ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA INSTITUTE OF TECHNOLOGY

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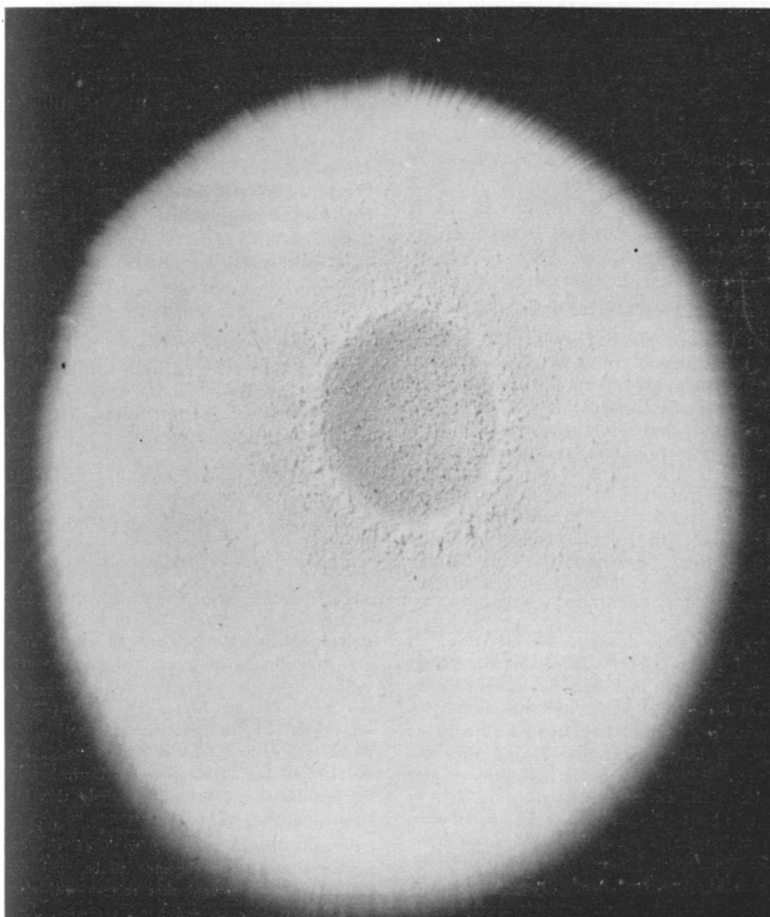

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TABLE OF CONTENTS

AN OPPORTUNITY TO HELP

The technological schools hold one of the most important keys to the nation's development of products for peace and war. It is in the intellectual environment supplied by these schools that tomorrow's industrial planners will develop. If the schools fail to train a sufficient number of men for our ever-growing needs, our productivity and our ability to develop new products will wither. However, the schools are not sufficient in themselves; they cannot possibly succeed unless sufficient numbers of suitably qualified men decide to study engineering and science. Many schools have adopted their own "recruiting" programs. Some of them, including Georgia Tech, feel their programs are very worthwhile, but all agree that additional help is always needed.

The strongest influence on the high school student is his immediate environment. The things his parents, teachers and friends believe about the various careers mold his thoughts to a great extent. Nevertheless, there is room for influence from the professions themselves.

The Cleveland Technical Societies Council has adopted a plan designed to stimulate the interest of high school

Continued on Page 24

Today our schools of engineering and science are playing a large part in determining our future. Through the years man's scientific efforts have improved his material welfare and security of life. Nevertheless, he has often feared his ability to annihilate himself or replace himself with machinery. Today we justly fear possible destruction by biological warfare or atomic bombs. But, we can take heart when we compare our present anxieties with those of the past. The fearsome expectations for poison gas and the industrial revolution never materialized. For all our past problems, solutions have been found as man's knowledge has increased.

Thus there is hope for the future. A substantial portion of it rests with the technically trained man, who must continue to seek and apply new knowledge. Furthermore and most important to those of us who believe that man is divine, that this world did not happen by accident but is being operated by an omnipotent engineering brain, we believe—we have faith that there are ways and means of solving all our problems if we but have the intelligence and the will to apply that intelligence.

For all these reasons the work of the engineering schools must continue to be well done, then we will be assured that science will always be a servant of man, and not his master.

BLAKE R. VAN LEER
President, Georgia Institute of Technology

THE DOMAIN OF LOW TEMPERATURES

By W. T. ZIEGLER*

As 1953 winner of the Georgia Tech Sigma Xi Chapter's annual award for the most significant research performed by a faculty member, Dr. Ziegler was invited to address the Chapter and its guests on a subject of his choosing. He selected the subject above, lucidly describing one of his own fields of specialization, research at temperatures near absolute zero.

Several weeks ago, while thumbing through a book entitled *Greek Historical Thought,* by Arnold Toynbee, I came upon this statement:[1] "Thinking is as unnatural and arduous an activity for human beings as walking on two legs is for monkeys. We seldom do more of it than we have to; and our disinclination to think is generally greatest at times when we are feeling the most comfortable." I shall lean heavily on this comfortable after-luncheon feeling to make my remarks appear more original than they, in fact, are.

I have chosen for my address the title, "The Domain of Low Temperatures." This is an area of special interest to me. I will first discuss briefly the natural occurrence, production and measurement of low temperatures, then describe some of the research problems currently being investigated, and finally point out some of the present-day and possible future uses of low temperatures.

Almost anyone may produce temperatures well above room temperature by simple means, such as by burning a fuel, or may heat an object to hundreds of degrees above room temperature by putting it in a simple electric furnace. It is an interesting fact that there is, on the other hand, no correspondingly simple means of producing temperatures much below room temperature. Witness the complicated air-conditioning and refrigerating equipment which is generally required. It is true, of course, that one may put ice into one's drink, and this simple refrigerative device works well as long as the ice holds out—which is usually not for long. The upper bound of the low temperature domain is room temperature, or the environmental temperature; the lower bound is the unattainable absolute zero of temperature. Within this domain the properties of matter change in striking ways. For instance, the specific heat or electrical resistance of a metal may change by only a factor of 2 or 3 in going from 30° C to +330° C, a change of 300°, whereas these same properties may change by a factor of 1,000 to 10,000 in going from 30° C to −270° C.

Natural Occurrence of Low Temperatures

In winter when the air temperature falls to 0° F, we begin to classify the temperature as low. Indeed, in many circumstances, whether it be weather or refrigeration, the lowest temperature commonly encountered is about −30° F. It is natural to ask, "How low do temperatures actually go and is there any limit to such cold?"

The lowest temperature recorded in the United States is −66° F, observed in Yellowstone National Park.[2] However, the world's record appears to be −94° F, reported for Verkhoyansk in northeastern Siberia.[3] In this place the January mean temperature is given as −58° F! I came across a description of the weather in Verkhoyansk by a Russian, Zenzinof, who wrote as follows, and I quote:[3] "The action of severe cold on everything about you is certainly striking. You take a glass of water and dash it high into the air, the liquid will come down in the form of ringing crystals of ice. All live things seek deep shelter during the winter. Partridges dig themselves far into the snow and stay there. There have been cases of their falling like stones while in flight, freezing to death in the air. . . . Live wood becomes petrified, and when one chops it, sparks fly as if from flint. . . . The air one exhales issues forth to the accompaniment of a feeble crackling sound in the air, the result of a rapid contraction of the warm breath. . . . I covered my face with my fur headpiece and left only my eyes exposed, but I felt the unpleasant sensation of the freezing of the moisture on my eye-balls; it was rather painful to have little icicles stuck in the eyes. . . . One of the strangest phenomena was the rumbling of the earth in

*Research Professor of Chemical Engineering.

the burning cold. The ground seemed to crack underneath, with a sound that resembled artillery blasts; the dull roars reverberated in the still air."

As one leaves the earth and proceeds outward into the upper atmosphere, the temperature falls until, at a height of eight to ten miles, a temperature as low as −67° F is reached.[4] Above this height the temperature of the atmosphere rises again. As one proceeds outward still farther, one reaches the outer planets. The surface temperatures of these become lower the farther the planets are from the sun. Thus, the surface temperature of Jupiter and Saturn appears to be about −240° F (−150° C), while that of Pluto is calculated to be −300° F. (−230° C or 44° K).[5] The lowest naturally occurring temperature is that of interstellar space, the temperature of which has been estimated to be about −455° F (3° K).[6]

These same temperature levels, as well as even lower temperatures, can be and are being produced by man under controlled conditions. Indeed, each of you may, if you desire, now purchase a refrigerator which, with some supervision, will produce temperatures of −455° F. The apparatus, known as the Collins Helium Cryostat, is made and sold by the A. D. Little Company of Boston, Massachusetts, for approximately $25,000.

