THE JOURNAL OF

ENGINEERING DRAWING

CONTENTS

Analysis

Synthesis

Communication

Vol. 21, No. 2 **MAY, 1957** **Series No. 62**

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of the American Society for Engineering Education

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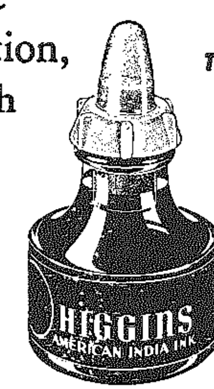

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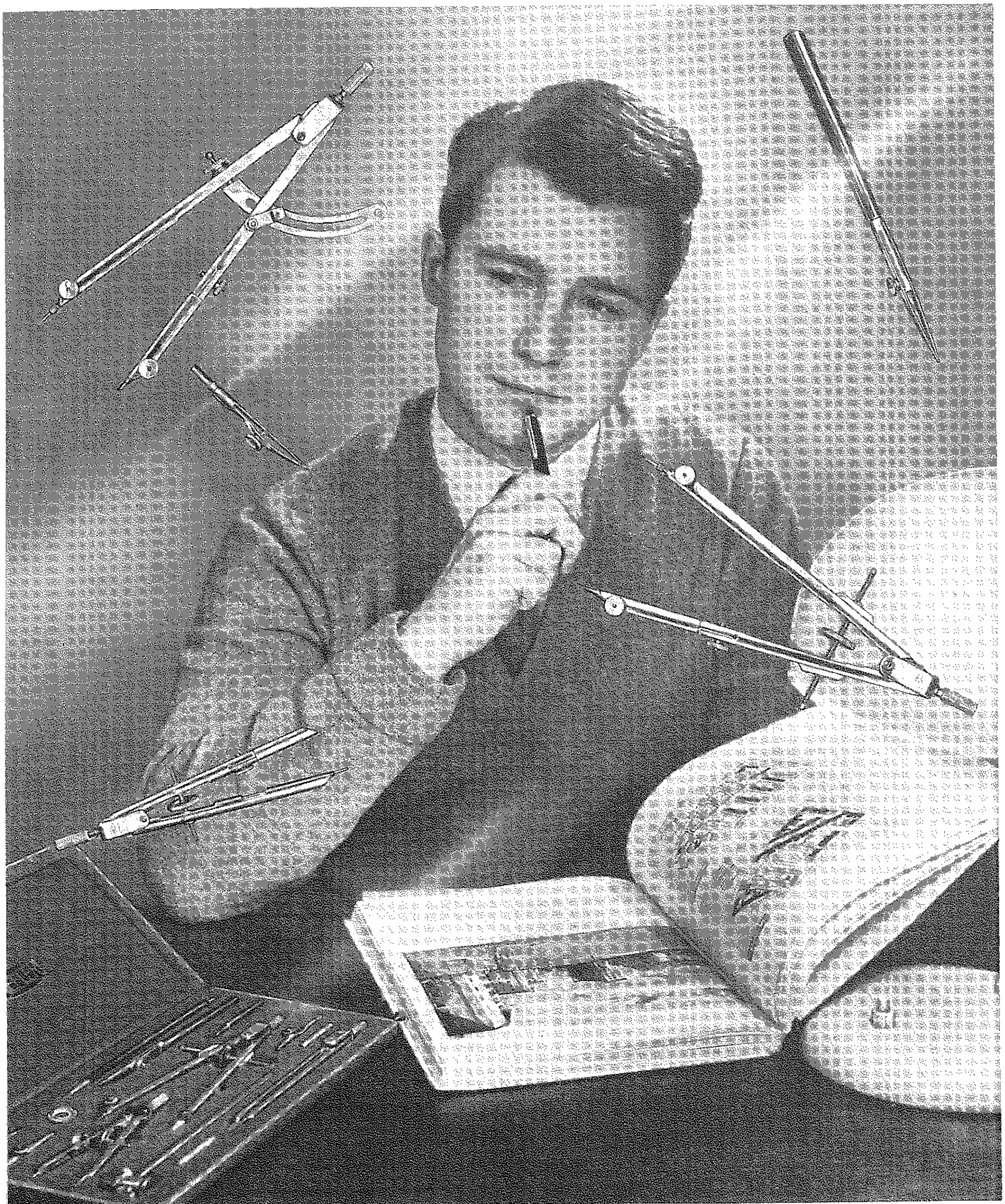

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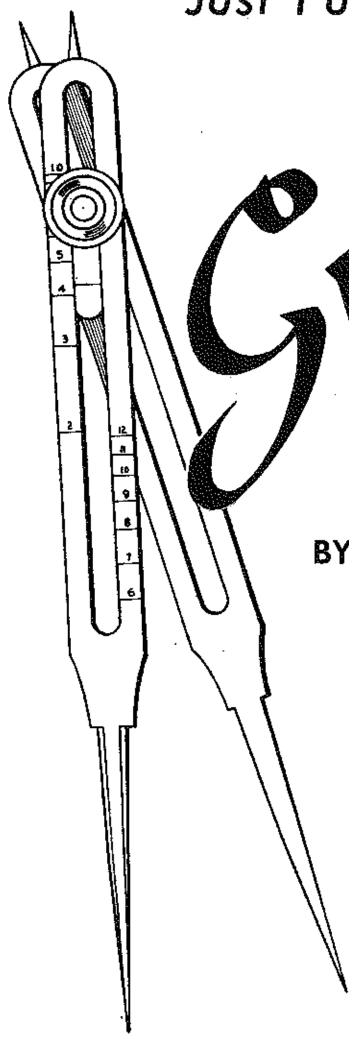

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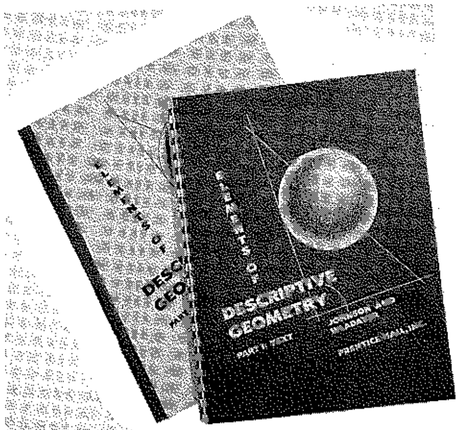


Elements of Descriptive Geometry

Part I (text) — Part II (problems)

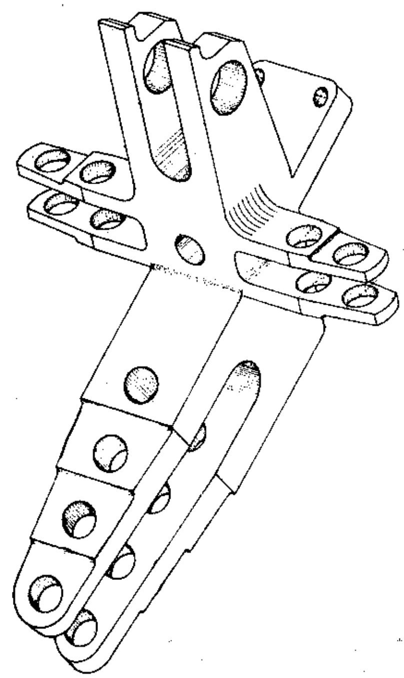
by LEWIS O. JOHNSON and IRWIN WLADAVER, both of New York University

HERE IS A COMBINATION text-and-workbook for a basic course in descriptive geometry. It covers the fundamentals which should be part of the stock in trade of every beginning engineer.

The authors stress underlying principles and familiarize the student with the equipment he will need to understand and interpret what he sees on a blueprint. In the Text (Part I) the illustrations and text matter are placed on the same or facing pages so both can be seen together. Seventy-one problems are presented in Part II. In addition, a key for all the leading text-books in descriptive geometry is given in the form of a helpful chart.

Published 1953   Part I: 73 pp.   Text list $1.95
Part II: 76 pp.   Text list $3.50

ENGINEERING DRAWING PROBLEMS



FEATURING ASSIGNMENTS DRAWN from more than 20 industrial firms, this new text gives students realistic problems in engineering drawing. The problems, drawn from over 20 prominent industrial firms (such as Grumman Aircraft, American Manganese, and Pittsburgh Steel) provide a special motivating force for the beginning student. Ample opportunity to assign plenty of freehand drawing is provided — practically every topic is introduced by means of freehand work.

Grids are supplied for assistance in teaching, especially in the elementary stages. Some problems, however, are presented without grids, thus making freehand or instrumental work optional. Pages are perforated for tear-out and punched for binder filing.

Published 1956   67 pp.   Text list $5.00

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Engineering Drawing	PROBLEMS IN ENGINEERING DRAWING - ABRIDGED Fourth Edition 1956 by W. J. Luzadder and J. N. Arnold, Professors of Engineering Graphics, Purdue University and F. H. Thompson, Senior Technical Artist, Allison Division, General Motors Corporation. These problem sheets were developed from industrial practices and many years of successful use in colleges, universities, and technical institutes. The loose-leaf sheets provide a compact package of student materials and include instructions to the student and problem sheets for the areas of: Lettering, instruments and geometrical construction, freehand sketching and multi-view drawing, auxiliary views, sectional views, detail drawings, and assembly drawing. The 40 plates provide an opportunity for selecting projects in terms of individual needs and course requirements. 40 Loose-leaf plates with envelope $8\frac{1}{2}$x11 Price $1.70
Engineering Graphics and Descriptive Geometry	PROBLEMS IN ENGINEERING GRAPHICS AND DESCRIPTIVE GEOMETRY Second Edition 1954 by by J. H. Porsch and S. B. Elrod, Professors of Engineering Graphics, Purdue University and R. H. Hammond, Course Supervisor-Graphics, United States Military Academy.* The problems follow the authors' text (Engineering Graphics and Descriptive Geometry) but may be used with most standard texts in the academic area. The 73 problem sheets include instructions to the student and provide for variances in course content and for individual differences. 73 Problem sheets, perforated to tear out and punched for 3-ring notebook 9x11 Price $3.00
Engineering Graphics and Descriptive Geometry	ENGINEERING GRAPHICS AND DESCRIPTIVE GEOMETRY First Edition 1953 by the above authors* This text is designed for students in all branches of engineering and provides chapters as follows: Introduction, common geometrical elements of design, accuracy in graphics, principal views, auxiliary projection, intersections, traces, plane representation, angular relationships, double-curved surfaces, conic loci, and appendices. It is profusely illustrated to facilitate instruction and learning. 124 Pages, paper cover, plastic binding, $8\frac{1}{2}$x11 Price $3.50
Materials Testing	A LABORATORY MANUAL FOR MATERIALS TESTING Second Edition 1953 by Edward C. Thoma, Associate Professor of Engineering Materials Purdue University. A work-book guide for students of engineering in conducting laboratory tests in steel, concrete, and plastics. Testing procedures are clearly outlined. 53 Pages + report sheets and graphs for 18 experiments, perforated, paper cover, side-stitched $8\frac{1}{2}$x11 Price $2.50

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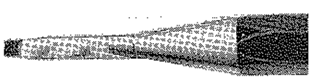

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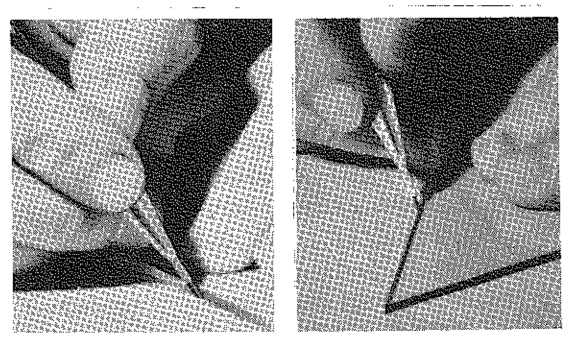

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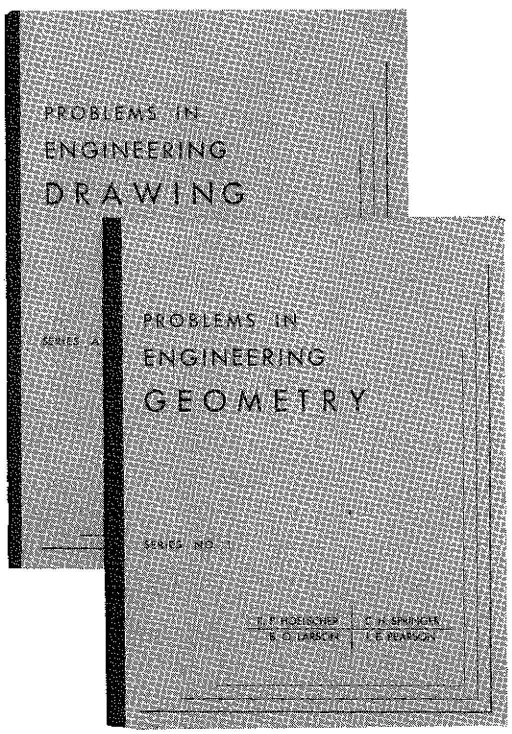

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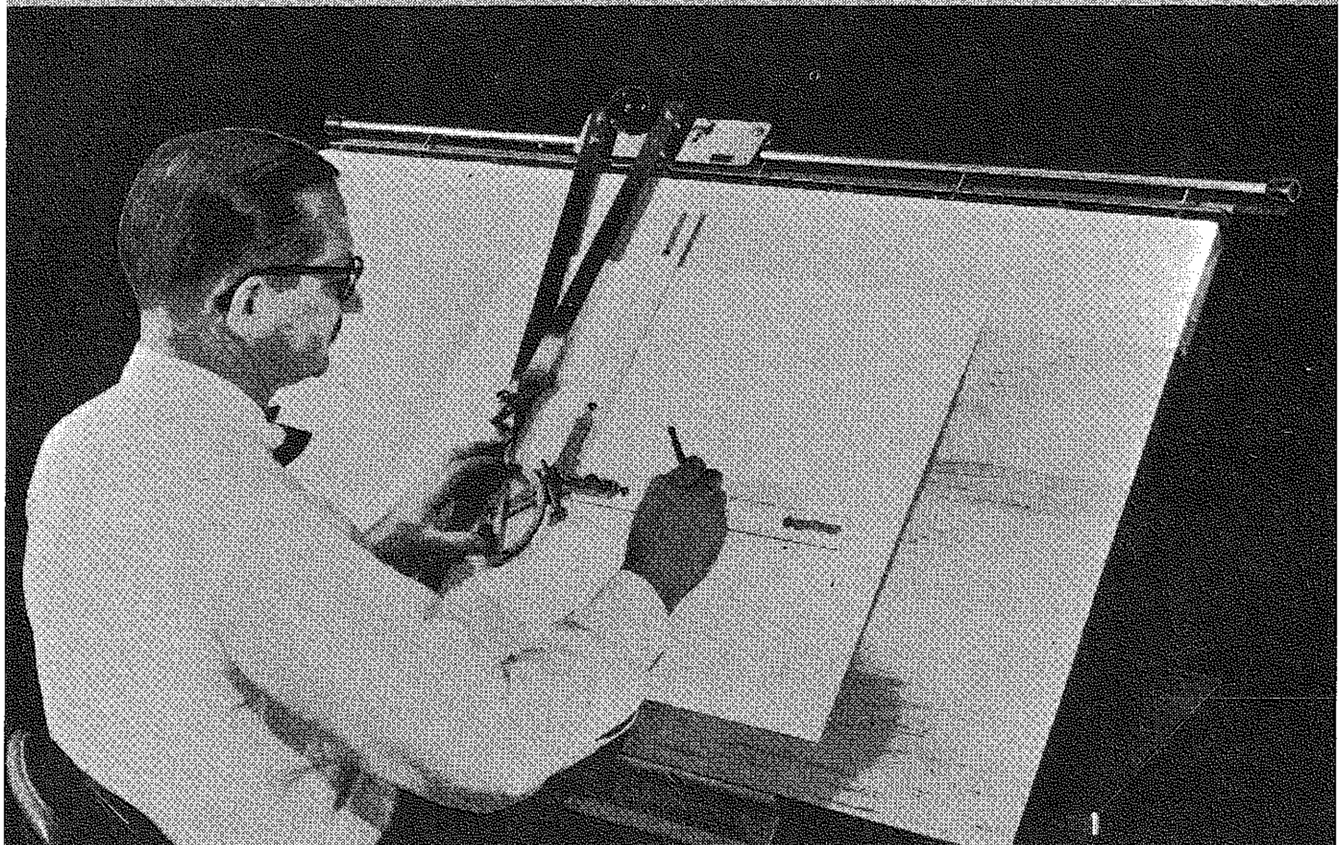

