from a secondrate teacher. This can be overcome by giving some of our better faculty members an opportunity to teach courses like graphics and allow our present graphics faculty to expand their horizons to courses in areas that are later in the curricula where their professional abilities and confidence can be stretched. This new experience can then be brought to their graphics classroom.

The solution I am trying to incorporate into our department requires that only those prospective faculty members who are willing to teach a share of graphics and bring their broad experience and knowledge to that important classroom are to be considered. I fully realize that this could be a chore and not an opportunity to the mature faculty member. It is my hope that I can develop a staff of real professional people who will welcome a teaching challenge and who are alive enough to see the opportunities in the graphics area. This compounds the problem of staff. When you inform a professional expert in some particular area of engineering that although this area will be his specialty, he will have some responsibility in graphics and will be expected to develop this area along with his major interest in an effort to help us get the young engineering student off to a good start, many quickly say "no thanks." This is a very unfortunate situation and is an especially difficult problem in this era of faculty shortage. However, if we are convinced, as I am, that this is a course to be pursued there are other compensating features that can be offered to a prospective faculty member which makes the position more attractive.

The person who has real enthusiasm for graphics and the development of this area will be selected as the lead or permanent professor of the graphics division. This man will be supported in his efforts to keep abreast of the field and to push forward the frontiers of the subject. It will be his assignment to keep the rest of us informed and guide us in the development of a proper syllabus. This, then, will be his major area of responsibility, although he will be asked to teach other courses, so that his outlook will not become colloquial.

In order that we can accelerate our teaching, introduce the new concepts and overcome some of the difficulties of the past, we should begin by reducing the teaching load in graphics. This is deemed necessary to adequate preparation and presentation of the more concise course. Mention was made of the acceleration of our teaching. The increasing knowledge in graphical methods that must be taught has to be weighed against the overall burdens of the complete engineering curricula. The end result is that we must teach a changed graphics course in a lesser amount of time without developing the art to the extent it has been in the past. While doing this we must increase the students' understanding of the basic concepts of graphics.

It was mentioned earlier that there was some merit in combining graphics with one of the professional engineering departments. I think you may be beginning to see my reasoning. Only in the major departments does a man have the opportunity to teach at various college levels without crossing those very important boundaries found between departments. Also, I am inclined to believe that graphics is the language of the engineer and as such is better presented as a division of one of the major engineering departments. It is like English. Certainly few would advocate a separate freshman English Department. In the interest of a strong faculty and because of the advantage to the student most English Departments rotate their freshman responsibility among their faculty members. This gives further credence to the suggested approach to the problem.

We have another corollary with the English Department. Many of our students have had some graphics in their high school training as has the freshman English student. The reasonableness of teaching English at the college level is seldom questioned, but I have heard many questions asked as to why graphics is taught in college at all. I think there are a number of answers to this question. Graphics is a faculty that once it is understood and put into use becomes a part of you. You use it as a matter of routine and we are inclined to wonder why so much time is spent on such a simple subject. If the advocate for the elimination of graphics will but consider how often he thinks with a pencil and seriously contemplates whether he could have used this faculty to the extent that he does without some formal training, I think he will reconsider his position. More than this, the type of visualization that one needs to develop in the graphics course requires a degree of maturity that may not be available at the high school level. Assume for the moment that the student maturity and the qualified faculty are available at the high school level, what are the high school's responsibilites to all students entering college? When such a small percentage of our high school graduates enter an engineering curricula there is really no justification for an elaborate course in graphics at the high school level. There is another reason why I believe a sound graphics program belongs in the school curricula but I am perfectly willing to see a young man earn advanced credit for adequate preparation gained in high school.

Now that I have shown you my position with respect to the graphics division, you might well ask: "What type syllabus do you envision in your graphics program?" I will outline it briefly, calling to your attention that it is a fluent affair, it will be looked at every few years and revamped in keeping with the overall objectives of the engineering school and the latest knowledge in the fields of graphics and engineering as a whole. Much of the conviction on the syllabus is based on my teaching experience in the mechanical engineering department and my industrial experience with various companies. The basic concepts of projection and engineering must be briefly presented, not in detail, not to the point where we develop the art of drawing as was done in the past. This will be more or less a familiarization or basic presentation from which a student will gain the ability to study further and develop on his own. It should give him the basic concepts needed to understand drawing and properly communicate in engineering. This is to be followed with a little more training in sketching to put into practice his exposure to projection. At this point we will introduce three-dimensional visualization, incorporating it wherever possible with sketching and projection. Descriptive geometry as such, I would interweave throughout the course, taking every opportunity to present these very important spacial concepts. This course will then proceed

Continued on Page 16

REPORT OF THE BIBLIOGRAPHY COMMITTEE - BOOKS PUBLISHED 1957 TO 1961

S. E. Shapiro, Chairman

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N-DIMENSIONAL DESCRIPTIVE GEOMETRY AND MULTIVARIABLE FUNCTIONS

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1. Multivariable Relations and Geometry

We are all familiar with a contour map. Such a map is typical of the most general kind of geometric entity that exists in our three dimensional universe. It represents a surface, a locus in which a point can move with two degrees of freedom. In symbols, we write some such expression as

$$f(x,y,z) = 0$$

to indicate that there is some rule, f, which when applied to the three numbers x,y,z yields a fourth number which is always zero. Of course this will only happen provided the three numbers x y z are suitably chosen under the rule.

If the rule is $x + y + z = 0$

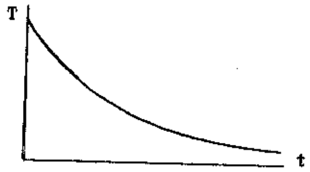
then any choice of x and y will demand a particular choice of z.

If the rule is $x^2 + y^2 + z^2 - 1 = 0$

there are a great many choices of x and y for which there are two possible choices of z, but there are also a great many choices of x and y for which z is not a real number, and for which the real surface does not exist. But we are not, for our purposes, interested in the complex numbers, which satisfy such a rule, and we intend to confine our attention only to real geometry.

This discussion is not intended as an argument designed to show that our geometrical universe is imbedded in a four dimensional geometrical universe, which in turn is imbedded in a universe of five dimensions, and so on. We often hear the question "What is the fourth dimension? Is it time? Is it a fourth spatial dimension?" In a way, such a question is meaningless, because it tends to confuse physics with mathematics. Perhaps the best answer I can think of is that dimensions are simply the variables that enter into a relationship, or that behave together according to some rule. Whether or not any or some or all of the variables have anything to do with space is a question of physics and not of mathematics.

For example:



The graph represents the relationship of temperature of some object plotted as a function of time. This is only a two dimensional relationship, but neither of the variables has anything whatever to do with space.

Again, consider an animated cartoon, like Mickey Mouse or Donald Duck. If we look at the strip of film on which the successive images appear, each image is a two dimensional (or in some cases a three dimensional) geometrical entity, but taken as a whole, the roll of film is a three or four dimensional entity, one of the dimensions being, of course, time. Indeed we can say that each frame is a section of time-space. This notion of sectioning is very important, and affords us the only device for representation of entirely general multi-dimensional relationships, even in the case of three dimensions.

