edited in retrospect

the changing scene

• Beginning with the fall term of 1956, Georgia Tech's expanded nuclear science program—first outlined for you in the January issue of this magazine—will officially get underway with the registration of the first students in the graduate program. The final green light for this program—approval for the granting of two new graduate degrees—was given by the Board of Regents, governing body of Georgia's University System, at their May meeting. The new degree designations are the Master of Science in Nuclear Engineering and the Master of Science in Nuclear Science. Applications for this program plus full information on the prerequisites and course content are now available from the Dean of Georgia Tech's Graduate Division on the campus.

Also scheduled for this fall is the beginning of construction on the radioisotopes laboratory building on the campus. This building and the graduate program were made possible through Governor Griffin's special allocation of $300,000 to start Tech on the road to becoming a major center of nuclear education and research. The new building will house a neutron physics laboratory (including a subcritical atomic pile) for use in the graduate program. It will also contain a classroom for demonstrating the uses of radioisotopes in special courses for industrial, medical and other groups from throughout the State and the South. The building will furnish Georgia Tech staff members with much-needed space and equipment to carry out an extensive program of basic and applied research in radioisotopes.

the Governor's Program

• Present indications are that Governor Griffin—well aware of the great benefits that industry, medicine, agriculture and the people of the State would derive from a research reactor located in Atlanta—will ask the 1957 Legislature for funds to build Georgia Tech a reactor. If this request were granted, the program of needs set down by the Nuclear Science Committee early this year would be satisfied. The interest and cooperation shown by the Governor and the Board of Regents is extremely gratifying to all who have worked so hard to get this program started.

engineer OCT. 1956
Georgia Tech Engineering Experiment Station

A new etching development – page 4

the research engineer

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the station

the staff

contents

the cover

Phillip (Mick) Daugherty, assistant research chemist in the Engineering Experiment Station at Georgia Institute of Technology, is shown operating the spray-etching assembly constructed at Tech for use in a research project for Photoengravers Research, Inc., the research organization of the American Photoengravers Association. Using a new powderless etching process perfected on the campus, Tech researchers have cut the etching time for a copper plate from forty minutes down to three minutes. The cover photograph of this issue was etched in Tech's research laboratories using this new technique. For more about this turn to page 24.

Cover photo by L. C. Prowse of the Engineering Experiment Station Staff

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. Acceptance 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.

the president's page

FOR SIXTY-EIGHT YEARS, the words *Progress and Service* have been a prominent part of the official seal of The Georgia Institute of Technology. Throughout its history the Institute has endeavored to live up to the true meaning of this motto. If, at times, it seemed that we have fallen short, it was never from a lack of cognizance of our responsibilities or of effort.

Today, more than at any time in the past, Georgia Tech is in a position to offer a much more complete program of progress and service to the State, region and Nation. This is true because Georgia Tech is now receiving more support from all interested agencies—the State, the alumni, industry and the Federal Governmental agencies—than at any time in its history.

Examples of the increased interest in Georgia Tech by the various State agencies have been numerous over the past few months. In this issue, there is an article detailing the new Industrial Development Program now getting under way at Tech. This program is a direct result of a $50,000 allocation from Governor Marvin Griffin to the Board of Regents for support of this work. A reading of the article will give you an idea of this program's great potential for aiding in the industrial growth of our State. Back in the past decade, Georgia Tech had a similar organization which did a great deal of good for Georgia's economic growth. It was discontinued in 1949 because of lack of funds.

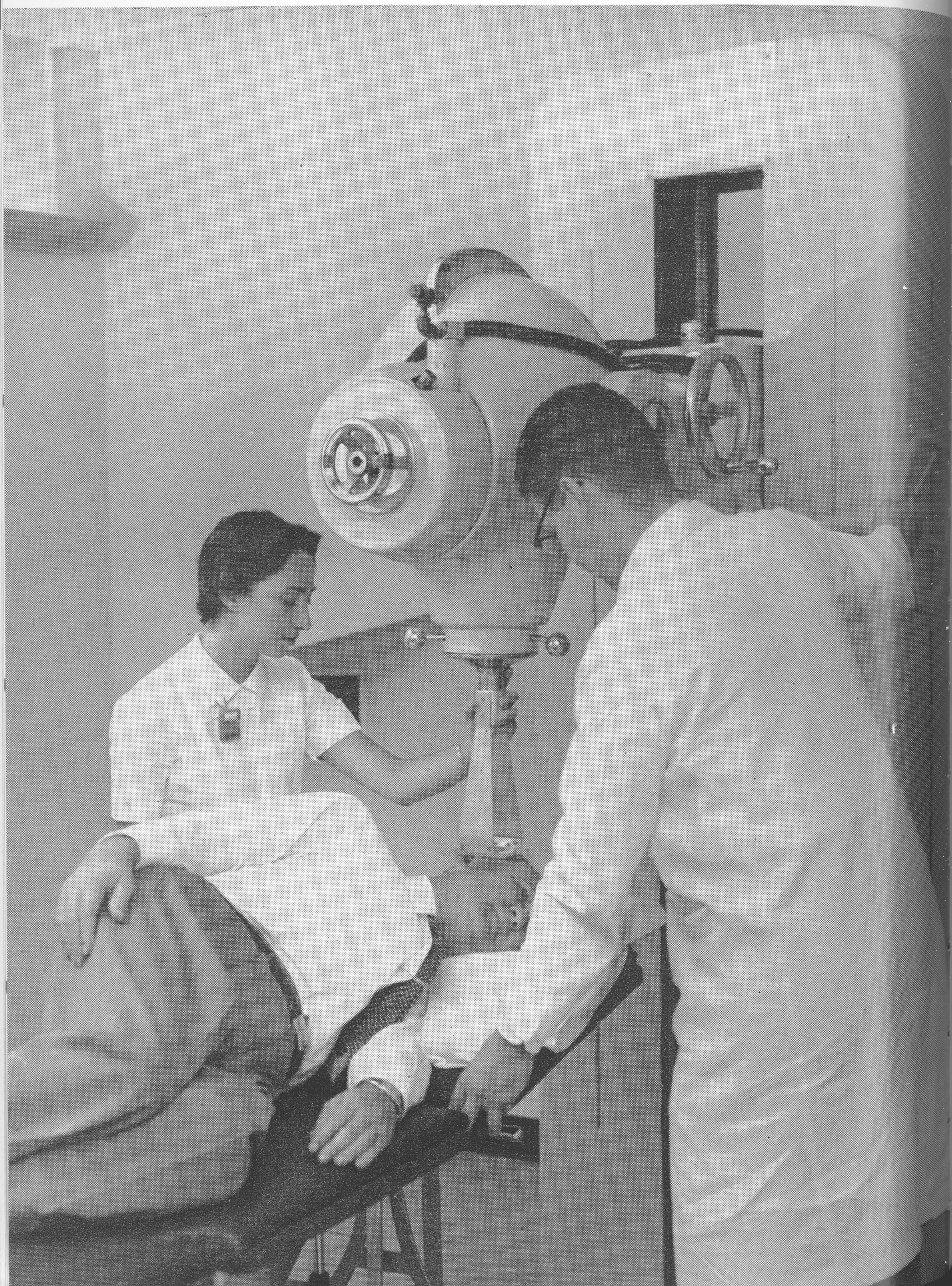
During the past year, Georgia Tech alumni and various Georgia Foundations contributed over $234,000 to the annual roll call. This is more than three times the previous record high for a Tech roll call and typifies the increased interest alumni and other friends of Tech are taking in our institution.

Generally, increased support from industry and the Federal Government might be typified by the record 1955-56 $1,960,000 income of the Engineering Experiment Station. More specific examples can be found in the joint Lockheed-Georgia Tech modernization program of the 9′ wind tunnel in the Aeronautical Engineering School and the Atomic Energy Commission's uranium loan to Georgia Tech detailed elsewhere in this issue.

Georgia Tech is a long way from having everything it needs to offer the optimum in progress and service to the people of our State and region. But recent increases in outside support implies a promise of a great future increase in the Institute's capabilities to live up to the letter of this motto.

Paul Weber
Acting President

The Emory University School of Medicine's Cobalt 60 teletherapy unit in clinical use. It was constructed for Emory at Georgia Tech.



CLINICAL USE

by Bryan L. Redd, Jr., M.D., Emory University Robert Winship Memorial Clinic

BEFORE DISCUSSING the clinical application of radioactive cobalt, let us review some of the historical background and development of radiotherapy.