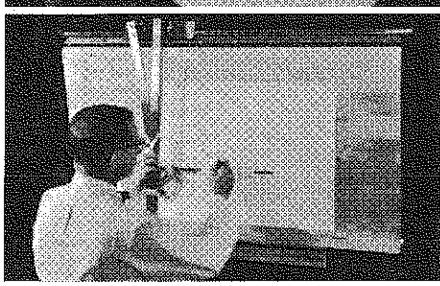

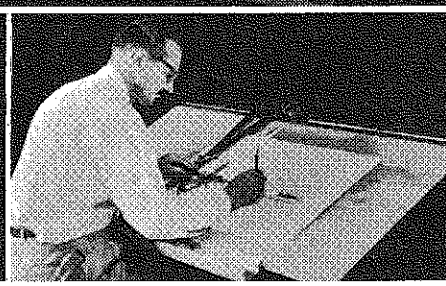

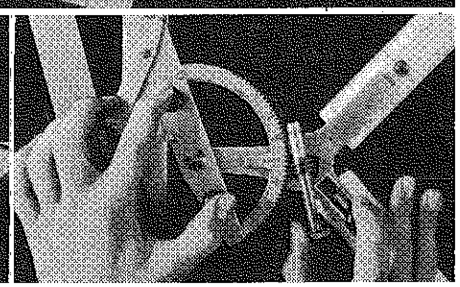

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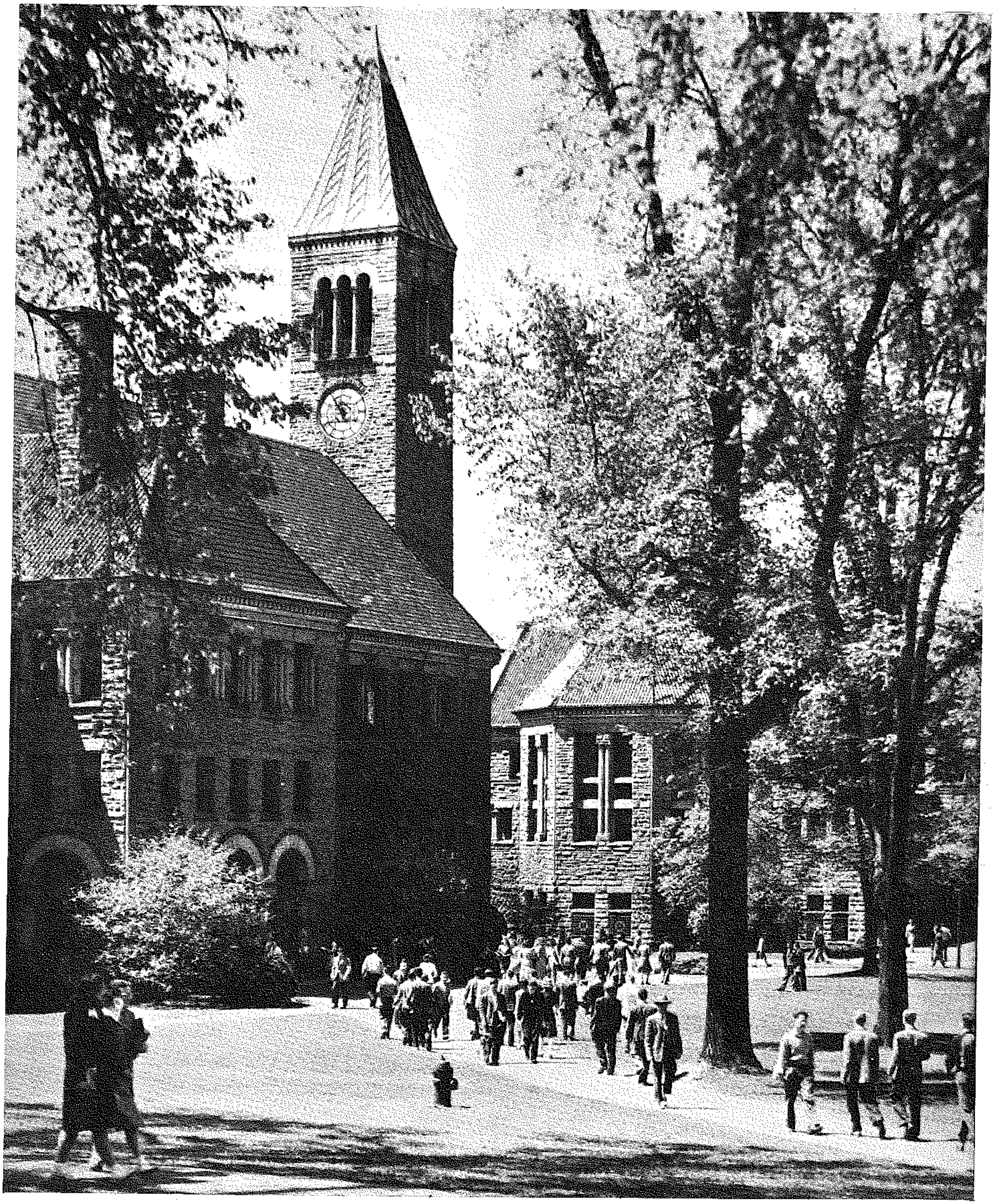

CORNELL UNIVERSITY—CAMPUS SCENE

Editorial Page

JOURNAL OF ENGINEERING DRAWING

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

PROFESSOR HAROLD B. HOWE

With this issue, Professor Harold B. Howe finishes his stint as advertising manager of the JOURNAL. Only the man who actually does the job can possibly understand what has to be done. In fact, when the advertising managership is handled competently and unobtrusively, in the capable manner of Harold Howe, no one else on the Publication Committee is aware that anything is happening at all. And that's the way it should be—and has been. Whatever needed to be done was done. No fuss. No feathers. Just work.

The Division of Engineering Drawing is indebted to Professor Howe for his quiet, unswerving devotion to duty. The other members of the Publication Committee are grateful to him and publicly express their thanks.

The new advertising manager, whoever he may be, may be sure that he can turn to his predecessor for any kind of help he may want.

THE MEETING AT RICE INSTITUTE

Those of us who had never visited Texas until last January know at last what is meant by Southern hospitality. The latch-string was out and the red carpet was spread. If there were any frustrations and exasperations, you'd never know it from watching Professor A. P. McDonald and Mrs. McDonald. While we're perfectly willing to confess it's more fun to watch Mrs. Mac than Professor Mac, still we were all delighted to be in their gracious care.

The Division of Engineering Drawing wants the McDonalds and their staff and the Administration of Rice Institute to accept our thanks for a profitable and enjoyable mid-winter meeting.

WHAT DOES AN ENGINEER HAVE TO KNOW?

Elsewhere in this Issue you will read the Report of the Industrial Relations Committee of our Division. Mr. Wayne Stone, of the Lycoming Division of the Avco Manufacturing Corporation, is one of the articulate men who responded vigorously to the survey.

Excerpts from letters often do injustice to the writers. But it's worth the risk in this instance because Mr. Stone vividly points out facts that we might easily overlook. He says:

"The results of the reduced instruction time in engineering drawing are beginning to be noticed in industry. We have been compelled to set up a definite training program . . . to complete the drawing knowledge of those possessing engineering background. We never employ an engineering graduate for a job on the board without putting him through this training. This practice was made necessary because we found that the average graduate's knowledge of engineering drawing was woefully inadequate.

"True, a certain percentage of the engineers we employ are being utilized in analytical capacities where at first glance it would seem they would not absolutely require graphic expression. However, such jobs are in the minority and are far outnumbered by our requirements in the design and manufacturing fields. Perhaps it should be emphasized that all engineering jobs in industry are not 'scientist' jobs and that the engineer on the board is not necessarily just a detail draftsman but more often a designer who not only needs all of his engineering training but also needs to know how to express himself on a drawing. . .

"While it is recognized that additional college courses are needed, I am of the firm opinion that no course, as important to the graduate in his future work assignment as engineering drawing, should be arbitrarily reduced. There is no substitute for graphic expression. Industry would be happier to see this basic training increased and the graduate would be certainly more useful."

Industrial Relations Committee Report

By Ralph S. Paffenbarger

Chairman Ivan L. Hill of the A.S.E.E. Engineering Drawing Division appointed a divisional Industrial Relations Committee at the annual meeting held at Ames, Iowa, June 25-29, 1956. This committee consisted of the following: H. C. Spencer, Illinois Institute of Technology; C. H. Springer, University of Illinois; W. E. Street, Texas A. & M. College; Jasper Gerardi, University of Detroit; and Ralph S. Paffenbarger, Ohio State University. In addition, our committee solicited the services of the following members of the division: Irwin Wladaver, New York University; Matthew McNeary, University of Maine; Frank Heacock, Princeton University; E. W. Jacunski, University of Florida; W. J. Luzadder, Purdue University; F. A. Smutz, Kansas State College; T. T. Aakhus, University of Nebraska; and L. R. Schruben, University of Southern California.

The committee's objective is stated in the sample letter appearing below.

> Here is a matter that concerns every company employing engineering graduates.
>
> Last year the Evaluation Committee of the American Society for Engineering Education issued its report which recommended additional courses in our engineering colleges. Wherever a course is added it is necessary to withdraw another unless the period of study is extended. Frequently to make room for new courses, many colleges have reduced the time for instruction in engineering drawing and descriptive geometry. In some colleges this curtailment is so drastic that adequate instruction is impossible.
>
> If this trend continues to crowd these basic courses out of the curriculum, you must expect that engineering graduates will come to you without a working knowledge of the graphic language, unable to read blueprints, or make satisfactory technical sketches. In some areas you may have discovered some lack of competence in this direction. Aware of this serious situation, the Engineering Drawing Division of ASEE is opposed to any reduction in graphic instruction.
>
> At Ohio State University all engineers receive 240 class hours of basic instruction and supervision, equivalent to 6 weeks (40 hrs) in industry. We believe that this is a minimum requirement for proper teaching.
>
> As an employer of engineering graduates you probably expect these young men to have a reasonable competence in graphic expression. If you agree that college courses in engineering drawing and graphics should not be curtailed, but strengthened, please express your opinion in a letter to me. Our Industrial Relations Committee is conducting this survey throughout the United States. The opinions of industrial leaders will be combined in a report which will be sent to the Evaluation Follow-up Committee of the ASEE.
>
> Your cooperation will be gratefully appreciated.
>
> Sincerely yours,
>
> RALPH S. PAFFENBARGER
>
> Ralph S. Paffenbarger, Chairman
> Industrial Relations Committee
> Engineering Drawing Division, ASEE
>
> RSP:ec

Letters such as this were sent throughout the United States. The areas, together with the solicitors, are tabulated on the summary sheet. Slight variations from this letter were made in accordance with the number of hours of instruction that prevailed in the solicitor's school.

The tabulated results represent the data gathered from quite a sizable return. These results were then sent to all members of the subcommittee on Analysis and Design and the Follow-Up Committee on the Evaluation Report on Engineering Education as well as all the officers of A.S.E.E. A copy of the letter to Professor Ver Planck (Chairman of the subcommittee on Analysis and Design) is reprinted here.

> January 4, 1957
>
> Professor D. W. Ver Planck, Head
> Mechanical Engineering Department
> Carnegie Institute of Technology
> Pittsburgh 13, Pennsylvania
>
> Dear Professor Ver Planck:
>
> I am taking the liberty of writing to you and your committee on Analysis and Design in the Follow-Up Survey on the ASEE Evaluation Report because I feel that what is herein contained is pertinent in your evaluation.
>
> At the annual meeting held at Iowa State College last June, the chairman of the Engineering Drawing Division, Professor Ivan L. Hill, appointed an Industrial Relations Committee. This committee was instructed to make a survey of industry in the entire United States relative to needs in college instruction in engineering drawing and graphics. This survey was made through letters similar to the copy (marked sample letter) enclosed. There were slight modifications made from this letter by different individuals for different areas. The variations were in the fourth paragraph, where the hours of

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ENGINEERING DRAWING DIVISION
INDUSTRIAL RELATIONS SURVEY

Number of Replies Rec'd.	Favorable	Unfavorable	No. Rdc't. Time	Add Time	Less Time	Sp. Mention Desc. Geom		Sp. Emphasis Sketch	Extend Prog. Beyond 4-yr.	Board Tr'g. In Industry		AREA	SOLICITOR
						Fav.	Unfav.			Start or in Prog.	Reluctance of Indiv.		
140	137	3	95	39	1	42	3	12	2	8	11	Ohio, Virginia, W. Va., Maryland	R. S. Paffenbarger Ohio State University
111	104	7	57	47	1	29	1	37	16	6	30	Chicago, Wisconsin, Minn.	H. C. Spencer Illinois Inst. Tech.
110	100	1	27	31		36	2	15	12	8	1	New England States	M. McNeary Univ. of Maine
92	90	2	68	19	3	25	1	14	14	9	7	New York Pennsylvania	I. Wladaver New York University
73	69	2	59	19		19	1	2	11	2	2	Illinois (Outside Chicago)	C. H. Springer U. Illinois
72	68	4	32	20	2	4		6	11	1		New Jersey Delaware	F. A. Heacock Princeton Univ.
55	55		52	5	1	21	1	4	12	2		Texas and So. States	W. E. Street Texas A and M
48	48		30	11		12	1	3.	11			Michigan	J. Gerardi Univ. of Detroit
31	27		16	2	4				3			Florida	E. W. Jacunski Univ. of Florida
19	22		19	3		4	1	2	1	3		Indiana	W. J. Luzadder Purdue University
11	11		1	1				1	1			Kansas Nebraska	F. A. Smutz, KansS T. T. Aakhus, U.Neb.
5	5		3	2								California	L. R. Schruben Univ. of S. Cal.
767	745	19	459	199	12	192	11	96	94	39	51	TOTALS	

basic instruction were changed between 200 and 280 class hours in accordance with that which prevailed at the solicitor's university.

The committee members, together with others selected to assist in this survey, have forwarded all replies to their letters and I have coordinated the results. Eighty-three per cent of those solicited replied, which constituted 767 letters. The various totals from these letters are tabulated on the attached survey sheet.

Since this was not a questionnaire type form, it gave those who replied much more freedom of expression. A breakdown in many phases of expression is shown on this tabulated summary. Over 97% of those replying were favorable toward the information contained in the letter. Only 1 1/2% of the replies favored any reduction in instructional time in basic drawing and descriptive geometry. This survey proved conclusively to our committee that an overwhelming majority of industries favor retention of all engineering drawing and descriptive geometry courses that are being taught in our colleges and universities, and many of these favor an extension of time of instruction for these courses. Just a few of the items that received special mention were tabulated. It is interesting to note that over 12% favored extension of the program beyond 4 years. Replies from several sections of the country did not mention this since many schools are now on programs over 4 years.

I am also enclosing copies of 69 of the letters received in this survey so that you and your committee may fully understand the strong feeling in industry on some of this curtailment. I regret that expense of reproduction prevents me from sending you the entire 767 letters, but I shall be glad to furnish a list of all companies replying. These letters are from different sections of the country and represent a cross section of opinion of the entire United States. The industries canvassed were selected from the Thomas Register of American Manufacturers, Poors Index, and other similar sources. The majority were those capitalized at $1,000,000.00 or over.

I sincerely hope that you will not feel that our committee is encroaching upon your study. We will be only too glad to furnish additional assistance if it would aid in properly evaluating this problem.

Copies of this letter, typical solicitation letter, and a tabulation of our results are being sent not only to members of your committee but also to all members of the Follow-Up Committee on the Evaluation Report and the officers of the Society.

Yours sincerely,

RALPH S. PAFFENBARGER

Ralph S. Paffenbarger, Chairman
Industrial Relations Committee
Engineering Drawing Division, ASEE

RSP:ec
Enclosures

Since the above letter explains several of the details of our committee's procedure and some of the analysis of results, I will brief only a few things other than those mentioned. The letters of inquiry did not ask for specific comment on any particular course or topics covered in these courses. Nevertheless, many voiced their sentiments on things which should be especially emphasized.

Just a few of these show in the tabulations. The columns marked "Board Training in Industry" refers to those companies which start their young graduates in drafting and design as well as the reluctance of many of these employees to working on the board. Many companies still include a period of drafting as a part of their training program.

A few replies are also reprinted here to show how emphatic some companies are relative to their views on this instruction and unprepared personnel.

To summarize results, our committee feels that this furnishes conclusive evidence that an overwhelming majority of industry approve as much or more instruction in engineering drawing and descriptive geometry than the present-day student in engineering is now receiving.

On behalf of the committee I would like to thank all who assisted us in gathering these data. We had wonderful cooperation from many people besides those listed and we want you to know that your help was greatly appreciated. Further effort will be expended in making our results known.

The following excerpts from letters in reply to the survey are thoroughly typical. They have been chosen because they are typical. The excerpts have not been taken out of context in such a way as to misrepresent the intent of the signers of the letters. On the contrary, the samples that have been selected are representative of opinions held by important officers of prominent companies. In each case following, the name of the company is given together with the name of the signer of the letter and his official title in the company. The chairman of the Industrial Relations Committee invites queries about any of the letters excerpted below:

From THE GLENN L. MARTIN COMPANY,
Baltimore, Md.
Signed by H. Pusin, Chief Engineer:

"In my opinion, the basic engineering courses of descriptive geometry and engineering drawing are of extreme importance to the engineering student. These basic courses provide the background necessary for the engineer to properly present his own ideas as well as to understand the engineering language of others. We believe that the only way an engineer can become a competent designer is by designing and that this requires a thorough understanding of these basic courses. Further, as an industrial organization employing engineers, we believe we are much better equipped to train a graduate engineer in the details and specific applications of his chosen specialty as applied to our work than we are to provide training in basic engineering courses.

"In addition to our strong opinion that the basic courses mentioned in your letter should not be deemphasized, we are also concerned with the reluctance of many engineering graduates to accept "board work". In our business, the largest portion of our design work is accomplished by engineers working out their ideas by layouts and, in the final form, by the preparation of engineering drawings. If an engineer is to become a competent and well-recognized designer, we feel that he must accept this type of assignment until, by experience and demonstrated ability, he can fill a more advanced position. We have found in some of our newly employed engineers a reluctance to accept this type of assignment and believe that a re-evaluation of this subject by the engineering colleges is in order so that the graduating engineer may come to industry with a more realistic approach to the work that he will be doing."

From RADIO CORPORATION OF AMERICA,
Camden, N. J.
Signed by S. H. Watson, Manager, Corporate Standardizing Division

"Any engineering graduate whose work in industry is associated with the design of end products and includes the supervision or direction of draftsmen, model makers and tool makers in the process of product development and design is seriously handicapped if he is not well grounded in the fundamentals of drawing practice, descriptive geometry, dimensioning and tolerancing and shop practice. Inadequate education and training in these fields can seriously retard individual advancement, compromise product design, contribute to inordinately high tooling and manufacturing costs and impair mutual respect and confidence between engineering and manufacturing personnel.

"Engineers whose efforts are devoted to pure research and advanced development do not feel the impact of this deficiency to so great an extent but nevertheless are frequently hampered, consciously or otherwise, due to their inability to effectively express themselves and interpret the expressions of others through the medium of the engineering drawing.

"Some years ago a new deal was introduced in the teaching of reading and writing in elementary schools. As a result, I am informed, high schools and colleges are now dealing with an alarming number of students who cannot read and write properly. I hope this type of mistake will not be made in basic engineering education.

"I trust this is the type of comment you seek and wish the ASEE committee every success in stemming the rising tide of degradation in engineering education."

From AMERICAN MACHINE AND FOUNDRY COMPANY, Greenwich, Conn.
Signed by Jay H. Bergen, Director, Engineering Services Laboratory

"We strongly oppose reduction in the time devoted engineering drawing and descriptive geometry courses in engineering curricula. Although an engineer must know far more than engineering drawing or drafting, he still must be able to express his use of math and physical sciences in the form of a drawing or sketch. Otherwise his effectiveness is severely limited.

"The trend of engineering graduates towards work other than design should not change the fact that design is the basic element in engineering. Any further reduction in engineering drawing will seriously impair this design function. The engineer must learn the pictorial language of engineering before he can adequately express his engineering ideas.

"There are several dangers in reduction in engineering drawing training. If engineers cannot design, the function will fall to subprofessionals with consequent loss to the profession and reduction in quality of the work. The graduating engineer may think that design is not a promising career and tend to avoid it. Also, his usefulness to his employer is reduced and on-the-job training in engineering graphics becomes necessary."

From THE NATIONAL CASH REGISTER COMPANY, Dayton, Ohio
Signed by W. C. Rosener, Technical Assistant to Vice President in charge of Engineering & Product Development

"We in Engineering at NCR definitely feel that most Engineering graduates are lacking in their ability to understand basic mechanisms due to inadequate instruction in the design and descriptive geometry fields. We realize that many engineers will enter fields other than the creative end, but for the true creative engineer, we feel that these courses are very essential."