Thus if the animated cartoon were a movie of the geological evolution of mountain ranges, each frame would show contour sections to represent three dimensional geometrical information, and these frames in turn would each by each represent time sections in which the contour sections would undergo distortions as the surface shifted and reshaped itself. Such a movie would be in a very real sense a four dimensional graph of the most general kind.

2. Points, Lines, Planes, and Their Generalizations

To study ordinary three dimensional Descriptive Geometry, we begin by studying points, lines, and planes. We can do the same thing in multi-dimensional geometry, except that we need some new geometric elements, and we shall proceed to investigate what they are.

The single linear equation

$$0 = a_o + a_1x_1 + a_2x_2 + a_3x_3$$

represents a plane in three dimensions.

In a geometrical sense, it represents the locus of a point moving with two degrees of freedom, since any two of the three variables x_i may be arbitrarily chosen, and then the third variable will be uniquely determined.

Two such equations, taken together, represent a line:

$$0 = a_o + a_1x_1 + a_2x_2 + a_3x_3$$

$$0 = b_o + b_1x_1 + b_2x_2 + b_3x_3$$

These equations represent the locus of a point which moves with one degree of freedom, because if we assign some fixed value to any one of the x variables, then the other two variables are immediately fixed also.

Similarly, three equations in three variables

$$0 = a_o + a_1x_1 + a_2x_2 + a_3x_3$$

$$0 = b_o + b_1x_1 + b_2x_2 + b_3x_3$$

$$0 = c_o + c_1x_1 + c_2x_2 + c_3x_3$$

represent a point, a geometrical entity with zero degrees of freedom, since the three equations may be "solved" simultaneously to yield the three coordinates x_1, x_2, x_3 in one and only one way.

As interesting special cases, we may have

$$x_1 = a$$

a single equation; if our space is three dimensional, this represents a plane. We may have

$$x_1 = a \qquad x_2 = b$$

and these two equations represent a point in two dimensions, or a line in three dimensions.

Finally, the three equations

$$x_1 = a \qquad x_2 = b \qquad x_3 = c$$

represent a point in three dimensions. In these examples we may think of the equations as though they were the more general equations with certain coefficients zero.

If we now extend these ideas, we may have for instance e equations in n variables,

$$x_1 \quad x_2 \quad x_3 \quad \dots \quad x_n :$$

$$0 = a_o + a_1x_1 + a_2x_2 + \dots + a_nx_n$$

$$0 = b_o + b_1x_1 + b_2x_2 + \dots + b_nx_n$$

$$0 = m_o + m_1x_1 + m_2x_2 + \dots + m_nx_n$$

This set of linear equations represents the locus of a point in an n-dimensional space, with a certain number of degrees of freedom. We have seen in the three dimensional cases that the degrees of freedom, d, equals the number of variables, or dimensions, 3 minus the number of simultaneous linear equations e:

$$d = 3 - e$$

This relationship may be extended so that for e equations in n dimensions the degrees of freedom d are given by $d = n - e$

As soon as we enter spaces of more than 3 dimensions, we run out of names for the geometrical entities that these combinations of dimensions and equations represent; the point, line, and plane symbols no longer suffice, and we need a new system of symbols. We shall call the geometrical entities represented by systems of linear equations "linear manifolds". The two characteristics of these manifolds of greatest interest are the number of dimensions, and the number of degrees of freedom, and we shall symbolize a typical manifold as an

$$L_n,d$$

where the first symbol "n" gives the number of dimensions of the space in which the manifold is immersed, and the second symbol "d" gives the number of degrees of freedom of a point in the manifold.

For example, a point in three dimensions is represented

by the symbol	L3,0
a line is	L3,1
and a plane is	L3,2

We may read the symbol Ln,d as "the linear manifold with d degrees of freedom in an n-dimensional space" or " the linear manifold of dimension n and degree d".

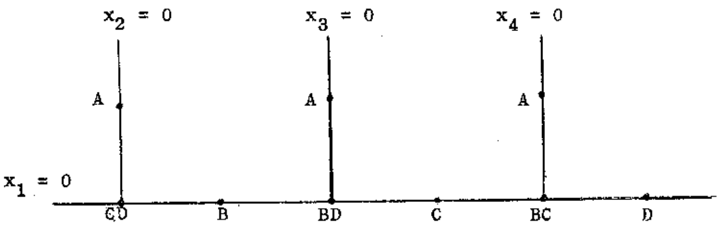
In a space of n dimensions, Sn, Ln, n represents the entire space, since it implies that the x_i are free to take on any arbitrary values independent of one another, and without restrictions imposed by any equation, since e = 0.

3. Representation by Orthogonal Views

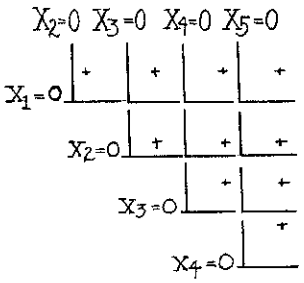
Consider the linear manifolds L4,0, points in S4. Such points may be represented by the symbol $P(x_1,x_2,x_3,x_4)$ to indicate that they have four fixed coordinates. We may have four points in S4 so chosen that three coordinates vanish at a time:

A(1,0,0,0) C(0,0,1,0)
B(0,1,0,0) D(0,0,0,1)

We may represent these points in three graphs with a common coordinate:



Although we are here discussing L4,0, it is clear that similar graphs may be drawn to describe Ln,0 for any number n of x_i coordinates. We may represent points by means of n-1 graphs, with one coordinate common to all.



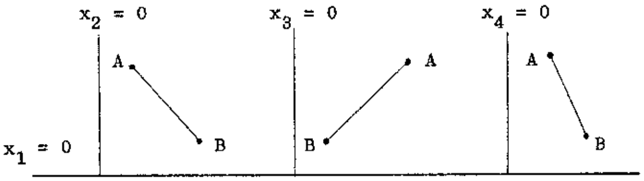
A point defined in five dimensions. The point is defined by the four views in the top row. All other views were obtained by projection.

Using four graphs, a five dimensional extent may be represented. From these four definitive graphs, all other graphs each showing two dimensions may be obtained, by "projection", just as in the case of ordinary descriptive geometry. In the figure, the point P is defined in x_1x_2, x_1x_3, x_1x_4, x_1x_5, from which by eliminating x_1 we obtain the graphs

x_2x_3 x_2x_4 x_2x_5

Again, eliminating x_2, we obtain

x_3x_4 and x_3x_5, and finally x_4x_5



In S4, assume that we have two distinct points, A and B. If in each graph of the two points we connect the points by a line, we have a representation of an L4,1, a linear manifold of four dimensions with one degree of freedom. This is to say that it is represented by three linear equations in the four variables.

$$0 = a_o + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4$$
$$0 = b_o + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$
$$0 = c_o + c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4$$

We may eliminate from this set of three equations two x_i at a time, yielding $\binom{4}{2}$ = 6 equations, each involving two x_i. Any set of three such equations also represents the L4,1. Thus

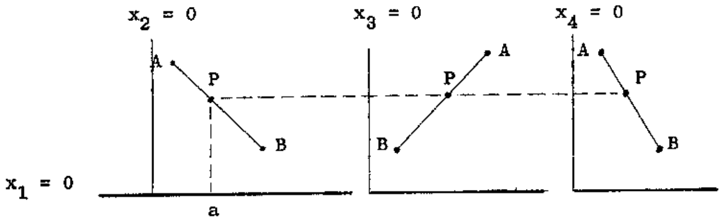
$$0 = A_o + A_1x_1 + A_2x_2$$
$$0 = B_o + B_1x_1 + B_3x_3$$
$$0 = C_o + C_1x_1 + C_4x_4$$

may be obtained from the original set of equations by elimination of suitable x_i, and these three equations are equivalent in meaning to the original set; they are also the equations for each of the graphs.