The Absolute Zero of Temperature

Let us examine briefly the question of the limit of low temperatures. We have read a great deal recently of the temperatures reached when an atomic bomb explodes. The figure of 20 million degrees (°C) is sometimes given. There appears to be no well-defined upper limit to high temperatures. On the other hand, there is a theoretical limit to the low-temperature end of the scale. This limit is referred to as 0° Absolute or 0° Kelvin after Lord Kelvin who first proposed that such a limit existed (1848).[7] Expressed in Fahrenheit degrees, this limit is −459.69° F, or in centigrade degrees, −273.16° C. You will remember that the temperature of interstellar space (−455° F) is close to this limit. I will return to the problem of the absolute zero of temperature later.

The Measurement of Low Temperature

Let us consider very briefly the problem of measuring low temperatures. We might use as a thermometer any property of matter which changes with temperature—the expansion of a liquid, the change in the electrical resistance of a wire, the change in pressure of a gas maintained at constant volume. In one of the commonest types of thermometers mercury is used as the liquid whose expansion or contraction is observed. The higher the mercury stands in the thermometer stem, the higher is the temperature. Conversely, if the thermometer is cooled, the mercury column contracts. However, if we cool the mercury thermometer to −38.9° C (−38° F), we find that the mercury freezes, whereupon the thermometer loses its usefulness. We could employ another liquid such as alcohol. This material freezes at −112° C (−170° F) and so cannot be used below this temperature. Every substance which we have at our disposal, except helium, freezes at some sufficiently low temperature.

Another difficulty which arises is that the temperature scale so derived depends upon the thermometric substance chosen.

It was Lord Kelvin who proposed in 1848[7] that a so-called thermodynamic temperature scale could be defined which was independent of any actual substance. This scale is based directly on the First and Second Laws of Thermodynamics. Kelvin[8] and Rankine[9] showed (1854) that an "ideal" gas could be used as a thermometric substance, since for such a gas at constant volume the pressure varies directly with the temperature. As the gas is cooled at constant volume, its pressure decreases regularly until at some sufficiently low temperature its pressure would become zero. This point is defined as the absolute zero of temperature. Now no actual gas meets this requirement of ideality exactly. However, helium and hydrogen gases approach this ideal behavior very nearly at low pressures, and when suitable corrections are applied, the helium gas thermometer can be used to measure temperatures as low as about 1° K. From measurements with such a thermometer the absolute zero of temperature can

Continued on page 12

LIMNOLOGY AS A SCIENCE

By H. E. MILLER* *and* R. S. INGOLS**

The varied forms of aquatic life in inland waters and the factors which control its growth are the subject of the little-known science, limnology. In this article, the authors discuss the science itself and point out how some important characteristics of our local waters govern their suitability for the development of living organisms and for our own enjoyment.

The term limnology, derived from the Greek, carries the idea of information pertaining to marsh life. It was first used as the name of that branch of science which deals with lakes. Today it has two usages: a restricted usage which deals with the various units of the standing (lentic) waters, such as lakes, ponds and swamps, and an extended usage which includes all forms of inland waters, both the standing (lentic) and flowing (lotic) or moving waters.

Several decades ago limnology was generally considered to cover the physiology of lakes, and fresh-water biology of streams was considered a more or less separate science. However, as the biology of flowing water developed, it was often included within the range of the word limnology. Within the last decade, limnology has come to include the study of everything connected with inland water—both stagnant and running. Now it includes a knowledge of geography, physical features, chemical features, meteorological and biological properties, as well as the geology of the substrata and basin, or as Strom[3] has said, limnology embodies "the natural history of fresh water in the broadest sense of the word." Welch[5] defines limnology as: "that branch of science which deals with biological productivity of inland waters and with all of the causal influences which determine it."

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Figure 1. Senior author and his assistant sampling the Pomona Pond on Potato Creek. This pond has a maximum temperature of 104° F.

Limnology has been recognized as a distinct field of science less than fifty years. The beginning of our knowledge of fresh-water life goes back to the remote past. As time passed and man's knowledge of his surroundings slowly increased, certain fresh-water phenomena were observed and recorded in simple fashion. The story is really that of the rise of biological science in which the roots of future subdivisions of biology were present but undifferentiated. No significant contributions of a strictly limnological nature occurred for at least nineteen hundred years after the time of Aristotle, although certain facts relating to the habits of fishes, emergences of aquatic insects, aquatic plants and many other similar, easily observed phenomena were described.

The influence of the invention of the microscope on the rise of biology is well known. It contributed greatly to man's knowledge of aquatic life by providing effective means for studying the various types of life in water. Especially, it led to the discovery and study of the plankton, which include all the minute animals, plants and debris that are suspended in natural waters.

During the nineteenth century, various men began to recognize the real biological opportunity in lake investigation and established fresh-water biological stations, both in Europe and America, thus laying the foundation of modern limnology.

Since 1900, much work has been done in the limnological field, and a number of American universities offer work in the field.

Limnology, like most branches of science, has been developed on practical as well as theoretical lines. Since it includes study of the factors affecting fresh-water life, limnology contributes to greater production of fish in fresh waters.

Other branches of applied limnology deal with hygiene, since streams and lakes serve for water supplies and the disposal of sewage. Limnological knowledge is essential to an understanding of the self-purification of polluted bodies of water, either rivers or lakes. The hydrochemistry of streams determines the chemical effect of different waters upon man-made structures such as concrete dams and metal ships, especially where acids occur. The acids may be added directly, as industrial wastes, or they may be produced as a by-product of bacterial action. Thus, ammonia may be leached from igneous rocks and converted to nitric acid, or sulfides may be dissolved in seepage from abandoned mines and oxidized to sulfuric acid.

Life in Fresh Water

Fresh water is deposited on land principally in the form of rain or snow. Some may evaporate back into the atmosphere. Much of the precipitation soaks into the ground and reappears by seepage to feed springs, ponds and streams. The rate of movement distinguishes the temporarily quiet water of ponds and lakes from the flowing water of streams.

The transition of flowing water from a spring or rivulet to that of brooks, creeks and rivers is usually gradual, and the size of the stream has only a secondary influence on its biological life. The principal natural factors determining a stream's biological life are its temperature, rate of flow, the physical and chemical character of the soil over and through which water drains into it and the nature of the soil from which its banks and beds are formed.

From the smallest rivulet to the mightiest river one finds numerous intermediate stages. The mountain torrent imposes mechanical limitations on the development of life within its waters, limitations which are not present in slower streams. The biological wealth of a stream varies inversely with its rate of flow, and any obstruction which checks or stops the flow helps to make conditions more favorable for the development of life.

Static waters, characterized by lack of flow, form a series by gradations: from swamps or morasses through pools, ponds and lakes to inland seas. Those in the last group (i.e., the large lakes or inland seas) offer more wind action and greater stability in level and in thermal and chemical conditions. Since they have only limited communication with the ocean, these bodies of water are well-defined biological units.

However, distinctions are often difficult to make between water bodies of different

Continued on page 15

LATHE CUTTING TOOLS

By Joseph L. Morris*

The shapes and angles of the various surfaces of a machine tool have a pronounced effect on the tool's cutting characteristics. A general discussion of these effects is presented in this article. In addition, the author gives data concerning the actual forces acting on lathe tools.

Metal-working craftsmen have long recognized that only slight changes in the cutting angles and nose radii of their tools occasionally produce differences in performance, such as cutting pressures, tendency to chatter, surface finishes, etc., that appear greatly out of proportion to the shape modifications made. Experience has provided information on the optimum angles and nose radii for cutting the more common metals under average metal-working conditions, and typical values are listed in Table I. However, under some circumstances, cutting tools formed to these specifications do not perform as well as would be expected. To investigate why this is so, to study tool pressures at various combinations of depth of cut, rate of feed and size of nose radii, and to derive additional information on why chip shape serves as a rough but effective yardstick of cutting efficiency, a study has recently been conducted at Georgia Tech.

The shape of the chip removed, the shape of the tool employed and the tool pressures developed are interdependent factors that in some combinations lead to good machinability while in others they militate against the highest rates of metal removal. Before examining the results of the study on tool pressures and discussing the design of the apparatus used in that study, let us consider the relationship of chip shape to tool shape and tool pressure.

Chip Shape

The metal stuff that evolves from the lathe tool and collects around the operator's feet or in the tray is not just an inherent nuisance of the machine-tool process; it bears a significant message. True enough, after the chips are comfortably away from the locality of the cutting tool they have only scrap metal value, but the distortion which results during their rapid separation from the parent work piece may readily serve as a yardstick of the cutting efficiency and the suitability of the work material for the proposed processing.

By implication it would appear that the nature of the chips or the waste metal removed has something to do with the amount of power consumed in machining, the tool pressure encountered, the smoothness of the work-piece surfaces obtained, tool life and other factors. These considerations are summed up in "machinability," a relative and loosely used term. If a material is capable of being rapidly converted into acceptable production parts at the lowest possible unit cost, we generally agree that the element of machinability is high. To date no method has been proposed to evaluate this property numerically.