From LOCKHEED AIRCRAFT CORPORATION, Marietta, Ga.
Signed by T. C. Pritchard, Chief Draftsman

"We welcome the opportunity to voice our opinion on the reduced training in graphic expression being provided for engineering students, by some colleges today.

"The effect of the curtailment of this course is evident in that it has been necessary for us to establish our own training course to in simple drafting and descriptive geometry for new graduates joining our Engineering Organization. Some of our new hires have been almost completely devoid of knowledge in descriptive geometry and basic drafting practices, making their immediate utilization in design work impossible.

"Since graphic presentation is the language by which the engineer expresses his knowledge, severe curtailment of this, in the engineer's education, will, of course, hamper his ability to convey his idea to the people by whom they will be used. Unless he is reasonably competent in graphic expression, his abilities are lost for all practical purposes.

"Frequently, new engineers arrive, not only deficient in the ability to graphically express themselves, but imbued with the idea that it is insulting to ask them to draw. They seem to feel they are ready to take over the administration of a design activity. "Beefing-up" drafting courses would tend to overcome the shock of finding that drawing work is a normal requirement.

"It is gratifying to know that this educational shortcoming, that is evidently developing, is recognized, and corrective action is being taken.

"Industry's immediate utilization of newly graduated engineers would certainly be improved, if college drafting courses were always adequate. It should not be necessary for Industry to immediately continue a new graduate's education, before deriving any benefit from him."

From GENERAL MOTORS CORPORATION, Detroit, Michigan
Signed by Roy P. Trowbridge, GM Engineering Standards

"I believe that engineering schools do their students a disservice when they shortcut fundamentals of engineering for the purpose of crowding into their curricula courses leading toward specializations which the engineering student may or may not follow upon graduation.

"The current de-emphasis on drafting instruction in the colleges is, to my mind, a sad thing. Drawing is to the engineer what the written word is to the professional writer. Although neither the student of engineering nor the liberal arts student can be expected to be of high professional ability on graduation from college, it is to be expected that they should be well grounded in the fundamentals of their chosen field.

"De-emphasis of drawing in engineering curricula creates the impression in the minds of young engineers that work on the drawing board is undignified and that he would be stepping beneath his caste if he were to accept a job which involves drawing. This impression is false. The drawing board is one place where all problems connected with design, materials, manufacturing, and assembly are fully explored and documented. Most top engineers in the automotive industry today owe a measure of their success to the lessons which they learned on the board.

"I heartily agree with members of the Industrial Relations Committee of the Engineering Drawing Division, ASEE, that further curtailment of engineering drawing would be a grievous error on the part of our engineering schools."

From AMERICAN BRIDGE, Pittsburgh, Pa.
Signed by J. D. Rollins, Vice President—Engineering

"It is our opinion that many colleges have already reduced the time for instructions in engineering drawing and descriptive geometry to below the minimum required; further, the graduates have the impression that engineering drawing work is subprofessional and should not be performed by them. It is our belief that such an assignment is fundamental for the young engineers and that six to twelve months' experience is vital to their future development."

From FEDERAL TELECOMMUNICATION LABORATORIES, Nutley, N. J.
Signed by Andre G. Clavier, Vice President and Technical Director

"We asked a number of our Drafting Department supervisors to comment on your remarks; excerpts from their opinions are listed below:

" 'I am in complete accord that drafting should be augmented rather than curtailed as indicated by ASEE. Some engineers now employed have no drafting background and it is very difficult for them to express themselves.'

" 'It is my opinion that the engineering drawing course should be strengthened because we have experienced some difficulty in trying to get engineers to understand layouts and drawings. If the engineer had a better understanding of reading drawings, it would result in a saving of both engineering and design time now lost in explanations.'

" 'If an engineer is to understand many of the conditions and requirements as we find them in today's industry, then surely more classroom hours are necessary. As we progress year after year these engineers must of necessity become more skilled in every way than their predecessors and, in my opinion, the more suited for industry they can become before graduation, the more valuable a person he is in actual Engineering practice.'

" 'My suggestion is that, if anything, the drafting courses should be expanded. I suggest that formal drafting be de-emphasized and great concentration be given to free-hand sketching, basic dimensioning, tolerancing methods, some cost coverage as costs of fabrication go up with decreasing tolerances, practical casting, and sheet metal design. Also, some coverage of welding techniques and its limitations.'

" 'I agree that engineering students should receive more, not less, instruction in engineering drawing. An engineer who cannot read a drawing or effectively sketch out his ideas is handicapped in his communication with the drafting department which, after all, must make the drawing which reflect engineering efforts.'

" 'Past experiences with engineering personnel has convinced me that their training in graphic representation has been sadly neglected and/or very poorly organized in engineering colleges. Any curtailment of instruction in this subject is ridiculous and unfair to the engineering graduate and the company who employs him.'

" 'A strengthening rather than curtailment of engineering drawing courses is certainly recommended. The majority of engineers, and this is not exaggerated, have little knowledge of simple perspective sketching, plan reading, thinking in the third dimension or even the ability to speak in the language of the designer or draftsman.'

"While the above information is certainly forceful, it represents the opinions of those who are actually producing drawings at the direction of engineering personnel. We also queried some of the engineers on the problem. A typical point of view was expressed as follows:

" 'There is too much exercise or practice in the present Engineering School drafting courses. It does not seem desirable to spend too much time on skill or lettering or extreme neatness in drawing. The engineer should spend more of his time in learning the basic principles of drafting and methods used. He should learn to read various kinds of blueprints and be able to make simple freehand sketches in both two and three dimensions. Emphasis should also be placed on simplicity of design as a means for reducing cost of the manufactured product. A working knowledge of machinery and its capabilities is basic to such simplified design.' "

From AMERICAN INSTITUTE OF STEEL CONSTRUCTION, New York, N. Y.
Signed by L. Abbett Post, Executive Vice President

"We therefore urge that your committee continue its efforts to strengthen these basic courses in graphics and try to prevent any shortening of the hours assigned to this work in engineering colleges."

From MINNEAPOLIS-HONEYWELL REGULATOR CO., Minneapolis, Minn.
Signed by A. Lachlan Reed, Director, Industry-Education Relations

"In the direct contact we have with faculties and students at universities, and through the graduates who come to us, we know that the significance of competence in the area of engineering drawing can hardly be overrated. We feel very strongly that the ability to make a useable drawing is one which must be cultivated rather than allowed to languish. A great many young engineers cannot make satisfactory technical sketches, and we foresee that if there is a continued diminution of the drawing and descriptive geometry courses, this tendency will be accelerated with possibly very serious consequences.

"I might add that recently when we undertook to lend some of our top engineers as instructors at a nearby university, we found that the ability of their students to make sketches was so lacking that we brought in a specialist who gave them a rapid course on the fundamentals of drawing. While I do not mean to suggest that this situation is endemic, it is indicative of what may be happening on a broad scale. We ourselves feel very strongly that such abilities should be strengthened rather than weakened. At the same time, educators always face the problem of a wise apportionment of teaching time and teaching emphasis. Wisdom suggests the importance of not overlooking the crucial significance of engineering drawing."

From CLIFFORD MANUFACTURING COMPANY, Waltham, Mass.
Signed by S. I. Gabrielson, Chief Engineer, Bellows Division

"Any reduction in graphic instruction as part of the basic engineering curriculum would be definitely in the wrong direction. My own personal experience as related to engineers with whom I have been associated as a supervisor or co-worker shows a definite lack of understanding in basic drawing fundamentals.

"For example, it is becoming increasingly important that engineering personnel understand the fundamentals of descriptive geometry expecially as related to the aircraft and allied industries. In studying the design of all airborne components, it is very necessary for engineering to be able to describe pictorially various attitudes of a plane or missile in flight. This is important for mechanical, electrical, and electronic engineers in order to evaluate design of any component in the initial development stages, as to whether or not the proposed design will function properly under all flight conditions.

"The above is but one example wherein proper teaching in the graphic arts is important for engineering, but just in personal experience alone, many more could be cited.

"You state that most engineers receive about 200 class hours of basic instruction and supervision in graphics. This is certainly a basic minimum and any curtailment of this program would seriously affect the efficiency of a young engineer attempting to progress rapidly in his profession. Personally I believe most industries would like to see more of this training rather than less. We realize this is not entirely possible because proper consideration to other basic engineering studies, that are equally important, must also be given.

"It is my firm conviction that engineering drawing and graphics should not be curtailed but strengthened particularly for mechanical, electrical, and electronic engineers. Complete understanding of this phase of engineering is absolutely necessary to produce efficient and dependable designs for the constantly growing needs of our industries today.

From SOCONY MOBIL OIL COMPANY, INC., New York, N. Y.
Signed by R. E. Jenks, Asst. to Paul W. Boynton, Co-ordinator—College Recruiting

"We submitted your letter to two engineering divisions of our Company. Their replies indicate that they have given serious thought to the matter. We quote below excerpts from the remarks of two of our chief engineers:

" 'It is our opinion that the proposed changes in engineering education is a serious mistake.'

" 'Drafting is the language of the engineer, in the same manner as shorthand is to the stenographer or Latin to the doctor. Without a common language the designer is unable to pass his design to the draftsman, or the structural field engineer to follow the design as described in the drawing.'

" 'The elimination of drafting would be to eliminate his foundation.'

" 'We definitely feel that every engineering graduate should come to us with some knowledge of engineering drawing. We would be extremely unhappy to have to employ graduates who have no knowledge whatsoever of the subject. If colleges were to turn out people with no training along this line then we would have to train them after they came to us and this we should not like to find it necessary to do. The graduate who comes to us now is seldom much of a draftsman. He usually just has a basic idea of the subject with only a limited knowledge of industrial practices. In many cases we feel that these men should go into the drafting room for a period but we find many graduates just refuse to do this for fear that they will be 'stuck at the board' for life. This fear seems to be instilled in them by some of their professors who advise them to stay out of the drafting room at all costs. If graduates come to us in this frame of mind with no training in drawing, we doubt if they would very receptive to the idea of taking a concentrated course in the subject after they are hired or to going into the drafting room for a couple of years. This only reinforces our feeling that the time to teach engineers a basic knowledge of engineering drawing is before they come to industry.

" 'In our opinion the engineering graduate should be able to make simple orthographic projection drawings. He should be able to make isometric and cabinet projection sketches and should be able to read the usual mechanical, civil and architectural drawings used in industry. He should be able to do these things even though he never has to make a finished drawing himself.

" 'There is one comment which we might make on the teaching of engineering drawing and its place in the education of young engineers:

" 'We appreciate the problems that the colleges will have in putting more general courses into the engineering curricula but we certainly feel strongly that there is an irreducible minimum of knowledge of engineering drafting which every engineering graduate should have before he comes to us.' "

An Appraisal of Simplified Drafting

By J. Gerardi

University of Detroit

When Mr. Rattner asked me to participate in this panel, I was reluctant to accept the invitation because the theme—"Simplified Drafting, Its Contribution to The Total Engineering Effort"—implied that results of extensive statistical investigation were to be reported and appraised for this audience. I am not an industrialist, nor do I have the time or means to conduct an impartial study of such a complex and somewhat controversial subject. Mr. Rattner informed me that the purpose of this discussion was not to give the audience specific examples of simplified practices, but to evaluate these concepts in view of the fact that these practices had received nation-wide attention and that the amount of experimentation seemed to justify an appraisal.

Having been directly involved in extensive reviews of the drafting practices presently used by two large corporations located in Detroit, and because engineering education is implementing some innovations which may have an effect on the supply of competent draftsmen, I thought that I could contribute a few facts which might be of value to your future plans. Moreover, I had been branded as a complainer by the "Wall Street Journal" and a sense of pride motivated me to meet, once again, with those who were here last February, and with my friends on the panel.

The purpose of this presentation is to show the relation of drafting to engineering, the importance of a competent draftsman and his contribution to the engineering effort. I shall also attempt to show that simplified practices which have been proposed for implementation in industry do not and cannot relieve the shortage of competent draftsmen, and that different requirements in the training of engineering personnel may further complicate the present situation relative to the utilization of engineering draftsmen.

Industrial concerns are in business because they have products to sell. If top management decides that the product is marketable and approves an appropriation for manufacture, the project is usually engineered for design and development. During this phase of the work engineers concern themselves with stresses, deflections, physical and chemical properties of materials, vibration, heat transfer, efficiency and other engineering sciences. Usually this kind of work is beyond the duties normally assigned to design draftsmen, manufacturing, processing, and inspection personnel. In other words, engineering is responsible for the mathematical and scientific requirements of a project. Having analyzed and solved these problems two paths which lead to manufacturing are open. The engineer can take the freehand sketches, which are decorated with mathematical symbols, computations, and notes to the shop or laboratory, or he can have working drawings made without the technical "gobbledegook" which is of no interest to the technicians. The path the engineer chooses depends on time, complexity of the product, whether the product is to be mass produced or custom built, and many other factors.

If a product is in its early stages of development and if the engineering offices and shops are within walking distance, the engineer who insists on having preliminary drawings made in ink on tracing cloth with shading and ornate lettering should be fired, or given Messrs. Healy and Rau's book on "Simplified Drafting" to learn the facts of life. The contribution the book would make to this kind of engineering effort would be phenomenal.

If, however, the product has been through its initial stages of design and is to be manufactured at an inconvenient distance from the engineering department, drawings should be made according to American Standard practices, using every concept of simplification which has been documented. If the drafting supervisors were to encourage and enforce the simplified conventions illustrated in the American standards, their contributions to the total engineering effort would also be phenomenal. These are old chestnuts, so let us move on to something more important.

What has evolved from investigations and experiments relative to simplified drafting techniques? The book "Simplified Drafting" and the numerous brochures which have been published and widely distributed have made industrial concerns, large and small, conscious of drafting costs and have made them take a good look at the practices used in their drafting rooms. Regardless of whether or not the practices illustrated and proposed in the literature were adopted, the fact remains that in many cases, top management, vice-presidents and general managers, became interested in the statement made in the Wall Street Journal that the American Machine and Foundry "sees possible savings of $720,000 per year for the laboratory's two hundred man staff." Who wouldn't be interested in saving $3600 per man per year? Now let's do a little evaluating.

As a result of recent publicity, one large corporation (Company A) called a meeting of all its divisions' chief draftsmen and engineers for the specific purpose of making a thorough review of its drafting practices and reporting its findings to the vice-president in charge of engineering. The committee reported that principles of simplification such as omission of dotted lines, omission of elaborate pictorial, and repetitive detail had been recognized and in use for many years, but, that the practices advocating use of symbols, unconventional short cuts, so called "datum dimensioning" and the use of descriptive notes to replace actual drawings could not be applied without disrupting the operations of the entire corporation.

Corporation "B" had issued in printed form simplified practices to its draftsmen. Following two years

* Presented at the Drafting Institute, University of Wisconsin, December 1956.

of experimentation, the practices were discouraged because confusion predominated in view of the fact that some of its divisions utilized the proposed techniques and some did not, and disagreement between drafting supervisors made enforcement almost impossible; the purchasing department had all it could do to interpret standard drawing for the company's suppliers and could not take on the added burden resulting from short-hand drafting. Result—no simplified technique to be used on drawings except those prepared for local internal communication.

Company "C" reviewed its company standards because of the present activity in ASA—Y14 and SAE. New concepts of simplified drafting were also considered. Result—all useful principles of simplification which it could use were found in all documents. No two documents on simplified drafting agreed on new methods of simplification or their interpretations and of course could not be adopted. A cost analysis showed that approximately $40,000 had been saved in the corporation resulting from bringing the company standards which were based on national standards and that most of this saving resulted from reduced cost in training drafting personnel.

It has been argued that the shortage of competent drafting personnel and the change in the present national situation has made it expedient to introduce the proposed methods of conventionalizing a drawing. I submit that there is no justification for this kind of logic. Moreover, what is meant by a competent draftsman? To my way of thinking, a competent draftsman is one who understands how to delineate and specify information on a drawing in a manner which leaves no doubt as to the function of a part, or parts, in an assembly. The competent draftsman has by training and experience learned to appreciate some principles of mathematics, physics, and chemistry, which are inherent in most designs. He will have learned that statics is not a phenomenon peculiar to radio, that dynamics is not necessarily a characteristic monopolized by Marilyn Monroe, and that the best example of fluid flow is not in Joe's Bar.

A competent draftsman is analogous to the engineer's eyes. It is he who can show the engineer that his structure is statically unbalanced. It is he who can show the engineer that a costly error has been made in his mathematical calculations. It is he who can show the engineer that the dimensions, implied manufacturing specification, and tolerances have raised the cost of the product to a point where it may be necessary to "re-engineer" it. A competent draftsman is quite a person. He must be an expert on dimensioning, tolerances, and know something about planning, tools, manufacturing, inspection, not to mention algebra, trigonometry, descriptive and analytic geometry, and an understanding of some phases of statics and strength of materials. No books or brochures on simplified drafting can do all this. Hence I submit again that it is not expedient to introduce "simplification" because of a shortage of "competent draftsmen."

Regardless of my opinion on this subject, it appears that the "goose that lays the golden egg" is rapidly becoming an extinct animal. Until 1948 and even today, a large number of engineers are actually serving as engineers and technicians. The young engineer accepted and even looked forward to the beginning of his career in a drafting room. There was a feeling of accomplishment, dignity, pride and technical competence implied in the fact he had hurdled the first obstacle in a profession. Today this condition no longer exists. The draftsman has become a specialist in his own right and the engineering graduate is asked to bypass this area of specialization in favor of more advanced technology. Today the engineering graduate must have some knowledge of engineering, and a good foundation in engineering science. In these days of jet propulsion, electronic computers, ultrasensitive complex control systems used in guided missiles and man-made earth satellites, the engineer, like the physician, must know the latest scientific facts as they exist at the moment and engineer his product in a manner which he hopes is better than that of his competitor. Our economy demands a high standard of living and a technological superiority which can challenge any aggressor.

Our government is spending 40 billion dollars a year on national defense. A good share of this money is allocated to research and development to maintain our technological superiority. Moreover, industries themselves have seen the benefits which can be derived from scientific research, with the result that engineers must have more training in mathematics and science if they are to serve this complex and versatile economy of ours. Engineers get their training in colleges, and since the engineering curricula cannot be extended to six or seven years, it follows that if more engineering science is to be added, something must give way. Engineering Drawing has been chosen to make the "supreme sacrifice" and now less than 4% of the total number of credits required for graduation are in the field of graphics. In most colleges only 1 (approximately 30 hours) of the 4% is devoted to drafting and the other 3% is used to teaching graphical solutions of mathematical problems. Let me give you an idea what is in the minds of a majority of engineering teachers regarding drawing courses. Professor B. L. Wellman, of Worcester Polytechnic Institute does this so well that I quote from a paper he presented at the June '56 meeting of the American Society for Engineering Education.

