

• For the third consecutive year, the January issue of this magazine is devoted to a progress report on Georgia Tech's nuclear program. The overwhelming success of the first two issues on the subject (they were the most popular in the history of *The Research Engineer*) dictated this third progress report.

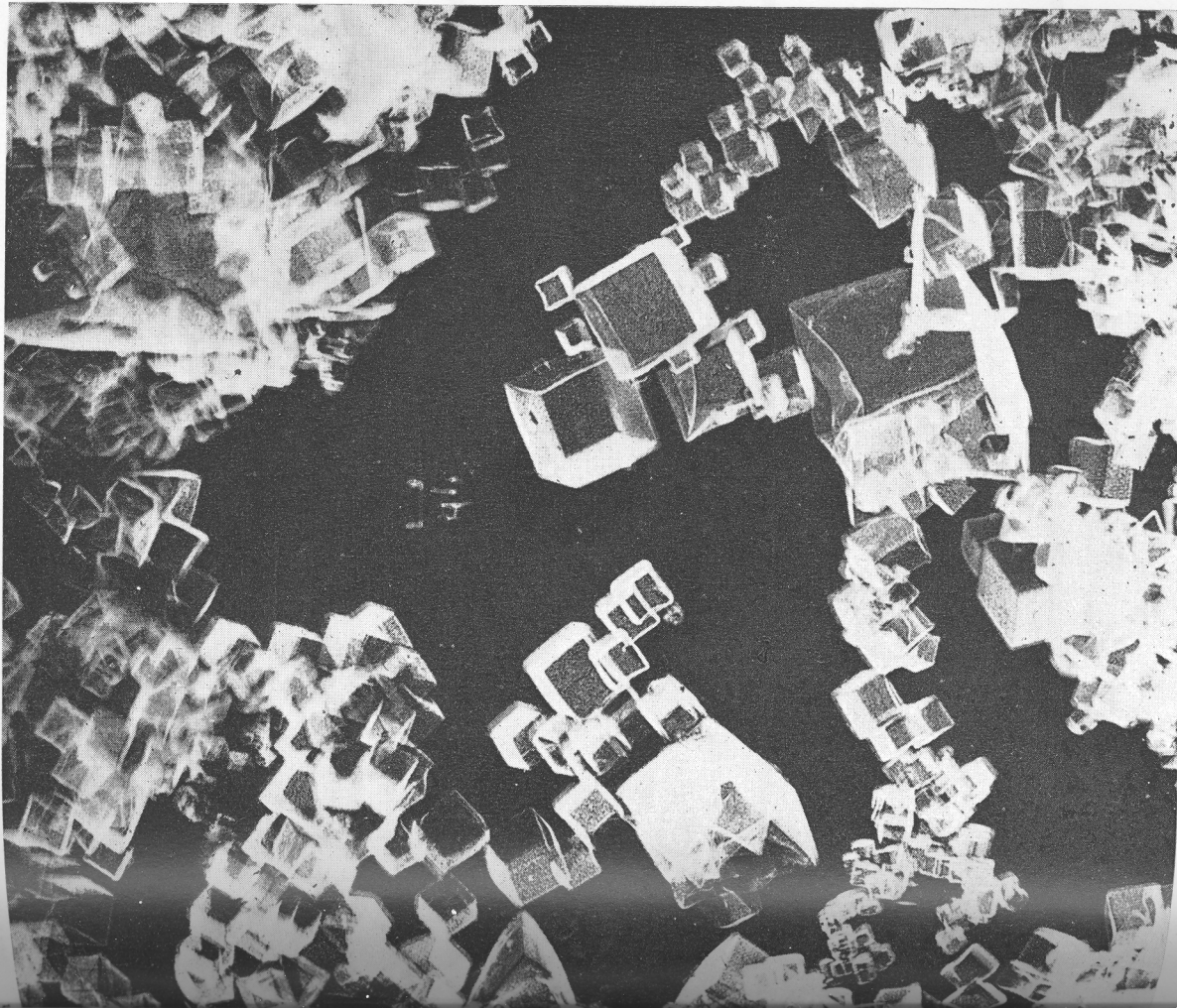
Georgia Tech's nuclear program has come a long way since January of 1956 when our first progress report was published. The master's level educational program in nuclear science and engineering is in full swing as you can see from the article on page 12. In the past two years several significant additions have been made to Tech's teaching and research staff in the nuclear fields making possible this expanded educational program. The sub-critical assembly, which last year at this time was under construction, has been used as a laboratory tool in the educational program since last April.

The final plans for the radioisotopes and bioengineering building—expanded over 60% as a result of grants from the National Institutes of Health and the Board of Regents—have been completed. The building should be near completion by the time you get next year's progress report.

During the past year, Governor Marvin Griffin (see cover) turned over \$2,500,000 in State surplus funds to the Board of Regents for the proposed research reactor. Proposals for aid from various federal agencies have been submitted by Tech to secure the \$1,400,000 still needed for the construction of this heavy-water-moderated, enriched fuel, heterogeneous, tank-type reactor. The conceptual design of this reactor has been completed and the site selected. By the time the 1960 progress report is published, one of the finest nuclear research tools connected with any institution of higher learning should be well on its way to completion.

It's been a great twelve months for Georgia Tech and its nuclear program. We hope that we will have as much progress to report in next January's issue.