The discovery of x-rays by Wilhelm Konrad Roentgen in November, 1895 was another step forward in the never-ending progress in science. This discovery was made possible only by the assemblage of many milestones in seemingly unrelated fields of science. These milestones include advances in the art of glass blowing, progress in the fields of metallurgy and electrical engineering and the development of the photographic emulsion.

The possibility of using x-ray pictures in medical and surgical diagnosis was immediately recognized and soon became widely used. That the new rays might have therapeutic application was cautiously mentioned in an editorial in the Journal of the American Medical Association in February, 1896. As early as April, 1896, many sources reported that roentgen rays would produce "Changes in the skin which are very similar to the effects of sunburn.

On observing the vari-colored fluorescence of the vacuum tube through which high tension discharges were sent, early workers postulated that the fluorescence was responsible for the production of roentgen rays. Subsequently, known fluorescent and phosphorescent substances were investigated for the production of rays similar to the x-rays. Following this line of experimentation, Henry Becquerel discovered the phenomenon of radioactivity while working with uranium salts. After the publication of Becquerel's findings in late 1896, many other scientists conducted similar research. Marie and Pierre Curie continued Becquerel's experiments and after exhaustive work announced in December, 1898 the discovery of a new highly radioactive substance which they named radium.

Because of its scarcity and difficulty in preparation, only small amounts of radium were used in the laboratories for studying its various physical properties. The discovery of the x-ray and of radium opened entirely new fields in medicine and the natural sciences.

The biological effect was soon investigated by many scientists using numerous experimental animals, plants and microorganisms. That exposure to radium would produce reddening and blistering of the human skin was first reported by Walkoff and Giesel in 1900. During the same year Rollins, a physicist of Boston, suggested the use of radium as a therapeutic agent. Rollins gave Williams, also of Boston, a small metal box containing 500 milligrams of a low intensity radium preparation which was used in the treatment of certain benign and malignant skin diseases. This preparation was found too weak to be of therapeutic value and its use was temporarily abandoned.

While performing some experiments in April, 1901, Becquerel placed a tube of very active radium in the pocket of his waistcoat where it remained for approximately six hours. The skin, immediately beneath the pocket where the radium was placed, soon developed an ulceration which required 49 days to heal. M. Curie then conducted an experiment on himself and as a result of the discovery of the new property of radium loaned the specimen to DanLos of the St. Louis Hospital in Paris for medical purposes. In the same year DanLos reported on the treatment of certain benign skin lesions with the use of radium chloride. As rapidly as the amounts of radium available permitted, the experiments in its use were made by other workers in Europe and America. In August, 1903 Dr. Sowers of New York City revealed an interesting letter from Alexander Graham Bell suggesting the insertion of small radium tubes within tumor masses, thus being the first to suggest implanting radium sources within tumor tissues. In

... This is believed to be one of the earliest uses of this technique.

As the supply of radium increased, more experience was gained in its use as a therapeutic agent. In 1913, N. Bohr proposed a theory that the structure of the atom was similar to an infinitesimally small solar system with a central nucleus and electrons moving in certain orbits around it. On the basis of this theory, there was greater understanding of x-rays and the radioactivity of radium and the biological effects of these ionizing radiations. Roentgen rays and radiation from radioactive substances produce physical, chemical and biological effects. Certain radiation changes are produced only if the radiant energy is absorbed in the irradiated medium. When roentgen or gamma rays strike matter, they first remove electrons from the shells of the atoms they strike. Therefore, any of the effects from radiation are the result of the removal of electrons from the atomic shells of the irradiated medium. Energy is transferred to these accelerated electrons and they in turn travel variable distances in the irradiated object, producing positive and negative ions by repeated collisions with orbital electrons of the surrounding atoms. These ions have definite electrical and chemical properties which later result in the effects observed following irradiation. It is this ionizing property used under carefully controlled conditions which is utilized internationally as the method of measuring radiation quantities. The physical or ionizing changes caused by irradiation occur during a small fraction of a second but the chemical changes produced by the ionization may last from a few moments to a very long time. There are several chemical changes produced by ionizing radiations which are considered to be of biological significance. These include reactions of water which may result in the formation of hydrogen atoms (H), hydrogen gas molecules (H_2), hydrogenation ions ($H+_2$), oxygen atoms (O), oxygen gas molecules (O_2), hydrogen peroxide (H_2O_2). All of these atoms, molecules and radicals by process of oxidation, reduction, or direct action affect inorganic and organic compounds, hormones, enzymes and other constituents of the nucleus and protoplasm of the cells. The ionization may modify the electrical charge of the colloids and the crystaloids in the cells and tissue fluid so that the metabolism of the cell, as well as its function, is disturbed and the change may be sufficient even to destroy the cell.

In order to know more specifically what biological effects the physical and chemical changes of ionization produce on normal and abnormal cells, it is necessary to review briefly certain histological and physiological facts. With proper blood supply the cell grows, divides and differentiates for specific function through nuclear control. The cell may divide by amitosis or mitosis. In amitosis the nucleus and nucleolus divide into two parts not necessarily equal and later, as the cytoplasm divides into two parts, two cells are formed. Amitosis is more frequently found in rapidly growing tissues and is also observed in certain one-cell organisms.

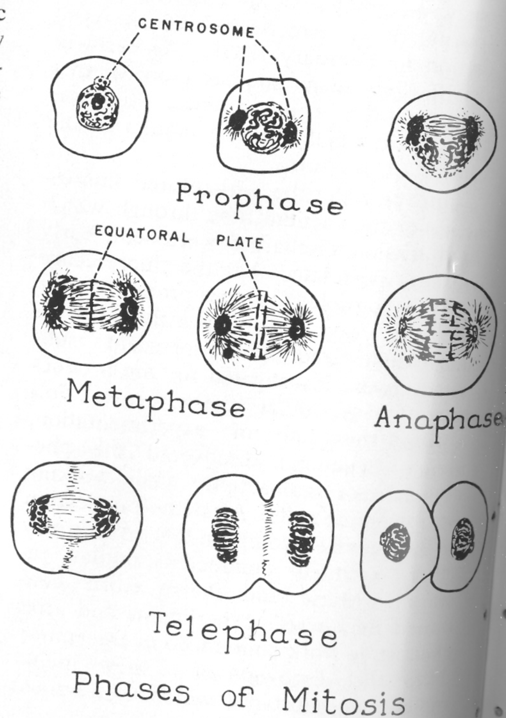


FIGURE 1—PHASES OF MITOSIS

Mitosis is the more common method of cell-division and this may be divided into four stages: the prophase, metaphase, anaphase and telephase (*See fig. 1*). The prophase requires the greatest length of time. After a resting period the centrosome divides into two parts which move toward the opposite poles of the nucleus and the chromosomes become aligned upon the equatorial plate. The metaphase is very brief. After complete alignment, the chromosomes split longitudinally and go toward the opposite poles. The anaphase is a period during which the split chromosomes are drawn towards the opposite poles. The telephase is the stage in which an annular constriction appears in the periphery of the cell membrane in the equatorial region of the cell and proceeds toward the center of the cell until two daughter cells are formed. The time for the complete process of mitosis varies in different cells and tissues. Mitosis may require as short an interval as 10 to 12 hours in very rapidly growing tissues and several days in more slowly growing tissues.

Malignant cells show cellular overgrowth with bizarre changes occurring in the nucleus of the cells. The cells are of varying sizes, some being smaller while others are much larger than normal. There is displacement of the normal tissues by overgrowth of the malignant cells with invasion of the surrounding tissues. This results in destruction of various anatomical structures and the cells have the ability to spread to distant sites either by passage through the blood stream or through the lymph vessels. An abundance of mitosis is usually found in rapidly growing tumors and there is a change in the number of chromosomes. The human chromosome count is normally 48, while chromosome counts in various forms of cancer may vary from 31 to 583. In cancerous tissues, the rate of mitosis varies widely but is generally more rapid than that noted in the tissues from which the cancerous growth originates.

Following small doses of radiation, no immediate effect is seen in the cells. After a variable latent period the nuclei may swell, the chromosomes may become granulated and fragmented and the cytoplasm becomes turbid and granular. Those cells in the final stages of mitosis may complete their division, while those in the early stages of division will be temporarily delayed. These changes are reversible and the cells resume their growth and activity. With larger doses of irradiation, the latent period is shorter, the delay in mitosis is prolonged and more of the cells become granulated and fragmented, resulting in degeneration of the cells and death.