> "The ability to read a multiview engineering drawing is absolutely essential to success in engineering. The ability to make such a drawing is definitely secondary. We should therefore concentrate our instruction on the first, and minimize the second.
>
> Consider, for example, the case of a small machine unit that consists of several dozen parts. Give the student a photograph of the assembled unit and a complete set of working drawings for each part. In about one hour he can study the detail drawings, observe the place and function of each part, and understand the entire unit well enough to answer twenty brief objective questions about it. Another

hour of discussion by the instructor will clarify and resolve all remaining questions of any importance.

Of first importance is instruction in sketching and the continual use of sketches at every opportunity. The technique of sketching can be taught in a few hours at the very beginning of the course. Thereafter, every drawing principle that can be satisfactorily demonstrated with a sketch should be drawn freehand. Straight edges, scales, and quadrule paper should not be allowed. Sketches can usually be made in half the time required with instruments, and if the lines are reasonably straight, the proportions approximately true, and the method of solution correct, the sketch is entirely satisfactory. The beauty and accuracy of the sketch is not important, but the solution is. The idea of sketching engineering problems should be so thoroughly inculcated that the student will carry it over into all of his subsequent courses."

Can you imagine how much the engineer who has this kind of training in drawing will know about drafting? Several years ago (1954), in discussing this subject with Mr. Rau in New York, I predicted that he need not worry about simplification of drawings, but that he and other industrialists should be more concerned with the fact that the training in drawing received by an engineering student could be so meager that when asked to draw "a plan view" he might ask "What is it?" My prediction has materialized. What does all this have to do with simplified drafting? Just this—

Industry must assume the responsibility of training its own competent draftsmen. For its own sake, it must give its draftsmen training which can be used regardless of his place of employment. If industry really believes in standardization, and if industry wants to reduce its training cost, then the cheapest, best, and most efficient training which can be given to develop competent draftsmen is to teach and advocate the practices which have been acknowledged, debated, reconciled, approved, and standardized by such agencies as the ASA, SAE, ASME, ASEE and others.

What contribution does an effort of this kind make to the total engineering effort? Would it not be priceless?

It may be of interest to inform this audience of the action taken by the S. A. E. Joint Aeronautical-Automotive Drawing Committee which met in New York on October 12, and the Executive Committee of ASA-Y14 which met in Washington October 19, 1956. It was agreed that, as in the past, accepted conventional (simplified) practices would be illustrated and placed in the appropriate sections of their respective manuals. I can also assure you that both groups are conscious of many other improved practices and innovations particularly in dimensioning which have evolved since their last standards were published. These will be included in the new standards, and should be published following an ABC conference which is scheduled to take place next Spring.

The conclusions are evident. Simplified drafting techniques may be profitable if used locally, but cannot be tolerated where communication involves a large number of people or inconvenient locations. The competent draftsman has become a specialist whose knowledge is no longer limited to the delineation of drawing, but who is required to know technology which formerly was performed by engineers. Engineering education is changing rapidly as a result of the impetus of science and research in our industrial economy; as a result fewer and fewer engineering students and graduates are asked to begin their careers in the drafting room, thereby contributing to the shortage of draftsmen. Simplified drafting does not and cannot relieve this situation. Finally, most of the new concepts of simplification have not been adopted by industry or by authorized standardizing agencies.

In attempting to evaluate the contribution which simplified drafting has made to the total engineering effort, I took the liberty to presume that the word "contribution" is relative. Obviously each of us has his own idea as to its value. No doubt, you have yours.

Convolute: The Basic Developable Surface

By F. O. Leidel

University of Wisconsin

There are three curved surfaces that are developable—the cylinder, the cone, and the convolute. Although the cylinder and the cone are the simplest, the convolute is the most basic and the most useful, as this article will establish.

Developable curved surfaces are one of the two types of ruled curved surfaces; curved surfaces of the other type are called warped. Ruled curved surfaces are those that can be generated by the motion of a straight line. The various positions of the generating line are called elements or mantle lines. If adjacent elements are either parallel or intersecting—that is, if adjacent elements lie in the same plane—then that ruled surface is developable. If adjacent elements are non-parallel and non-intersecting—that is, if adjacent elements do not lie in the same plane, then that ruled surface is not developable, but warped.

Adjacent elements of the cylinder are parallel. Adjacent elements of the cone are intersecting, and all of the elements of one cone intersect at a single point. The convolute is more complicated; its elements, if considered sufficiently close to one another, will intersect, but only two by two. That is, adjacent elements will intersect, but elements not adjacent to one another or not sufficiently close to one another will not intersect. In one sense, the convolute is like a cone with adjacent elements intersecting at a vertex, but with successive pairs of elements having different vertices.

The convolute can be defined either by its generating lines or by enveloping planes, as follows:

Definition I: A convolute is the locus of all of the lines that are tangent to one space curve.

Definition II: A convolute is the curved surface enveloped by the family of planes tangent to two curved lines not in the same plane.

Figure 1 shows orthographic top and front views of a right helical convolute, which is the classical example of a convolute by Definition I. Its elements are the tangents to a directing helix. In the sense that the elements are not all the same length, and are therefore not the locus of the position of a single real line in motion, this might be considered a truncated convolute. It is a right helical convolute because its base is perpendicular to the axis of the helix. If its elements were to extend on both sides of the tangent point on the helix, then the convolute would have two nappes, just as a cone extended on both sides of its vertex has two nappes. The base curve of this convolute is an involute. The curve of any right section, such as that cut by horizontal plane h'h', is also an involute. If the directing curve were a space curve other than the helix, then the surface would still be a convolute, but not a helical convolute.

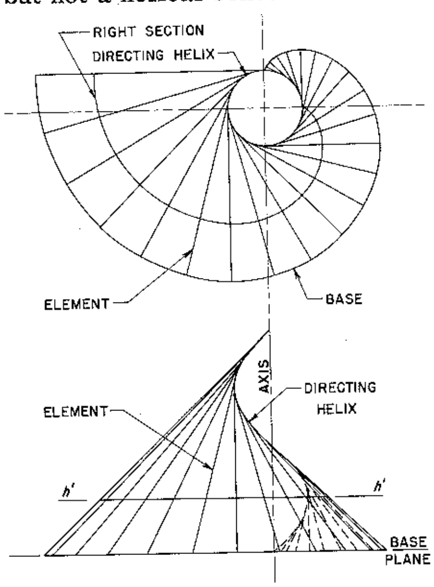

Fig. 1

Figure 2 shows orthographic top and front views of a convolute that has been generated in accordance with Definition II. The directing lines for this convolute are two curved lines in parallel planes, which might be considered rim lines of bulkheads of the surface. A plane tangent to the two rim lines as shown can be represented by two lines, one tangent to the one rim line and the other tangent to the other. Since the two bulkheads are parallel, to be in the same plane with each other the two tangents must be parallel. The element of the surface connects the two tangent points, and is the line of intersection of the tangent plane and the convolute surface. Successive elements are obtained by rolling the tangent plane to

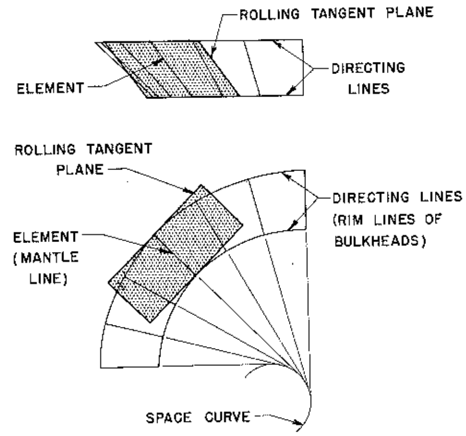

Fig. 2

successive positions, one of which is shown in Figure 2. If successive elements are drawn sufficiently close, and if they are extended (as in the front view of Figure 2), they will intersect one another two by two, and it will be possible to construct a space curve tangent to (or enveloped by) those elements.

As a matter of fact, the bulkhead rim lines for Figure 2 are involutes (identical to a portion of the involutes of Figure 1), the space curve tangent to the extended elements is a helix, and the surfaces of Figure 1 and Figure 2 are portions of the same helical convolute. Bulkhead rim lines of a different curvature would also direct the rolling plane to generate a convolute, but it would not be a helical convolute.

Definition II does not preclude the possibility of a convolute directed by rim lines of two non-parallel bulkheads, as illustrated by Figure 3. In this case,

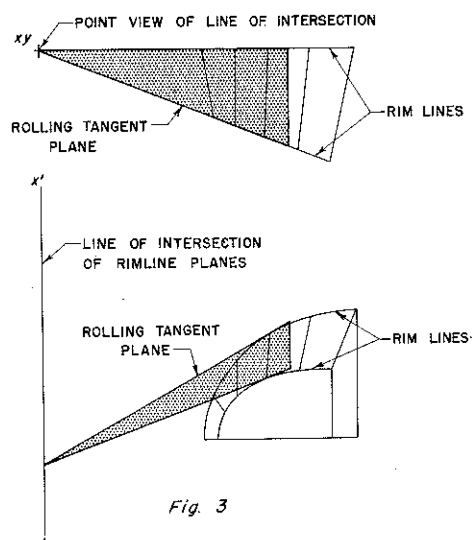

Fig. 3

the rim line tangents that determine any one position of the rolling plane are not parallel, but intersect along the line of intersection XY of the planes of the bulkheads.

Neither does Definition II preclude the possibility of a convolute directed by rim lines that are space curves rather than plane curves, as illustrated by Figure 4. In this case (which will seldom occur in practical work), the rim line tangents that determine any one position of the rolling plane may be parallel or intersecting, and are found by the trial-and-error method shown in the illustration. In this illustration, AB and CG are the rim lines, and XY is drawn tangent to CG at X. The problem is to find the tangent to AB that will be in the same plane as XY. This tangent, MN, is the result of two previous trials, and the check that MN is in the same plane as XY is the fact that intersection N projects from top to front view. MX is the resultant mantle line, and the work must be repeated to find additional mantle lines.

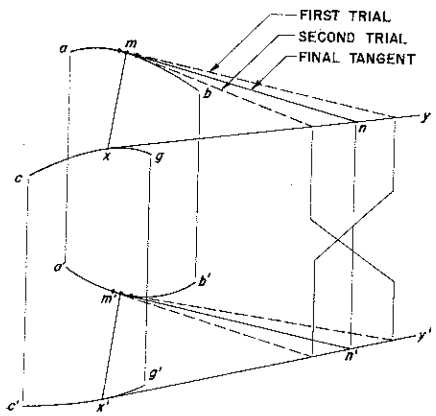

Fig. 4

The surface obtained by the application of Definition II to controlling bulkhead rim lines is a convolute only in the general case. If it is a convolute, it will be possible to extend the elements or mantle lines until they intersect, which they will two-by-two as explained at the start of this article. When the mantle lines are extended, a curve drawn tangent to the extended lines is the space curve of Definition I.

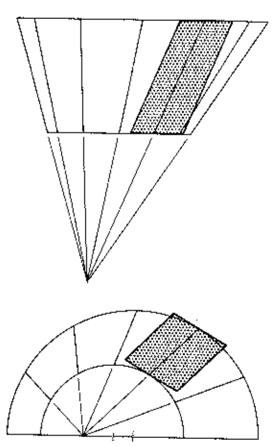
Fig. 5

However, if the rim lines of parallel controlling bulkheads are curved lines that are similar in shape but different in size, as in Figure 5, the mantle lines generated by the rolling tangent plane will, if extended, pass through a single point or vertex. The surface generated is therefore conical. In the sense that the surface generated by using the theory of the convolute has degenerated into a cone, the cone can be considered a degenerate convolute.

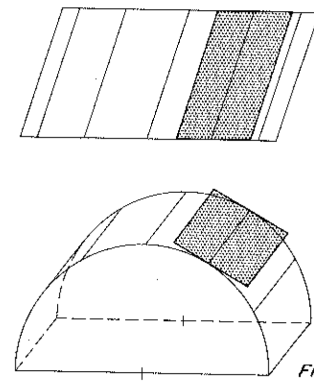
Fig. 6

If the rim lines of parallel controlling bulkheads are curved lines that are identical in size and shape, as in Figure 6, then the mantle lines generated by the rolling tangent plane will be parallel. The surface generated is therefore cylindrical. In the same sense that the cone can be considered a degenerate convolute, so can the cylinder be considered a degenerate convolute.

If the rim lines of parallel controlling bulkheads are one curved and one a series of straight lines as in Figure 7, the developable skin between them is

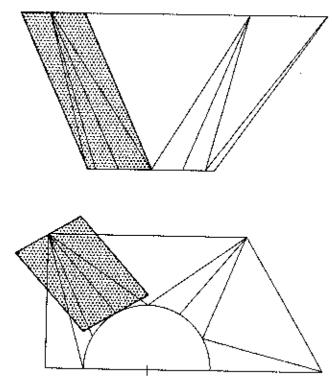
Fig. 7

what is commonly a transition piece. The rolling plane theory of the convolute is necessary to establish the proper mantle lines for the transition piece, which makes even the transition piece a degenerate convolute. (Even a plane is a degenerate convolute having straight parallel rim lines!)

Especially when using non-parallel bulkheads, or rimlines that are space curves, it is sometimes difficult to anticipate whether or not a convolute or a portion thereof might degenerate into a cylinder, cone, or transition piece. It is the concept of the

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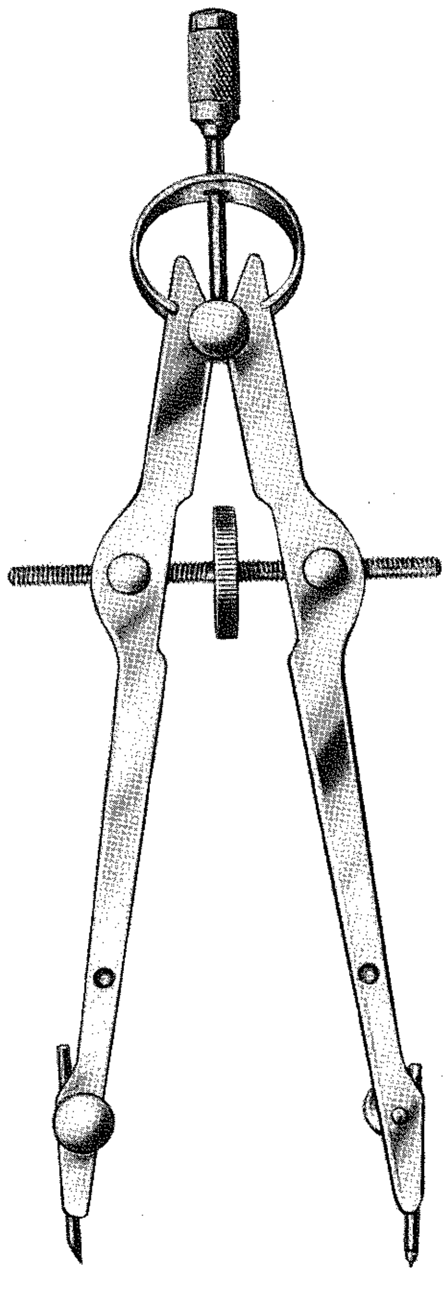

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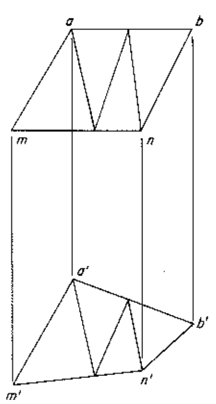
possible degeneracy of the convolute that makes it the basic developable surface.

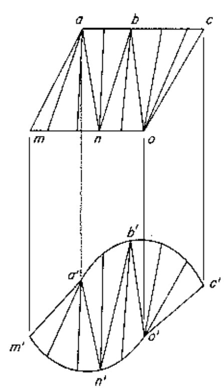
It is possible for the rimlines of directing bulkheads to control a surface that is in portions plane, cylindrical, conical, and convolutical. The surface will, however, blend from one to the other without an abrupt bend, unless the two rimlines each have an abrupt bend at the ends of a single mantle line.

There are two other rimline conditions that will not control a smooth developable surface between them, as follows: One, straight rim lines that are non-parallel non-intersecting, can be connected with a developable surface consisting of an arbitrary number of two or more triangular plane surfaces meeting abruptly, as in Figure 8. That the triangular segments meet abruptly is best understood after folding a sheet of paper into triangles similar to the surface of Figure 8, with the folds alternately up and down, and then holding the piece of paper with the edges corresponding to the rim lines straight, but skewed. (This rimline condition does determine a smooth ruled curved surface, the hyperbolic paraboloid, which however is warped and therefore not developable). Two, rim lines that are one convex and one concave, can be connected with a developable surface consisting of an arbitrary quantity of two or more conical surfaces meeting abruptly, as in Figure 9. The abrupt bends of Figure 9 are along mantle lines AN, BN, and BO which connect the vertices of the several cones.



AB & MN ARE RIM LINES

Fig. 8



ABC & MNO ARE RIM LINES

Fig. 9

Cones and transition pieces are traditionally developed by rotating all base or bulkhead rim lines, and all mantle lines, to true length, and then laying out the pattern by triangulation. Cylinders are traditionally developed by laying off lines of true length along the right section line and perpendicular to the right section line of the pattern, with the true length lines determined by auxiliary views if necessary. The following two methods are used in developing the true convolute:

I. The Extended Element Method: If adjacent elements are sufficiently non-parallel that they can be extended to intersect within practical space limitations, the convolute can be developed by triangulation, as in Figure 10. In this illustration, MP and AE are the given rim lines, which have been connected with mantle line PE, OC, NB, and MA by the rolling plane method of Figure 2 (the actual construction has been omitted). These mantle lines have been extended and found to intersect at W, and NB and MA intersect at X, which points V, W, and X project from top to front views, as they should if they are real intersections. Because they are horizontal, the rim lines appear true length in the top view. As samples, VE and VC have been rotated about an axis through V into the horizontal plane HH, in which position they appear true length in the top view. Note that, in rotating line VC, points W and D have been rotated as a part of the line, which then provides the true length not only of VC, but also the true length of VW and VO. After all of the mantle lines have been similarly rotated (actually the rotation of WB is the only one that has been omitted, since XA appears true length as given, in the front view), the pattern has been constructed as an outside development by the usual process of triangulation. It should be recognized that the traditional development of the cone derives from this basic construction; if points V, W, and X were a single point, the surface would be conical.