A cutting tool in its most basic form and the chips it removes are illustrated in Figure 1a. Theoretically, this mode of cutting is pure shear, and it incurs a considerable amount of tool stresses. Experience has shown that a modification in shape near the cutting edge, as in Figure 1b, will

TABLE I

Average Tool Angles Recommended for Cutting Common Metals (High-Speed Tool Steel Cutters)

Work Material	Nose Radius (Inches)	Side Rake (Degrees)	Back Rake (Degrees)	Side Relief (Degrees)
Aluminum and its alloys	1/16	15-40	15	8
Brass	1/16	0	0	6
Cast Iron, gray	1/16-1/2	14	8	6
Steel, low carbon	1/16	18	8	6

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reduce the tool load and produce better finishes on the processed parts. Since a tool of the modified shape has a greater degree of sharpness, the means of chip removal in ductile metal will more nearly resemble a wedging, tearing-away action. Convincing proof of this is had by observing a tool that has sustained a heavy cut for a few minutes. Small particles of metal collect on the extreme cutting edge and, with the assistance of increased temperature, are rather firmly secured to it by high unit pressures. The built-up edge, as shown in Figure 2, occupies a wedge-shaped space resulting from the splitting-away action and may serve as an actual cutting edge. An edge built up in this way is temperamental, tending to vary in depth of cut, quality of surface finish, etc. Light cuts and high speeds tend to diminish build-up. Cutting angles produced by the build-up are smaller than those normally ground. From this fact might arise the idea that metal cutting tools, as they are presently being ground, could be shaped to a sharper edge and effect more efficient metal penetration. To some extent this might be done, although tools having small cutting angles (greater sharpness) are usually fragile and short-lived.

Chips from brittle metal, such as cast iron, are removed as segmental particles by shear regardless of the degree of tool sharpness. In cutting, high unit compressive stress by the tool is brought to bear against the ledge of the work material, as indicated in Figure 3a. Since brittle metals have no intrinsic compressibility or no ability to distort appreciably, at the instant the compression strength is exceeded a segment shears out as shown. The tool point drags along the new surface, producing a burnishing effect.

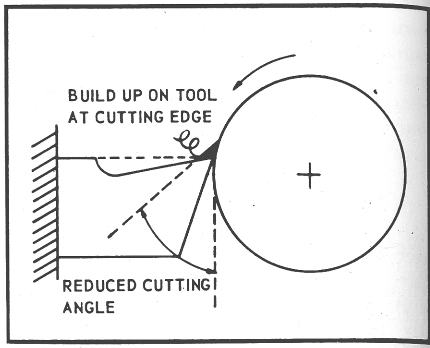

Figure 2. Metal accumulation at the cutting edge of the tool reduces the cutting angle.

Figures 3a and 3b, respectively, illustrate brittle and ductile chips and the method of their removal by tool action.

The amount of front clearance (Figure 1b) does not appear to bear a relationship to the tool pressure or chip shape; it is provided only to permit freedom of tool use and to avoid galling of the finish from small, dislodged particles of metal. Obviously, the front clearance angle cannot be excessive if support at the cutting edge is to be adequate.

Besides influencing both the chip shape and the tool pressure, the size of the back-rake angle also affects the tool sharpness.

Continued on page 17

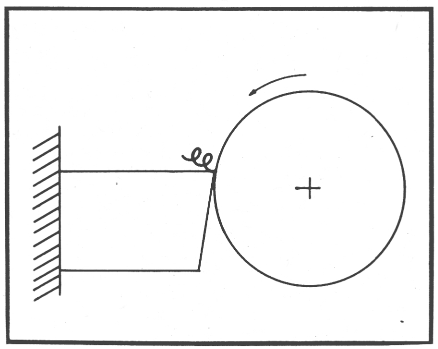

Figure 1a. Basic metal-cutting tool.

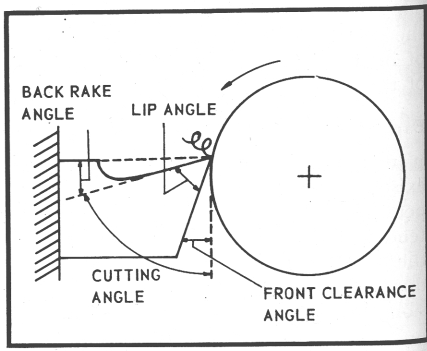

Figure 1b. Modified basic metal-cutting tool.

THERMAL REPULSION

By Mendel T. Gordon*

In a thermal gradient, small particles suspended in air tend to flow from the hotter to the cooler regions. In this article the author briefly describes the phenomena, and tells of some of the early application of thermal repulsion in addition to describing the work at Georgia Tech.

In 1951, the Engineering Experiment Station began to study the effect of certain chemicals upon the agglomeration of bacteria in air. In order to carry out these studies, a special filter was needed, for it was necessary to collect all of the bacteria in the air samples tested without injury which would prevent their culture.

It is always difficult to remove very small particles from gases, but when the particles are bacteria which are to be subsequently cultured, the difficulties are expanded tremendously. The extent to which viable organisms are damaged by impact is debatable, but it is generally believed to be significant. The effect of electric discharge is known to be deleterious. Thus, it can be seen that the common commercial dust-collection methods, i.e., impact collectors and electrical and electrostatic precipitators, are not suitable. In addition, the bacteria are only about one micron (10^{-4} centimeters) in diameter, a size which most collecting equipment cannot handle efficiently.

At the suggestion of Dr. J. M. DallaValle, Professor of Chemical Engineering, the author undertook the design of a thermal precipitator which could be used for bacterial aerosols at adequate flow rates without killing the bacteria. Before discussing the results of this work, it will probably be of interest to review the early development of thermal precipitators.

Early Studies of Thermal Repulsion

In a space where a thermal gradient exists, that is, in a space in which the temperature is not uniform, small particles tend to migrate from the hotter regions to the cooler regions. The force which produces this motion is termed thermal repulsion. The magnitude of the force of thermal repulsion is relatively small and can only be observed when it is acting on objects of small mass suspended in low-viscosity fluids. The only systems in which thermal repulsion has been observed are suspensions of finely divided matter in gases, i.e., smokes, fogs and other aerosols.

The effects of thermal repulsion are not often observed in everyday life, but there is at least one example that is well-known to everyone. The black streaks which are observed on the walls above radiators and hot-air registers are caused by thermal repulsion. Minute dust particles are separated from the warm air and deposited on the cool wall as the air moves slowly upward. It should be noted that a room heated by radiant heating systems where the entire wall is warm would not be troubled by these unsightly deposits.

A graphic demonstration of the effect of thermal repulsion is given by an experiment first performed by Lord Rayleigh[1] in 1882. If a small transparent container of a dense tobacco smoke is brightly illuminated and a heated rod inserted, a dark dust-free space is observed in the immediate vicinity of the rod. This dust-free space is an example of the action of small particles in a thermal gradient.

These and other qualitative results of thermal repulsion have been recorded in the literature at various times since the phenomenon was first discovered by John Tyndall[2] over 80 years ago. However, most of the efforts to use these results have been concentrated in recent years. In fact, it was not until 1952 that the first quantitative values for thermal repulsion were published by Saxton and Ranz.[3] These investigators were the first ones to measure the magnitude of the force of thermal repulsion, and they expanded the understanding of the variables which affect it. They also devel-

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oped a mathematical equation for the calculation of the magnitude of thermal repulsion forces under various conditions.

Thermal Precipitators

The early investigators of thermal repulsion perceived that a sampling device or filter utilizing this phenomenon would have an efficiency of 100 per cent for air-borne particles. Several types of apparatus based on this principle were designed and built.

The classical design of a thermal precipitator was the work of J. Aitken,[4] a pioneer in the study of air-borne dust. Aitken discovered that, if a stream of air was made to flow slowly between a hot object and a cool surface which intersects the dust-free space, the suspended particles would actually collect on the cool surface. Therefore, the air rising between the plate and wire would be entirely free of particulate matter. Aitken's first precipitator consisted of a horizontal heated wire placed between two vertical glass plates. The aerosol flowed upward past the wire by natural convection, and the dust particles were collected on the glass plates.

Aitken constructed a second precipitator which consisted of two concentric tubes. In this device, the dust-laden air was drawn between the inner and outer tubes; the outer tube was heated by a gas flame or by steam. From his experiments with this filter, Aitken concluded that it was possible to obtain complete precipitation of the particles providing proper flow rates and thermal gradients were used.

In 1920, the U. S. Army Chemical Warfare Service[5] experimented with a slightly modified form of Aitken's concentric-tube thermal filter but discarded it as impractical because of its high power consumption and low flow rate.