From experimental studies with tissue cultures, the nucleus appears to be approximately 25 times more sensitive to irradiation than the cytoplasm. The late prophase, when the chromosomes are discrete but prior to the breaddown of the nuclear membrane, appears to be the most vulnerable phase of mitosis. The more rapidly growing tissues are found to have more cells undergoing mitosis at any one time and are, therefore, more radiosensitive than slower growing tissues. Thus, we find that the different tissues and organs of the body possess varying degrees of radiosensitivity depending upon their rate of growth, the length of their mitotic phase, and the degree of specialization of the cells.

The white blood cells and the germ cells of the ovary and testis are the most radiosensitive cells of the human body. The nerve cells and the muscle fibers are the least radiosensitive. New growths arising from normal tissues will be more radiosensitive than the normal tissues from which they arise because of their increased mitosis, metabolism and lower degree of specialization. From clinical experience, it has been learned that giving small doses of irradiation over a period of several days or weeks is more effective in sterilizing

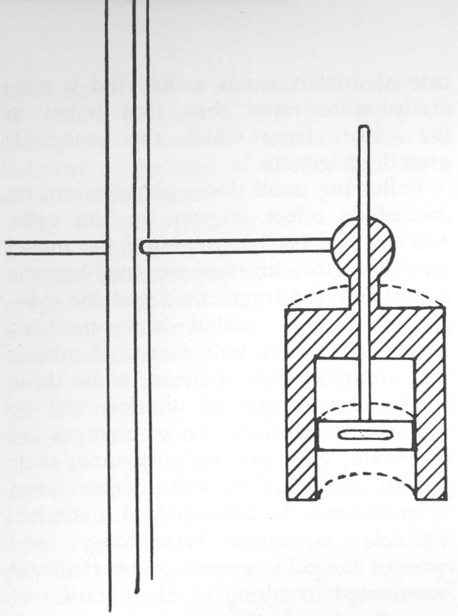


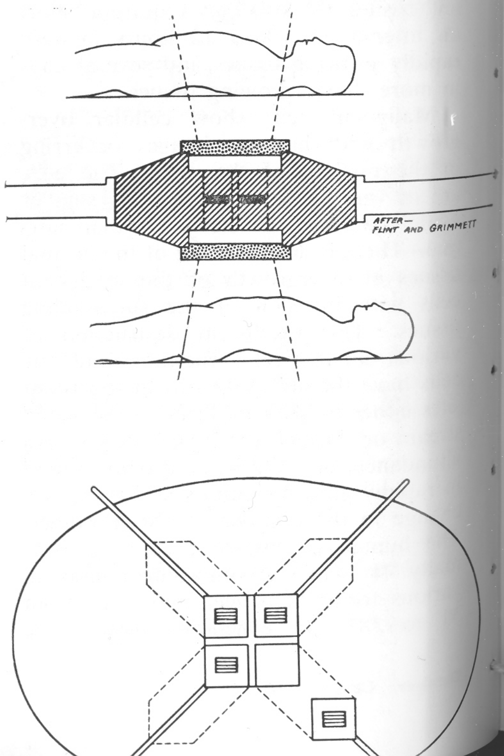
FIGURE 2—EARLY TELERADIUM UNIT

tracted-fractional method results in less damage to the normal surrounding tissue and is the method most generally used in radiotherapy at this time.

The large doses of irradiation used in the treatment of malignant lesions result in changes of the normal skin and mucosal membranes which are included in the treatment areas. There is a latent period of one to two weeks followed by redness, blistering and ulceration of these areas. These reactions heal spontaneously in two to three weeks, resulting in normal skin in the treatment areas. The severity of the reaction depends upon the size of the area treated and the patient's type of complexion.

Initially, radium was loaded into small capsules which were held against the tumor tissues being treated. Dominici learned that the penetrating ability of the radiation from radium could be increased by the use of thicker walled containers, thus stopping the less penetrating alpha particles and beta rays and allowing only the highly penetrating gamma rays to reach the tissues. It was soon noted that the tissues tolerated the gamma rays from radium much better than the x-rays produced by the early x-ray therapy machines. The gamma rays resulted in less severe skin reaction and the patients tolerated their course of therapy much better. With the application of radium in contact with the skin, rather small doses reached the tissues a few centimeters below the skin surface. By placing a thickness of wax or balsa wood between the radium and the skin surface, the relative dose received by the underlying tissue is increased, thus following the principle of the inverse square law. Increased distance between the radium source and the skin surface causes a considerable drop in the dose rate, thereby requiring longer exposure times or the use of larger radium sources. The use of these large radium sources at a distance was called "Radium pack therapy." The radium pack had certain advantages over the early x-ray therapy units in that it could be easily transported and used in any room, could be applied without difficulty to any part of the body, there was no high tension electric current to consider or danger of serious electrical shock. The disadvantages to this method of treatment were, as the radium emitted its radiation in all directions, it was impossible to restrict the area to be treated and difficult to protect the personnel working with the patients.

Figure 3—Early teleradium unit top figure illustrating position of unit and patients during treatment and lower figure illustrating a cross-section of unit showing radium positions.



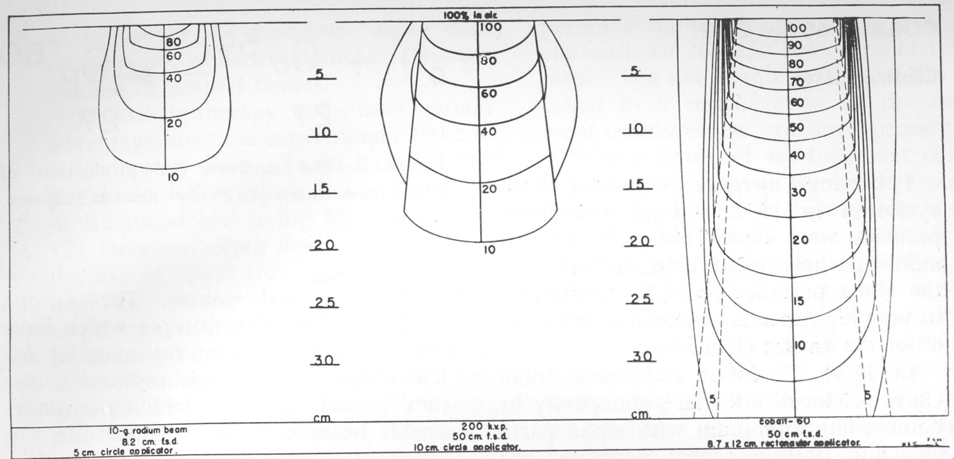


Figure 5—Isodose curves. 50% depth dose for radium unit occurs at 3.3 cms because of short treatment distance, 50% depth dose for 200 K.V. is at 8 cms. because of increased distance while 50% depth dose for CO^{60} is at 11 cms because of depth and penetration.

One of the first modifications of the radium pack was used in 1916 at the Memorial Hospital in New York City in the treatment of carcinoma of the cervix. This lead container resembled somewhat the hand grenades used in World War I and was referred to as a "radium bomb." Lysholm of Stockholm in 1923 described the use of a cylinder of lead to house the radium source. (*See Fig. 2*). The radium preparation is placed on a short piston which can be moved up and down in the cylinder. The percentage depth dose and the size of the area to be treated can be altered by changing the position of the radium in the cylinder or by placing different diaphragms at the opening of the cylinder. The lead cylinder is attached to an ordinary x-ray treatment stand, thus avoiding direct contact with the patient and restricting the beam of gamma rays to a small volume of tissue containing the tumor.

An early Westminster Hospital unit was designed with two large apertures which permitted the simultaneous treatment of two patients, one positioned above and the other below the unit. (*See Fig. 3.*) The unit contained four grams of radium which was arranged in four groups. Each group could be withdrawn into the walls of the container when not in use so that it was buried in lead of three inches minimum thickness.

Continued research and experience with different kinds of units resulted in the design and construction of a highly flexible unit producing sharply defined areas of irradiation and adequate protection of personnel. Many of these units have been in iperation in this country, England and Europe during the past 20 years. Because of the scarcity of radium and its high cost, the amount of radium used in these teletherapy units was generally limited to five to ten grams. With sources of this strength, rather short treatment distances (4 - 10 cm.) are required to avoid excessively long treatment times. For example, a ten gram teleradium unit positioned 8 cm. from the skin delivers 50% of its surface dose at a depth of 3.3 cm. (*See Fig. 4*). Thus, it becomes apparent that cases chosen for treatment with the teleradium unit are those in which the growth is situated at a depth of not more than 5 cm. below the skin surface. Treatment with these units generally requires the use of several treatment areas which may be very complicated in their arrangement.

Continued on page 10

Clinical Use

$$_{0}n^{1} + {}_{27}Co^{59} \longrightarrow {}_{27}Co^{60}$$

Figure 5—The equation for production of CO^{60} from stable CO^{59} by neutron capture.