II. The Approximate Diagonal Method: If adjacent elements cannot be extended to intersect within practical limits, the convolute can be accurately developed

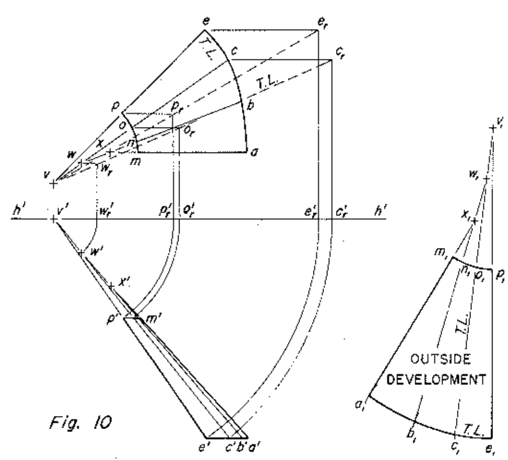


Fig. 10

by triangulation, by following the process suggested by Figure 11. Without extending mantle lines, beyond the rim lines, straight line diagonals are drawn between the mantle lines, all in the same general direction. Since the convolute is actually curved between the mantle lines, but the diagonals are assumed to be straight, a trial pattern obtained by rotating the rim line segments, mantle lines, and diagonals, to true length, and triangulating, will be short in the direction of the diagonals. If a second trial pattern is then developed using the diagonals in the opposite direction, that pattern will be short in the opposite direction from the first pattern. A final pattern drawn as an average of the two previous patterns will provide the proper correction for the assumed-straight diagonals. Note that the approximate diagonal method is applicable also to cylinder and truncated cone development, since it is a basic method.

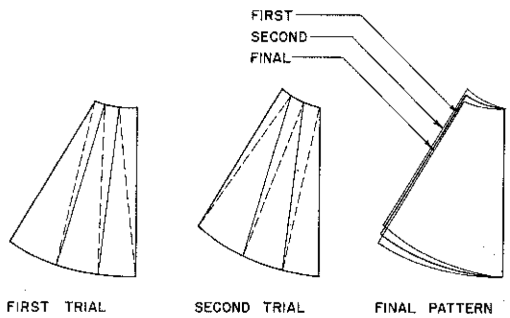


Fig. 11

It should not be overlooked that a practical (but not graphical!) method for developing a convolute is to trace two real bulkheads assembled in correct relative positions, as they are rolled across the pattern material, as in Figure 12.

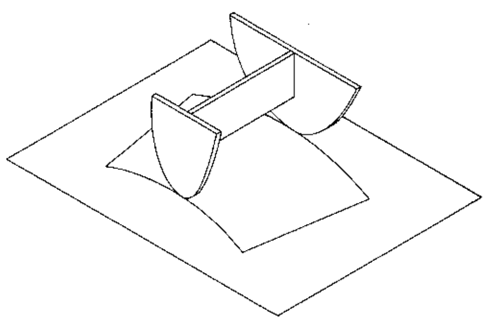


Fig. 12

The development of a convolute, even when accomplished by the Extended Element Method, is subject to the following four basic types of inaccuracy:

One, normal drafting inaccuracy, which can be kept within .01".

Two, the inaccuracy inherent in measuring chord lengths rather than arc lengths along the rim lines (or along the right section of a cylinder). This inaccuracy amounts to .0068 inches per inch of average radius of curvature if the measurement is taken between points that are 30 degrees apart, and only .0014 inches per inch if the points are 15 degrees apart. It can be corrected for mathematically in the case of the right section arc length of the cylinder, but must be controlled by careful drafting and judicious choice of element spacing other developable surfaces.

Three, the inaccuracy in locating ends of mantle lines by tangents drawn by eye. If the rim lines are known mathematical curves, such as the conics, there are graphical methods for determining exact points of tangency, which should be used. If the rim lines are not known mathematical curves, good accuracy can be maintained by assuming the exact point of tangency of a tangent line to be half way between the ends of the shortest parallel chord that can be seen.

Four, while mathematicians and graphical analysts are agreed that the convolute is a developable surface because its adjacent elements are intersecting straight lines and therefore lie in the same plane, in reality adjacent elements exactly intersect only in the limiting case when they coincide. Experience has shown that if element or mantle line spacing is sufficiently close to keep the chord length/arc length accuracy within reason, to assume that adjacent convolute mantle lines intersect will give no practical difficulty.

The author has made use of the information contained within this article while working for Hamilton Standard Division of United Aircraft Corporation, in the development of patterns for the skin of small sheet metal aircraft propeller blades, and aircraft propeller spinner plateaus. He has also used it in the development of boat hulls. It is used extensively in the aircraft industry. When used in classes in Descriptive Geometry, as is recommended, it gives the student an understanding of developments far beyond that which he obtains from the usual treatment of cones, cylinders, and transition pieces (but not convolutes).

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The Use of Ellipse Templates in Technical Illustration

By H. W. Blakeslee

Drexel Institute of Technology

The use of pictorial drawing, or as it is usually referred to, technical illustration, is becoming more common in industry. At present the companies making most use of it are in the aircraft industry. Some of the automobile companies are beginning to use it, and last summer at Ames, Iowa, a reference was made in one of the papers to the fact that it is being used for agricultural drawings.

The advantages of a pictorial drawing are that it looks realistic and an inexperienced person can recognize the parts and their relative location, while an experienced person can understand it readily and may even take measurements directly from the drawing. A logical use for this type of drawing is in the preparation of catalogues and instruction and maintenance manuals, and another use is to show clearly the arrangement of a complex pipe or wiring system.

These drawings usually fall into one of two classes:

1. Assembly drawings, showing the complete machine, with enough background included to show its location.
2. Exploded drawings, showing each part of an assembly "blown out" along its center line, to show its proper shape and the order of assembly.

In any pictorial drawing a circle will appear as an ellipse. Most drawing texts, when they mention the subject, show the ellipses (and in fact the whole pictorial drawing) constructed by projecting points to it from two orthographic views. This can be a very tedious task, specially when the details are small. There are a large number of ellipse templates on the market which are great time-savers. However, their use is somewhat of a mystery to anyone who is not familiar with the principles of axonometric projection. Obviously an ellipse on the right front face of a drawing must be properly oriented if it is to appear to represent a circle. The theory of axonometric projection is available in several texts, and only enough of it is repeated here to explain the proper use of ellipse templates.

Fig. 1 shows the orthographic "transparent box" turned as it would appear pictorially. The near corner is cut off to make the picture plane. OA is normally (but not necessarily) vertical. If OB and CC make angles of 120° with OA, the drawing is isometric (all sides foreshortened equally). If OB and CC make other angles with OA, the drawing is either dimetric (two sides foreshortened equally), or trimetric (each side foreshortened differently). A drawing may be made on these axes when they make any desired obtuse angles with OA as long as no two axes are perpendicular. However, when the construction is carried out to determine the angle of foreshortening for each face, it will probably turn out to be some odd figure like 33° 37° or 64°. Most templates on the market provide ellipses of the following angles of foreshortening: 15°, 20°, 25°, 30°, 40°, 45°, 50°, 60°, and 35° 16' for isometrics. (These numbers

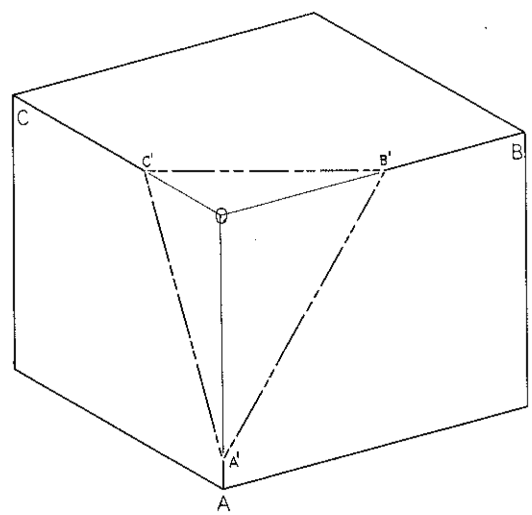


Fig. 1

represent the angles between the line of sight and the plane of the circle. Thus a 20° ellipse is "thinner" than a 60° ellipse). Therefore the axes should be arranged so that each face is foreshortened to one of these even figures. A little experiment will show that arranging the axes for any given angle of foreshortening is largely a matter of trial and (mostly) error. The writer's first ellipse template contained ellipses of 25° 45° and 60° and he wrongly supposed that these three could be used on a single drawing. It took several days to prove that this is not so.

There is one combination which works very well, and that is to foreshorten the faces to 20°, 30°, and 50°. This is the combination which is used extensively in industry. For this combination, OB is drawn 15° above the horizontal to the right (or left) and OC is drawn 30° above the horizontal on the opposite side. The foreshortening of the faces is: AOC-30° AOB-50° and BOC-20° (this is line-of-sight to plane of surface). If you try to prove these angles you will find that the 15° and 30° slopes are not exactly correct, but they are close enough so that the convenience of using the 15 steps on a drafting machine overrides the slight resulting inaccuracy. (This appears in the construction in Fig. 3).

To draw a certain ellipse with a template requires two steps: (1) Select the proper size from the template having ellipses of the right angle of foreshortening. (2) Orient the template.

Taking (2) first, and applying some descriptive geometry, we have (Fig. 1):

1. A'B', A'C', B'C' are the traces of the picture with the plane surfaces of the transparent box.
2. OC is perpendicular to any line in the right front face (AOB).
3. OC is perpendicular to A'B' (in space and on the drawing because A'B' is true length and OC is foreshortened).
4. Therefore at any position on face AOB a true length line will be parallel to A'B'.

These same statements apply to the other two faces, each taken with the opposite axis. (AOC and OB, BOC and OA).

On the template each ellipse is marked with two short lines indicating the major and minor diameters. (Fig. 2) As each ellipse is full size on the template,

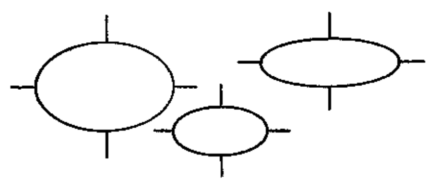


Fig. 2

its major diameter is a true length and must be placed on the drawing parallel to A' B' (for the right front face). The minor axis will then be parallel to OC. To orient the template properly it is only necessary to place it with the minor axis marks parallel to the proper axis.

As to the size of the ellipse, when making a scale drawing it is not always convenient to make use of the true length major diameter. A better way is to draw a rhombus, centered at the right place, and then from the template pick the ellipse which comes closest to fitting inside it. The rhombus in pictorial is the same as a square in orthographic, and a circle drawn in a square is tangent to the midpoint of each side. Therefore the correct ellipse will be tangent to the midpoint of each side of the rhombus.

To draw a 1" ellipse on the right front face in Fig. 3:

1. Using the center lines shown, draw a rhombus 1" on a side, to scale (see the next paragraph).
2. Through the center, draw a light line parallel to OC.
3. Through the center, draw a light line perpendicular to OC.
4. Place the template so the minor diameter marks coincide with the line drawn in (2), and the major diameter marks coincide with the line drawn in (3).
5. Draw the ellipse which most nearly comes tangent to the sides of the rhombus.

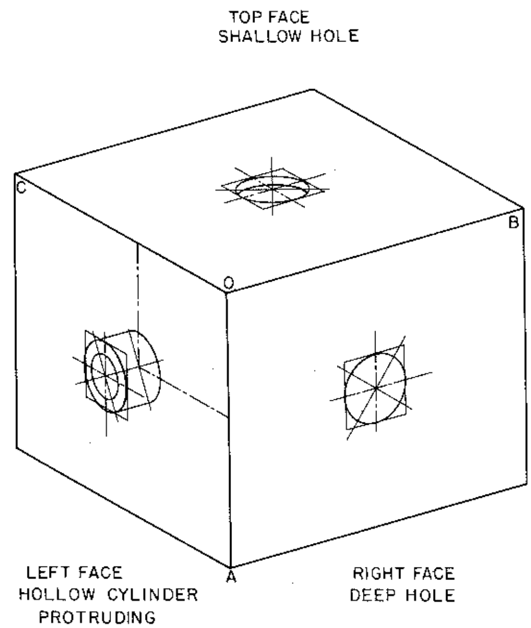


Fig. 3

After the proper size has been determined, for succeeding ellipses of the same size, the rhombus is not necessary. Fig. 3 shows similar constructions on the other two faces.

As to the scale, even on a full size drawing vertical distances along OA and horizontal distances along OB and OC are foreshortened differently, depending on the angles between the three axes. It is an easy task to make scales on a strip of plastic or heavy paper. The procedure is well described in at least two texts; Industrial Production Illustration, and Engineering Drawing and Geometry, both by Professors Hoelscher and Springer, Basically it is only necessary to measure off true lengths along A'B' and project the points, parallel to OC, onto OA' and OB'. This provides an OA scale and an OB scale. A similar construction on A'C' will duplicate the OA scale and provide an OC scale.

One more point which is confusing when making a pictorial drawing. Suppose a section of pipe has to be drawn, whose orthographic projection appears in Fig. 4. As it slopes down to the left, its axis makes

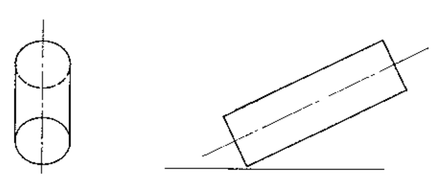


Fig. 4

an angle of 26° with the OB axis. This angle may be set off (Fig. 5) using the tangent values x (on the OB scale) and y (on the OA scale). The ends of this pipe

(continued on page 41)

New and Old Style Drafting Tables

A Direct Comparison

By Ralph E. Lewis

Duke University

This discussion was inspired by Professor Grant's article on New Style Drafting Tables in the November, 1956 issue of the Journal of Engineering Drawing, mainly because the writer's experience and conclusions differed so sharply from those given in Professor Grant's paper.

When war time emergency faced us with a temporarily increased load in engineering drawing amounting to approximately a five hundred percent increase, problems of space, staff and equipment became severe. The only solution as to drawing tables seemed to be a table very similar to the one Professor Grant describes. Top size was 26" × 38", front height 29", rear 31". We omitted the pencil rail (a mistake) and the manufacturer included a "knee hole" drawer about 14" across without the writer's knowledge. This latter proved fortunate for the boys made good use of this drawer as a tray for case instruments and equipment. These tables, equipped first with stools and later with ordinary straight backed chairs, were used during the war period. Afterward, when we moved to our new building, one of the drawing rooms used mainly by engineering drawing was still equipped with the same tables and they were in use up until the fall semester of 1955; so it would seem we had occasion to give them a thorough trial. Based on this, we arrived at an evaluation definitely different from Professor Grant's.

First, as to the elimination of boards, we have done that for a period of some fifteen years. We have tried, in the passing of time, several different types of tops; plain wood which does damage more quickly, masonite which can be quite satisfactory if properly constructed and just the opposite if not; and at present a plastic surfaced top that is the most satisfactory type used to date. We have not rated drafting machines but storage of T-squares is much less of a problem than storage of boards and squares.

We found that our students did not like the lower tables, nor did the instructors. Students coming in for make-up would invariably fill all vacancies in the room with standard tables before going willingly to the other room. The ability to change position, to kick back the stool for a time and draw standing, the freedom to move about the board, all were appreciated. And incidentally these conclusions about the desirability of change of position are in line with good motion-economy practice.

From the instructor's viewpoint the lower tables were harder to see, required more bending over or, in the writer's case since the necessity for bi-focals has been laid upon him, a request that the student let him have the chair so that he could see the drawing clearly, when offering individual help and criticism. All in all there was so much dissatisfaction with the lower tables that we re-equiped this room with standard tables during the summer of 1956.

The 1" × 1" finished structural member as a straight edge is an excellent idea. However we have found that carefully constructed tops with an adequate edge have been obtainable.

The smaller size top is definitely adequate for drawing, descriptive geometry, kinematics and statics courses. It is not large enough to satisfy when used for other work and in our case this is a matter of some importance since it is desirable to use our drafting space with the greatest degree of flexibility.

To recapitulate: We have had occasion to use these lower tables over a period of some fourteen years, for four years the low tables only and from then on in combination. We were thoroughly convinced that the students tired more rapidly when working on the low tables, that they did not like them as well when offered a choice, (the writer once, as a test, moved a class one day a week when the room was vacant, into an adjoining room with standard tables and had very definite proof of student preference), and that the job of instruction became physically more tiring. A class seated at the lower tables was easier to lecture to and a somewhat larger group could be accommodated in a given room. From our standpoint this is not a desirable result since we try to limit our section sizes to what we consider the most workable size. The smaller top size was perfectly satisfactory from the drawing standpoint but, in our particular case, undesirable for more advanced work.

The writer is inclined to speculate on how much of the difference between Professor Grant's and his own experience may be due to the use of drafting machines. These are desirable but, in our case, not available. It is gratifying to note that others, too, have found it possible to eliminate the individual drawing board with only a reasonable amount of maintenance of the table tops.

Among the interesting articles planned for the coming November issue are the following:

"Movable Scale Nomographs," by J. N. Arnold, Purdue U.;
"Advanced Principles in Dimensioning," by P. G. Belitsos, General Electric Company;
"Operational Symbolism for Graphical Processes," by Steven A. Coons, M.I.T.

In addition, you may look forward to papers that were presented at the Rice Institute meeting at Houston and papers to be presented at Cornell in June.

Multi-View Drawing by the Direct Method

By David I. Cook
University of Nebraska

The general acceptance of the direct method for teaching descriptive geometry is ample evidence of its value. In spite of this fact many teachers of engineering drawing prefer to introduce the subject by using the indirect or "glass box" method.

I was a victim of the "glass box" as a student and an advocate of it as a teacher, until a few years ago. A critical analysis of both methods now leads me to believe that the direct method is far superior to the other.

The inherent value of the direct method lies in the fact that the student begins his training with the visualization of actual objects. He is instructed to look directly at some object and record what he sees. This is a perfectly natural process. If he chooses to look at a particular side of the object in order to obtain a clear picture of a characteristic contour, he will probably record what we know as a front view.

Once this view has been chosen, the positions of the other related views are determined in accordance with standardized practice. The student should be told that these standardized positions are entirely arbitrary, in order that he may be assisted in understanding the numerous positions for auxiliary views.

The direct method teaches the student that a drawing of an object should be visualized as an actual object and not as a projection of an object. I believe the first idea is most desirable. The glass box method encourages the second idea by introducing an artificial plane between the observer and the object. The observer must first imagine the object projected on a plane, and then reverse the process. How much simpler it is to look directly at the object.

What machinist, die maker, or engineer, who is accustomed to reading drawings daily, thinks of a drawing of a handle, for example, as a projection on a plane? I am sure you will agree that this person sees the drawing as an actual handle which he could reach out and grasp.

It is true that the glass box demonstrates the theory of orthographic projection clearly, and that it may be of some value in showing the relative positions of the principal views. But beyond demonstrating these concepts, which are extremely simple ones easily understood, without its use, by college students, I believe the glass box has very little value. When constructed to include single or double auxiliary views, it is cumbersome to manipulate and has limited application.

By contrast, if the direct method is taught, a model may be constructed to demonstrate the various directions of sight in viewing an object. Figure 1 shows such a model with a complex object placed in position for viewing.