An Ln,1 may be called a line.

We may fix some coordinate in one of the three graphs of the line. Then all other coordinates are also fixed, and we obtain a single point:

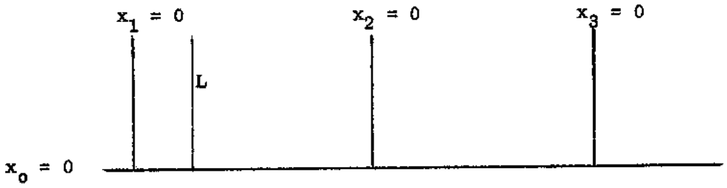
(See diagram)
Continued on page 28.



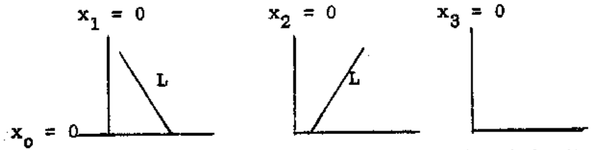
Thus if we fix the coordinate x_2 by setting $x_2 = a$ it is seen that the point P is uniquely located on the line AB, and the coordinates x_1 x_3 x_4 are thereby fixed also. But in our notation, the single equation $x_2 = a$ is an L4,3 so that we observe that the intersection of an L4,1 and an L4,3 yields an L4,0 in this case. We may formulate the tentative conjecture that this is always the case for all intersections of L4,1 and L4,3 so that we may always expect L4,0 as the result.

Indeed, Ln,n-1 and Ln,1 represent analogous manifolds in n dimensions, the first defined by one equation, the second by n-1 equations. If we cause these manifolds to intersect, we obtain a new manifold with 1 + (n-1) equations, which, as we have seen, is an Ln,0, since it has precisely n equations in n dimensions.

We shall discuss this in more detail in the acticle on intersections.

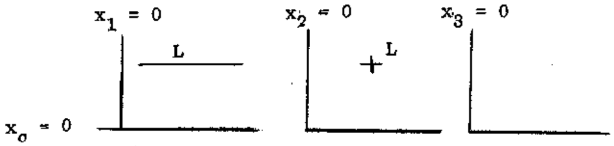


If L appears in only one view, but not in the others, e = 1, and d = n-e = 4 - 1 = 3. Hence L represents an L4,3, a 3-space. The entire 3-space is represented by L, which may be called an "edge view".



Again, if L appears in two views, but not in the third, e = 2 d = 4 - 2 = 2 and L represents an L4,2 a 2 space, or plane.

In this geometry, a plane can appear as a point:



4. Intersection

We may generalize this notion of the intersection of two manifolds.

Write $$Ln,d_1 \quad Ln,d_2 = Ln,d_3$$

to read: "The intersection of Ln,d_1 and Ln,d_2 in n-space yields the manifold Ln,d_3". We wish to deduce the relationship of d_1 d_2 and d_3. By definition of d, we have

$$d_1 = n - e_1 \qquad d_2 = n - e_2$$

where e_1 and e_2 are the number of equations taken to represent the two manifolds. Then the intersection of these manifolds yields $e_3 = e_1 + e_2$ equations, which define a manifold of degree d_3: $d_3 = n - e_3 = n - (e_1 + e_2) = n - (n - d_1 + n - d_2)$

$$= -n + d_1 + d_2$$

Hence we have the formula $Ln,d_1 \quad Ln,d_2 = Ln,(-n + d_1 + d_2)$
In the plane, n = 2, and two lines intersect to yield a point:

$$L2,1 \cdot L2,1 = L2,(-2 + 1 + 1) = L2,0.$$

But two points do not intersect, since

$$L2,0 \cdot L2,0 = L2,(-2 + 0 + 0) = L2,-2$$

We shall postpone the investigation of the meaning of manifolds with negative degrees of freedom, and say that they are undefined.

In ordinary 3 space,

$$L3,1 \cdot L3,2 = L3,(-3 + 1 + 2) = L3,0$$

or, a line intersects a plane in a point.

Again, $$L3,2 \cdot L3,2 = L3,(-3 + 2 + 2) = L3,1$$

or, two planes intersect in a line.

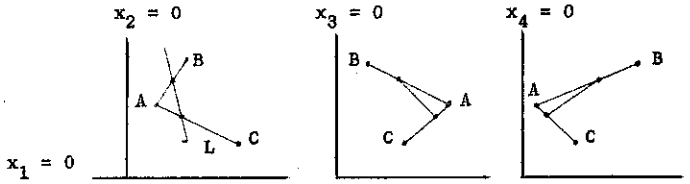
But $$L3,1 \cdot L3,1 = L3,(-3 + 1 + 1) = L3,-1$$

indicates that two lines in space do not intersect. Evidently intersection is a function of the space in which the manifolds are immersed.

With this device, we are prepared to investigate the nature of intersections in higher dimensions. Thus

$$L4,3 \cdot L4,3 = L4,(-4 + 3 + 3) = L4,2$$

says that two ordinary linear spaces like our universe intersect in a "plane" in fourth dimension, a result which we would scarcely be able to visualize.



If we have three points, we have seen that we may connect them by means of any two lines of the three possible ones, as for example lines AB and AC. If the three points define some manifold, of unknown degree d, then it may be symbolized as L4,d. Now this manifold may be intersected by an L4,3 shown in the first graph by line L, but not appearing on the other graphs. The intersection of L4,d with L4,3 yields an L4,1 since it is determined by a line appearing in all three views.

Hence $$L4,1 \cdot L4,3 = L4,1$$

whence $$-4 + d + 3 = 1$$

But then d = 2, indicating that the manifold defined by 3 points is an L4,2 a "plane".