A small portable hot-wire thermal precipitator based on the original design of Aitken was developed in 1936 by a British group headed by Watson[6] and Cawood.[7] This group utilized their precipitator in the study of toxic industrial dusts. In practice, the precipitator was hung around a workman's neck, and a sample large enough for microscopic investigation was collected. Like all other early samplers of this type, the maximum flow rate was very limited—only 10 cubic centimeters per minute.

A third type of thermal-repulsion device was patented by S. C. Blacktin[8] in 1939. His device was designed to filter dust-laden air by drawing it through a heated screen. This filter had a very high power consumption which, combined with design difficulties, prevented its widespread adoption.

Quite recently, a slightly modified concentric-tube precipitator was developed by Bredl and Grieve[9] for the collection of suspended matter in flue gases. This device consisted of a tapered, heated inner tube and a readily removable outer tube of aluminum foil upon which the particulate matter was deposited. The aerosol entered the precipitation chamber at the large end where only the most readily precipitated particles were deposited. As the aerosols progressed further into the chamber, the space between the hot and cold surfaces diminished, and the materials least affected by thermal repulsion were deposited. Bredl and Grieve found that the fly ash in their flue gases was deposited near the entrance and the carbon near the exist. This filter was said to be capable of handling flow rates up to 150 cubic centimeters per minute.

GEORGIA TECH PRECIPITATOR

The author's first thermal precipitator was one in which the bacteria were to be collected directly on culture media. A heated disk three inches in diameter was suspended one hundredth of an inch above the media surface. The aerosol was drawn radially inward through a hole in the center of the disk. The medium normally used for bacteria culture is a gelatin solution which melts at 40° C. The attempt to collect a sample directly on the culture surface was finally abandoned because of difficulties in keeping the heated surface and the collecting surface parallel and because of the difficulty in keeping the collecting surface cool enough to prevent melting of the gelatin.

In the final form of the sampler,[10] bacteria are collected on a glass cover slip as the flow of aerosol is directed radially outward. The use of a cover slip as a collector

Continued on page 22

RECENT STATION PUBLICATIONS

These abstracts cover publications subsequent to those listed in the September, 1952, issue. Others will be published as space permits. A complete list of the Engineering Experiment Station's publications may be obtained without charge from the Publications Office.

BULLETIN

E. A. Walker, *Summary of the Conference on Administration of Research at Georgia Institute of Technology, September 8 to 10, 1952*, Bulletin No. 14, 1952, 20 pages. Fifty cents.

This bulletin consists of a summary of the addresses presented at the Sixth Annual Conference on the Administration of Research which was held in Atlanta, Georgia, at the Georgia Institute of Technology on September 8 to 10, 1952.

The various addresses summarized in this bulletin were classified under five general headings—communications in research, vitalization in research, basic research, planning research projects and research manpower.

Three addresses pertaining to communications were given. These addreses were entitled "Balanced Research Communication," "Pass the Word Along" and "Technical Progress Into Air Force Capability."

The general subject of the vitalization of a research laboratory was discussed by three speakers from widely different types of industrial laboratories.

Three addresses were given concerning basic research. These addresses were entitled "A Research Engineer's Views of Basic Research," "The Place of the National Science Foundation in Basic Research Programs" and "Basic Research in Germany."

The subject of program planning also included three talks. These talks were entitled "Planning the Research Project," "Defense Research" and "Training in Planning for Research."

Four speakers contributed valuable information on the subject of research manpower. Their talks were entitled "Keeping Research Young," "The Shortage of Technical Manpower," "Effect of Military Manpower Policies on Personnel for Research" and "Research Manpower Situation in Great Britain."

REPRINTS

R. S. Ingols, *Chlorine Dioxide as a Bactericide for Water Treatment*, Reprint No. 54, 1951, 6 pages. Twenty-five cents.

Chlorine dioxide has been used in the past decade to improve the taste of drinking water; however, very little effort has been made to utilize it for its bactericidal properties. This paper discusses various bactericidal studies of chlorine dioxide and presents conclusions indicating that it can safely be used for the bactericidal treatment of most city water supplies.

M. W. Long, *A High-Speed K-Band Switch*, Reprint No. 55, 1951, 2 pages. Twenty-five cents.

This article describes a high-speed rotary three-way switch which was designed to permit rapid scanning of a sector by means of a multiple-dish rotary antenna. This switch may be utilized to reduce the required rotating speed in rapid-scan radar systems, thereby minimizing mechanical difficulties inherent in high-speed systems, or, at a given speed, decreasing the dead time which is present in a single antenna system. Performance characteristics of this switch are also given.

C. Orr, Jr., and P. T. Bankston, *A Rapid Liquid-Phase Adsorption Method for the Determination of the Surface Area of Clays*, Reprint No. 56, 1952, 3 pages. Twenty-five cents.

In recent years the correlation of the surface area of clays with their physical properties has been increasingly recognized. Conventional methods for measuring surface area are too elaborate and time-consuming to allow specific surface area to be used as a control measure. Therefore, a simplified technique for measuring surface area is desirable.

This paper describes a relatively simple, rapid and reliable method for the determination of the surface area of clays. This method employs the liquid-phase adsorption of stearic acid, a surface-active agent, which, under the proper conditions, forms a unimolecular layer of oriented molecules on the solid surface of the clay.

This method should be of value in making predictions regarding properties such as total adsorptivity and catalytic activity.

THE DOMAIN OF LOW TEMPERATURE

Continued from page 4

be calculated to be −273.16° ±0.01° C. The same result can be obtained using other gases, such as hydrogen and nitrogen, at higher temperatures and extrapolating to zero pressure. If we assign to this temperature the value of 0° K, then the freezing point of water becomes 273.16° K.

The helium gas thermometer is a cumbersome device, so that in actual practice resistance thermometers, vapor-pressure thermometers, and magnetic thermometers are used. These are always calibrated, at least in principle, against a gas thermometer.

Production of Low Temperature

Historically, the production of low temperatures was intimately connected with the problem of liquefying gases, since the usual refrigerants are liquefied gases. By immersing an experimental apparatus in liquid air, for instance, one can carry out experiments at 79° K (−318° F), the boiling point of liquid air. Michael Faraday was one of the first to do extensive work on the liquefaction of gases. In 1823 and 1824 he described the liquefaction of such common gases as chlorine, carbon dioxide, ammonia, and hydrogen chloride. All of you are familiar with "dry ice." This is solidified carbon dioxide, and it has a temperature of about −110° F. Carbon dioxide is unusual in that when the solid absorbs heat it is converted directly into a gas instead of into a liquid as when ice melts.

By 1850 many substances which are gases at room temperature had been liquefied. In 1877, with the aid of liquid sulfur dioxide and solid carbon dioxide, oxygen was first liquefied by Pictet in Switzerland and Cailletet in France. With these liquid substances, temperatures of −320° F could be produced. In 1898, Sir James Dewar (inventor of the Dewar flask or "thermos bottle") liquefied hydrogen (b.p. = 20.4° K, −423° F) with the aid of liquid air (b.p. = −318° F). In 1908, Kamerlingh Onnes, working at the University of Leiden in Holland, liquefied helium (b.p. = 4.2° K, −453° F), the most difficult of the gases to liquefy, with the aid of liquid hydrogen.

In our laboratory in the Engineering Experiment Station here at Georgia Tech, we produce liquid hydrogen (which boils at 20.4° K, −423° F) by cooling high-pressure hydrogen to about 65° K with liquid nitrogen and then allowing the cold high-pressure hydrogen to expand through a valve, whereupon a considerable fraction of the hydrogen liquefies. Our liquefier produces about 1.5 liters of liquid hydrogen an hour. We purchase the liquid nitrogen in Atlanta or make it ourselves in another apparatus. The liquid hydrogen is then used to cool a limited amount of high-pressure helium gas which, in turn, is allowed to expand, with the result that part of the helium is liquefied. Approximately 75 cc of liquid helium is produced in a single expansion. This amount of liquid helium permits us to carry out experiments for several hours at 4.2° K, the boiling point of liquid helium. By reducing the pressure on the liquid helium we can lower its temperature to about 1.5° K. With larger-capacity pumps and specially designed apparatus, investigators at the University of Leiden have produced temperatures as low as 0.7° K, which is probably very nearly the lowest temperature that can be achieved by this means.

The only satisfactory means of producing temperatures much below 1° K is a magnetic method, known as the adiabatic demagnetization method. This method was proposed independently in 1926 by Giauque[10] of the University of California and by Debye,[11] then of the University of Zurich. It makes use of the fact that certain magnetic salts, cooled to about 2° K in an externally applied magnetic field, cool still further when the field is reduced to zero. By this means temperatures as low as 0.0014° and 0.001° K have been reached recently at the University of Leiden[12] and at Oxford University,[13] respectively. These are the closest approaches yet made to the absolute zero of temperature.