The various arrows are adjustable and can be positioned to point in any desired direction. Different classes of auxiliary views and their associated direction of sight can also be demonstrated. The

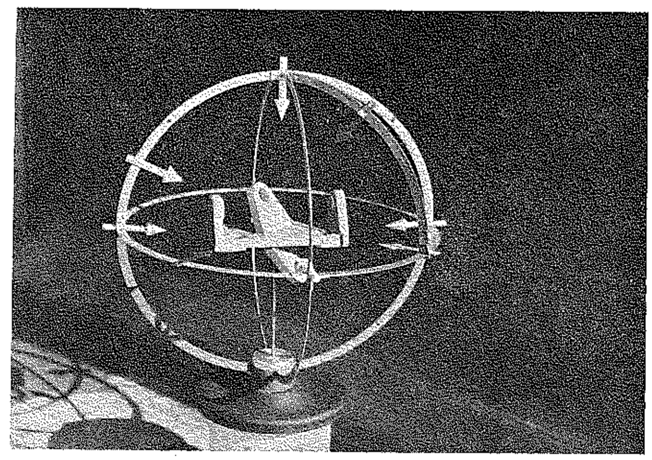


Fig. 1

object may be removed, and different objects of increasing degrees of complexity may be inserted as the student progresses.

Since all possible directions of sight may be demonstrated and all possible views explained with equal facility, the method has unlimited application in special visualization. This model, recently completed at the University of Nebraska, is now being used as a visual aid in teaching the elements of multi-view drawing to freshmen engineering students.

If you have been laboring with the glass box method and are not completely satisfied with the results (what teacher is ever completely satisfied with the results of his effort?) let me urge you to try the direct method from the start. Tie the beginning concepts of multi-view drawing closely to the more advanced concepts of descriptive geometry with the direct method, rather than separate them with the glass box.

Graphical Field Mapping

By John F. Calvert
University of Pittsburgh

INTRODUCTION

Steady state field problems appear in many engineering areas. They arise in relation to the flow of electric current, electromagnetic and electrostatic phenomena, heat flow and, under certain special conditions, in relation to liquid and gas flow. An electrical design engineer solves steady state field problems to determine resistances for both electrical and heat flow phenomena, and he is concerned with electromagnetic forces and torques, and with voltage stress in electrostatic fields. A civil engineering designer might be involved with the flow pattern for water seepage through earth dams. The need for engineering training in the solution of steady state field problems is wide-spread. There are simple graphical methods for predetermining these fields which can be presented with little symbolic mathematics, employing instead a system of geometric logic. The purpose of this paper is to make such a presentation.

In each steady state field a family of curves is found which looks like the flow lines for an incompressible fluid. In these fields a "source" is a point or an area from which the flow lines emanate, and a "sink" is one to which they go. We shall be concerned in this study not only with these "flow" lines but also with the orthogonal set of curves. To predetermine such a field by strictly analytical or mathematical means, would call for the use of Poisson's equations. Where the work was entirely outside of the sources and sinks, LaPlace's equations would be used. However, we are interested only in graphical procedures—methods based upon the same physical assumptions as those governing a mathematical approach and exhibiting equal rigor in the theoretical development. The desired theoretical exactness can be achieved even though in practical applications graphical procedures, by their very nature, may yield somewhat less accurate answers than the analytical. Nevertheless, the graphical methods are usually adequate and possess compensating features that make them desirable for many engineering applications.

The first job in relation to a problem involving a steady state field is to obtain the actual shape or distribution of that field with both accuracy and dispatch. A discussion of graphical methods for accomplishing this forms the main content of this paper. But, before proceeding further, some brief comparisons will be made between the mathematical, the experimental, and the graphical techniques to show some of the advantages and limitations of each.

Mathematical or anlaytical methods, as suggested earlier, give the most accurate results. However, this tacitly assumes that a practical mathematical solution or statement for the field distribution actually can be obtained. Experience shows this may be far from the case. There exist, today, engineering problems in which the boundary conditions are so complicated that they have defied all attempts to achieve such solutions. In cases where accurate mathematical solutions have been obtained, often much time has been expended in achieving the result —more time than a designer could afford to give to it. The training for this kind of mathematical work is extensive and specialized.

Model methods are useful and, on occasions, they are necessary as they may well be the only means for achieving a solution. Yet, despite the fact that model techniques have been improved and simplified during the past ten years, they remain laboratory rather than design office methods. They are a bit clumsy to use, and do not lend themselves to quick changes of boundary conditions when the designer wishes to experiment. Electronic tubes, which react to illustrate the electromagnetic field; electrically semi-conducting paper; electrolytic tanks; and the flow of colored liquids between two plates of glass may suggest some of the model techniques which, in the past, have been employed with success.

Graphical procedures require the development of skill in a restricted branch of free-hand sketching. With few exceptions, applications are limited either to two dimensional problems or else to three dimensional problems in which the boundaries are cylindrically symmetrical. Usually, the graphical methods cannot be made to yield results which are better than one to three per cent in flow density. This is close to the order of accuracy which might be expected for most experimental techniques, but not up to the attainable accuracies of the mathematical methods.

Sufficient drawing skill can be developed within a few weeks of practice to make the graphical procedures useful. This is a motor skill like walking or swimming; once developed, little is lost through lack of use. A very wide variety of engineering problems with complicated boundary conditions have been solved with requisite engineering accuracies. The published results not only attest to the usefulness of the procedures but often serve as guides in relation to the solution of other problems. Skill with the graphical methods brings to the engineer a "feel" or "design sense" for field problems, which the author believes is unlikely to be achieved through any other training or experience.

BASIC THEORY FOR GRAPHICAL FIELD MAPPING

In the development of the basic theory we will employ electric flow and then magnetic fields. In this section we start with the conditions which must exist outside of sources and sinks. After this, more general techniques will be developed that are applicable both inside and outside distributed sources and sinks. In a later section flow analogues will be discussed for a variety of physical phenomena.

Outside the Sources and Sinks

In Figs 1a and 1b we assume a sheet of paper covered with a thin, continuous, constant thickness graphite coating. Two copper electrodes are placed on the graphite and voltage is impressed between them. The resulting flow of electric current is shown by the solid lines in Fig. 1b. The dotted lines, lying perpendicular to these, are equipotentials. We might lift out a piece of this field as shown in Fig. 2. Each elemental section shown in the drawing has the same ratio of length to width as has each other section. Thus $\ell_1/w_1 = \ell_2/w_2 = 1$. The graphite thickness is "x" for these two sections and therefore these parts have the same resistances as follows:

$$R_1 = \rho \frac{\ell_1}{W_1 x} = \rho \frac{\ell_2}{W_2 x} = R_2 = \rho \frac{\ell_3}{W_3 x} = R_3 \qquad (1)$$

where ρ = resistivity per cubic inch for the graphite.

In Fig. 1b, we have endeavored to divide the entire space for current flow into sections like those of Fig. 2. These are called "curvilinear squares." The following conditions have to be met in order that the field distribution be correct:

(1) The continuous flow lines leave perpendicularly from one electrode and arrive perpendicularly at the other.

(2) Each equipotential line (shown as a dashed line), which meets the edges of the graphite sheet, arrives perpendicular to the edge because the flow direction there is parallel to the edge.

(3) The rate of flow into a curvilinear square is equal to the rate of flow out of that curvilinear square. Thus it is noted in Fig. 2 that voltage drops $(V_1 - V_2)$ and $(V_2 - V_3)$ are equal and that the currents I_1 and I_2 are equal.

In the foregoing, the conditions under (3) correspond, very closely, to the general requirements of LaPlace's equations and the conditions stated under (1) and (2) give the boundary conditions for this particular physical problem. The boundary conditions must be satisfied whether a graphical, a mathematical, or an experimental procedure is employed.

Much as was done in Fig. 1b, a great many field distributions have been determined by freehand or graphical flux mapping procedures.

Inside and Outside the Sources and Sinks

In the development of the more complete theory, the simple magnetic field of Fig. 3 will be employed.

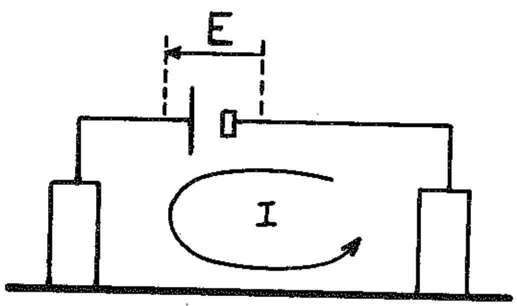


Figure 1a. Electric flow in thin sheet. Elevation view

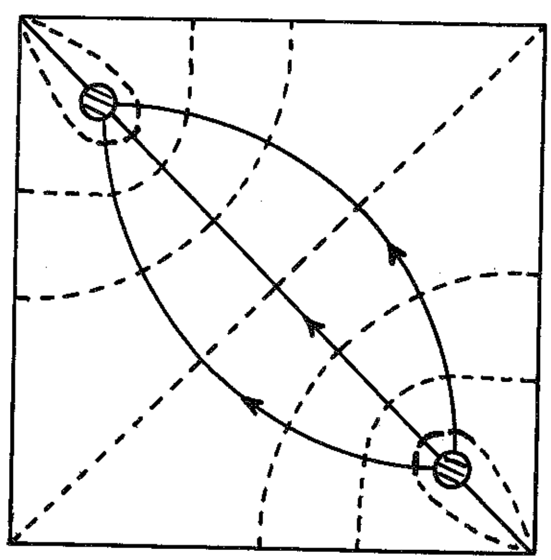


Figure 1b. Electric flow in thin sheet. Plan view

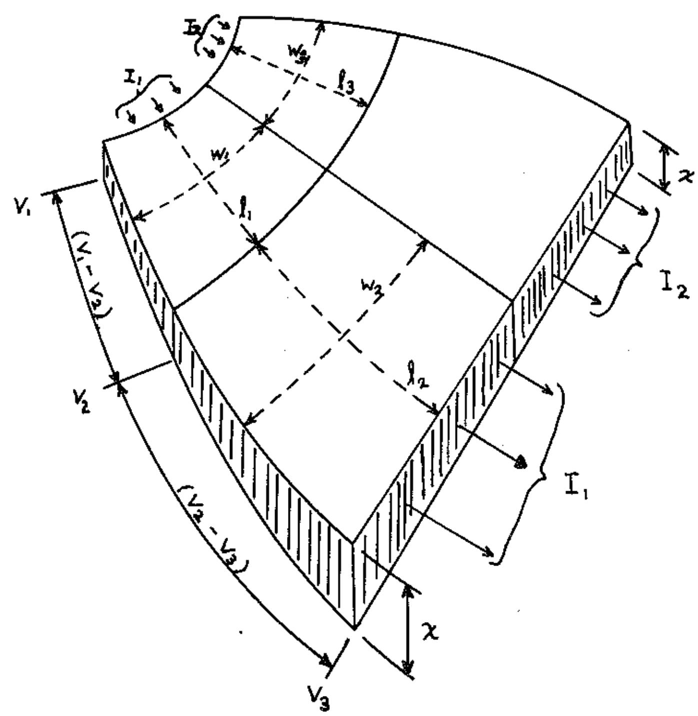


Figure 2. Section of flow taken from previous figure to illustrate parts of equal (ℓ/wx) dimensions. These parts offer equal resistance to flow.

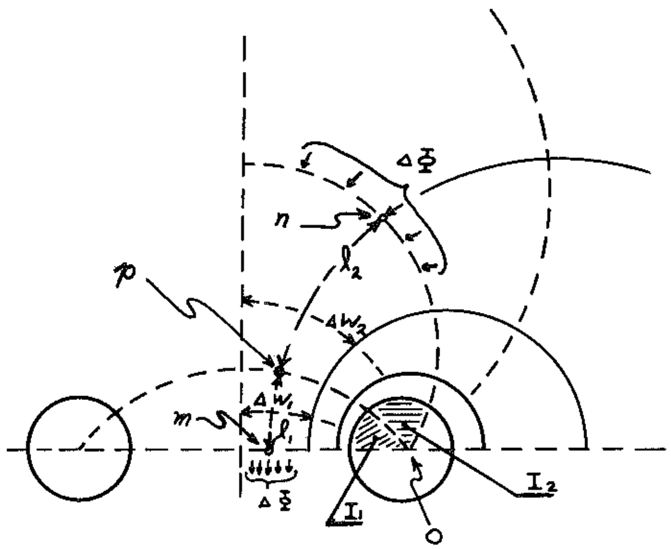


Figure 3. Employing Ampere's circuital law, $\int \overline{H} \cdot d\overline{\ell} = 0.4\pi I$, the basic relation for two dimensional graphical flux mapping is obtained, this relation follows: $I_1 \div I_2 = (\ell_1/\Delta w_1) \div (\ell_2/\Delta w_2)$.

The following relation, sometimes called Ampere's circuital law, will be introduced:

$$\oint \overline{H} \cdot d\overline{\ell} = 0.4\pi I \tag{2}$$

where

H is the force in dynes on a unit pole (a vector).

$d\overline{\ell}$ = centimeters (a differential, and a vector).

The "dot" product, $(\overline{H} \cdot d\overline{\ell})$, of the two vectors shown is, of course, a scalar. It is the product of the magnitudes of the vectors times the cosine of the included angle.

I = practical amperes (a scalar).

This law says that if we move a unit pole around a closed path the $(\int \overline{H} \cdot d\overline{\ell})$ is the work done, and that this is proportional to the current I which is enclosed by that path of integration. (This statement, it may be added, is related, in a way, to Poisson's equation.)

We will make use of Ampere's circuital law. Refer now to Fig. 3, where two closed paths are shown. One path, o-m-p-o, enclosed current I_1, and the other path, o-p-n-o, encloses the current I_2. Force on a unit pole could be exerted only in the directions of the magnetic flux and these directions are shown by the family of solid lines. Therefore, in relation to the two paths mentioned work can be done only along m-p and along p-n because the lines o-m and p-o, in the first case, and lines o-p and n-o, in the second case, lie perpendicular to the directions of magnetic field.

In going around the first path, o-m-p-o,

$$\oint_{ompo} \overline{H} \cdot d\overline{\ell} = H_1\ell_1 = 0.4\pi I_1 \tag{3}$$

For the second path, o-p-n-o,

$$\oint_{opno} \overline{H} \cdot d\overline{\ell} = H_2\ell_2 = 0.4\pi I_2 \tag{4}$$

where H_1 and H_2 are the mean values of H along ℓ_1 and ℓ_2, respectively.

Now, noting that μ = permeability, the value of H is numerically related to the magnetic flux density, B, and hence to the flux, $\Delta\Phi$. The flux, $\Delta\Phi$, is continuous along the tube shown in Fig. 3 and it may be written that:

$$(\mu H_1)\ell_1 = (B_1)\ell_1 = (\Delta\Phi/(\Delta w_1)x)\ell_1 = 0.4\pi I_1\mu \tag{5}$$

$$(\mu H_1)\ell_2 = (B_2)\ell_2 = (\Delta\Phi/(\Delta w_2)x)\ell_2 = 0.4\pi I_2\mu \tag{6}$$

Dividing equation (5) by (6),

$$\frac{I_1}{I_2} = \frac{\ell_1/(\Delta w_1)x}{\ell_2/(\Delta w_2)x} = \frac{\mathcal{R}_1}{\mathcal{R}_2} \tag{7}$$

where $\mathcal{R}_1$ and $\mathcal{R}_2$ are called reluctances. They have the dimensions of a resistance to flow of magnetic flux since each is proportional to length along the flow of the magnetic flux tube and inversely proportional to the mean cross-sectional area in the same space.

Equation (7) presents the basic relation to be satisfied in the flux field. It applies both inside and outside of the current carrying conductors. It shows, for example, for a given flux tube, $\Delta\Phi$, that the driving force, I_1, is proportional to the reluctance, $\mathcal{R}_1 = [\ell_1/(\Delta w_1)x_1]$.

The drawing in Fig. 3 presents as boundary conditions only the currents, i.e., the distributed source and sink. However, in other problems we have iron sections that, in many instances, may be treated as solid parts of nearly infinite permeability. At these boundaries the flux lines must meet the iron nearly perpendicularly. With very high permeability a very small part of the total driving force is required within the iron. Relative to the air, the iron acts almost as a perfect conductor for magnetic flux. Hence there can be very little "pressure drop" just inside and parallel to the iron surface. This surface must be nearly perpendicular to the flow in air and to this flow appear as an equipotential surface.

Many magnetic flux distributions involving distributed sources and sinks and also involving iron parts have been "solved" or predetermined by graphical techniques.

ARTIFICES AND ANALOGUES

The basic principles for graphical flux mapping have been laid down in the previous section. In the present section techniques and concepts of wide applicability will be developed. This discussion will be presented in terms, which are not restricted either to electric or to electromagnetic phenomena.

In the two dimensional fields to be discussed there will be found:

(a) Positive and negative point sources of given relative strengths or else distributed sources of given relative strengths per unit of cross sectional area. "Relative strength" refers to the relative number of flow tubes emanating from a source or arriving at a sink.

(b) Finite and constant resistivity to flow over well defined regions which, in general, includes the areas occupied by distributed sources and sinks.

(c) Ideal boundary materials, each of which is characterized either as a material that acts as a perfect conductor for "flow" or else one that acts as a perfect barrier to "flow."

The two drawings of Figs. 4 and 5 illustrate all of the features mentioned above. In Fig. 4 there is no flow into or out of the cross hatched sections. Hence these sections are perfect barriers; the "flow" goes from source to sink without entering these barriers. Lines at right angles to flow meet the barriers perpendicularly. In Fig. 5 the cross hatched sections permit flow within them and, in fact, require no force to drive the flow through them. These, then, are perfect conductors for "flow." "Flow" enters and leaves the surface of these conductors perpendicularly.

Fig. 6 lists various analogous "flow" systems. Each system is represented by a horizontal row in the chart. The upper group of five systems are completely analogous one to another. Flow occurs between sources and sinks, that is between positive and negative sources. In order to make the electromagnetic case, numbered 5, analogous to the other four, the family of curves normally considered as "flow", and the family of curves normally considered as equipotentials have been given a reverse interpretation.