In general, if $Ln,d \cdot Ln,n-1 = Ln,1$

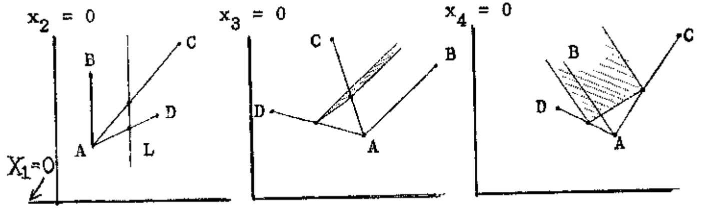
then $$-n + d + n - 1 = 1 \qquad \text{so} \quad d = 2$$

Using this notion, we see that if $Ln,d_2 \cdot Ln,n-1 = Ln,d_1$

then $d_1 = -n + d_2 + n - 1 = d_2 - 1$ or $d_2 = d_1 + 1$

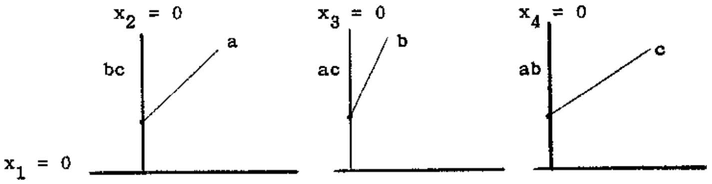
Hence a manifold of degree d is cut by a manifold of degree n-1 in a manifold of degree d-1. By repeated application of this rule, we may show that two Ln,0 define an Ln,1; three Ln,0 define an Ln,2; four Ln,0 define an Ln,3; and so on.

In fact the Ln,d are independent of n, and d depends only upon the number of Ln,0 or points.

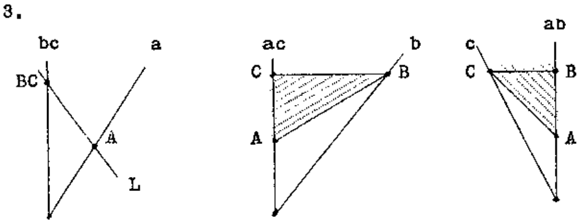


An L4,3 is shown, defined by the points A,B,C,D. When cut by the L4,3 represented by L, it yields the L4,2 shown shaded.

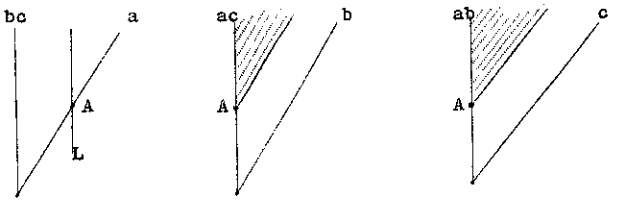
It is clear that the L4,3 (A,B,C,D) may be cut by the three distinct L4,3, $x_2 = 0$, $x_3 = 0$, $x_4 = 0$ to yield a new representation for the original L4,3:



These lines, a,b,c may be thought of as the "traces" of the L4,3.



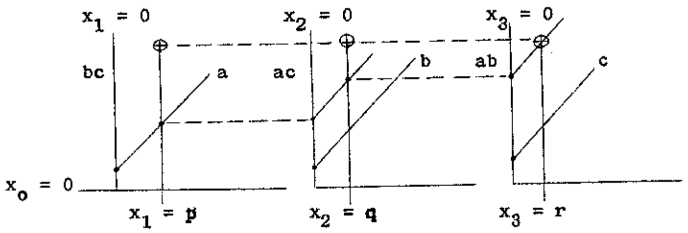
As another example, if one of the L4,3 is given by the three lines abc, and the other by the line L, the intersection is the plane ABC, given by its traces.



In the figure the L4,3 (L) has been chosen so that points B and C are ideal points. The plane, as before, is given by its traces.

Intersection of an L4,1 with an L4,3:

$$L4,1 \cdot L4,3 = L4,0$$

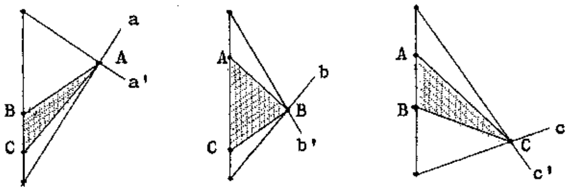


Let the L4,3 be represented by the three traces, a,b,c and the L4,1 by the equations

$$x_1 = p \qquad x_2 = q \qquad x_3 = r$$

As before, the $x_1 = p$ manifold intersects the abc manifold in a plane, and then we may find the intersection of this plane with $x_2 = q$ $x_3 = r$.

Intersection - two L4,3 given by their traces:



The L4,3(a b c) and L4,3 (a'b'c') intersect in the L4,2(A B C) plane.

In a space of n dimensions, there are the manifolds

Ln,0; Ln,1; Ln,2; ... Ln,n-1

All problems involving intersections in this space are solved by the use of "cutting" Ln,n-1 manifolds, just as cutting planes are used in 3-space. The general process may be indicated. First, any manifold may be represented by combinations of Ln,0, which may then be connected by Ln,1's. If two manifolds defined thus by lines, Ln,1 intersect, we may cut them both by means of a cutting manifold Ln,n-1, shown as a line in one view only - (what we have called the edge view of the manifold). This cutting manifold Ln,n-1 must cut all lines of the other two manifolds, for

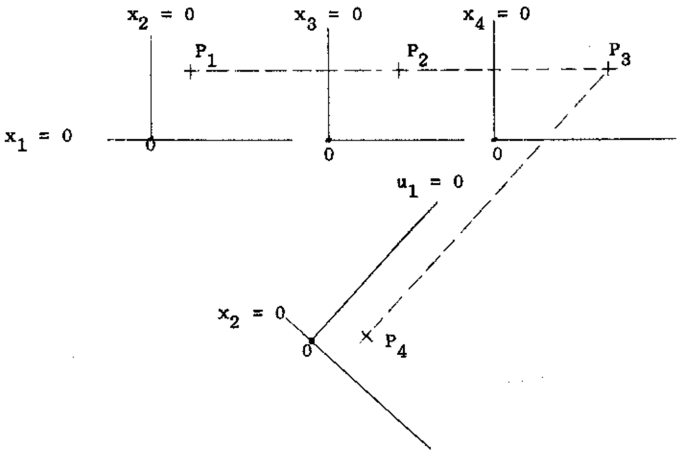
$$Ln,1 \cdot Ln,n-1 = Ln,0 \text{ points.}$$

This set of points obtained by the cutting manifold Ln,n-1 lies entirely within the manifold; that is to say, it lies in n-1 space of the manifold. Moreover, if one of the original manifolds is Ln,d, its section by Ln,n-1 is Ln,d-1, that is, it possesses one less degree of freedom. Hence the original problem of intersection of Ln,d_1 and Ln,d_2 has been reduced by means of the cutting manifold Ln,n-1 to the new problem of intersection of the manifolds Ln-1,d_1-1 and Ln-1,d_2-1. In the familiar case in 3-space of the intersection of two planes, each an L3,2, we use a cutting plane to yield two lines, L3,1. But both these L3,1 lie in the cutting plane, and hence we have to find the intersection of two L2,1 which of course occurs in an L2,0. Moreover, since the original problem yields

$$L3,2 \cdot L3,2 = L3,1$$

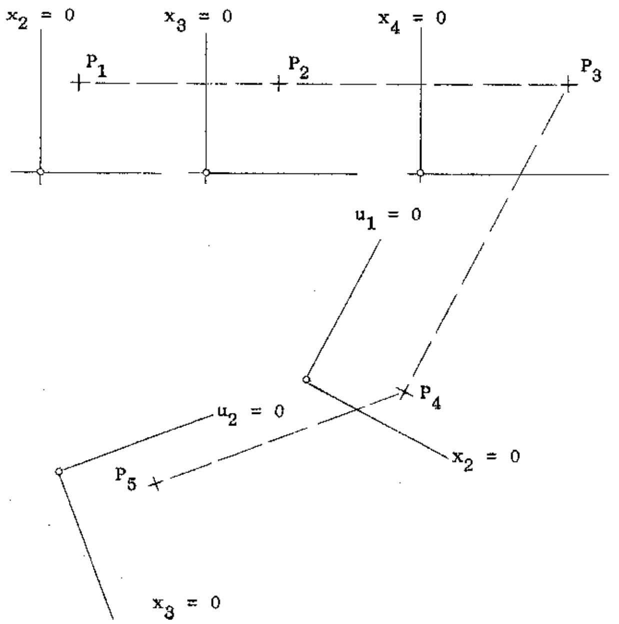
that is, the planes intersect in a line, it follows that we must find two distinct L2,0 to define the line. Hence we must use two distinct cutting planes, each good for one point.