Research at Low Temperatures

Certain properties of materials, for instance the specific heat and the electric resistance of metals, change only slightly with temperature at room temperatures, whereas at low temperatures these properties may change very rapidly with temperature. The formulation of satisfactory theories of the specific heat and electrical resistance of metals must take these facts into account. Obviously, a theory which is devised to explain only the behavior of metals near room temperature cannot be considered to have very wide applicability. Thus, research at low temperatures often increases our understanding of materials at higher temperatures. At the same time, such experimentation makes available information on the actual behavior of materials at low temperatures. This may later be put to use by the engineer in the design of industrial equipment.

Studies of matter at progressively lower temperatures have revealed hitherto unsuspected phenomena. For example, Kamerlingh Onnes in 1911 discovered that the electrical resistance of mercury suddenly became zero when the metal was cooled below 4.2° K. Since that time, many elements, alloys, and compounds have been found to exhibit this remarkable behavior which has been aptly termed "superconductivity." Not all metals show this loss in resistance. Copper, for instance, one of the best conductors of electricity, does not exhibit superconductivity down to 0.05° K, the lowest temperature at which it has been studied.

Liquid helium itself exhibits very strange properties below 2.19° K. Above this temperature helium is a normal liquid, while below this temperature it has almost no viscosity; it crawls along surfaces in apparent defiance of gravity and exhibits other properties observed in no other liquid. Helium in this state is referred to as "superfluid" helium.

Neither superconductivity in metals nor superfluidity in liquid helium has, as yet, been satisfactorily explained in terms of current theories of matter, although the helium problem appears to be nearer solution than that of superconductivity.

Another area of research which is receiving much attention is that of the magnetic properties of matter at low temperatures. These researches are intimately connected with the problem of reaching temperatures below 0.001° K, the present limit.

Research on these problems, from both an experimental and a theoretical standpoint, is being actively pursued at the present time by large research groups working in England, Holland, the United States, and Russia, and by smaller groups in France, Germany, Belgium, Switzerland, Canada, Australia, and Japan. In this country alone there are approximately forty laboratories, mostly in universities, which have facilities for producing liquid helium. In our own laboratory we have been studying the occurrence of superconductivity in certain metals and compounds, among them lanthanum metal and transition-metal carbides and borides.

Research at low temperatures is by no means limited to these three areas. Other problems which are actively under study at low temperatures are the mechanical properties of engineering metals; thermal properties such as specific heat, thermal expansion, thermal conductivity, etc.; the effects of low temperatures on living matter; and the rate and nature of chemical reactions, to name only a few.

Some Results of Low-Temperature Research

I want to turn briefly now to some practical results of low-temperature research.

In 1895, Linde in Germany and Hampson in England, working independently, devised a simple apparatus for producing liquid air (boiling point −318° F). Their ultimate objective was to separate the liquid air into gaseous oxygen and nitrogen, its principal components. In 1945 the liquid-air industry in this country produced about 14 billion cubic feet of oxygen gas, most of which was used for cutting and welding steel.

Since 1947, new uses for oxygen have been found. One of these is in the controlled combustion of natural gas to form a mixture of carbon monoxide and hydrogen gases. This mixture is then converted by catalytic processes to hydrocarbons (including gasoline) and oxygenated organic compounds. Another large-scale application has been the use of oxygen in place of air in metallurgical processes, such as in heating blast and open-hearth steel furnaces. These new uses have doubled the annual production of oxygen from liquid air within the past five years, and further expansion is contemplated.

This expansion has come about as the direct result of new equipment capable of producing oxygen at about one-twentieth the previous cost. The design of air liquefaction and separation equipment requires a knowledge of the thermal, electrical, and mechanical properties of metals down to −320° F.

Liquid oxygen (boiling at −300° F) is a component in the alcohol-liquid oxygen rocket fuel used to propel the V-2 and similar rockets.[14] This use requires the design of suitable containers, pumps, etc.

Another interesting possible rocket fuel is the combination of liquid hydrogen and liquid fluorine. If this proves feasible, then the engineer will be confronted with the need to design not only structures capable of using liquid hydrogen as a fuel, but also apparatus for producing the large quantities of liquid hydrogen required to operate rockets of even experimental sizes. Such design requires a knowledge of the properties of materials at 20° K (−423° F). Very little information is available at the present time on the large-scale production of liquid hydrogen and on the mechanical properties of engineering materials at these temperatures. The recently completed Cryogenic Engineering Laboratory of the National Bureau of Standards, located at Boulder, Colorado, can liquefy hydrogen continuously at a rate of 320 liters per hour.[15] This is approximately ten times larger than the capacity of the largest research-laboratory equipment. Research on the mechanical and thermal properties of engineering materials is under way in that laboratory, as well as in the Laboratory of Cryogenic Engineering at M.I.T.[16]

Thus we see that in the field of low temperatures, as has happened so often in other fields, the laboratory curiosity of yesterday has become the industrial commodity or process of today. I want to emphasize this point. In a school such as Georgia Tech, in which the major emphasis is on engineering, the contribution of research in the basic sciences to the future growth of engineering may sometimes be overlooked.

The engineer and the industrialist are primarily concerned with application, while the scientist is primarily concerned with discovery and interpretation of discoveries. The research and development laboratories of the Bell Telephone Company, the General Electric Company, the du Pont Company, to name only a few, are examples of the recognition by industrial organizations that these two functions are interdependent. The effectiveness of such research activities by industrial organizations is indicated by the fact that "in 1949 alone 60 per cent of the (du Pont) Company's sales resulted from products that were unknown or in their commercial infancy twenty years ago."[17]

The Search for Lower Temperatures

One might ask: Can we reach still lower temperatures? From a theoretical standpoint it appears that the absolute zero of temperature is unattainable. On the other hand, this is no real barrier to research in this area, for, if the properties of matter change in a striking way below 0.001° K, then these same changes can be utilized (that is, provided we are sufficiently ingenious) to cool the material to that temperature range in which the change occurs. It is only when the properties of matter no longer change significantly that we have come to the lowest attainable temperature.[18]

And finally we come to the question: "Why try to reach still lower temperatures?" It is the age-old fascination of the unknown, the challenge of the unexplored which attracts the intellect of man. The compelling force is the same curiosity which man exhibits concerning the microcosmos of the atom and the living cell, the problems of interplanetary travel, the structure of the stars and the farthest galaxies, the nature of man himself. He is endlessly concerned with bringing theory into harmony with experiment, for he is convinced that there is an order in nature, can he but find it.

* * * * *

The Sigma Xi prize award was presented to

Dr. Ziegler for his article "The Crystal Structure and Superconductivity of Lanthanum," coauthored by Mr. R. A. Young and Mr. A. L. Floyd, Jr., and published in the *Journal of the American Chemical Society 75*, 1215, (1953). The paper was a result of the low-temperature research program jointly sponsored by the Office of Naval Research, the Engineering Experiment Station and the School of Chemical Engineering.

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LIMNOLOGY AS A SCIENCE

Continued from page 6

size. Lakes, ponds and puddles form a continuous series. Lakes are characterized by a region deep enough to exceed the limit of growth of the flora in the shore zone, while ponds are shallow lakes of relative permanence but of a smaller area. Both are distinct units of the environment and are usually rich in life.

Puddles or pools, which are usually temporary bodies of water of limited area, regular or irregular in occurrence, afford conditions for transient existence. They are inhabited by organisms which reproduce very rapidly during the favorable season and have special means of tiding the species over the unfavorable periods. Temporary bodies of water, such as pools that form in hollows after a rain, develop little or no life. Pools on poor soil are most barren, the aquatic life increasing with the fertility of the soil, the age of the water body and the accumulation of organic debris.

Lakes vary widely in abundance and character in different regions. They vary in the chemical character of the soil of their basins, beds and banks, as well as in relative inflow and outflow in proportion to their volume and in degree of exposure to winds and sunshine. All of these factors, and others besides, modify and control the types of living organisms and their abundance in the water.

Lakes noticeably influence the life of a stream system, since they act as filters or settling basins for inflowing water and also regulate the volume of discharge so that the outflowing stream approaches constancy in level and may be free from sediment, thus favoring certain types of life and hindering others.

In general, great depth in a water body and a large inflow in proportion to volume are unfavorable to the abundant development of the plankton organisms (the free-floating organisms). Conversely, minimal depth and scanty flow favor the production of plankton.

The physical factors in the environment of water organisms are determined by the material held in suspension or in solution in the water and by its temperature, depth, movement and illumination. The chemical factors include the water's acidity or alkalinity and its content of gases, salts and other materials. The biological environment is made up of the organisms themselves.