Another
year
of Progress



A TECH MICROGRAPH
FOR A GT ENGRAVING
see page 2

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THE PRESIDENT'S PAGE	3
SCIENCE AND PHOTOENGRAVING	4
COMMUNITY PROBLEMS OF NEW INDUSTRY	9
CLASS SIZE AND LEARNING	11
EDITED IN RETROSPECT	16

contents

The electron micrograph pictured on the cover and again on page 4 of this issue is a carbon platinum replica of magnesium oxide smoke. Taken by Georgia Tech's electron microscope it makes an ideal subject to illustrate the powderless etching process developed for the photoengraving industry by Georgia Tech researchers. In fact the cover plate as well as the two plates on page 4 were made in Tech's own Industrial Products laboratories using the now well established Georgia Tech process. You can learn a great deal more about this process and the entire art of photoengraving by turning to page 5 of this April issue.

the cover

THE RESEARCH ENGINEER is published quarterly, in January, April, July and October by the Engineering Experiment Station, Georgia Institute of Technology. Entered as second-class matter September 1948 at the post office at Atlanta, Georgia under the act of August 24, 1912. Accepted for mailing at the special rate of postage provided for in the act of February 28, 1952. Section 528, P.L.&R., authorized on October 18, 1948.

ON MARCH 25, the Trustees of the Georgia Tech Foundation voted grants totalling \$138,650 to supplement salaries of teaching members of the Georgia Tech faculty for the 1958-59 school year.

This is the second year of the faculty supplementation program co-sponsored by the Tech Foundation and the Georgia Tech National Alumni Association. Last year grants totalling over \$85,000 were set aside for faculty supplementation at Tech.

The continuation of this program helps to answer Georgia Tech's greatest single need—a higher salary scale for the faculty. Through this program, Tech's two alumni organizations—the Foundation and the National Alumni Association—acknowledge the necessity for paying higher salaries to teachers in the engineering and scientific fields in this technological age.

Approximately 100 members of the Georgia Tech faculty will benefit directly from these grants. And the entire college community and all it serves will receive the indirect benefits.

The Governor, Legislature and Board of Regents have done their best through increased allocations and special grants, to insure the continuing advance of higher education in Georgia. These Foundation grants will supplement Tech's increased allocations from the Board of Regents and help to keep many of our faculty members who otherwise might be lost to other colleges or to industry in today's highly competitive engineering and scientific teachers' market. The grants will mean also that Tech can continue to bid competitively for the services of well-qualified teachers to maintain and to increase the level of our faculty.

The funds for these grants came from contributions of over 9,000 alumni through the annual Roll Call of the National Alumni Association and from Tech's share of the joint Tech-Georgia development appeal to business and industry in which over 300 companies participated. Georgia Tech is indeed fortunate in having alumni leaders who are so intensely interested in their college's welfare that they will take the time and effort to solicit business and industry as well as the alumni to produce such needed financial aid for their institution.

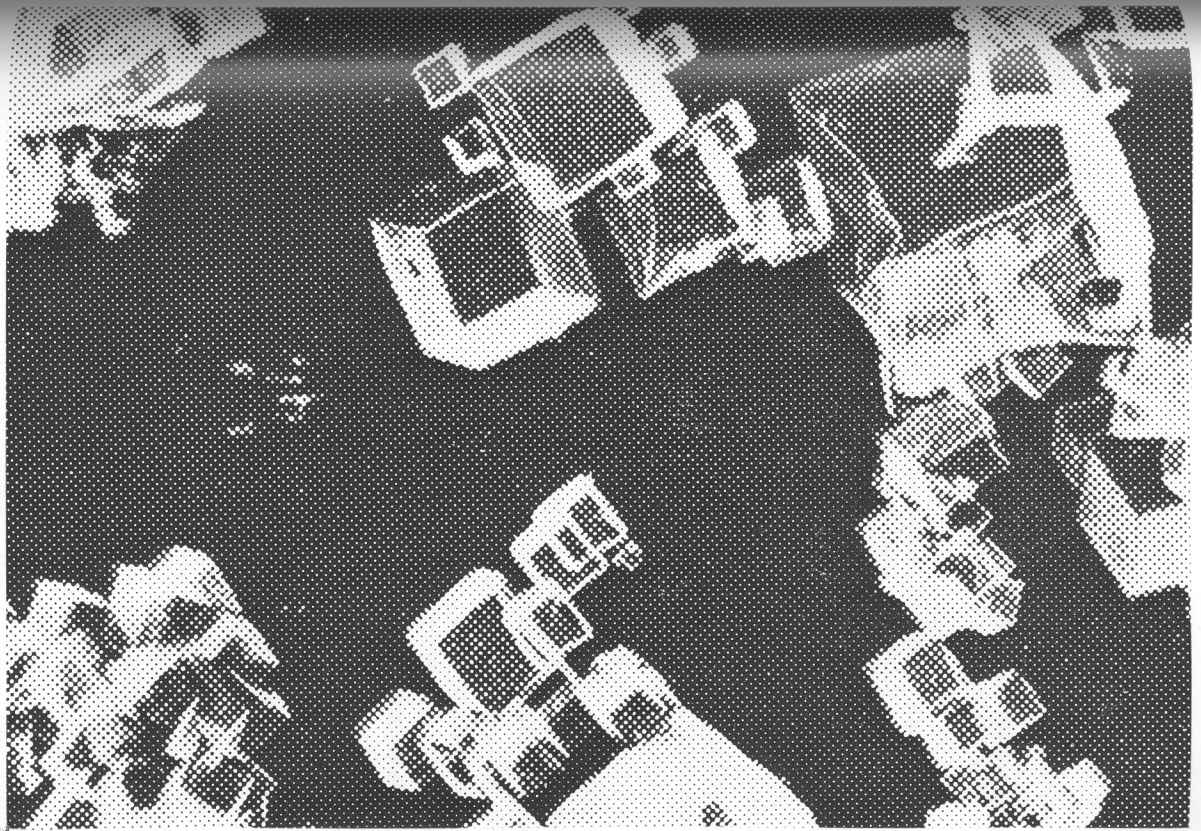
Last year we suffered the fewest losses of teaching faculty in the recent history of Georgia Tech. To me, this exceptional record reflects the real worth of this supplementation program.