5. Auxiliary Views



We may introduce a new coordinate u_1 into a system $x_1\ x_2\ x_3\ x_4$. When this is done, the three graphs $P_2\ P_3\ P_4$ are equivalent in content of information to the original graphs $P_1\ P_2\ P_3$.

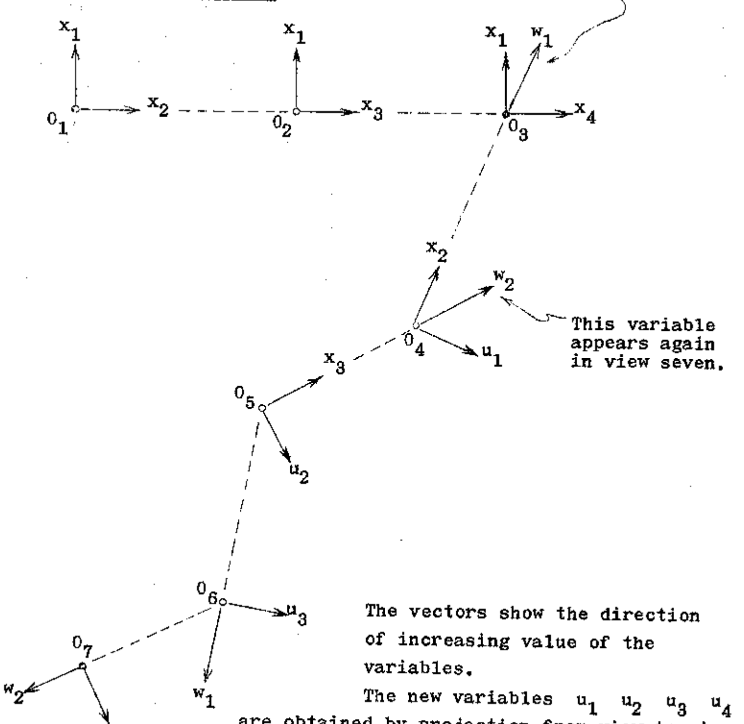
Obviously, given $P_2\ P_3\ P_4$ we may find P_1.



We have carried the process one step farther - The new coordinate u_2 has been introduced. Given P_2 P_3 P_4 we may find P_5; but we may reverse the procedure and, given P_5 P_4 P_3, we may find P_2.

AUXILIARY VIEWS IN FOURTH DIMENSION

The new variable w_1, will appear again in view six.



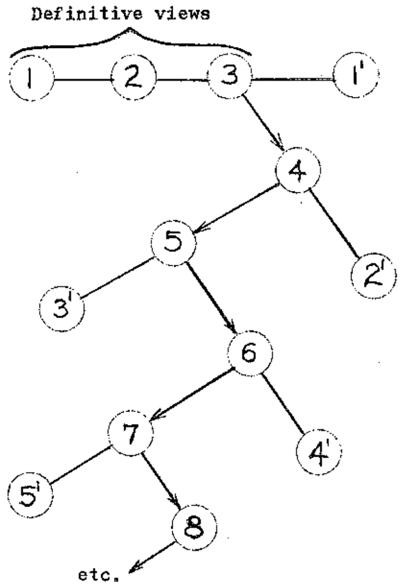
This variable appears again in view seven.

The vectors show the direction of increasing value of the variables.

The new variables u_1 u_2 u_3 u_4 are obtained by projection from view to view; the new variables w_1 and w_2 are measurement variables.

Scheme of Projection

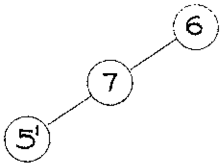
The accented views 1'2'3'4'5' may be constructed by taking information from the corresponding unaccented view. Then the sequences



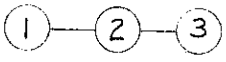
are the same as for ordinary descriptive geometry, and this idea may be used in constructing proofs for n-dimensional descriptive geometry projections.

It is to be understood that these accented views are really not needed, except as they help to understand n-dimensional projection in terms of three dimensional projection, and they would ordinarily be omitted.

We may point out, however, that three views in the sequence such as



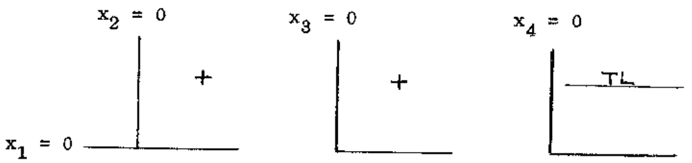
have the same significance as the original views



or

except that the coordinates have been transformed.

6. True Length of a Line

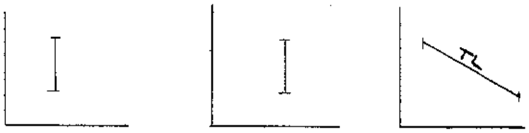


The manifold represented is an L4,1, and the third graph gives the true length of the manifold if length is defined by

$$l = \sqrt{\Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2 + \Delta x_4^2}$$

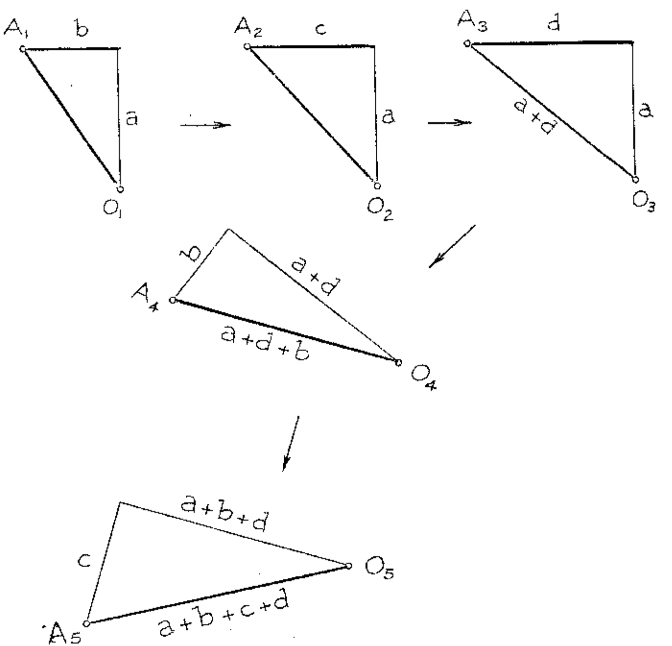
for $\Delta x_1 = 0$ $\Delta x_2 = 0$ $\Delta x_3 = 0$ so that $l = \Delta x_4$.