Following Lawrence's invention of the cyclotron in 1932, various sub-atomic particles were discovered. Of the sub-atomic particles, the proton, deuteron and the alpha particles could be accelerated to very high speeds and used to bombard all of the known elements.

In 1934, F. Joliot and Irene Joliot Curie produced artificial radioactivity by bombarding aluminum with alpha particles and observing that neutrons and positively charged particles were emitted from the aluminum. In 1935, Amaldi and associates and Ratblat reported the production of radioactive cobalt^{60} from the stable isotope cobalt^{59} by the use of neutrons which were generated by bombardment of iridium with the alpha rays of radium. *(See Fig. 5).* As a result of these exhaustive studies, many artificially radioactive isotopes were produced and their characteristics closedly studied. By 1940, several hundred artificially radioactive isotopes had been discovered and some of these were used in medicine as tracer materials and in the treatment of certain diseases.

In December, 1942, the first self-maintained nuclear chain reaction was produced in a uranium graphite pile at the University of Chicago. Following this, several larger and more efficient nuclear reactors were constructed. These reactors were operated during World War II for the production of fissionable material. After the end of the war, more reactor space was available for the production of radioactive isotopes for medical and research purposes.

In 1946, Mitchell, Maynard and others suggested that certain of the artificially radioactive isotopes which produced gamma rays might be a cheaper alternative to radium. The isotope chosen should have a half-life of several years, a gamma energy higher than 400 KEV to avoid differential absorption in bone and tissue and should permit concentrated activity in a small-sized source. The gamma emitting radioactive isotopes which have been considered as source material for teletherapy units include iridium^{192}, cesium^{137}, and cobalt^{60}. Iridium is undesirable because of its short half-life (74 days), thus requiring frequent reactivation within the nuclear reactor. Cesium^{137}, which is a by-product of the production of fissionable material, requires a costly and complicated extraction process to separate it from the other radioactive by-products. A suitable separation plant is under construction but sufficient quantities of cesium^{137} required as sources in teletherapy units will not be available until 1957. Presently, cobalt^{60} is the only readily available gamma emitting radioactive isotope which can be produced in suitable quantities for use as sources in teletherapy units. However, the relatively short half-life (5.3 years) may lead it its replacement with some other radioactive isotope in the future.

In August, 1951 the first teletherapy unit to be loaded with cobalt^{60} was placed in operation at the University Hospital of Saskatoon, Saskatchewan. Since that time over 80 telecobalt therapy units have been placed in operation in the United States, Canada and England.

In the telecobalt therapy unit much larger sources (600 to 3000 curies) can be used because of cobalt's increased availability. Much greater source skin distances (35 to 100 cm.) may be used, resulting in an appreciable increase in percentage depth dose *(See Fig. 4)*. Therefore, malignant growths in any anatomical location may be treated with very simple arrangement of treatment areas. The source skin distance may be varied according to the depth of the tumor so as to deliver the maximum depth dose to the tumor while irradiating a minimum volume of normal tissues.

Telecobalt therapy units have certain advantages over the conventional 200-250 K.V. therapy units. These include: (1) less skin reaction, which makes the course of treatment less trying for the patient; (2) increased depth dose, which permits the use of fewer treatment areas to deliver the desired amount of irradiation to the tumor, thus a simpler arrangement of treatment areas; (3) the simpler treatment technique results in a smaller volume of tissue treated, thereby reducing the frequency of irradiation sickness.

The advantages of the telecobalt therapy unit over the teleradium unit are due to the use of larger sources which result in: (1) greater depth dose; (2) simplified treatment techniques using fewer treatment areas; (3) shorter treatment times.

The major disadvantage of the teleradium and the telecobalt unit is that they require the construction of special treatment rooms with very thick walls (up to 30 inches of concrete) for the protection of the personnel operating the equipment.

Since all of these forms of irradiation produce similar ionizations within the tissues, their biological effect, except in the superficial layers of the skin, will be very similar.

Extensive use of the teleradium unit during the past thirty years has not produced an appreciable improvement in the cure rate of malignant tumors of the head and neck. It is, therefore, unwise to expect the use of the telecobalt therapy units to result in miraculous achievements.

The telecobalt therapy unit at Emory University Hospital, described in previous articles, has been in clinical use since November, 1954. Over two hundred patients with malignant tumors located in all anatomical sites have been treated. Close observation reveals that there has been less skin reaction and less irradiation sickness in these patients. The initial tumor response to this type of treatment has been encouraging, but the period of observation has not been long enough to permit a statistical comparison with the conventional 200-250 K.V. type of treatment. The use of this equipment has resulted in a simplification of the treatment techniques as explained previously.

With a group of six treatment cones, treatment areas may be varied from a circular field 2 cm. in diameter to a rectangular area 12 x 15 cm. in dimensions. The treatment times vary from 5 to 15 minutes, depending on the source skin distance and size of area treated. With a therapy unit of this design, short source skin distances (30 cm.) may be utilized in the treatment of lesions located near the surface. The more deeply located lesions are treated at 50 to 60 cm. source skin distances. The unit is installed in a treatment room which permits the use of the beam in either a vertical or horizontal direction. With the use of an easily maneuverable treatment couch, lesions of any anatomical sites may be easily treated even with this limited movement of the therapy unit.

In lesions of certain anatomical locations, much better distribution of irradiation is obtained by using wedge filters or attenuators. These permit the use of two small fields at right angles to each other, without the production of dangerously over-irradiated area along their adjacent margins.

In addition to its routine clinical use, this telecobalt therapy unit has been used in several animal experiments which are designed to study the relative biological effect of gamma irradiation produced by the radioactive cobalt and those of x-rays generated in the 200-250 K.V. range. The various species of animals used so far include bats, rabbits and monkeys.

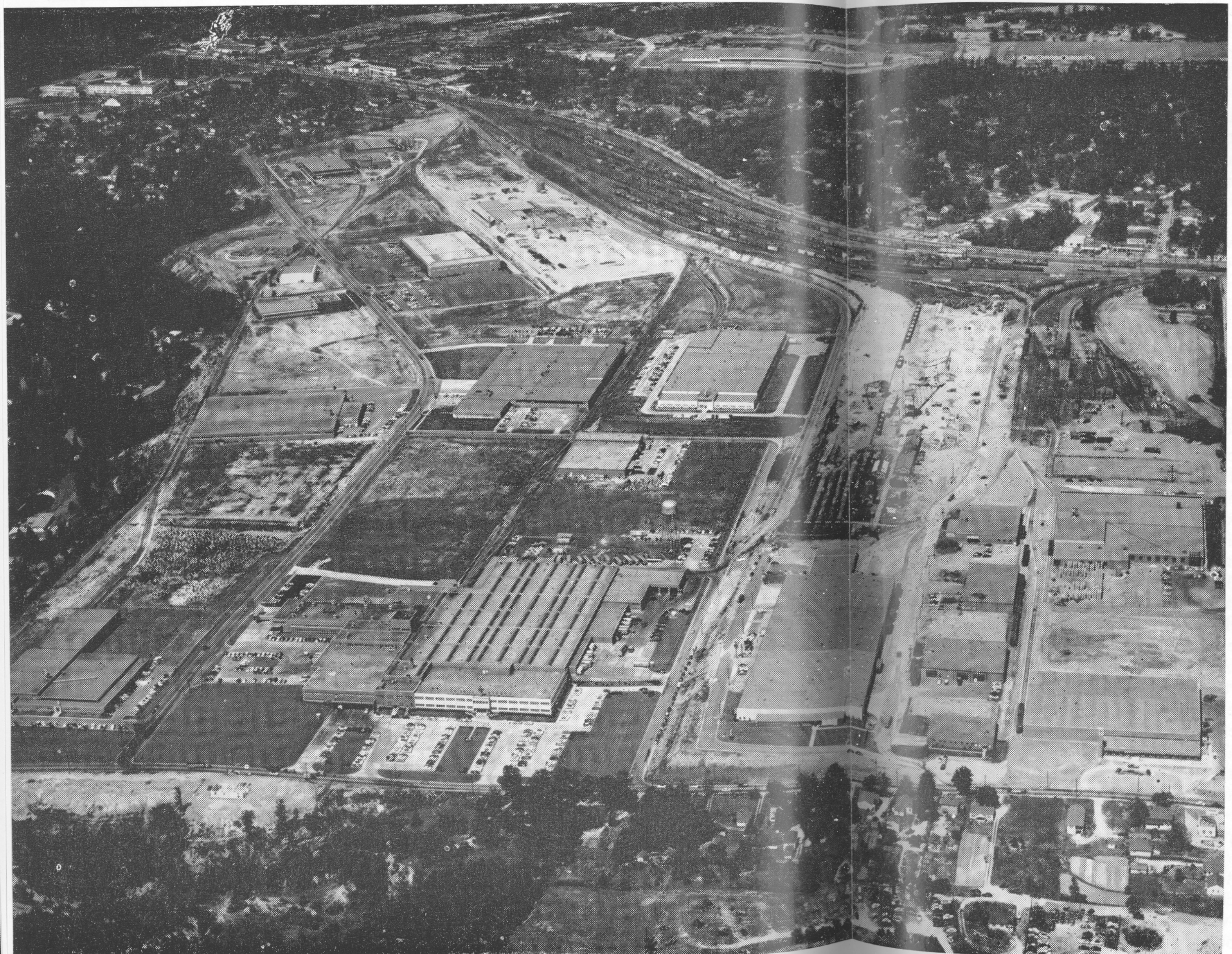
As for the future, there remains much work to be done in the field of radiation biology. One of the foremost projects in this field is the development of drugs which will make the malignant cells more sensitive to ionizing irradiation. Until this feat is accomplished, our greatest opportunity of improving the cure rate of cancer lies in the utilization of all diagnostic aids at our command in an unceasing attempt to find the malignant lesions in their very earilest stages.