E. D. Harrison
President

SCIENCE AND THE ART OF PHOTOENGRAVING

by W. H. BURROWS, Research Associate Professor

Enlargement of the screen pattern showing dot structure, the basis for halftone reproduction.



On the Next Five Pages Is the Story of How Georgia Tech Research Solved One of the Biggest Problems Associated with Photoengraving

WITHOUT PICTURES life would not be the same. Pictures draw our eyes to a news story, sell us toothpaste and bunion pads, send us scurrying to the kitchen to try a new palate-tickler or to the home workshop for another round of do-it-yourself mayhem, educate us, enlighten us, entertain us, make decisions for us, elevate us socially, and send some of us to jail. The father of the printed picture is *Photoengraving*, an art described as* "... the highest attainment of reproductive and interpretative art... a tonal interpretation of form and color... a powerful social, cultural and economic influence." To this great art Georgia Tech has had a part in bringing the benefit of the scientific approach. The result is a strong argument for science in the arts. For the techniques which have come out of the laboratory have not only broadened the potentialities of the art by reducing the cost of its practice; they have also provided the photoengraver with a means for more faithful preservation of the artistic quality of the original.

Photoengraving is a process whereby a page of type, a black-and-white photograph, a line drawing, or even a color photograph is converted into a printing plate. This plate may then be inked by standard letterpress operation, and its impression on paper will be a very close copy of the original subject material. The plate gives a proper impression because each portion of the plate which is to transfer ink to the paper stands in relief from the background material. In Figure 1 the letters in the word "printing" stand about fifteen thousandths of an inch above the background surface. The faces of these letters receive ink and transfer it to the paper, whereas the background material does not.

The letters in Figure 1 give the impression of having been set in some sort

*"The Art of Photoengraving," *American Photoengravers Association*, Chicago, 1952, p. 2.

of modified linotype machine, which molds letters from molten lead. Such is not the case. These letters started out as a photographic image on the surface of the metal. The surrounding metal was then dissolved away by an acid solution. The letters were not attacked by the acid, but were left standing.

Reproduction of printed matter by photoengraving has not been extensively used in the past except in such instances as combinations of text and illustration in advertising material. At the present time, however, there is a distinct interest in exploiting this method of reproduction of printed material, especially in the magazine field. This interest stems largely from two sources; new and improved methods of preparing bookface copy without recourse to typesetting procedures, and the increasing desire of publishers to intermingle illustrative material with text.

Photoengraving owes its conception, birth, growth and maturity to the need for a method of reproducing *art* (any pictorial representation from simple line drawings in black and white to reproductions in color of the works of the great masters) on the letterpress. Certainly the greatest field of application has been the reproduction of photographic material in news reporting and advertising.

Line work (printed copy and line drawings) has only two tones, black and white. Consequently, a photoengraving plate like that of Figure 1 is adequate for the reproduction of such material, giving a fully inked impression where the unetched face of the metal contacts paper, and complete absence of ink in the etched areas. On the other hand, reproduction of material which shows gradations in tone from black to white, including all tones of gray, requires a preliminary photographic step, the production of a "halftone" negative.

Continued on page 6

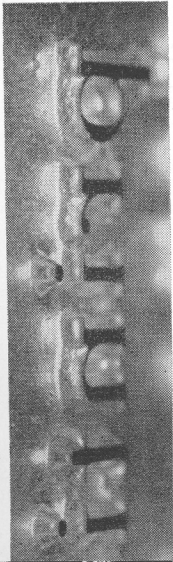


Fig. 1—PROFILE OF ENGRAVED TYPE

The halftone negative is produced by photographing the original through a special screen. At one time wire screens were used for this purpose, but today's screens are gratings accurately ruled on glass to provide remarkably faithful duplication of the tonal gradations of the original. As light from the original passes through the halftone screen, it is broken up into dots of varying size, depending upon the intensity of the light. A nearly white original produces dots so large that they merge into a continuous black image, with only fine white specks showing, as in the left end of Figure 2. As the tone of the original deepens from white towards black, the size of the white dots in the negative increases, leaving less black area, until for a nearly black original the negative shows a nearly white background with small black specks on it. In Figure 2 the size of these dots is greatly magnified to illustrate the principle of tone gradation; in actual practice, very fine screens are used so that individual dots are invisible to the naked eye (or nearly so), and the gradations of tone in the ink impression bear a very close resemblance to those of the original photograph. Newspaper illustrations are printed from halftones having 65 dots to the linear inch, the finest dot pattern which can be used on a coarse paper like newsprint; these dots are visible to the

naked 20/20 eye. Magazine illustrations are printed on a much smoother paper, so a 120-line screen is used; these dots are on the threshold of visibility. Fine art work requires much finer screens, 150 or more lines to the inch, and these dots can be seen only under magnification.

The art of photoengraving begins with the shooting of the negative, unscreened for line work or screened for halftone work. The quality of the finished photoengraving plate depends largely upon the skill and knowledge of the photographer, who must know in advance the extent to which the etching process is going to alter the size of the dots in a halftone or the thickness of the lines in line work. It is his job to shoot the negative in such manner as to compensate for such *color loss* or *area loss* in the etching bath. The photoengraving trade is a large consumer of highly specialized photographic materials, among which is an ingenious negative material called *stripping film*. After the negative has been developed and fixed, the gelatin layer containing the negative image is stripped off of its temporary backing and mounted on another backing. At the same time, other negatives may be mounted on the same backing, making possible the production of a *combination plate* containing both halftone and line work.