Within certain limits of time and space, the aquatic life of a fresh-water body is variable. Each season sees the appearance and disappearance of certain types which are active during definite periods and which bridge over the intervening time by dormant spores, eggs, or gemmules. Thus we have a seasonal succession that is just as definite and regular as the seasonal succession of plants on land. Therefore, a broad background of information and experience is required for properly evaluating the biological condition of a stream in studies of the effect of pollution therein.

One also finds stratification of the organisms. Some species are found to occur within definite limits of depth. Others are restricted to particular areas or regions of the stream or lake, i.e., organisms in shallow waters near the shore line differ from those found at the same depth in the open waters of a lake.

During the last century, human actions have greatly modified fresh-water life, especially in bodies of water near large cities. By hunting and fishing, man has partially or totally exterminated a number of forms. For commercial purpose, he has modified streams and shore lines, indirectly eliminating more forms. By polluting the waters with sewage and waste, he has rendered extensive areas of water almost devoid of fresh-water life, except bacteria which live on the pollution.

Georgia's Limnological Conditions

Limnological conditions in Georgia range from favorable to unfavorable for fresh-water life. The temperature of some of our streams and lakes is so high that their fish have relatively little resistance left to withstand the effects of pollution. For example, the maximum temperature of Pomona Pond near Griffin is about 104° F, only a degree or two below the top temperature that most fish can tolerate.

However, in the mountainous areas of North Georgia, leaching of soft igneous rocks provides the stream waters with a high concentration of minerals essential to the development of algae. Impounding of these streams results in lakes that are biologically very productive, since small marine animals feed on the algae and fish feed on the small animals.

Because lakes near Atlanta have plowed fields along their head-water streams, they are usually very turbid. As a result they are almost devoid of biological life, since the algae cannot get enough sunlight to grow, even when the essential minerals are present.

Turbidity, quite aside from its deleterious effect on fresh-water life, also reduces our enjoyment of some of our lakes. By limiting the depth that sunlight penetrates, turbidity determines the temperature of our waters at various depths. Although few swimmers may know thermoclines by name, most of them probably have been chilled while swimming in lakes where the thermoclines lie only four to six feet deep. These thermoclines are zones of such rapid temperature change that the warmer water cannot penetrate the cooler, denser water below it. The depth of a thermocline is determined largely by the extent of the sunlight's penetration which, in turn, is determined by the shade of trees, turbidity and algae concentration. Water having a thermocline at ten or more feet down is not chilling to most swimmers.

Thus, we Georgians can see, as indeed can men everywhere, that certain unfavorable limnological conditions are natural in origin and cannot be ameliorated. However, we can refrain from polluting our waters, thereby giving our fresh-water life its best chance for abundant growth and giving ourselves water safe for use and enjoyment. By observing the fishing laws, we can preserve and increase our fish population, and we can minimize the destruction of marine life by properly considering the effect on it of stream and shore-line modifications made for commercial purposes. To a considerable extent, consistent with intelligent use and conservation of our farm lands, we can reduce the turbidity of our streams and lakes, thus providing the condition necessary for Nature's great miracle—photosynthesis in plants and utilization of plant life by animals.

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LATHE CUTTING TOOLS

Continued from page 8

As shown in Figure 1b, an increase of the back-rake angle decreases the cutting angle and as a result increases the tool sharpness. It has roughly the same effect as sharpening the wife's favorite kitchen knife. However, there is a significant difference between metal-cutting tools and bread knives—the cutting edges of slicing knives have equal and opposite side pressures of relatively low magnitude, whereas those of the lathe tool and other metal-cutting tools have pressures as high as 500,000 psi on one side only. Instead of using small cutting angles to produce undistorted chips (the slices of bread) with low edge pressures, metal-cutting tools employ large cutting angles that cause the chips to curl and, from internal friction, to become warm. Large cutting angles are necessary to provide tool strength and long life. Generally speaking, the cutting angle is chosen to give the optimum balance of several factors: tool life (as it is influenced by temperature), tool strength, power input, etc. Tool angles that have been found to be satisfactory for average conditions of machining metals are listed in Table 1.

Tools are frequently ground with side-rake and side-clearance angles as depicted in Figure 4. The side-rake angle affects the chip shape in approximately the same way as its back-rake counterpart (Figure 1b). In one instance, the chip is forced off along the tool (back rake) and, in the other instance, it is forced to the side of the tool (side rake). If the tool has a sharp nose (small nose radius), as in Figure 4, and the ratio of rate of feed to depth of cut is relatively great, the action of the back-rake angle will prevail and cause the chip to evolve as a simple spiral. As the depth of cut is increased, the direction of chip escape will change successively from a to d, as shown in Figure 4. From the standpoint of total tool pressure, frictional heat generated and horsepower consumed, the sharp-nosed tool and relatively great depth of cut are more nearly ideal, but the sharp point is fragile and may have a short life.

As the nose radius is increased, the back-rake angle plays a more important part and, in conjunction with the side rake, tends to complicate the chip shape. The effect is evidenced both by a blue color of the heated chip, if the cutting speed is sufficiently high, and by increased tool pressure (greater horsepower requirement). These circumstances might lead us to believe that the tool would soon fail from the heat generated and the attending temperature rise, but usually this is not the case. Where larger nose radii are employed, the sharp cutting edge is more completely surrounded

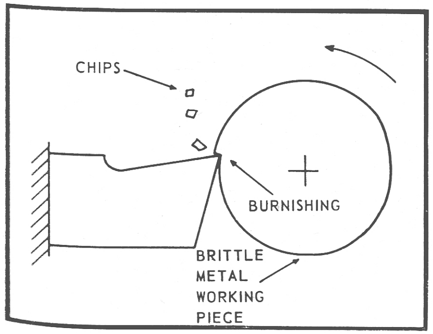

Figure 3a. The metal waste produced in the machinery of brittle metals is broken into individual chips.

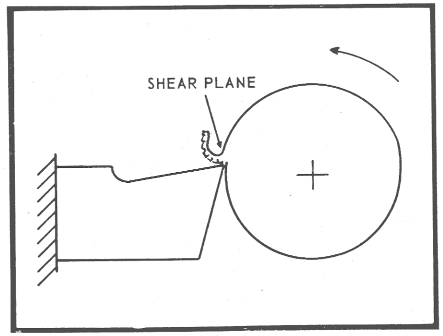

Figure 3b. In the machining of ductile metals, the metal waste is more or less continuous.

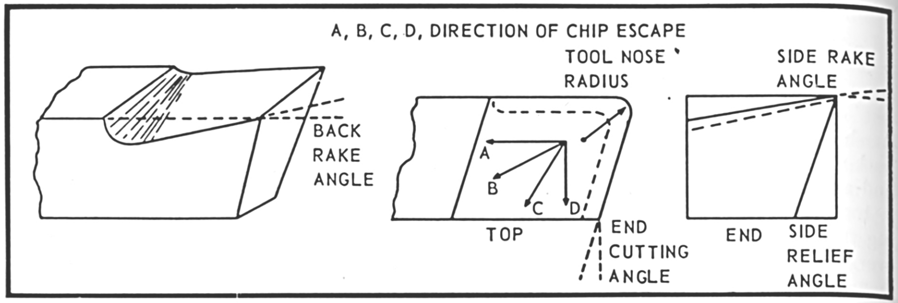

Figure 4. Metal-cutting tool angles and direction of chip escape.

with heat-absorbing mass and, within certain limits of tool proportions, this tends to keep the cutting edge sufficiently cool to promote its stability and long life. Although some authorities have doubted that an increase in nose radius increases the tool pressure, dynamometer tests made at Georgia Tech indicate that this is so. These tests are discussed later in this article in conjunction with the data presented in Figure 15.

Study of Tool Pressures

Since the power required to remove a given volume of material per unit time is equal to the average recorded force times the surface speed, and since any excess power is converted to heat that may shorten tool life, a study of the force (or tool pressure) required for various depths of cut, rates of feed and tool-nose radii should provide information useful in determining better, more economical machining conditions. Consequently, a dynamometric apparatus to measure tool pressures in three cardinal directions at any instant under any set of metal-cutting conditions has been designed

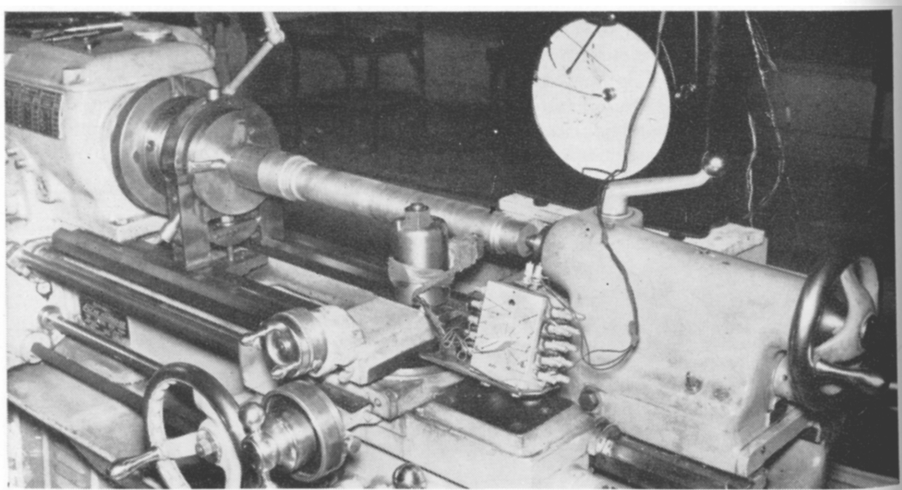

Figure 5. The instrument for measuring tool force includes a torsional dynamometer secured to the lathe face plate, a tool holder which serves as a tool-post dynamometer and a recording device which can be connected to any of the strain gages by the selector switch shown in the foreground.