Line number 6 in Fig. 6 shows the electromagnetic case in the conventional form. For this case the magnetic flux lines (which encircle the source or sink) are considered to represent "flow". In this field, one must imagine that the driving force is used up as it is produced for every incremental length along a flow tube. For line 7 of Fig. 6 the reader should refer also to Fig. 7. In the latter drawing suppose that a pair of laminated field poles were so arranged that a "pencil" of magnetic flux pierced a horizontal, circular, rotatable disk. Assume, however, that the disk is locked in position. This is somewhat like an electric watt-hour meter which is prevented from turning. If the disk is so locked and if the flux density in the "pencil" varied sinusoidally with time, then voltages would be induced in the disk by transformer action. Let $d\Phi/dt$ be the rate of change of flux in the flux pencil which links certain electrically conducting paths in the disk. Suppose that the electrical resistivity of the disk is rather high so that the currents flowing in the disk as a result of this transformer action are so weak that flux produced by these induced currents is insignificant relative to the pencil of flux referred to above. Voltage will be generated in the disk of Fig. 7 and, in accord with one of Maxwell's equations, the integral of the voltage E around a closed path is numerically equal to the rate of change of the enclosed flux. Thus,

$$\oint \bar{E} \cdot d\bar{l} = \frac{d\Phi}{dt} \tag{8}$$

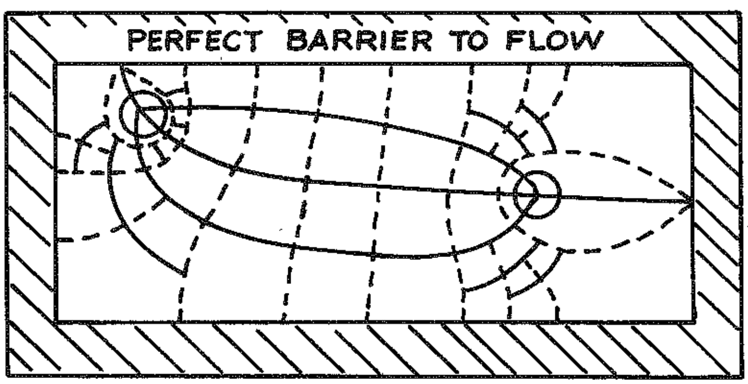


Figure 4. Flow between source and sink enclosed by perfect barrier to flow.

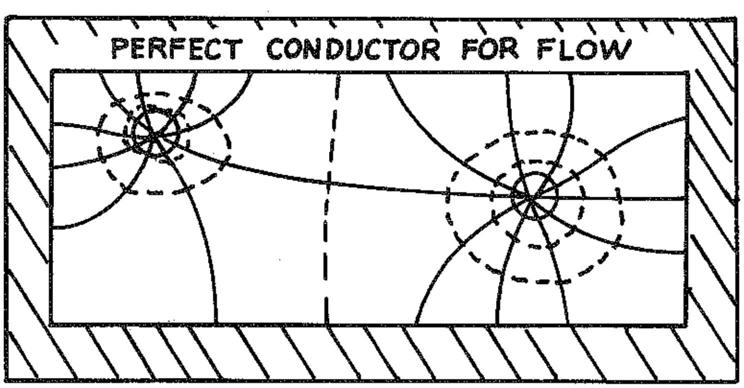


Figure 5. Flow between source and sink assisted by perfect conductor for flow.

IMAGING

The idea of perfect conductors for flow and of perfect insulators to flow leads directly to the use of images.

Fig. 8 shows, in the upper half, the electromagnetic flux produced by two long parallel current carrying conductors which form a closed circuit near an iron plate. The iron plate is assumed to be of infinite extent in two directions, and is also assumed to be of infinite permeability and infinite resistivity? These later two features mean that the plate may be regarded as a perfect conductor for magnetic flux regardless of whether the current in the two parallel conductors is dc or ac.

If the plate is removed and two new conductors are introduced as shown in the lower half of the drawing, the electromagnetic flux in the upper half of the drawing remains unchanged while flux, which is its mirror image, appears in the lower half.

Fig. 9 differs from Fig. 8 in that the plate is

PHYSICAL PHENOMENA	PHYSICAL TERMS			IDEAL BOUNDARY MATERIALS	
	Pressure Between Sources	Flow Between Sources	Unit Resistance to Flow	Perfect Insulator For Flow Tubes S is ⊥ to boundary	Perfect Conductor For Flow Tubes ℓ is parallel to boundary
1 Electric Flow	Voltage Difference V	Current Flow I	Electrical Resistivity	$\frac{\partial I}{\partial S} = 0$	$\frac{\partial I}{\partial \ell} = 0$
2 Heat Flow	Temperature Difference T	Heat Flow W	Heat Resistivity	$\frac{\partial W}{\partial S} = 0$	$\frac{\partial W}{\partial \ell} = 0$
3 Hydraulic	Pressure Difference P	Fluid Flow G	Fluid Flow Resistivity	$\frac{\partial G}{\partial S} = 0$	$\frac{\partial G}{\partial \ell} = 0$
4 Electrostatic	Potential Difference E	Electrostatic to Flux $\propto$ To Charge ψ	Reciprocal of Dielectric Constant 1/K	$\frac{\partial \Psi}{\partial S} = 0$	$\frac{\partial \Psi}{\partial \ell} = 0$
5 Electromagnetic (current "pencil" flows in confined boundaries).	Flux Between Conductors ϕ	Current I	Permeability Factor μ	$\frac{\partial I}{\partial S} = 0$	$\frac{\partial I}{\partial \ell} = 0$
STANDARD TREATMENT BUT NOT ANALOGOUS TO ABOVE					
6 Electromagnetic current "pencil" usually considered to flow in confined boundaries	Current I	Flux ϕ	Reluctivity $\mathcal{R}/cm^3$	$\frac{\partial \Phi}{\partial S} = 0$	$\frac{\partial \Phi}{\partial \ell} = 0$
7 Electromagnetic "AC" $(d\phi/dt)$ pencil, considered to flow in confined boundaries	$\frac{d\phi}{dt}$	Current I	Resistivity ρ	$\frac{\partial I}{\partial S} = 0$	$\frac{\partial I}{\partial \ell} = 0$

Figure 6.

assumed to be metal of unit permeability and almost infinite electrical conductivity and the two long electrical conductors located above the plate are assumed to be carrying alternating current. Under these conditions eddy currents are generated in the top surface of the plate such that the alternating electromagnetic flux is almost kept out of the plate. Thus the plate is a "shield"; it is nearly a perfect barrier to the flow of the alternating flux. If the electrical conductivity were infinite the plate would become a perfect barrier to the flow of alternating magnetic flux.

If the plate is removed and this time two conductors are introduced below with the instantaneous current directions as shown then, again, an imaged field is obtained.

While imaging of the kinds described above can be extended to a variety of configurations, the possibilities are not unlimited. Usually plane surfaces or cylindrical ones are the surfaces with respect to which imaging is done. In any case, when the surfaces are replaced completely by imaging, all the free space is exactly filled. It is this last feature which puts limits on the imaging process. To illustrate this, start with the two conductors located inside a 60° iron corner. With the idealized material assumed

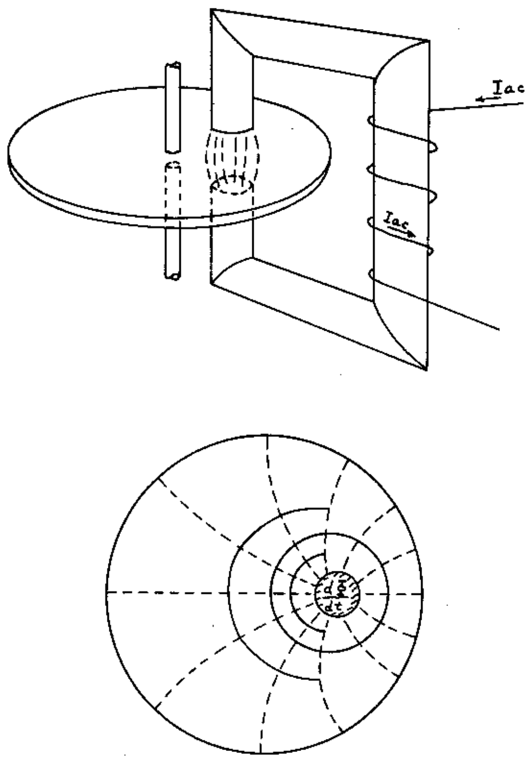


Figure 7. Current flow induced in disk by alternating flux. Solid lines show current flow. Dotted lines show equipotentials.

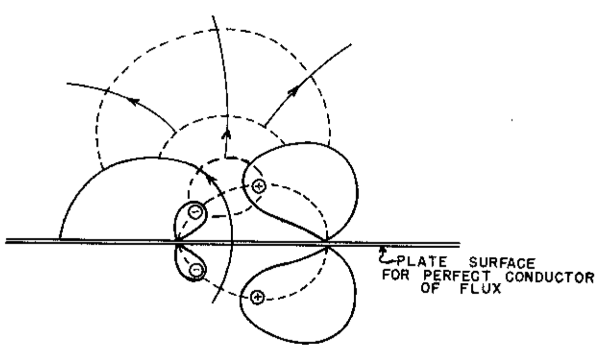


Figure 8. The flux above the plate is produced by two parallel conductors. The image field is shown below plate surface.

in place of the iron, imaging is feasible. If, however, the angle is slightly different, say 59° or 61°, imaging won't work.

CURRENT SHEETS AND IDEALIZED MATERIALS USED TO DIVIDE A FIELD

Superposition in field theory is usually thought of as laying down one component field which occupies

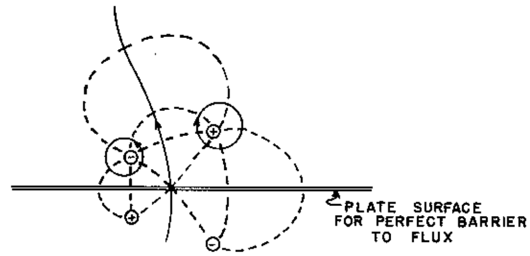


Figure 9. Flux above plate produced by two parallel conductors form part of an alternating current circuit, imaged field shown below plate surface.

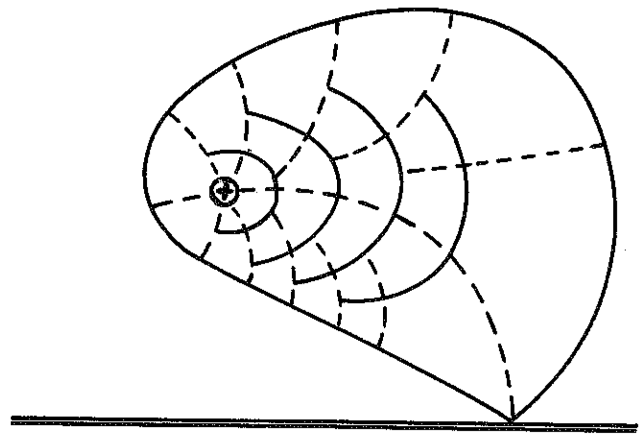
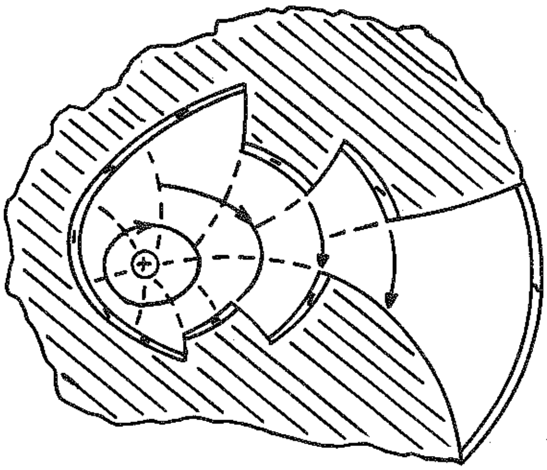


Figure 10a. A section of the field from the upper right hand part of Fig. 8. Refer, now, to next figure.

the entire space and then adding on top of this another component field which occupies all space and finally determining the resultant flux directions and densities everywhere for the establishment of the total field. In the foregoing the same perfect conductors for flow and/or the total barriers to flow are present in all the components and total field. In the component fields different sources and sinks are assumed. Thus in a dc generator the iron parts may be treated as perfect conductors for the flow of magnetic flux. One component field can be established by the main field currents which in a cross section drawing provide the sources and sinks. Another component field may be the flux established by the armature currents only. Adding these two fields give the resultant.

However, the total field may be divided into components of a different but equally useful type. The total field may be divided, like a jigsaw puzzle, into components each of which occupies its own specific part of the total area. These components, which can be extremely useful, will be described next. For illustrative purposes refer to Figs. 10a and 10b. Fig. 10a is a section of the drawing shown in Fig. 8, while Fig. 10b shows part of Fig. 10a as a complete electromagnetic system. It is a component part of Fig. 8 obtained by introducing a perfect conductor for magnetic flux and current sheets, where the strengths of the

Figure 10b (below). This is a part of the field of the previous figure but, in itself, presents a complete electromagnetic system. The shaded area represents a perfect conductor for magnetic flux (this is like iron but idealized such that the permeability and resistivity are each considered to be infinite), artificial, or idealized, current sheets carrying minus signs are introduced as sinks to receive the dashed lines from the small circular positive sources.



current sheets are those needed just to produce the field strengths formerly existing at the same locations. It is seen that the shape of the flux field within a component is the same as that formerly existing in the resultant field.

SUMMARY

The paper has been held primarily to a discussion of graphical techniques for predetermining steady state fields, and to the use of images and also idealized surfaces for developing useful field components. In themselves these techniques would be only intellectual curiosities. However, the engineering applications make the predetermination of fields vitally important. It provides the means for computing the directions and the densities of flow. To suggest the uses of such graphically determined fields, areas for their application in electrical machine design are listed below:

1. Heat flow
2. Air flow through narrow passages
3. Magnetization curves
4. Iron losses
5. Eddy current losses in solid parts
6. Electromagnetic forces and torques
7. Reactances

The electrical machine is an interlaced set of fields and circuits and, while it is not within the province of this paper to describe the interrelations, it is hoped that the reader realizes that fields as well as circuits must be well understood by the designer of the whole machine. Doubtless similar examples can be found in other areas but suffice it to say that the ability to predetermine fields is a somewhat neglected technique in engineering which can be greatly helped by graphical approaches.

(continued from page 32)
will be ellipses of unknown angles of foreshortening. Rather than construct the exact angle, it is easier to make a quick orthographic drawing and set up the

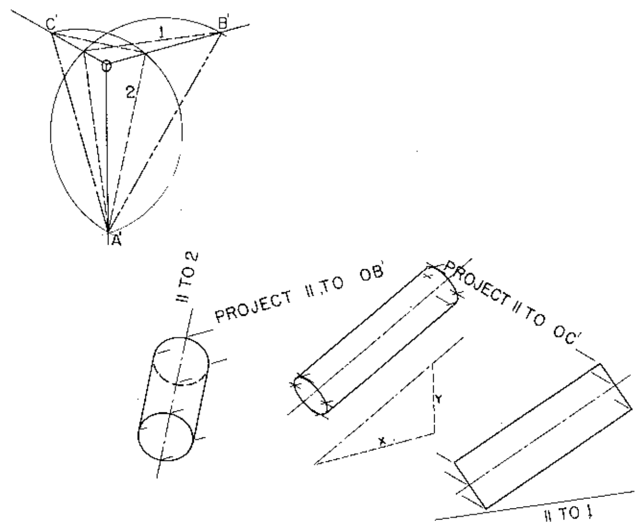
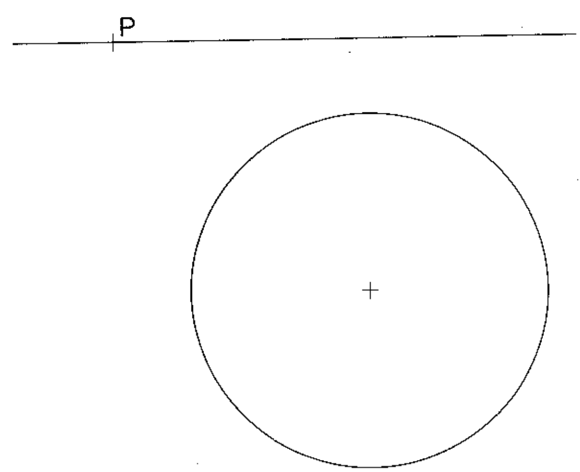


Fig. 5

two views of projection, as explained in the books mentioned, and project in only four points for the ellipse. These four points will be sufficient to find an ellipse on a template, placed so that its minor diameter lines co-incide with the center line of the pipe.

SOLVE BY GRAPHICAL METHODS



CONSTRUCT ARCS TANGENT TO A LINE AT A GIVEN POINT P AND TO A GIVEN CIRCLE.

DIVISION OF GRAPHICS, UNIVERSITY OF VERMONT
V. H. PAQUET
G. H. DEWEY
G. R. CHARRON

Cornell University
Ithaca, N.Y.

Cornell University, where the American Society for Engineering Education will meet in June, has been described as America's all-round university. It is the land-grant university of the State of New York, but also an Ivy League school. It is co-educational and non-sectarian. It has been called the most western of the eastern universities, and the most eastern of the western ones.

Cornell is privately controlled, but four of its 15 divisions are contract units of the State University of New York. Its student body of 10,000 represents all 48 states and more than 70 foreign countries, and one-fifth of them are in engineering.

With its main campus at Ithaca in the beautiful Finger Lakes area, Cornell also has divisions across the state—from the Cornell Aeronautical Laboratory in Buffalo to the Medical College and School of Nursing in New York City. Anthropological stations are in India, Thailand, Peru, Nova Scotia and the American Southwest.

Cornell owes its existence to a piece of legislation —the Federal Land Grant Act of 1862—and to the vision of two men—Ezra Cornell, founder, and Andrew Dickson White, first president. Under the act, which gave public lands to provide colleges to teach agriculture and the mechanic arts, Mr. Cornell purchased western timberland that eventually produced $5,000,000 for the university. He also gave an endowment of $500,000 from his own fortune, made in Western Union, and the campus site overlooking Cayuga Lake.

The university was chartered in 1865 and opened three years later with 412 students and a set of new educational principles. Instead of following the traditional diet of classics and mathematics, Cornell and White added such new studies as modern languages, history, social studies, science and engineering. Mr. Cornell's words, now the university motto, were, "I would found an institution where any person can find instruction in any study."

In this century the pioneering has continued in the founding of the first School of Hotel Administration, School of Industrial and Labor Relations, and School of Nutrition.

Cornell was the first non-technical university to introduce engineering courses, and established the first school of electrical engineering. Recently it introduced the five-year undergraduate course in all engineering divisions.

The College of Engineering now includes divisions in aeronautical, chemical and metallurgical, civil, and mechanical engineering, and engineering physics. Agricultural engineering forms a department in the College of Agriculture.

Nearing completion is a completely new engineering quadrangle of nine units—four are completed, four are under construction, and one remains in the planning stage. Each building offers the most modern facilities for teaching and research.

Cornell has been a leader in research since its founding. In the 1870's the first practical dynamo of the western hemisphere was built here and used to power one of the first outdoor electric lighting systems.

The university's total research program in 1956 received outside funds alone of $25,000,000 and its projects range from new recipes for nutritious bread to investigations of radio signals that originate in outer space.