The image is now ready to be applied to the surface of the copper plate; the plate must first be prepared to receive the image by application of a photosensitive *resist* coating. Early resists were made from glue, water, and gelatin; more recently polyvinyl alcohol has been used to a limited extent. Most photoengravers become wedded to a particular resist

early in their careers and remain faithful to the end. A *sensitizer*, which is usually ammonium bichromate solution, is added to the resist to render it sensitive to light, the resist is applied to the copper surface, and dried. The negative is placed against this sensitized surface and the two are exposed to ultraviolet light from an arc lamp.

Light passing through transparent portions of the negative hardens the sensitized resist, but portions of the resist which are protected by black portions of the negative remain soft. The plate is developed by washing out the soft portions of the resist, then the remaining portions are further hardened by *burning in*, that is, heating in an oven or over a gas flame. The plate is now ready for the etching bath.

The etching bath used for copper engravings is ferric chloride solution, known to the trade as perchloride or iron, or simply *iron*. The copper plate may be placed face down just below the surface of the solution in a tray; this *still bath* method is quite satisfactory for some very fine halftone work, where the *bite* cannot be very deep. For other halftone work and line work, the plate is placed in an etching machine, in which a rotating paddle splashes the plate with ferric chloride solution.

Inspection of the plate after the first bite is taken shows clearly that the ferric chloride solution has no sense of direction; instead of attacking the copper straight down, which would be highly desirable, the solution eats sideways as well, even etching under the edges of the resist coating. This *undercutting* reduces the thickness of lines in line work and the areas of dots in halftone work; it is this kind of reduction for which the photographer must compensate in shooting the negative.

Work which is to be deeply etched involves more undercutting than can be compensated for photographically; therefore, means must be taken to prevent such undercutting. The method which has been in use for many years is *powdering*. The plate is given a light bite,

then a very finely powdered fusible resin* is brushed onto the surface so as to fill in the undercut places, but not the bottom of the bite. This resin is fused in place by gentle heating, a second bite is taken, and more powder is brushed on. If a fairly deep etch is to be taken, the powdering process must be repeated some four or five times, which would not be excessive if each powdering were a single operation. Such is not the case, as a single brushing serves to coat only one side of a dot. The other three sides must be coated in like manner, each brushing being followed by heating to fuse the resin in place, then cooling and drying to take the next brushing. Thus, four powderings may well involve sixteen to twenty separate brushings, each followed by heating, cooling and drying.

It is a matter of small wonder that the photoengraving industry has been dreaming for years of a material which could be added to the bath to impart to the ferric chloride molecules a better sense of direction and arouse within them a sense of moral responsibility towards their employers, or, lacking this, to drop a curtain on the sidewalls as the etching proceeds, so as to restrain the molecules in their roquish designs.

The dream has now been realized at Georgia Tech in a project sponsored by a group of members of the photoengraving industry, organized as Photoengravers' Research, Inc. The project has had the benefit of very generous advice and assistance from one of their members, Mr. J. W. Bradley, who owns and operates an Atlanta photoengraving plant together with his sons. Working in close cooperation with the industry, the research group has developed an additive, GT-1 (guess who GT is!), which is added in small quantities to the ferric chloride etching solution. This material is so effective in preventing undercutting that no powdering is necessary for halftone work; consequently, it is possible to etch *Dragon's blood, a resinous secretion of certain fruit in Borneo, Sumatra and India, has long been used for this purpose, and still is. However, some of the market has gone to synthetic resins.

a halftone plate by a single bite in less than two minutes, where at least thirty minutes would have been required by the powder method.

Inasmuch as management in this industry considers its artisans to be extremely well paid, a time saving like this can get to be rather popular. The chemical composition of GT-1 was released to the sponsor in May 1957, and by the end of summer two manufacturers were producing it commercially for the industry. Some photoengraving shops are now using this material exclusively for halftone work, not only because of the saving in time, but also because GT-1 produces a plate of higher quality than can be obtained by any other method. One publisher of national magazines has specified that all plates produced for their publications be etched by this method.

As soon as GT-1 was on the books, the research group turned to the bigger problem—an additive which would be as successful for line work as GT-1 was for halftone work, GT-1 was good, but not good enough. Where halftone work is completed within two or three minutes, line work must go much deeper; consequently, it must be in contact with the bath for twenty or thirty minutes. During this time enough ferric chloride gets through the GT-1 to cause serious undercutting. It was fairly obvious that GT-1 had had no effect upon either the sense of direction or the moral consciences of the ferric chloride molecules, but was simply serving as curtain material—and not impervious curtain material at that. It didn't have enough backbone, or body, or stickability, or something. Maybe its holes needed plugging.

Whatever it was, there was only one thing to do, and that was to try every material which seemed to hold any promise at all, and some which looked like pure folly. To make matters worse, the operating conditions proved to be very critical, especially the temperature and the force of the splash or spray.

The answer turned out to be (you guessed it) GT-2! That GT-2 is a success (at least for one plate) is demonstrated

in Figure 1, which was etched by the powderless method, using this additive developed at Georgia Tech. Not only is there a minimum of undercutting (none that you can detect in the picture), but the shouldering is good, and the bottom is clean. The shouldering must be at the proper angle, so that the engraving can be used as a master for making electrotypes, which are a form of duplicates of photoengravings. The first step in making an electrotype is pressing a plastic mold, and if the shoulders are too steep, the mold will not pull away satisfactorily. A clean bottom is necessary so that there will be no prominences to pick up ink and make spots where none should be.