INDUSTRIAL DEVELOPMENT RESEARCH AT GEORGIA TECH

by KENNETH C. WAGNER
Head, Industrial Development Branch

A special grant from the State enables Tech to initiate a program of great potential for the people of Georgia

Developed by the Central of Georgia railroad, Atlanta's "Empire Industrial District is an excellent example of a well-planned industrial development project. 16 companies occupy it.



FAR-REACHING and rapid changes dominate the economy of Georgia and the Southeast. In barely a generation industrialization has swept a predominantly agricultural area into a new world where manufacturing wages produce more than three times as much personal income as do the farms. The percent of workers in agriculture has plummeted to less than half its former total, while the percent of employees in manufacturing has increased almost 50 percent. Cities and towns have expanded at record-breaking rates as industry has lured increasing numbers of workers into urban areas. At the same time, the number of farms, farm operators and the farm population have dropped to the lowest point in history.

These unprecedented changes have created many new problems. At the same time they have thrown old problems previously overlooked into sharp relief. Business and management publications bristle with articles concerned with the difficulties individual companies have had to confront. Rapid expansion has created organizational and communications problems; the increased size of many firms has meant severe manpower shortages, both in executive positions and in such specialized fields as engineering. The construction of new plants to meet increased production needs has required decentralization and new administrative patterns. And larger size has forced managements to plan ahead for five, ten and even more years, rather than simply on a year to year or even seasonal basis.

Many of the articles referred to reveal a growing recognition of the increasingly important role which research plays in the effective planning of long-range growth. The astonishing increase in the sums spent for research and development in the United States in recent years underscores this fact. The total spent in the five years 1950 through 1954 reached

Continued on page 14

$17 billions—an estimated 45 percent of the total outlay for research over the country's entire history!

Communities and states in which new plants are being located or in which existing facilities are expanding find themselves confronted with problems even more complex than those faced by giant corporations. Perhaps the most spectacular are those which quickly come to mind: jammed highways, crowded schools, inadequate housing. But other, more basic problems require attention. Occasionally a dramatic example is brought to our attention: the community which has brought in new industry without regard for balance and then must wrestle with the double-barreled problem of having too many firms employing women but too few employing men. Families in which an unemployed husband must rely on his wife as a source of income are a likely source of community and management problems. Or we read of a case where indiscriminate solicitation brought in a fly-by-night company which went bankrupt and all but ruined a small community. Digging deeper, we may find a town which is slowly atrophying, despite the fact that it has valuable resources which could be developed.

Data Needed

Unresolved problems and questions of this sort abound. There are no adequate answers to such fundamental questions as "What natural resources does Georgia have?" Companies and communities alike find themselves frustrated by a lack of basic data. Some months ago an Illinois firm sought information about the market in the South for the metal products it manufactures. Company officials and industrial development groups in several states were convinced that such a plant would be an asset. But the plant has not been built because no one could provide the market data required to satisfy the company that the large sum involved would be a sound investment.

Detailed knowledge of its assets, whether minerals, markets or manpower, is of tremendous value to a community or state which desires to develop its industrial potentials. The collection of original data is required in virtually every case. It may only be necessary to count the noses of skilled workers available for a particular type of job. More likely, however, a thorough analysis of a wide range of subjects is essential.

A typical audit might include: (1) a survey of available raw materials; (2) the collection of data on the area's labor supply; (3) an analysis of existing and potential markets for products that might be manufactured from available resources; (4) an evaluation of present and future transportation, power, education and other facilities; (5) the determination of suitable sites for industrial districts or for individual plants; or (6) an estimation of local capital available for development purposes. This partial list, any one item of which might involve months of study and thousands of dollars, gives some idea of the complexities of securing suitable industrial development information.

Established firms may face similar problems in connection with plans for expansion, or they may have quite different needs. Rapidly expanding manufacturing operations may make reorganization necessary. Additions to existing plant facilities may require equity capital, and an increase in production capacity may dictate the revamping of the company's marketing organization. Technological innovations may involve drastic changes in manufacturing procedures, as well as the retraining of personnel and the reorganizing of departments.

A paradox that remains to be resolved is that, despite the fabulous increase in the sums spent for research and development, essential industrial development research remains undone. The lack of basic data has forced large corporations investing huge sums in plant expansion to set up their own industrial development departments. Although their total budgets remain small in comparison with the funds spent for other research purposes, such groups often perform invaluable services to their own organizations. They cannot meet the needs of outside groups, however. Their purpose requires that they confine their efforts to the particular problems which concern their companies. Even when their work might be of value to a community or state which they may be investigating, it is unlikely that they could justify making their findings available to outside agencies.

Industrial Development Branch Aims

It was to meet the tremendous research needs of Georgia and the Southeast that the Industrial Development Branch of the Engineering Experiment Station was established. Its purposes, as stated in the outline of the research program, are:

. . . to provide the factual, scientific foundation needed to assess the State's and the region's industrial potentials; to determine, through scientific research and analysis, what new industries can be developed profitably and what existing industries can be expanded; and to analyze the means by which established industries can be made more efficient or more productive.

To achieve these aims, the program of the Branch necessarily includes a wide variety of projects. They range from short-term projects designed to answer specific questions of immediate concern to a single company, to long-range, basic research relating to the growth of the entire state and region. The lack of pertinent information requires that a great deal of original work be done to secure data not hitherto available. Intensive field work insures that the most useful data are secured.

One wide range of subject areas involved in the Branch's program emphasizes in particular the opportunities for team research designed to make effective use of skills and knowledge from related fields. Close collaboration with other divisions of the Experiment Station and with other departments at Georgia Tech provides a reservoir of skilled personnel in many subject areas. This manpower pool makes it possible to extend the Branch's services when necessary.

The opportunities offered by the physical facilities of the Experiment Station and other departments on the campus enhance and undergird the value of Tech's manpower resources. To cite only one example, the Rich Electronic Computer Center offers opportunities for the analysis of masses of valuable data which, because of the prohibitive costs, could simply not be processed manually. Exploratory work in process is expected to produce important information regarding the rates of industrialization of all 159 counties in the state. More important, these findings should help pin-point reasons for differences in the rates of growth of various sections. They should also eliminate much of the guesswork presently involved in efforts both to gain new prosperity and to prevent regressing areas from further loss of wealth. The project would also identify the counties most in need of further economic research.

Basic Data Reservoir

The need for basic resource data has been cited. The collation of available materials and the collection and analysis of new information will be a major continuing project. A complete audit of the state's resources during the early months of the program was decided against for several reasons, the tremendous cost and large number of man-hours involved being major considerations. Another primary reason for avoiding a broad, general study is that the value of a resource audit multiplies rapidly if the data can be analyzed in terms of possible uses of the resources. If masses of resource data are tabulated and filed, further work would be necessary later to make them meaningful. Our rapidly changing technology creates still another problem, since certain information quickly becomes obsolete. If data were collected for the entire state, including the areas not interested in or not in need of further industrialization as well as those areas greatly interested or in dire need, it is entirely possible that a major reassessment might be required by the time much of the information could be put to use. Instead of a comprehensive audit of the entire state, a series of more limited studies will be undertaken.