Similarly, a manifold may have the appearance



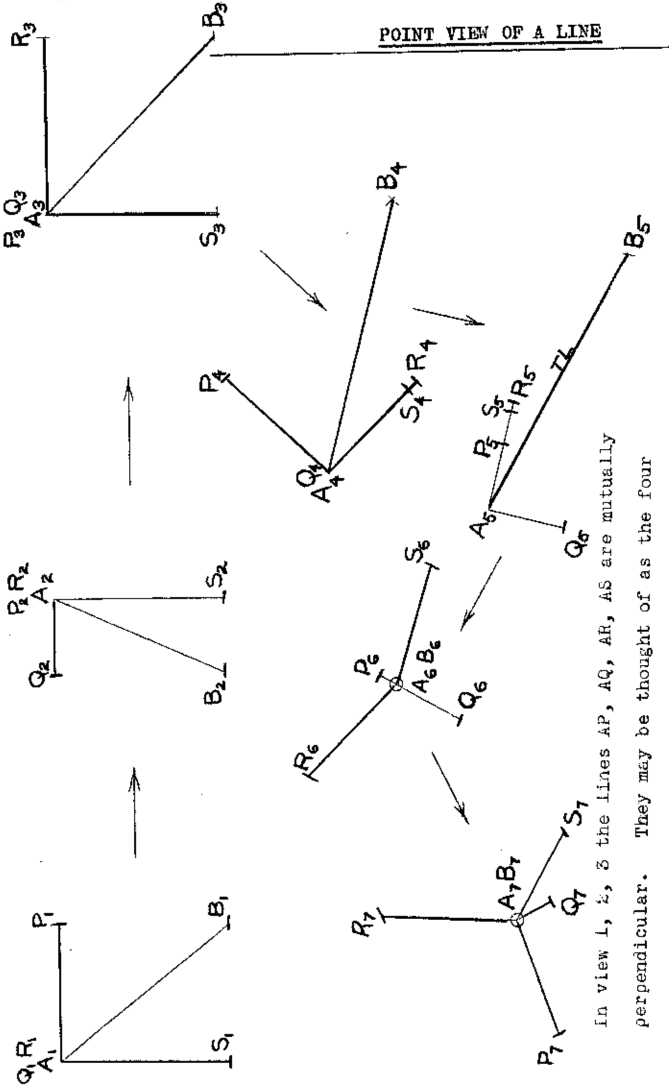
and again the third view shows the true length.

TRUE LENGTH OF A LINE - GENERAL CASE



a, b, c, d are vectors representing the relative 4 dimensional displacements of points 0 and A. Typically, $|a| = \Delta x_1$

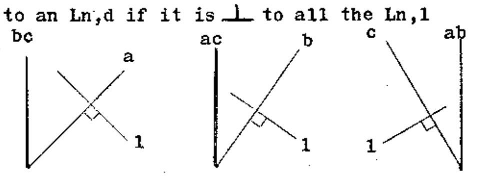
POINT VIEW OF A LINE



In view 1, 2, 3 the lines AP, AQ, AR, AS are mutually perpendicular. They may be thought of as the four adjacent edges of a rectangular four-dimensional box. Line AB is the body diagonal of the box.

7. Perpendicularity

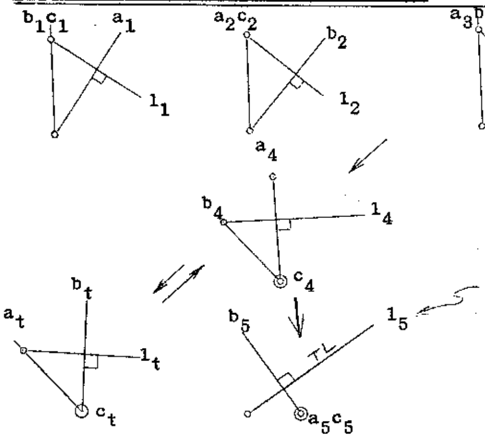
A line is ⊥ to an Ln,d if it is ⊥ to all the Ln,1 contained in Ln,d.



L4,1, (1), is perpendicular to L4,3 (a b c). Lines a b c each show T.L. in one view. 1 is ⊥ to these T.L. lines, and hence 1 is ⊥ to the lines in 4-space. We need now only show that 1 is ⊥ to all the lines of L4,3 (a b c).

We can do this by obtaining an edge view of abc, in which 1 shows true length and perpendicular to abc.

Proof of the Perpendicularity Theorem



In this view, the L4,3 defined by a, b, c shows on edge; 1_5 shows T.L. and perpendicular to a, b, c, --.

The proof that 1_5 is T.L. will follow if $1_4 \perp a_4c_4$; but this involves only views 1, 3, 4, as in three dimensional descriptive geometry, and line 1 is evidently ⊥ plane ac, which shows on edge in view 4.

It remains to prove that 1_5 is $\perp$ $(abc)_5$. This involves only views 2,4,5. Construct the temporary view T from views 2 and 3. In this view $1_T \perp b_Tc_T$, which shows on edge, by reasons of ordinary three dimensional descriptive geometry. Now views T 4 5 also obey these principles, and since ab shows on edge in view 5, $1_5 \perp (abc)_5$ which was to be proven.

8. Multi-Variable Relations

The foregoing discussion revolves around linear manifolds, a very restricted class of relationships. Now in ordinary three dimensional descriptive geometry we can represent graphically, and in two views, the most general kinds of three dimensional relationships, in the form of contour maps, as we well know. We have presented the rudiments of a multi-dimensional descriptive geometry, and it is natural to inquire whether this geometry is useful for the representation and manipulation of what we might call "curve manifolds", that is, manifolds in which the relationships are as general as contour maps, but in n dimensions. Specifically, we might argue: If only two views always enable us to represent any three dimensional relationship, then perhaps three views always enable us to represent any four dimensional relationship, and so on.

Unfortunately, this is not true for the general case, although it is true for linear manifolds as we have seen, and for certain kinds of curve manifolds that we will exhibit. But in general, what is required for the description of a multi-dimensional relationship is a set of sections of the manifold, chosen at appropriately close values of the several variables.

As an indication that this remark is true, our animated cartoon of the geological evolution of mountain ranges that we mentioned at the beginning of this paper consisted of a set of geometrical sections (elevations) and temporal sections

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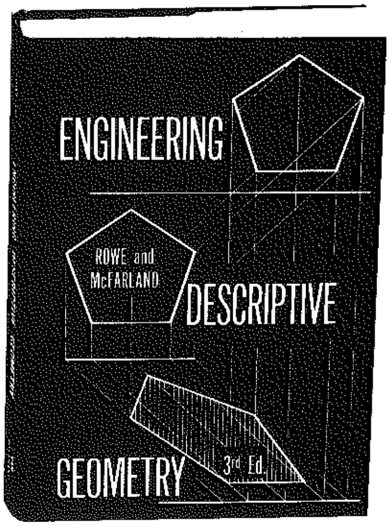
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University of California, Berkeley.