If GT-2 had succeeded only in eliminating undercutting and had not also provided good shoulders and clean bottoms, it would have been unsatisfactory in spite of the saving in time, which is several hours per plate for line and combination work. Instead, it appears that GT-2 might do for line work what GT-1 has done for halftone work, giving a higher quality plate that can be obtained by the powdering process.

One of the main factors in the application of GT-1 and GT-2 to the powderless etching of copper is the use of proper equipment and exercise of proper control, as this method which brings out the best qualities of a good plate also emphasizes the worst qualities of a bad plate. To meet the demand for proper equipment, two manufacturers of photoengraving equipment are now marketing machines designed especially for use with the powderless process. These machines are receiving their final tests in the Georgia Tech laboratories and will be marketed with the Photoengravers' Research seal of approval.

The success of this project has aroused widespread interest among photoengravers. It has been the subject of a number of write-ups in the magazines of the graphic arts industries both in this country and abroad, and has brought visitors from as far as England to observe the work of the laboratory and consult with the project personnel.

by **FREDERICK BELLINGER**, Chief, Material Sciences Division

Community Problems of New Industry

GORGIA'S INDUSTRIAL PROGRESS, and its need for new industries—with particular emphasis on the urgent need of most of the smaller counties—has become a popular, fertile, and fruitful subject of many speeches, articles, conferences, and editorials. Sometimes, not often, "bad" effects of industry are mentioned. But are these effects bad? Medicines, or shots, to treat an illness may taste badly or hurt, but the advantages of being cured are far more important than the temporary discomforts.

Recently, one of the weekly magazines reported on a town that made up its mind it wanted to retain its placid existence—wanted to be known as a town whose inhabitants enjoyed gracious living, and turned thumbs down on efforts to increase its prosperity through industry. A town, or a county, that is looking ahead to an industrial expansion should be aware of the fact that growth does involve growing pains and base its actions on a well rounded knowledge of the entire picture.

The U. S. Department of Commerce has published case studies of two small rural communities: one in which a large textile-chemistry plant was constructed and affected the entire county; the other created 285 jobs in a town of about 1,000, and the total plant investment was at least equal to the assessed value of the town. Here briefly are the results of these cases.

Case No. 1

The impact of the new, large industry on the county and town can be judged from the following *increases* shown (while not completely true, we usually think of increasing values and income as "good" and increasing costs and debts as "bad").

For the entire county: manufacturing wages and wholesale sales increased over

20 times; while retail sales went up sevenfold. The number of employees required in wholesale and retail businesses quadrupled. For each 3.3 jobs in manufacturing, one additional job was created in other businesses. The county population increased by only 78%, as many of the subsistence farmers continued to live on their farms, but worked at the plant. In fact, about half of the plant employees lived even outside the county so that automobile, bus, and gasoline businesses were expanded over a wide area. Wages rose generally throughout the area. While the number and total acreage of farms decreased and the number of farmers dropped 47%, the value of farms increased 11% and, surprisingly, total value of farm production increased. The per capita income increased 340%.

The town found it necessary to expand its city limits to accommodate a 240% population increase. This also involved doubling its capital investment in its water and sewerage system, tripling its investment in the electric system, while its streets required a 347% increase. Operating expenses of its schools and street maintenance doubled, the sewerage costs went up 90% and the operation costs of the water and electric systems quadrupled.

Case No. 2

This town was a rural community, with agriculture the leading economic activity. Its three small manufacturing plants, employing a total of 50 people, were related to agriculture. (About 80 additional people—pickle pickers—were employed for a few weeks during harvest.) Retail trade in the summer boomed through tourist trade. Hence the town possessed quite a number of seasonal business establishments. The town had a population of somewhat less than 1,000. The new industry employed 285 people.

The impact of the new industry on the town was rather small.

Village and County Finances. The new industry, new homes and increased business increased the tax base, tax rates were not changed, assessments were somewhat lowered, and the 15% increase in village income took care of a new water system, and new street lights and pavement that would have been acquired anyhow. No new schools or village employees were needed.

Commerce and Trade. Only seven new retail and service businesses were needed, with less than 20 new employees required. Gross sales increased only 15% despite a 450% increase in industrial payroll. The greatest effects were a general sprucing up of business on the main street and a much greater stability of trade. Prior to the new industry, a newly established business had had a life expectancy of but two and a half years.

Population and Housing. Of the 285 plant employees, about half lived between 6 and 12 miles from the plant as surplus farm dwellings and summer cottages could be easily converted into year-round homes. Only 37% lived in the town itself. "Developers" planned on 5 new subdivisions but did not include integrated utilities expansion. Of the 31 new homes constructed, only 13 were in the new subdivisions. Although the subdivisions had large lots and apparently desirable restrictive covenants, the cheaper sites on good roads "in the country" and free from restrictions, were more attractive to the home builders and buyers.

Growth Generating Effects. Modernization and enlargement of the telephone company was needed to care for the 50% increase in phone calls. Banking business increased at a higher rate. A payroll increase of purchasing power of about \$1,000,000 had effect over a wide area, distributed roughly according to the geographical location of the homes of the workers.

Summary

Municipal Functions. Revenue and the taxable property base will increase. Operating expenses — maintenance, fire

and police services — will increase moderately, and perhaps even more than the revenue during the early stages of construction. The capacities of the water, sewerage, and street systems may have to be enlarged resulting in an increase of municipal debt.

Trade and Commerce. The volume of retail trade, finance, and services will increase—with most of the increase absorbed by existing firms without needing new employees. Some new businesses will be started, such as new outlets of national retail firms. Rents and land value will go up, and unless controlled, speculative increases in real estate will cause wider dispersion of the workers with resultant loss of buying, building, and potential property taxes to the immediate community.