Data concerning raw materials acquire much of their value as they are analyzed in terms of (1) possible commercial or industrial uses of the raw materials; (2) existing and potential markets for the various possible uses; (3) the cost of manufacturing, distributing and selling the various possible end products; or (4) the availability of labor required for the production process involved. The same is true for data on many other resources such as manpower, land and equity capital.

A two-fold approach will therefore be used in collecting basic resource data: First, a prescribed number of man-hours will be allocated to the systematic collection of the resource data considered of greatest value by the research staff. Specific requests for information from development groups will help guide the allocation of this time. Second, resource data will be collected as part of many specific projects, notably for the resource-market and industry projects described below. Except where a contract specifies that certain information shall be classified for a period of time to protect the contractor's investment, resource data collected as part of such studies will be integrated as rapidly as possible into the basic data file.

Market-Resource Analyses

Of primary concern to many of the projects undertaken will be the answers to the following questions: What products used in quantity in Georgia and the South must now be imported from other states or areas? Which of these can be produced economically within the state or region?

These questions involve a dual analysis of two variables so interdependent that they might best be referred to as "market-resource" or "resource-market" analyses. Market-resource analysis is both neglected and badly needed. One of the many instances where inadequate market data meant the loss of an industry was referred to earlier. If the market data required by the manufacturer had been available, the task of bringing the plant to the Southeast would have resolved itself to competition between the sites which offered the necessary resources.

Why wasn't the information available? And if it was not available at the moment, why didn't someone go out and collect it? The questions involved seem to be simple enough. But competition between the firms handling a product, whether at the manufacturing or retailing level, tends to make prospective informants reluctant to divulge the needed data. Only market-resource research would provide a reasonably reliable figure. In any case, the contact work and the analysis involved is time-consuming and expensive.

Predictions concerning the future market of a product often are as necessary as information about the number of units currently sold. When such is the case, population projections and estimates of economic growth must be made. This is a risky business, with only the expert willing and able to stick his neck out. The rapidity with which technological change occurs in many fields makes such estimates doubly troublesome.

Even assuming that a market-resource analysis can be completed successfully, a difficult task may yet remain. The manufacture of a product requires much more than raw materials. All the resources needed to manufacture a given product may include a wide range, from minerals and water to electric power and the supply of labor. The measurement of any one of several required resources could easily involve considerable cost.

Resource-market studies proceed from resource assessment to analysis of market demand. For example, Georgia has considerable deposits of kaolin and granite. A statewide study of the extent and quality of these deposits would determine the extent of the resources. A survey of the possible uses of the various types and quantities of such mineral resources would then be followed by a market demand analysis for each of the potential uses.

Industry Analyses

Industry-oriented analyses offer still another practical application of the resource-market approach. The South's oft-cited need for high value added industries—those which add greatly to the value of the products they manufacture and which generally produce high wages and profits—provides a logical reason for using an industry as a point of departure. General knowledge of markets or resources or both may indicate that a certain industry would likely prosper in Georgia. The collection of resource data, especially, would then be directed toward the answering of a different type of question: whether specific and selected resources are available, such as a particular quality of a certain mineral or workers with particular skills or aptitudes. The basic problem remains the same; the scope and direction of the study differ.

Area Analyses

A broader-gauged, more comprehensive approach is required for an important and relatively costly type of study: the analysis of the industrial potentials of an economic area. Such an area, although centered about a single medium-sized community, may include as many as 15 to 25 counties. If this is the case, the number of resource-market analyses required for an exhaustive study and the scope of each analysis are likely to be increased considerably.

An area analysis as discussed here goes far beyond the surveys so often undertaken. Most such surveys usually complete only the first of several steps included in a truly comprehensive area analysis. An example will illustrate the way in which such studies are designed to produce specific recommendations concerning industrial development problems and needs.

Let's assume that a community or firm in northeast Georgia wants to know whether the recently discovered process which makes it economical to extract small amounts of uranium from granite can be used profitably with the ore available in a particular area. A complete analysis would involve the following steps: First, ore samples would be collected and tested to determine the percent of uranium and other elements. Then, if the quality proved high enough, the costs of extracting the uranium would be calculated. Possible commercial or other uses of the granite and other minerals present would also be determined. This step would require analysis of the alternative opportunities for marketing the various products which might be secured through the extraction process or for marketing the by-products which might result.

Subsequent steps would include analysis of the costs involved in processing or manufacturing, and in the distribution and selling of the products; assessment of the capital required to establish the needed facilities and organization; and possible sources of necessary capital. If it proved desirable to bring in an established firm to set up the required plant, a survey of companies in the field would indicate the likely possibilities. Evaluations of the manpower and electric energy available would be integral parts of the over-all study. Other subjects which might be included, particularly if a local group were organized to set up the business, would be the type of organizational structure to employ, the most desirable type of physical plant, and the lay-out calculated to prove most efficient.

In the preparation of such studies every effort will be made to avoid duplicating services available from private research and consulting organizations. The Branch seeks to work closely with all interested groups active in the field; in effect, it will serve as a clearing house for all such activities and organizations. The special facilities which the Branch can offer, such as the basic industrial resources data file, should offer a valuable service to most concerns engaged in industrial development work.

Although many companies work in one or more of the fields which would be included in an area study as described above, it is apparent that in many instances services of the sort enumerated will not be obtainable from established research firms. In still other instances, costs to a community or area would prohibit needed research, unless the work were done by a non-profit organization.

A deficit in one of the key elements of industrial growth—entrepreneurship, or a willingness to risk available financial resources in the hope of future gain—has hampered the development of the South. The area's long established agrarian tradition has undoubtedly served as a strong deterrent to risk-taking. Whatever the reasons, the deficiency has been mentioned as a fundamental problem in building the South's economy by virtually every business, industrial or professional man with whom the Branch's program has been discussed.

Actually "home-grown" industries, started and sustained by local capital, have an unexcelled opportunity to contribute to the economic growth and stability of a community. An important factor in the retarded development of industry in the South has been the fact that investment or "risk" capital has so often had to come from the East and North.

But the rise in income in the South over the last decade and more is making possible an increase in savings. The South could readily convert these new sources of funds into the desired investment or equity capital and thus gradually supplant outside sources.

If this elusive but essential ingredient of progress called entrepreneurship could be analyzed into its component parts and if those elements could then be taught to individuals of ability, a further tremendous change in the economy and culture of the South would result. Intensive study of the backgrounds and behavior of entrepreneurs, both successful and otherwise, could be expected to shed light on this important subject.

Technical Training

A lack of entrepreneurship is only one one of many facets of the manpower problems facing the South. The critical shortage of scientists and engineers has demanded increasing attention in recent months from the general public as well as from executives harassed by shortages of key personnel. The analysis of Georgia's and the Southeast's current manpower situation and its future needs constitutes a major continuing project.

The importance of technical training shows up in the plant location policies of some of the largest corporations. An executive of a major electrical manufacturing firm recently pointed out that his company is looking more and more to cities with engineering and technical schools as their best plant site possibilities. The reason is simple: they need ready access to a continuing supply of scientists, engineers and technicians.

The intense and growing demand for highly skilled labor points to the need for additional technical training facilities. Georgia has only one engineering school and one technical institute, both located in Atlanta. Both schools offer inducements to firms in technical fields. But it is certain that a network of technical institutes like Southern Tech, located throughout the state at carefully selected population and development centers, would be a tremendous asset. North Carolina's plan for building seven additional technical institutes might serve as a model for Georgia and other Southeastern states. Like the existing technical institute at Gastonia, the new schools planned for other sections of the state will operate under the School of Engineering at North Carolina State College. A network of schools of this sort in Georgia and other Southern states would make it possible for many more workers to raise their skill levels and would offer important inducements for the growing number of companies looking for such made-to-order training centers.

Industrial Development Courses

Two further educational projects relate logically to the Branch's program. The first is a series of conferences or short courses which would present research findings to individuals and groups active in industrial development work. Such courses would instruct interested persons in the essentials of building the economy of a community or area. The task of assessing the resources of an area can often be undertaken, at least in part, by local groups. But such efforts are wasted unless the persons involved know exactly what to look for and how to guard against inaccuracies in their tabulations.

A different type of training which merits consideration would involve the establishment of an industrial development option within the School of Industrial Management at Georgia Tech.

Space limitations prevent the inclusion of other potentially important facets of the program as presently visualized. One of these is the potential for building so-called "satellite" industries in support of the major firms already established within the state and area. A large manufacturing company provides a ready-made market for many products; thousands of vendors may sell to a single plant. Large retail firms similarly provide large and usually stable markets for a wide variety of manufactured goods.