Those already familiar with *Graphics in Engineering and Science,* as well as those who have not yet read this valuable text, will be interested to learn that a second edition of this book will soon be available. The new edition has been modified and brought up to date so that it now includes all of the material in the first edition plus much new material that has evolved over the past few years. The sequence of chapters has also been revised in order to present the student with a clearer and more easily comprehended development of the subject matter.

This remarkable book enables the reader to appreciate the significant role of graphics in engineering research, development, and design. It emphasizes the importance of freehand sketching as a powerful means for expressing new ideas, and design concepts; for recording analyses of space problems, and for effective communication among engineers, scientists, and technicians. Stress is laid on the fundamental principles of orthogonal projection and their applications to the analyses and solution of space problems that arise in both engineering and science.

The power of graphical analysis and graphic methods of computation is set forth in the material on applications of the fundamental principles of orthogonal projection; vector quantities; and graphical mathematics. While the importance of algebraic methods in solving engineering problems is recognized, it is shown that in numerous instances these problems are best solved by the use of graphical methods.

The projects in this book are designed to show that there is often more than one workable solution to daily engineering problems. This serves to stimulate the creative potential of the student and calls forth all of his background in engineering and related studies. The result is that he gains a very practical approach to solving the real problems of engineering as they occur on the job.

1962. **In press.**

Send for an examination copy.

440 Park Avenue South, New York 16, N. Y.

AN EX-EDITOR TURNS CRITIC or HINDSIGHT IS EASIER

By Irwin Wladaver, New York University

Sometimes I think we had it coming.

I remember one morning during the Summer School at Michigan State. 1951, it was. John Rule of M. I. T. strode up to the speaker's lectern with a roll of what looked like--and was--brown wrapping paper. After his disarming opening remarks, Rule flung the roll of wrapping paper down on the floor, the paper unwinding like a carpet. The first roll turned out to be a king-sized sine curve. The next roll was an equally tremendous cosine curve. And naturally the next roll was the quotient, a correspondingly magnificent tangent curve.

And then, after the now reformed dean had our attention, he went on to develop some connection with projective geometry. Immediately some of us in the audience went back to our reveries. Weren't we having enough trouble squeezing in all that important descriptive geometry? Forget this projective geometry nonsense. Let's concentrate on the essentials of engineering drawing.

At that same Summer School, 1951 remember, Rex Waymack of Modesto gave a demonstration of overhead projection with many transparencies in color. Fine, but who had the time to do all that planning, drawing, developing, mounting? That stuff is all okay, but teaching--that's the important thing. Forget the frills.

A few years later, Douglas P. Adams gave a talk on three-dimensional nomography. Penn State, I think it was. Adams took it for granted that everyone present had sufficient command of two-dimensional nomography to make the "simple" extension from the plane into space. But many of us in the audience sneered at the idea of 3-D nomography. Weren't we having enough trouble trying to justify the inclusion of plain plane nomography into our already overstuffed courses? Forget three-dimensional nomography. Forget two-dimensional nomography, too.

Sometimes I think we had it coming. Many of us felt that if a topic could not be introduced into our course offerings there was no point in bothering with it. Projective geometry? Nomography? Graphical calculus? Empirical equations? What for? To neglect descriptive geometry, auxiliaries, assembly drawing, screw threads; and then to teach freehand? We must not turn out engineers that can't draw! This stuff is all crazy and so are its advocates. Let's stick to fundamentals!

And so I ask: What are the fundamentals?

Fundamental to our obligation as college teachers are two duties. One is to teach; the other is to study constantly to enrich our teaching and to publish what we have discovered. By no means must we crowd into our courses everything we have ever learned. And by no means may we ever be satisfied with what we do teach.

Nor do I mean that we should blindly embrace nomography, graphical calculus, empirical equations, projective geometry, and computer techniques as elements in our courses just for the sake of being in style. Many of us have surrendered, says Jerry Dobrovolny of the University of Illinois; and we have allowed pressures by "outsiders" to force out of our courses much more valuable stuff than we have put in under duress. I do not mean that we should resist change. On the contrary: I mean that we should initiate changes on the basis of what we know to be essential. On the assumption that we know our business better than anyone else does, we should be pressing for changes instead of reacting to pressures on us.

I said "on the assumption that we know our business." This is the big question. Every calculus teacher draws the pictorial, geometrical analogy to clarify differentiation, and in fact defines differentiation in terms of geometry. He knows the picture makes sense even if his words do not. When the statics teacher represents forces as vectors, he must draw the picture for he knows that the graphical adds measurably to the symbolic attack. Do we similarly use symbols to add generality and insight to the graphical? Have we developed ourselves in the fields peripheral or ancillary but yet intimately related to the central issues of our field so that we can move easily throughout and across the related areas? I think we have not. We have resisted, resented, reacted, resigned, and finally accepted. We have not initiated.

We have, many of us have, accepted nomography for example. Why? On what logical basis? True enough, the curriculum committee has approved. But what have they approved? A change? Any change? If so, then the approval is only temporary and we should be prepared for more changes to come. And the new changes will be even less desirable, unless we are able to suggest worthwhile changes of our own choice.

What we must do, I think, is to make up our minds what in engineering drawing, descriptive geometry, computational graphics, projective geometry, and all the rest of the available disciplines is utterly essential to the education of engineers, both graduate and undergraduate. What's more, we should prepare to study and to teach these elements whether our conclusions are accepted or not.

If we fail to win our point, we should do what every respectable rat would do under the same conditions. If the ship is sinking, desert!

Your affectionate rodent,

Irwin Wladaver

HIGHLIGHTS FROM THE MID-WINTER MEETING - MADISON, WISCONSIN, JAN. 17, 18, 19, 1962.

Reported by your Editor, Mary Blade

Our cover this month is the same cheerful red as the hats worn by our Wisconsin hosts, headed by Chairman of Arrangements, Prof. Bob Worsencroft. Dean Kurt F. Wendt welcomed over 200 members to the University of Wisconsin campus, which was blanketed in deep snow. It was sunny and clear but the temperature was minus 17F.

The program was "three phase". One session dealt with techniques for improving teaching, including an automatic teaching machine, introduced by Profs. Knoblock and Besel of the University of Wisconsin. The teaching machines are still in their infancy and require a great deal of costly and time-consuming nurturing before they can assist the student in learning a significant amount of his present course material. But we should be active and alert to assist in the development and trial of these teaching aids.

The second session concerned the use of computing machines in Graphics. We were introduced to the basic ideas of electronic computers in a brilliant talk by Prof. Davidson, who is teaching computer possibilities to the undergraduate students and faculties at the University of Wisconsin. The coming revolution of the machine tool industry through numerical controls programmed by computers was described by Mr. Chamberlain of Giddings and Lewis. Mr. Kilcrease of IBM described the method by which the engineer's hand-drawn sketch is converted to finished, manufactured panels of a computing machine. He forecasts the application of the mechanization of engineering design data to other systems such as structures, equipment and piping systems which have a high degree of standardization.