Labor and Wages. Wages probably will rise throughout the area. In our rural areas there seems to be an abundance of under-employed labor, and long range commuting is common, so that unless the new industry is very large, there will not be a large increase in population of a county. Agriculture will not be greatly affected except in exceptional cases. There will be an increase in part-time farmers with greater emphasis in "cash" crops.

What To Do? Each town should plan carefully in advance, and industrialize in an orderly manner. Can the town accept the anticipated population increase with the present schools, water, sewerage, street, fire and police systems? Or can an expansion of these services be financed within a satisfactory debt limit? Any existing plotting and subdivision regulations should be reviewed and the cooperation of land developers obtained so as to avoid the possible growth of but partially developed areas around the town resulting in "dead land." Obviously, it would be a sheer waste of money to expand utilities and services into such areas.

We believe firmly that increased industrialization in Georgia will produce a desirable increase in her economy, a more stable income to her people and a better way of life.

Class Size and the College Composition Course

A study by ROBERT HAYS, Southern Technical Institute

OVER THE LAST FIFTY YEARS many attempts have been made to discover the optimum number of students for a classroom. Various criteria of learning have been proposed and used, including achievement, conduct, teachers' knowledge of subjects, changes in attitude, and subjects' knowledge of teachers. Monroe (6) found that in a half century of research there have been published at least 73 studies dealing with class size.

These studies have been uneven, both in execution and in results. Of the 73 studies reviewed by Monroe, 16.4 percent were reported as significantly in favor of large classes, 23.3 percent in favor of large classes (not significantly so), 38.4 percent in favor of neither, 17.8 percent in favor of small classes (not significantly so), and 4.1 percent in favor of small classes. Grade-levels involved have included classes from kindergarten through graduate school.

The Problem

The present research involved two phases, historical and experimental. Both phases concerned teaching English composition at a technical institute. A null hypothesis was set up, with an assumption that "if all other variables are held constant (insofar as would be possible in a real teaching situation), then no significant difference in the efficiency of learning will be seen as a consequence of variations in class size." The researcher defined "efficiency of learning" as the change in means of test and retest scores on an English achievement test.

Procedure

A study was made of attitudes toward class size expressed by students and instructors at a technical institute. Students were selected randomly from the school dining hall, and faculty members were

sent questionnaires to elicit reactions to questions about class size and its probable effect upon learning. The questionnaire also sought opinions about the advantages and disadvantages of small, medium, and large classes.

In the second stage of the present research, all English classes taught at the school from Fall, 1950, through Summer, 1956, were studied. For each section a mean of quality points for final grades awarded to students was computed. For each instructor these means were converted to Z scores to permit future correlation with the instructor minimized as a variable. The resultant Z scores for each instructor were then correlated by the product-moment method with the number of students in each class.

The experimental stage involved instruction over a period of eleven weeks in the basic English composition course. Students took a locally devised, face-validated English test at the beginning of the quarter. At the end of the instruction period the students took the same test. Each of these instructors had taught a large class of approximately 45 students and a small class of approximately 15 students. Test-retest changes were calculated for each instructor.

The scores for each instructor's classes were statistically corrected by the method of covariance. Corrected means for each of the six sections were computed.

Subjects

Experimental subjects were approximately 180 students at a technical institute. All S's were male, with an estimated modal age of 19, and all had received high-school diplomas or had passed the GED tests. Each instructor taught approximately 60 S's, divided into a large section of approximately 45 and a large section immediately succeeding hour a small section of approximately 15. All S's were

	N	Favor small classes	Favor medium classes	Favor large classes
1. Which do you prefer:	24	14	10	0
2. In which size of class would students probably learn more:	24	19	5	0
3. In which size of class will a bright student learn more:	24	19	3	2

Chi-square and Probability

Question	Chi-square	P
Question 1	13.0	.01
Question 2	24.2	.01
Question 3	22.7	.01

first or second-quarter students studying for the Associate in Science Degree.

Materials

The experimenter used the following materials: (1) initial raw scores on an objective achievement test in English (2) a "standard" English text for college freshmen and a related workbook (3) a questionnaire administered to faculty members and students (4) final raw scores on the English achievement test.

Results

Table I shows the students' responses to the questionnaires administered to students and faculty members. Evidently the students believe rather strongly that

TABLE II — FACULTY OPINIONS

	N	Favor small classes	Favor medium classes	Favor large classes
1. Which do you prefer:	30	11	14	2
2. In which size of class would students probably learn more:	30	17	9	1
3. In which size of class will a bright student learn more:	30	13	8	0

Note: Some faculty members did not answer all three questions.

Chi-square and Probability

Question	Chi-square	P
Question 1	8.1	.02
Question 2	13.1	.01
Question 3	11.3	.01

small classes are "better" for the instructional program.

Table II shows the responses of faculty members to the same questionnaires. In general faculty members also favor small classes, although their preferences are not as biased as are those of the students.

The questionnaire also asked for advantages and disadvantages of the small, medium, and large classes. As might have been expected, the responses indicated that small classes offer individual attention, whereas large classes offer economical operation. Middle-sized classes suggested few advantages or disadvantages.

One of the problems involved in class-size research was the definition of "small" and "large." The questionnaire arbitrarily

defined small classes as those including from 1 to 15 students, medium classes as those including from 16 to 30 students, and large classes as those including 31 or more students.

At the next stage of the research, a study was made of all English courses (not including any literature courses) taught at the technical institute between Fall, 1950 and Summer, 1956. The students' letter-grades were converted to quality points (with A = 4, B = 3, etc.), and a mean of quality points was computed for each class. The resultant means were then converted to Z scores for each instructor. Finally, the Z scores were correlated by the product-moment method.