The breadth of subject matter taught on one campus allows a student to take almost any imaginable combination of courses. Some of the established "concentrations" are American studies, agriculture and engineering, city management (administration, engineering and law). Inter-disciplinary research centers concern social sciences, housing, computing, and aerial photograph interpretation.

Cornell's two gorges, Beebe Lake, and its view alone merit a visit to the campus. Other points of interest are the University Library and its 173-foot chimes tower; Anabel Taylor Hall, an interfaith center; Statler Hall, housing the hotel administration school and a practice inn; Willard Straight Hall, the student union; the Andrew Dickson White Museum of Art; the Lua A. Minns Memorial Garden; a 16-unit Veterinary College, completed this year; and Sage Chapel.

FAR ABOVE CAYUGA'S WATERS!

65th ANNUAL MEETING
CORNELL UNIVERSITY
ITHACA, NEW YORK
JUNE 17-21, 1957

Program

Annual Meeting of the
Engineering Drawing Division of the ASEE
Cornell University, Ithaca, N. Y.
June 17-21, 1957

Monday—June 17

8:00 A.M.— Registration
2:00 P.M.— Conference—Lecture Room R, Olin Hall
Presiding: I. L. Hill, Illinois Institute of Technology

1. Status of Engineering Drawing—1957. Warren J. Luzadder, Purdue University

2. A New Approach to Perspective. Frank Hrachovsky, Illinois Institute of Technology

3. Revised Drawings and Drafting Room Practice Standards.—Randolph P. Hoelscher, University of Illinois.

4. Discussions

6:30 P.M.— Executive Committee Dinner Meeting Kimball Room, Willard Straight Hall

Tuesday—June 18

9:30 A.M.— General Session
2:00 P.M.— Conference—Lecture Room R, Olin Hall
Presiding: Col. L. E. Schick, West Point

1. Who Should Teach Nomography—A Mathematician or a Graphition?—Robert H. Hammond, West Point

2. Teaching to Motivate Student Initiative. K. R. Gulden, Rensselaer Polytechnic Institute

3. Freehand Sketching—How to Teach It. Frank J. Burns, Newark College of Engineering

4. Discussions

Tuesday—June 18 (Cont.)

6:30 P.M.— Annual Division Dinner—Memorial Room, Willard Straight Hall
Presiding: I. L. Hill

1. Presentation of Distinguished Service Award. Ralph T. Northrup, Wayne State University

2. Conservation and Magic—David Hansalman, Cornell University Extension Division

Wednesday—June 19

9:30 A.M.— General Session
12:00 Noon— Division Luncheon—Memorial Room, Willard Straight Hall
Presiding: I. L. Hill

1. Reports by Chairmen of Standing Committees

2. Business Meeting

2:30 P.M.— Joint Conference (with M.E., C.E., E.E., and Educational Methods groups)
Presiding: E.J. Lindahl, University of Wyoming
Theme: Full and Effective Utilization of Laboratory Staff and Facilities

1. Time Allocation Between Class and Laboratory. Pier L. Bargellini, University of Pennsylvania

2. Are Laboratory Methods Consistent with Reports on Improvement of Engineering Education? Ralph S. Paffenbarger, Ohio State University

3. Discussions

Thursday—June 20

9:30 A.M.— General Session
2:00 P.M.— Field Trip (Optional)
Milliken Power Station of New York State Electric and Gas Corporation

I would be loath to cast away my speech, for besides that it is excellently well penned, I have taken great pains to con it.

SHAKESPEARE, Twelfth Night, Act i, sc. 5, 1. 184

He lays aside bombast and many-syllabled words if he wishes to touch the heart of his hearer.

HORACE, Ars Poetica, 1, 97

Construction of a Regular Inscribed Decagon and Pentagon.

By D. R. Mazkewitsch
University of Cincinnati

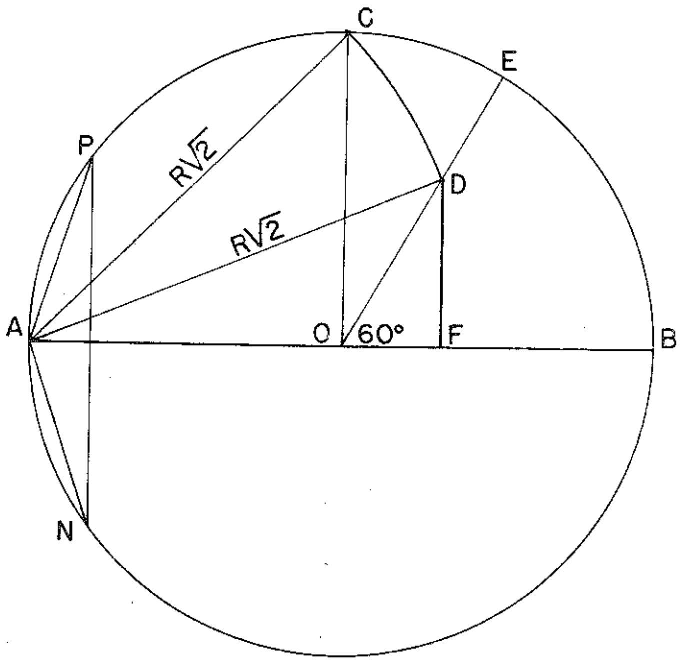


Figure 1

At point O of the diameter AB = 2R erect the perpendicular OC, and construct the angle BOE = 60°. Rotate $AC = R\sqrt{2}$ around A to intersect OE in D. Then $OD = s_{10}$ = side of a regular inscribed decagon. Proof: From D draw the perpendicular DF to AB. Then in triangle ODF, $OF = s_{10}/2$ and $DF = s_{10}\sqrt{3}/2$. From triangle ADF we have

$$(R\sqrt{2})^2 = (R + s_{10}/2)^2 + (s_{10}\sqrt{3}/2)^2$$

$$s_{10}^2 + Rs_{10} - R^2 = 0$$

$$s_{10} = \frac{-R + R\sqrt{5}}{2} \quad ..... \text{(a)}.*$$

This is the expression for the side of a regular decagon inscribed in a circle of radius R. Now lay off AP = AN = OD. Then PN is the side of the regular inscribed pentagon. From the formula for s_{10} follows the second construction:

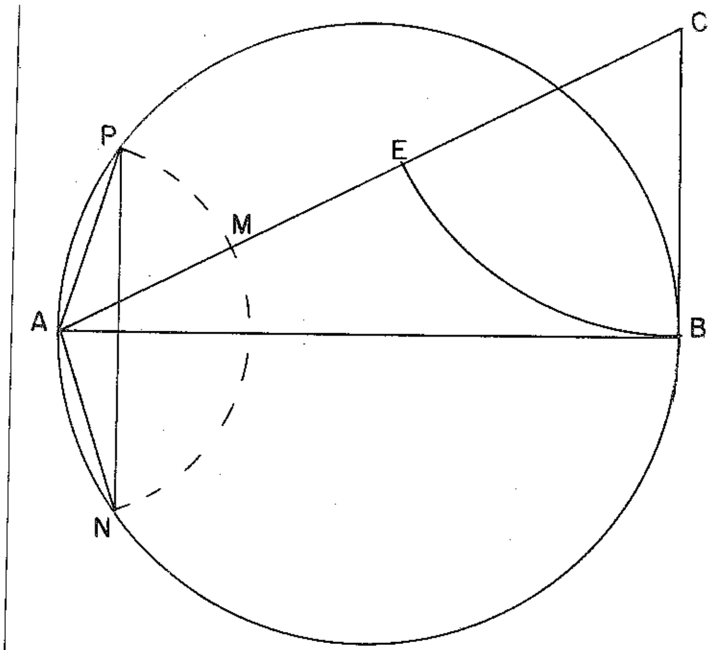
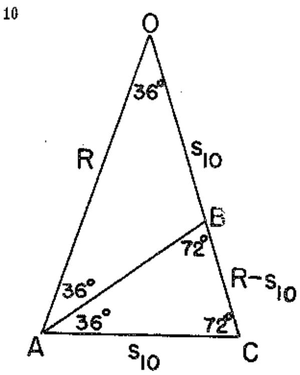


Figure 2

At point B of the diameter AB erect a perpendicular to AB and lay off BC = R. Connect C with A. Rotate about C point B into E on AC. Then $AE = R\sqrt{5} - R$. Bisect AE. Then $AM = \frac{R\sqrt{5} - R}{2} = s_{10}$. Rotate M about A into P and N. $PN = s_5$.

* Derivation of formula for s_{10}



$\triangle OAC \sim \triangle ABC$

$\therefore R : s_{10} = s_{10} : (R - s_{10})$

$\therefore s_{10}^2 + Rs_{10} - R^2 = 0,$

which gives (a).

The great tragedy of Science--the slaying of a beautiful hypothesis by an ugly fact.

THOMAS HUXLEY, Biogenesis and Abiogenesis

Geometry—the only science that it hath pleased God hitherto to bestow on mankind.

THOMAS HOBBES, Leviathan. Pt. i, ch. 4.

A New Approach to the Problem of The Shortest Grade Line Connecting Two Skew Lines

By W. G. Stinson

Queens University, Kingston, Ontario

The approach that I suggest is one that can be thoroughly explained and justified to students in the language of the subject and relying on only basic ideas. In all texts that I have examined the explanation or justification for the standard solution to the problem of establishing the shortest line of specified grade connecting two skew lines has been either omitted, avoided, or inadequately handled. It is insufficient to avoid the difficulty by saying that the solution is similar to that of the common perpendicular or shortest level line; in fact, the impression given is erroneous since all lines at a specified grade connecting the two skew lines will not appear parallel and of equal length in the elevation view where the skew lines project parallel. The solutions are similar but the reasoning required is different. Furthermore, to say, without giving proof or reasons, that the common perpendicular, the shortest level line, and the shortest line of any specified grade connecting two skew lines are elements of the same hyperbolic paraboloid is really no better than saying that all shortest lines of whatever grade connecting two skew lines will appear true length in the same elevation view. Both of these statements are true but do not explain why.

The solution that I suggest is more clearly explained when broken into two steps.

Step I: To establish the shortest line of specified grade connecting any point, P, to Plane A B E. See Figure 1.

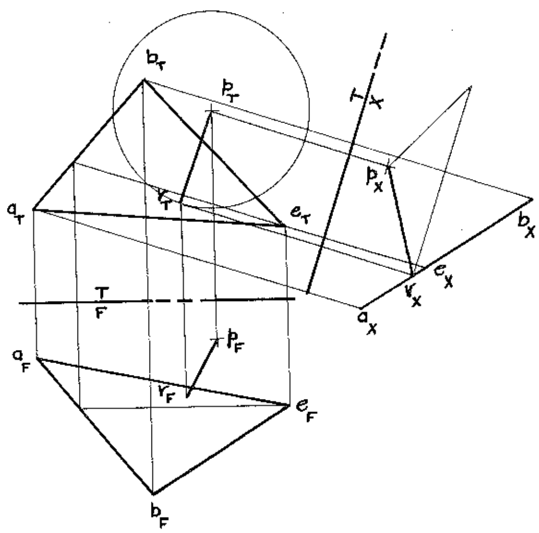


Fig. 1

All lines through P having the specified grade are elements of a right circular cone having its apex at P, a vertical axis, and a base angle equivalent to the specified grade. The required line, the shortest one, will be an element of the one such cone that just touches the given Plane ABE. This cone is readily established in the elevation view X where Plane ABE appears as an edge. Obviously the required line is the element PR which shows true length in view X and actually lies parallel to Plane X or perpendicular to the level lines of ABE.

Step II: To establish the shortest line of specified grade connecting skew lines AB and CD. See Figure 2.

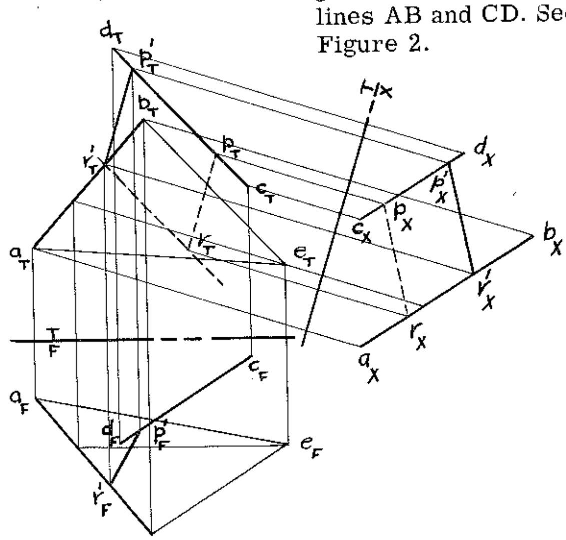


Fig. 2

Through AB pass a Plane ABE parallel to CD by passing line BE through B and parallel to CD. Obtain an edge view of Plane ABE on a vertical Plane X. Take any point P on line CD and establish the shortest line of the specified grade from P to the Plane ABE. This line, PR, is first established in view X where it appears true length and true slope, and then in the top view where it projects parallel to $FL\frac{T}{X}$ (as in Step I).

Now let P move along CD and PR move parallel to itself, with R in ABE. Since CD is parallel to ABE, PR remains the same length, and the path of R projects in the top view as a line through $r_T \parallel c_T d_T$ and is in fact a line in ABE parallel to CD. Through the point R' where this line is ABE intersects AB, establish $R'P' \parallel RP$. The line P'R' has the required grade and since it is equal in length to the shortest line from any point on CD to the Plane ABE, there can be no line from CD to AB that is shorter than P'R'.

Obviously this solution can be used to establish any shortest line, but its real value is in the explanation it provides for the solution to the problem of the shortest grade line connecting two skew lines.

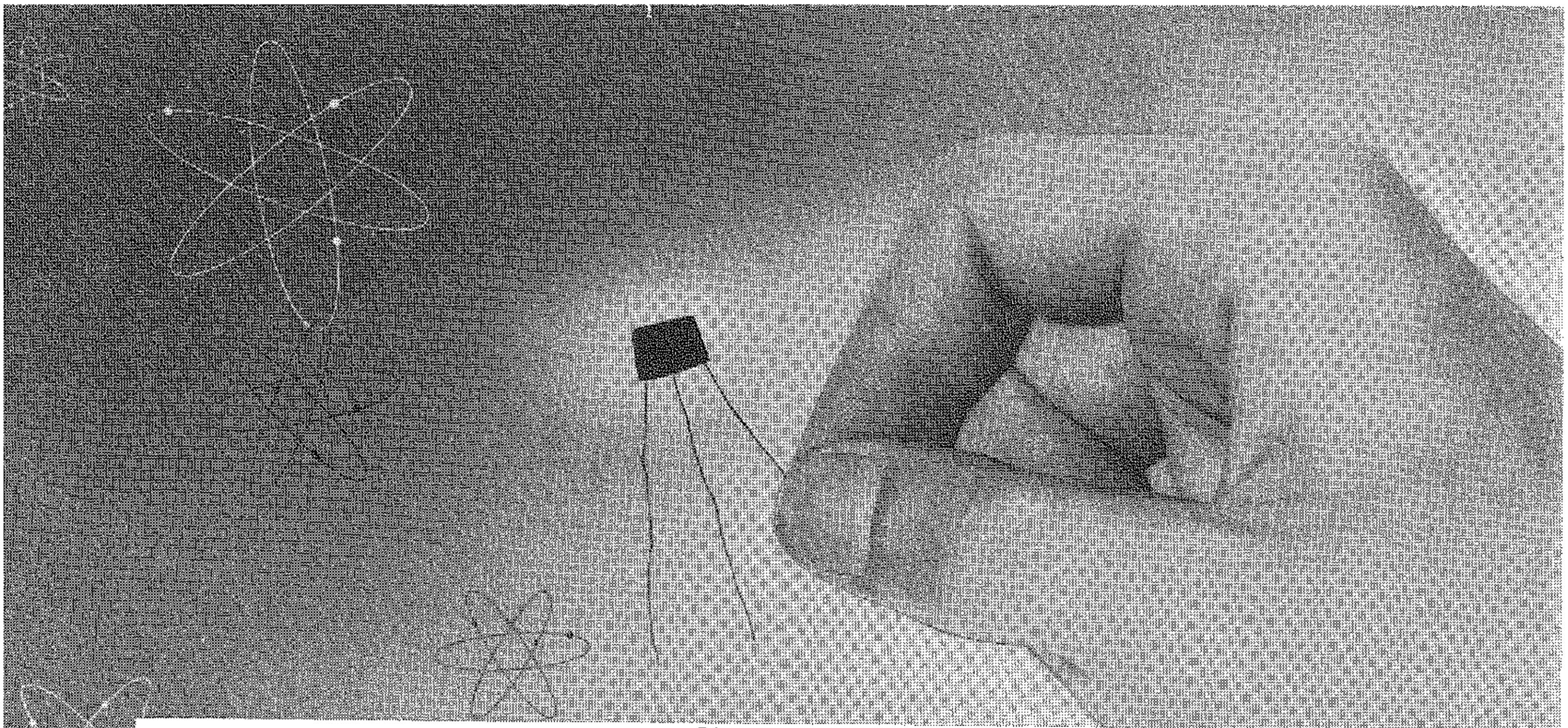
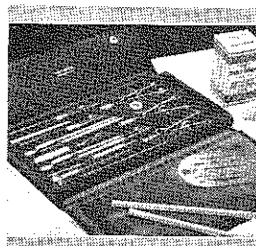


Photo: Bell Telephone Laboratories



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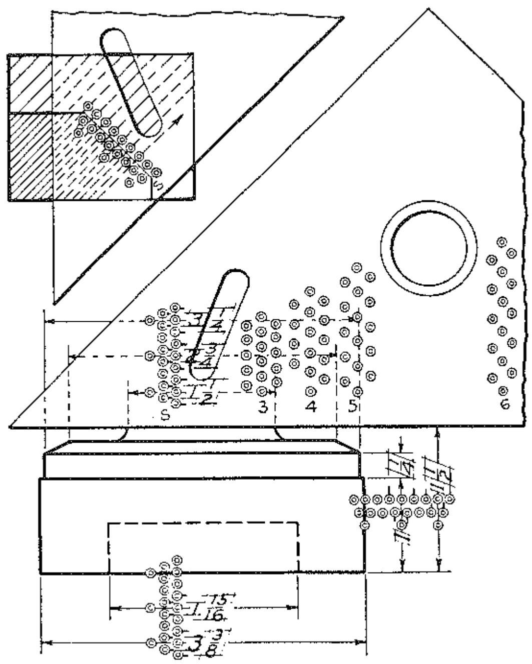

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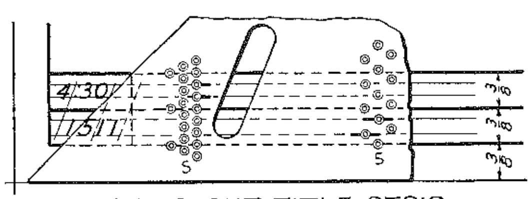

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