The third and most controversial session was crystal gazing. The future of Engineering Graphics not only was discussed by a panel from universities and industry but was the subject of most of the talks in the corridors and the late night sessions which were informally held by each member with a friend. Prof. Steve Coons said, "The future of Engineering Graphics is as a tool for creation, manipulation and communication of ideas....The content of a good graphics course of the future will not differ very markedly from today's good graphics course, but the emphasis and point of view will be changed. The elements of drill and detail will have disappeared to make room for elements of EXPLORATION, INVENTION, and UNDERSTANDING."

Dean Jasper Gerardi gave a vigorous and hard-hitting evaluation of Graphics in the engineering profession. He said, "We can no longer stress to our professional associates that the most important aspect of graphics is that it is a means of communication - a language - everyone knows that. We must emphasize graphics as an integrating device in the various disciplines of engineering; and that graphics can contribute to a more rapid progress in engineering education."

He also gave a report of the N.S.F. Graphics Course Content Study and encouraged widespread participation by the members of the Graphics Division. Professor Reinhard of the University of Detroit, Director of the Project, also circulated a progress report of the meetings of the Core Committee. As the result of a planning seminar in October at the University of Detroit, the committee has decided to concentrate activities in four broad areas. These are: Graphics as a device to develop creativity in design; Computer technology and its implications for Graphics; Graphical analysis and computation; and Graphics Research.

WANTED: Professor Irwin Wladaver requests copies of your tests and examinations for his workshop session of the Graphics Division Summer School in June. Please send any materials illustrating tests in any part of Graphics to him at New York University.

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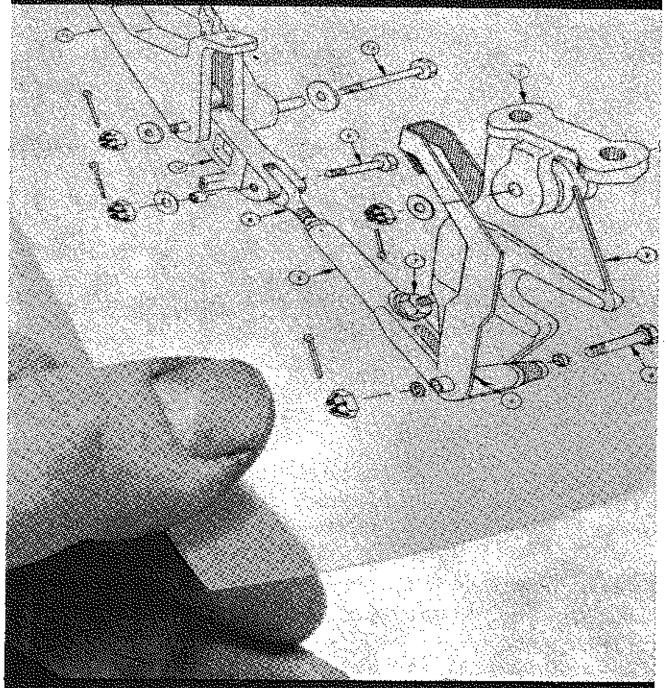

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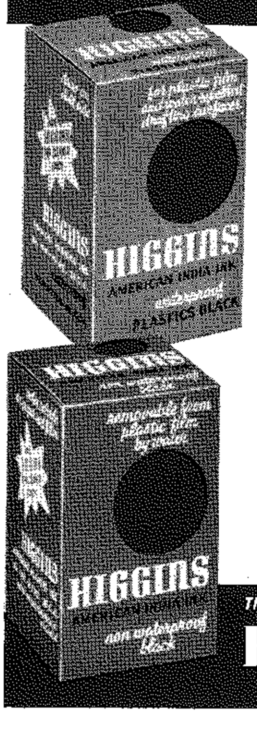

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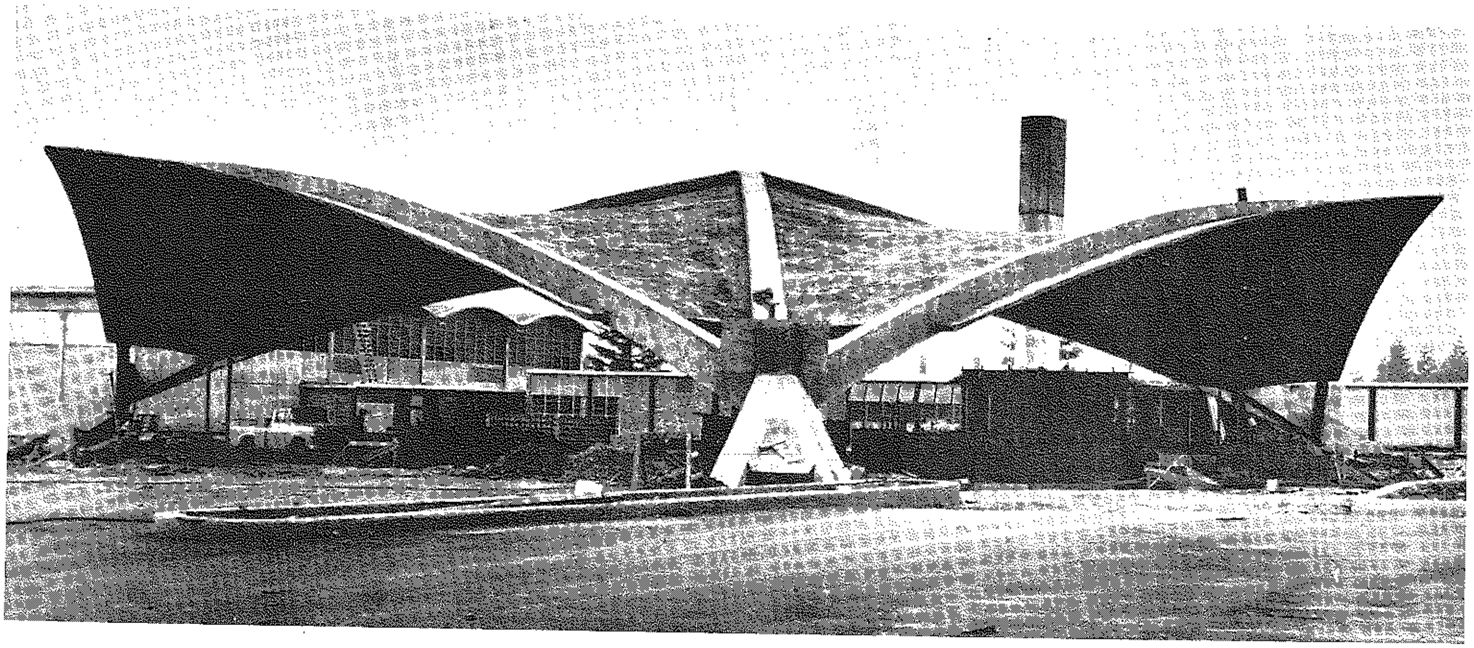

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