Very little of a consistent pattern emerged from these correlations, except that in general the absolute value of the r's varied inversely as the N of classes. None of the r's reached a probability as assured as .05. None of these classes were conducted as experimental sections, and no data on readiness of the students had been preserved. Hence, the data of Table III can only indicate that in six years of teaching, with eight instructors and 252 sections, no significant relationship between class size and achievement (measured by letter-grades) developed.

The final step of the research comprised a controlled experiment. Three instructors participated, with each teaching a large class and then a small class. Instructor A's large class included 45 students, and his small class included 18 students. Instructor B's large class numbered 39 students and his small class 15 students. Instructor C's large class en-

TABLE III — CLASS SIZE CORRELATED WITH MEAN OF QUALITY POINTS

Instructor	N of classes	r	P
A	76	-.0009	—
B	95	-.14	.50
C	38	-.06	—
D	23	-.365	.10
E	9	.51	.50
F	7	.14	—
G	3	.57	—
H	1	Not computed	—

TABLE IV — RESULTS OF INITIAL TEST

Instructor	Section	M	S.D.	S.E. _m
A	L	70.8	9.31	1.49
A	S	65.5	15.15	3.91
B	L	67.0	9.6	1.67
B	S	70.2	8.2	2.48
C	L	69.7	9.2	1.45
C	S	62.9	14.4	5.10

TABLE V — RESULTS OF FINAL TEST

Instructor	Section	M	S.D.	S.E. _m
A	L	79.1	10.1	1.62
A	S	77.3	11.6	3.00
B	L	77.0	9.3	1.62
B	S	78.3	8.9	2.69
C	L	75.8	7.2	1.15
C	S	73.3	16.2	5.75

Table VI shows the results of comparing test and retest scores:

TABLE VI — COMPARISON OF TEST AND RETEST RESULTS

Instructor	Section	Test-Retest Correlation	D	S.E. _D	C.R.(t)	P
A	L	.765	8.3	1.07	7.75	.01
A	S	.540	11.8	3.40	3.47	.01
B	L	.529	10.0	1.59	6.28	.01
B	S	.462	8.1	2.69	3.01	.02
C	L	.662	6.1	1.10	5.55	.01
C	S	.565	10.4	5.10	2.02	.10*

*Actually between .10 and .05.
April, 1958

rolled 47 students and his small class 11 students. These numbers represent slight decreases from initial enrollment; attrition from sickness, drop-outs, and other causes had reduced the numbers somewhat. Such attrition, a usual phenomenon of teaching, was not prevented.

A question would naturally arise about the instructors' attitudes toward their classes and the methods which they used. Instructor A had suspected that class size would not be a significant variable in achievement. Instructor B favored small classes. Instructor C apparently had no particular prejudices toward large or small classes, provided he could be relieved of the increased grading resulting from large sections. To supply aid in grading papers, a grader was employed, and none of the three instructors graded his students' papers.

All three instructors were supposed to use their own methods in teaching. They were, however, supposed to use the same methods for their large and small sections. Their classes were not audited to

ensure constant methods, for the researcher believed that auditing classes might improperly influence the results.

On the first class-day, all students took an objective, 50-item, locally devised English achievement test. This test had been validated by subjecting it to criticism from all members of the English Department; thus the test was at least face-validated. The researcher assumed that practice effect could make little difference on the test since eleven weeks had elapsed between test and retest.

Table IV shows the results of the initial test for each instructor, with 'L' designating the large section and 'S' designating the small section. Table V shows the same calculations for the retest. The data of Table VI show that each of the six sections showed a gain between test and retest, with the lowest assurance at 90 degrees of confidence. Even the lowest confidence-level, that for Instructor C's small class, was between the ninth and ninety-fifth level. It seems highly probable that the students showed a posi-

tive change in scores as indicated by the testing instrument. Any assumptions about initial equality in English achievement, the variable being measured, would be risky. Therefore, the test-retest results for each instructor were treated by the method of covariance. Tables VII, VIII, and IX show the covariance computations for instructors A, B, and C respectively.

As Tables VII, VIII, and IX will reveal, the ratio of between-groups variance to within-groups variance yields an F of less than 1 for all these experiments; thus, none of the three F's are significant. Moreover, with insignificant F's, the adjustment for initial inequality evokes the conclusion that there was no significant difference in achievement between the large and small sections for each instructor.

ADJUSTMENT FOR INEQUALITY

	b	d	y ²	xy	Squares	df	Variance
Within	.69	1.7 (L)	3632	1948	2675	42	64
Between		3.8 (S)	16	40	2	1	2
Total			4055	1988	2673		

TABLE VIII — COVARIANCE: INSTRUCTOR B

	b	d	y ²	xy	Squares	df	Variance
Within	.69	1.7 (L)	3632	1948	2675	42	64
Between		3.8 (S)	16	40	2	1	2
Total			4055	1988	2673		

ADJUSTMENT FOR INEQUALITY

	b	d	y ²	xy	Squares	df	Variance
Within	.45	1.3 (L)	3995	3279	2502	46	54
Between		5.5 (S)	47	126	3	1	3
Total			7542	3405	2505		

Adjusted final M
77.8 (L)
79.9 (S)

Adjusted final M
77.4 (L)
77.2 (S)

TABLE IX — COVARIANCE: INSTRUCTOR C

	x ²	y ²	xy	Squares	df	Variance
Within	7201	3995	3279	2502	46	54
Between	341	47	126	3	1	3
Total	7542	4042	3405	2505		

ADJUSTMENT FOR INEQUALITY

	b	d	y ²	xy	Squares	df	Variance
Within	.45	1.3 (L)	3995	3279	2502	46	54
Between		5.5 (S)	47	126	3	1	3
Total			7542	3405	2505		

Adjusted final M
75.8 (L)
75.2 (S)

large and small classes under the same instructor revealed no significant difference in favor of either size.