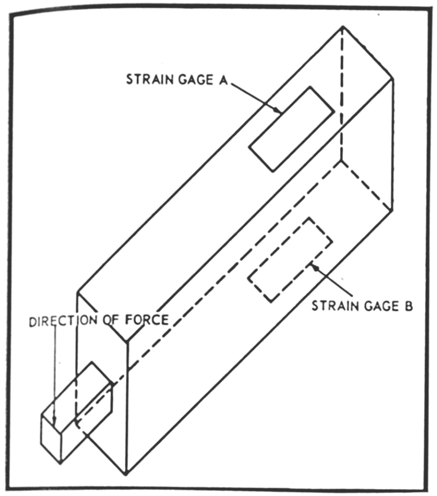

Figure 6. Location of strain gages for measuring tangential force.

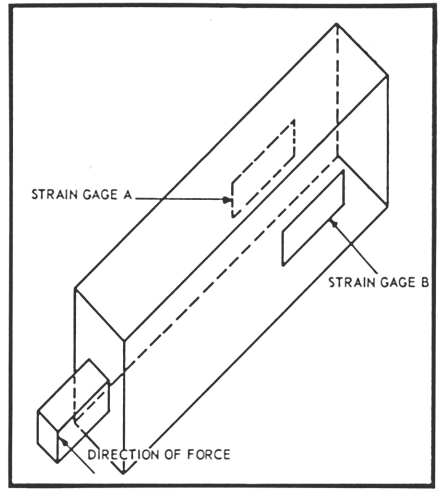

Figure 7. Location of strain gages for measuring horizontal force.

at Georgia Tech. This apparatus and the results obtained from its use form the subject matter for the remainder of this article.

In this work, tool loads were measured by means of tool-post and torsional dynamometers developed and built by Robert H. Breen, a 1951 senior mechanical engineering student. The graphs contained herein were prepared from data experimentally obtained by Harold D. Hole, a 1952 senior in mechanical engineering.

The Tool-Post Dynamometer. This instrument, which is shown in Figure 5, was designed to measure the force on each of the three axes of a single-point lathe cutting tool.

The most significant force was found to be the tangential component which is illustrated in Figure 6. Also shown are the locations of the two SR-4 Type A-1 strain gages used to measure the deflection caused by tool loads.

Figure 7 shows the location of the gages used to measure the horizontal component of the total force.

Figure 8 shows the location of the gages necessary to measure the radial force. In order to cancel the effects of all bending moments, the gages A and C are placed in the same side of a Wheatstone bridge. Gages B and D are not affected by either bending or compression and are arranged in the opposite side of the bridge.

The tool-holding element with strain gages attached is illustrated in Figure 9.

In application, the radial forces are low as compared to the horizontal, i.e., transverse, and the tangential forces although, with the instrument now used, the radial

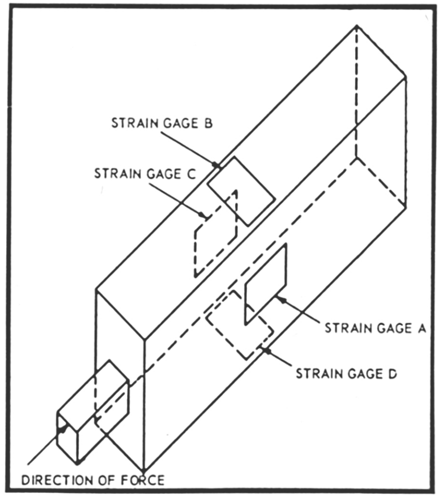

Figure 8. Location of strain gages for measuring radial force.

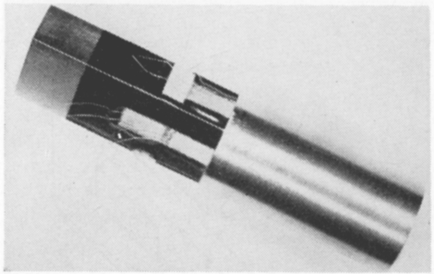

Figure 9. Tool-holding element with strain gages attached.

force is measured from the direct compression (or tension) in the tool holder. Forces in the three cardinal directions cause enough deflection to reproduce satisfactory instrument readings.

The tool-post dynamometer was calibrated by holding it in a suitable fixture and loading it directly in a compression testing machine.

The Torsional Dynamometer. At its inception, this apparatus was intended for use as a convenient and constant check against the stationary-mounted tool-post dynamometer. The torsional unit is depicted photographically in Figure 5 mounted on the face plate of a 12-inch Monarch lathe. The details of construction are shown in Figure 10. The torsional element of the dynamometer, including the slip-ring arrangement, is shown in Figure 11.

Result of Tests

The following paragraphs summarize a series of cutting-tool tests in which the objective was to evaluate tool pressure as tool shape, rate of feed, etc., were varied. No effort has been made herein to present extensive and tedious statistical matter in support of the results reported. The material has been condensed and reduced to graphic form as a convenience to the reader.

In these experimental runs all operating conditions were fixed, with the exception of those in which controlled variation was desired. Low-carbon-steel work material

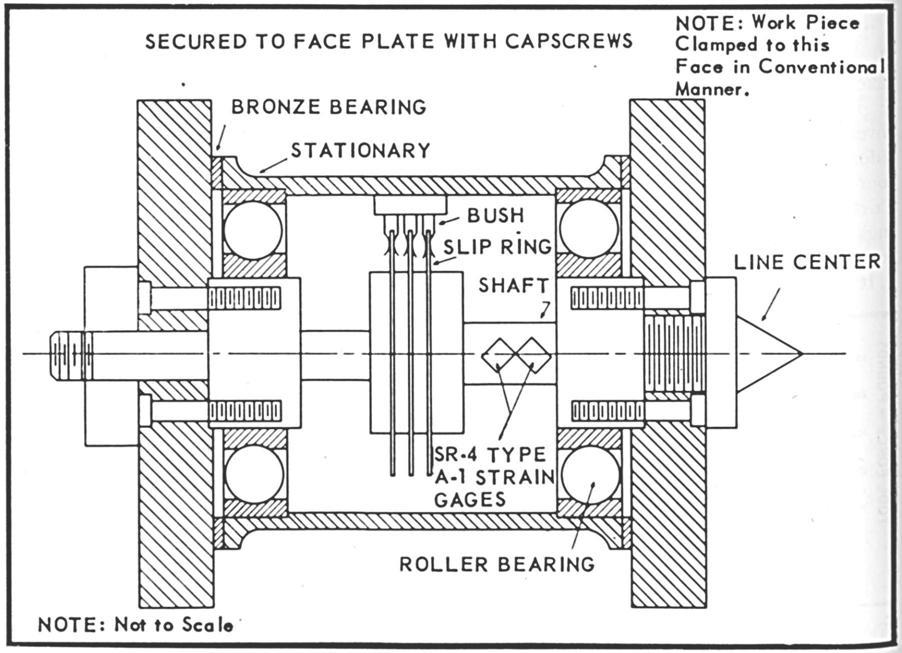

Figure 10. Assembly drawing of torsional dynamometer. See Figure 11 for a photograph of the torsional element.

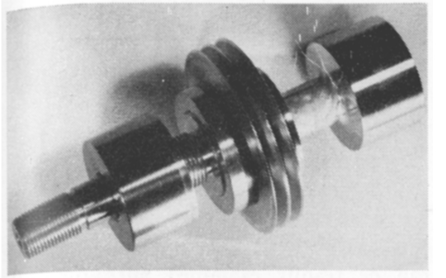

Figure 11. Torsional element of dynamometer (see Figure 10).

(approximating SAE 1010) was used. The lathe was a 12-inch Monarch having a 5-hp motor. The net torque input (resultant of all tool forces) was measured with the calibrated torsional dynamometer mounted between the face plate of the lathe and the work piece. (If desired, the product of torque and rpm can be calculated to obtain the net power input to the tool in foot-pounds.) In cross-checking, forces were also measured by a tool-post dynamometer that indicated forces in pounds along three axes simultaneously.