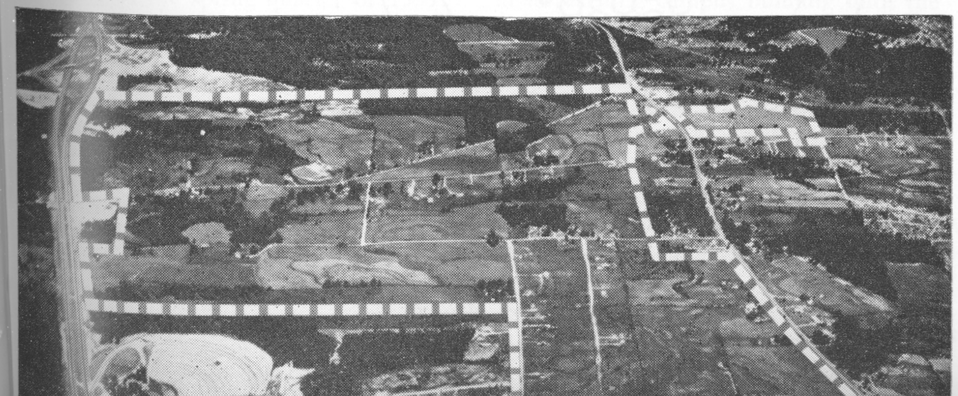
Human engineering—the design of machinery and equipment better adapted to the physical and mental limitations of its operators—is another field which relates directly to both of the Branch's major interests. New equipment can solve production problems for established concerns and may also provide the basis for the development of new industries.

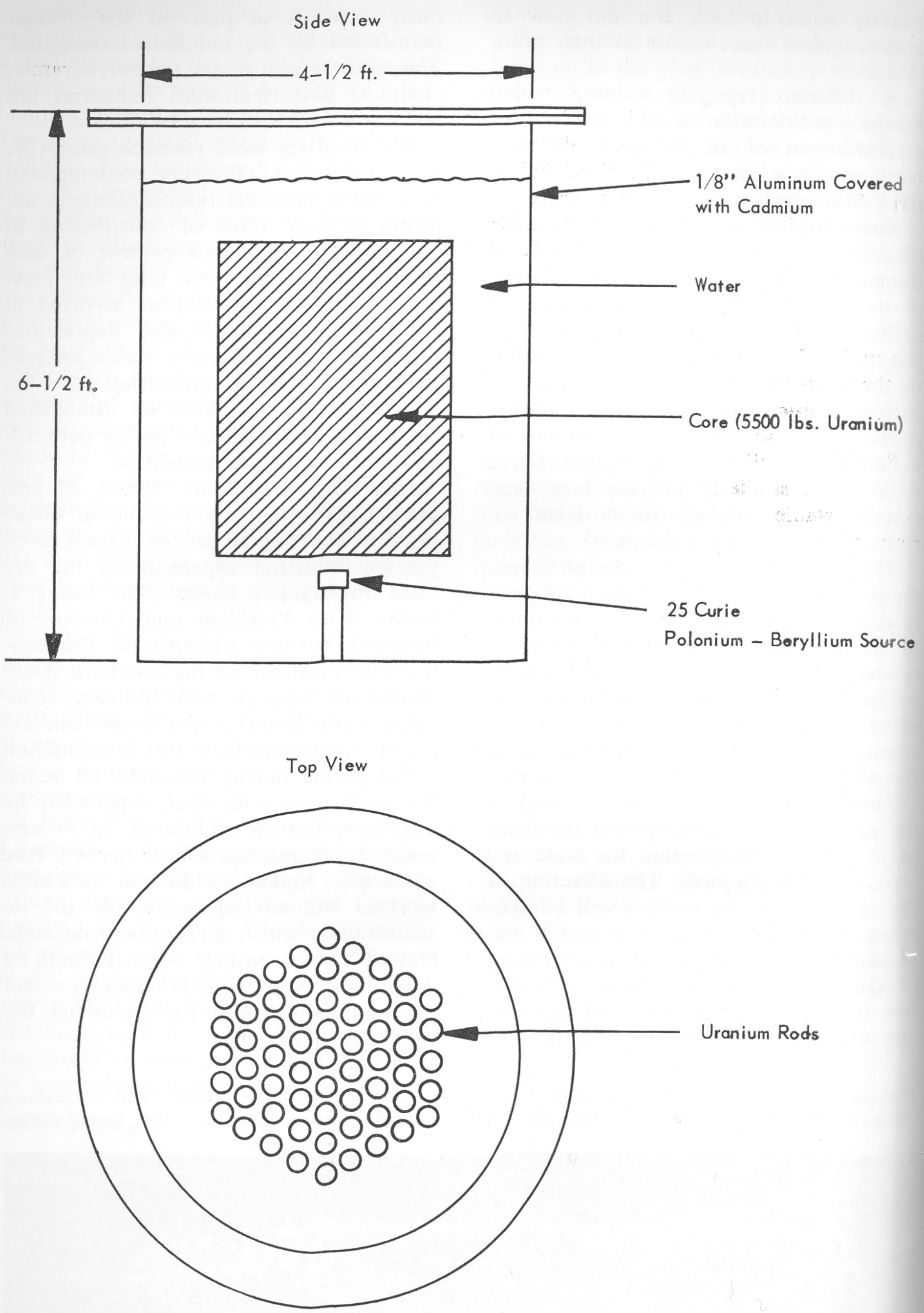
Special projects designed to analyze the economic and development problems of major industries within the state and area are also planned. The selection of the industries to be studied will be governed by their present or potential importance to the industrial development of Georgia and the Southeast. The extent to which the problems and needs of any one industry will be analyzed obviously depends in part on the interest manifested by the industries concerned. The textile, naval stores, lumber, ceramic, chemical and electronics industries are among those which may be studied.

The need for basic research cannot be under-estimated. Projects contemplated have many practical ramifications, in addition to their value of contributing to our understanding and control of economic phenomena. One long-term project would study the factors involved in the development of a stable, "depression-proof" economy. Another would analyze the impact of rapid industrialization on a community: its effects on established economic, political, and social patterns, and on individual personalities.

One thing is certain: Unless all predictions prove grossly inaccurate, Georgia and the Southeast can expect even greater industrial expansion in the decade immediately ahead. Dr. Frank J. Soday, Vice President and Director of Research for the Chemstrand Corporation and President of the Southern Association of Science and Industry, confidently predicts that the South can expect to acquire at least 200 multi-million dollar plants during the next 10 years. To keep pace with that expansion, he estimates that an additional 1,000 new research laboratories will be needed. And at least 10,000 additional scientific workers will be required to do the research upon which such growth depends. Should he be even half right, it would be difficult to over-estimate Georgia's and the Southeast's need for industrial development research.

The new "Central Industrial District" now being developed by Central of Georgia. It is also located near Atlanta and is planned to offer lower costs to the manufacturer.





A plan drawing of Tech's subcritical assembly now nearing the construction stage. The device will be used for instructional purposes in Tech's new graduate-level nuclear programs.

TECH RECEIVES AEC LOAN

5500 pounds of uranium and a neutron source alloted to four U. S. universities for use in nuclear education programs

The Atomic Energy Commission has authorized a loan of 2500 kilograms of uranium and a 25-curie polonium-beryllium source for use in Georgia Tech's nuclear education program. Tech was one of four American institutions of higher learning to be notified of the approval of a loan of this type on September 15, 1956. Prior to that date, eight other universities had received such a loan under the AEC's program of furnishing help for universities setting up educational programs in the nuclear science fields.

Georgia Tech's master's level program in nuclear science and nuclear engineering got under way in the fall term of this year. The loan of the aluminum-covered uranium rods and neutron source (total value approximately $107,000) will be utilized by Tech in a subcritical assembly, somewhat like the one shown in the sketches on the facing page. The assembly is being designed by Research Engineer Thomas A. Elliott and will be constructed in the Engineering Experiment Station's machine shop. It is scheduled for completion by January and will be tested and ready for student use by the beginning of the spring quarter of 1957.

The assembly will be used for the laboratory instructional program in experimental neutron physics, a course that is designed to acquaint the Tech graduate students with the working principles of nuclear energy. The assembly is designated subcritical because it can not maintain a chain reaction without a neutron source.

Briefy, here is how the assembly works: The uranium rods are positioned vertically in the tank containing water in a volume ration of 1.5 to 1 with the uranium. The neutron source is then positioned in the tank as shown in the figure at the left. Alpha particles emitted by the naturally radioactive polonium will react with the beryllium releasing the neutrons necessary to start the fissioning of the uranium atoms.