However, in the experiment, method of instruction remained constant for the large and small classes. The case for small classes may well rest on opportunities for more effective methods; hence further research, particularly in dealing with methods, is indicated.

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Edited In Retrospect

The Research Engineer

Published by the Georgia Tech Engineering Experiment Station

• Earlier in the year, the Industrial Development Branch of Georgia Tech's Engineering Experiment Station released a brand-new bimonthly publication called *IDEAS*. The big idea behind *IDEAS* is to pinpoint needs and disseminate research findings which can solve State and local problems in industrial development.

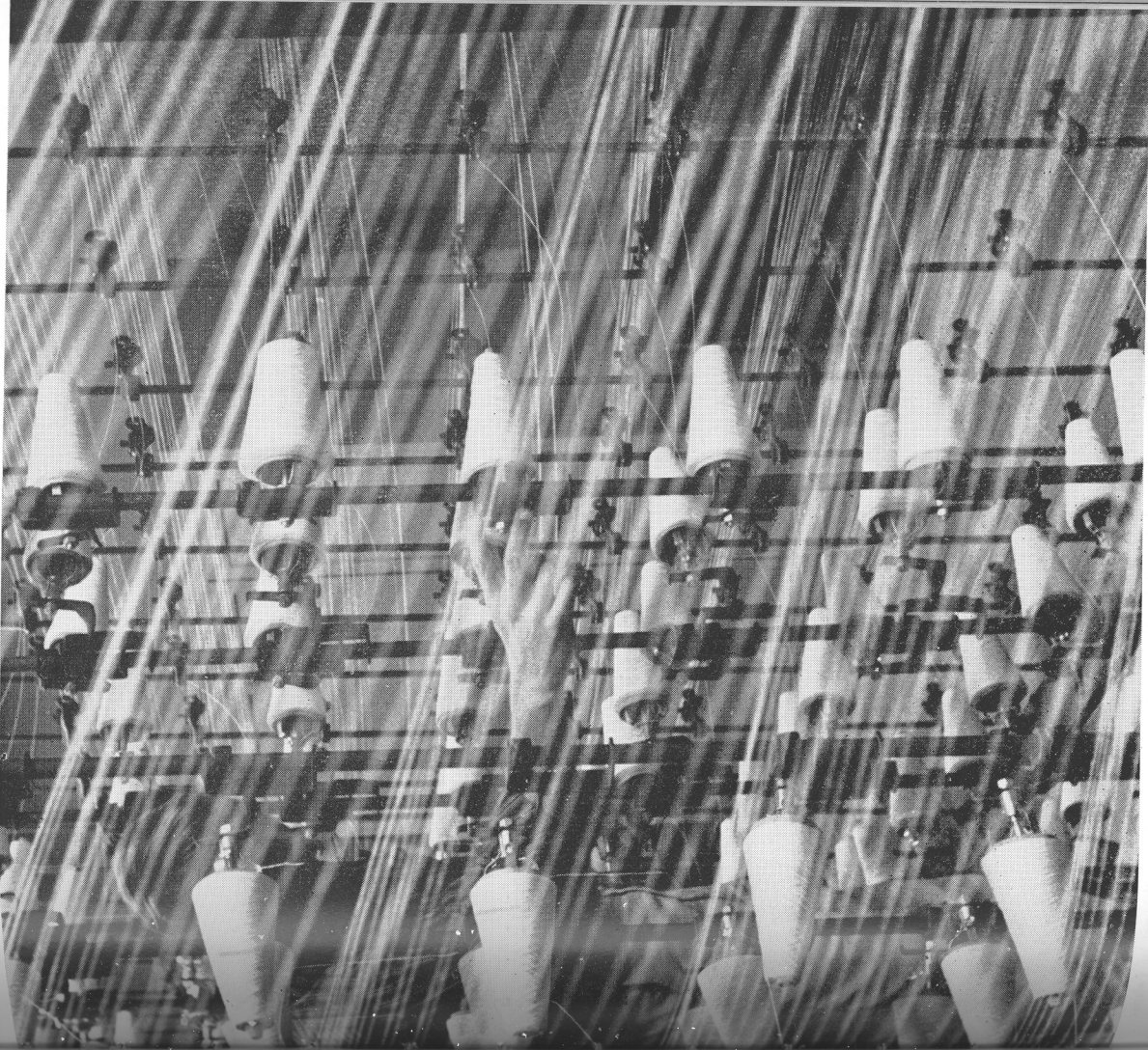
The initial issue featured a proposed 10-point program for the development of industry in Georgia. Based on 18 months of basic and applied research, the closely-related 10-points of the program are all considered essential by the Tech research group if the State's urgent and long-ranged industrial needs are to be met.

Key point in the program was the suggestion that an independent, non-political committee of business and industrial leaders be formed to provide a central, authoritative body which could concentrate on the elimination of existing weaknesses. This committee would also serve to add prestige to the State's drive for a more prosperous economy through industrial development.

Briefly, the other points in the optimum program prepared at the request of Governor Griffin are: (1) organization of a special *rural development* research group, (2) a greatly expanded market research program, (3) establishment of a metal resources research program, (4) establishment of a forest products research program, (5) an accelerated program of economic feasibility studies to present *packaged* analyses to industrial prospects, (6) expansion of spot analysis and consulting services, (7) aid to local development groups in setting up and carrying out effective action programs, (8) a manpower research program on the State's present and future labor supply, training needs and related problems, and (9) a basic data reservoir and *clearing house* to make available quickly, yet completely, data needed for industrial prospects.

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