The fission process then releases more neutrons to keep the reaction going. But as soon as the source is removed the fission process stops.

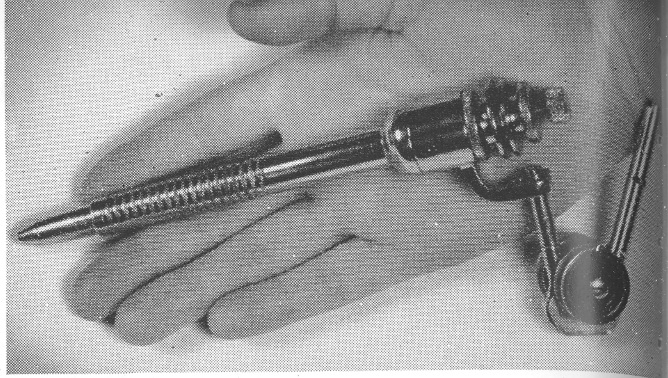
The assembly will be safe at all time, with no need for shielding or heat removal equipment. There will be no health hazard occurring from use of the equipment, Tech authorities pointed out in making the original announcement about the assembly plans.

The uranium and source material will be shipped from the Savannah River Operations Office of the AEC as soon as the subcritical assembly is completed. Tech's share of the costs for the use of this material and building the assembly will come to around $3,000.

The completed assembly will be housed in an existing campus building until the new Radioisotopes Laboratory is completed. At their September meeting, the Board of Regents approved the pre-preliminary plans for the new building and appointed an architect to start work on the building plans. The building, which will be located at the corner of Plum and Sixth on the campus, is expected to be completed by early summer of 1957.

Development of a high-speed dental handpiece

by Thomas A. Elliott
Research Engineer



One of the major functions of the Mechanical Design Section of the Georgia Tech Engineering Experiment Station is to develop new products or special machinery at the request of sponsoring agencies. For rather obvious reasons, many of these developments cannot be publicized until after their adaption in a particular industry, trade or profession. A typical example of such a development at Tech is the high-speed dental handpiece.

The dental handpiece (commonly referred to as the drill) is easily recognizable by anyone who has occupied a dentist's chair. It is a device used to grind or cut out cavities and to prepare a tooth for filling. From the average patient's standpoint, this is probably the most dreaded of all operations carried out by a dentist.

In the period, 1949-1951, a new technique for this operation was visualized by forward-thinking dentists in the Southeast. It encompassed the idea that if the burrs in the handpiece were rotated at higher speeds, the cavity preparation could be accomplished in a shorter period of time with a lessening of the vibration. From the patient's viewpoint, the overall result of this increased speed would be less pain, a shorter operation and less tension. At this time, there were no handpieces expressly designed for high-speed rotation. The normal speed for conventional handpiece was about 6,500 RPM. When rotated at higher speeds, the conventional handpiece developed many undesirable characteristics like noise, chatter and heating. It was obvious that the application of the highspeed technique to the conventional handpiece was not feasible.

Dr. Milton Smithloff, D.D.S., approached us with the problem and sponsored a project to develop a high-speed, ball-bearing handpiece. Several models were made, before the prototype model shown in Figure 1 was evolved. Two small precision ball bearings are used in this device. The smaller bearing carries the radial load at the tip while the larger bearing carries the thrust load and the upper radial load through the belt and pulley.

Our goal, speedwise, was to develop a handpiece that would turn at 25,000 RPM in initial tests. The prototype model eventually developed 42,000 RPM.

It is realized that the use of ball bearings is hardly a major engineering feat, but it is felt that Georgia Tech was among the first to point the way to this application of their use.

Subsequent developments in high-speed handpieces have continued. Today, speeds of 100,000 RPM are being achieved. The addition of air and water mists sprayed directly on the rapidly rotating burr is overcoming the problem of overheating. Greater cutting power and efficiency has been achieved by the use of carbide and diamond cutting tools rather than high-speed steel burrs.

Through the use of this new technique, the cutting time per tooth has been shortened by approximately 40% and the grinding and vibration effect has been lowered by 50%. Viva la research.

publications

Orr, Clyde, Jr., M. T. Gordon and Margaret Kordecki, "Thermal Precipitation for Sampling Airborne Microorganisms. Comparison with Other Methods." Reprinted from Applied Microbiology, Vol. 4, No. 3, May, 1956. Reprint 102. Gratis

Thermal precipitation using a newly developed instrument is compared with liquid impingement technics for the collection of viable, air-borne microorganisms. The technic is described, and results for a variety of humidity conditions using prepared aerosols of *Serratia marcescens* and *Bacillus subtilis* are given. It is concluded that thermal precipitation provides a valuable new collection method.

Belser, Richard B. and Walter H. Hicklan, "Simple Rapid Sputtering Apparatus." Reprinted from The Review of Scientific Instruments, Vol. 27, No. 5, May, 1956. Reprint 105. Gratis.

A simple sputtering apparatus that consistently deposits opaque films of nickel and the noble metals in 3 to 10 min has been made. The chamber is constructed from a standard Pyrex pipe reducer. By use of a large-diameter aluminum rod as the cathode support and a hemispherical aluminum shell as a shield for the pump orifice and base plate, the flow discharge has been confined primarily to the volume between the cathode and the work stand. The efficiency of the coating unit has thereby been increased. Films of nickel, iridium, ruthenium, and osmium formed on glass or quartz substrates were very adherent and were not readily scratched with a steel scribe.

Fetner, Robert H., "A Study of Factors Affecting X-Ray-Induced Chromosome Aberrations in the microspores of Tradescantia paludosa." Reprinted from Radiation Research, Vol. 4, No. 6, June, 1956. Reprint 106. Gratis.

The microspores of *Tradescantis paludosa* were irradiated with two equal doses of 200 r separated by 0 to 10 hourly increments between doses. It was found that the damage produced by the first irradiation remained available for interaction with the effects of the second irradiation in atmospheres of helium, for at least 9 hours with irradiation in air, and for at least 10 hours in atmospheres of pure oxygen. Those irradiations performed in air exhibited a cyclic rise and fall in the aberration frequencies produced with increasing hourly increments between administration of the two doses. It is suggested that this phenomenon may furnish a basis for understanding the discrepancies between the results of other investigators using this same material. Hourly increments between fractions were not used by these workers, and consequently these variations would not be obtained.

Woodward, Leroy A., "Variations in Viscosity of Clay-water Suspensions of Georgia Kalions." Reprinted from Proceedings of Third National Conference on Clays and Clay Materials, No. 395, 1955. Reprint 107. Gratis.

The viscosity of clay-water suspensions is an important factor in determining commercial uses of Georgia Kaolins. Impurities, such as montmorillonite type minerals, in these basically kaolinite clays play a part in causing variations in viscosity. However, seemingly pure kaolinite clays also show variations which seem to be related to morphology and degree of crystallinity. Studies are underway to determine the various factors involved.

These and other technical publications may be obtained, and the complete publications list requested, by writing Publications Services, Engineering Experiment Station, Georgia Institute of Technology, Atlanta 13, Georgia.

edited in retrospect

an etch in time

• The cover of this issue is the first commercial black and white application of the straight-line powderless etching process on copper perfected at the Georgia Tech Engineering Experiment Station. The new process was perfected for the Photoengravers Research, Inc., a non-profit organization of engravers from all over the Nation. Previously, the September issue of *The Photoengravers Bulletin,* official magazine of the American Photoengravers Association, carried a four-color cover etched in the Tech laboratories.

The cover photograph was taken by Georgia Tech photographer L. C. (Pappy) Prowse. It was printed as a positive and then taken to the engraving shop of Bradley and Son of Atlanta. From this positive a 120-line screen negative was made in such a manner as to retain, as closely as possible, the straight-line reproduction of the original. The one exception being that the highlight dots were made a little larger than would be required in the final reproduction. These screened negatives were printed to metal in the normal manner.

The plates were etched at Tech in one continuous operation in the bath previously proven in laboratory tests. In fact, the cover photo itself shows the spraying operation of this bath to etch a plate.

the next issue

• The success of the January, 1956, issue of the Research Engineer, which featured Tech's nuclear program, has prompted us to plan a progress report on this program for the coming issue. When we last reported this program to you it was strictly in the planning stage in its entirety. Today, the program is in the construction stage. The education phase has started with the present fall quarter. Money has been acquired by Tech for the radioisotope's laboratory which is in the hands of the architect. And, as you can see by the story on page 21 of this issue, some equipment of great value to the program has already been acquired. You'll get the complete story in January.

the research engineer JAN. 1957
Georgia Tech Engineering Experiment Station