The tools used in these experiments were all ground to the same angles—i.e., back-rake, 8°; side-rake, 20°; and all clearance angles, 6°. Nine tools were employed to cover the range of radii that were considered to be most common for the size of tool-bit stock used (5/16 square inch). Curves were plotted from the torque readings and verified from the readings of the tool-post dynamometer.

It was found that the increase in tool force was directly proportional to the increase in rate of feed when the surface velocity, depth of cut and nose radius were maintained constant. Some of the data substantiating this fact are given in Figure 12.

Figure 13 is a plot of depth of cut versus tool force with rate of feed, surface velocity and nose radius constant. From it we see that in the range investigated the increase in force is not in proportion to the increase in depth of cut. Thus, the efficiency of the tool is increased from the standpoint of power consumed, at least, when the depth of cut is increased.

In a plot of surface velocity versus tool force, as in Figure 14, it is seen that the force necessary to remove a given chip is independent of the velocity of the work piece. In determining the data of Figure 14 the depth of cut, rate of feed and nose radius were constant.

The results of the study of the effect of tool nose radius on the tool force are given in Figure 15. In this figure, special note should be made of the region in which the curve has a sharp "hump." With this combination of tool shape, depth of cut, and rate of feed for low-carbon steel, the chip was observed to be at a higher temperature than in other combinations, and its shape was the most complex (transversely cupped, sharply curled and saw-toothed). Large nose radii on tools usually foster machine vibration, chatter and tool marks on the work piece. If these objections can be avoided by rigid tooling, large nose radii are conducive to smoother finishes.

As the nose radius is increased, the de-

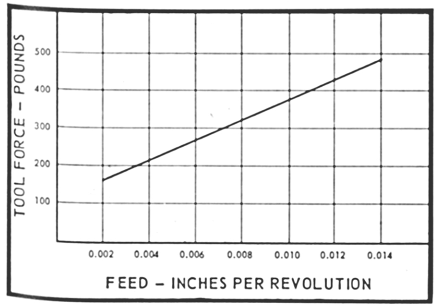

Figure 12. Cutting-tool force versus feed—velocity, depth of cut and nose radius constant.

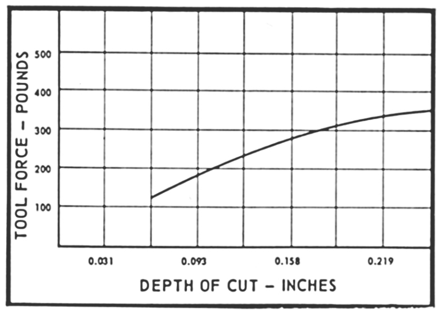

Figure 13. Cutting-tool force versus depth of cut—feed, velocity and nose radius constant.

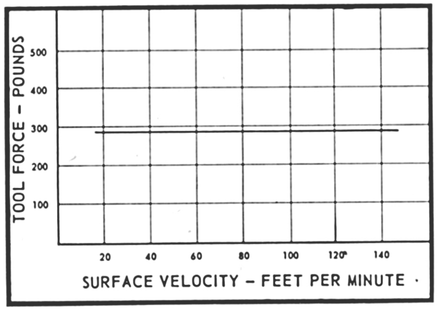

Figure 14. Cutting-tool force versus surface velocity—depth of cut, feed and nose radius constant.

formation of the chip is altered and the shape complexity, in some cases, becomes extreme. Chip shape is dependent upon the side-rake, back-rake and side-entering angle of the tool, as well as upon the nose radius. There appears to be a critical combination that gives a larger force than is needed to remove the same amount of material under a different set of conditions. A change in the resultant force required to remove a given chip with a change in tool-nose radius obviously corresponds to an increase in power.

If the power needed to remove a given volume of material per unit time is the average recorded force multiplied by surface speed, then any power in excess of this amount is consumed in further deformation of the chip and consequently is converted into heat. By this reasoning, the

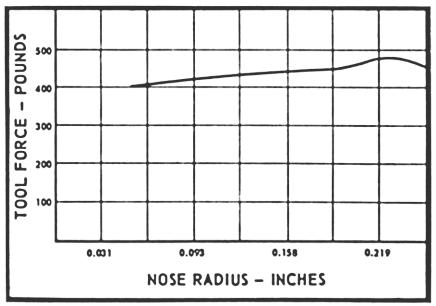

Figure 15. Cutting-tool force versus nose radius—feed, velocity and depth of cut constant.

temperature of the cutting edge will be higher for the critical radius than for any other radius. The higher temperature will cause shorter tool life or a reduced rate of stock removal.

THERMAL REPULSION

Continued from page 10

is especially convenient in that the sample can be readily examined microscopically. Figures 1 and 2 show this sampler. The device consists of three main parts: the base or cold plate, an insulating spacer and the upper-plate assembly or hot plate.

The base is a hollow brass disk through which cooling water can be circulated. The top of the plate has four regularly spaced studs around its periphery for attaching the spacer and upper plate. Also, the upper surface has a circular cavity three inches in diameter and 0.008 inch deep. The glass cover slip on which the sample is collected fits into this cavity.

The insulating spacer, made of heat-resistant plastic, separates the hot and cold surfaces and forms a piezometer ring (i.e., a manifold-like space) with the upper-plate assembly so that the aerosol flows evenly outward in all directions from the inlet. The spacing between the hot and cold surfaces can be varied by using brass shims of different thicknesses between the insulating spacer and the upper-plate assembly. A tube in the side of the spacer acts as an exhaust.

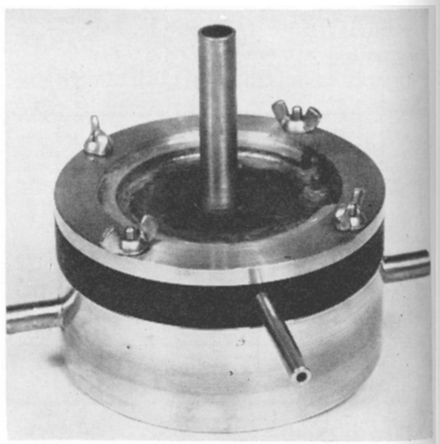

Figure 1. Thermal precipitator designed at Georgia Tech.

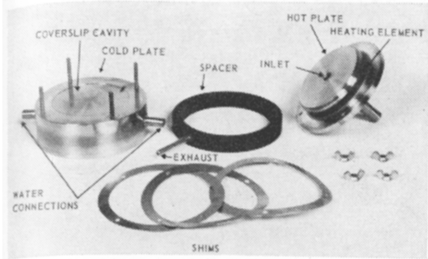

Figure 2. The components of the Georgia Tech thermal precipitator.

The hot plate or upper-plate assembly consists of a commercial disk heating element sweated to a circular brass plate. The outer edge of this plate fits tightly against the insulating spacer, making an airtight seal. A vertical tube which extends through the center of the upper-plate assembly acts as the inlet for the aerosol. The temperature of the hot surface can be controlled by adjusting a variable transformer in the heating-element circuit.

At normal operating temperatures, 80°-100° C, the sampler draws between 150 and 200 watts. It seems likely that this power consumption could be cut in half by suitable insulation.

The particulate matter is deposited on the cover plate in a circular area. A photograph of a cover plate on which a sample of magnesium oxide smoke has been deposited is shown on the cover. The diameter of the area in which the sample is deposited depends upon the distance between the surfaces, the volume rate of flow of the aerosol, the temperature difference between the plates, the thermalconductivity of the particle and, to a small extent, the particle diameter.

Tests using magnesium oxide smokes, tobacco smokes and various liquid aerosols indicate that the efficiency of this precipitator is essentially 100 per cent for particles of sizes in the range that can be examined in the electron and optical microscopes. It can be seen from the cover photo that a substantial area of the collecting surface is not needed in order to collect all of the particles. Inasmuch as the outer areas are free of particulate matter, it can be assumed that the precipitator was 100 per cent effective. The hollow spot in the center of the collecting area coincides with the chamber inlet. There is no heated plate over this area; hence, none of the particles are precipitated.

When collecting bacteria or liquid aerosols, the temperature gradient must be limited to about 80° C per one-hundredth of an inch in order to prevent damage and evaporation. For clays and solid smokes the temperature gradient can be doubled. Flow rates vary, but 300 cubic centimeters per minute will give satisfactory results under most conditions.

The previously mentioned equation derived by Saxton and Ranz for the calculation of thermal force under various conditions permits one to predict the operating characteristics of various types of thermal precipitators. Using this equation and the well-known relation for motion in viscous fluid and for gravitational forces, a general equation for the motion of a particle in the precipitator developed at Georgia Tech was derived. With this equation the performance of the precipitator under varying conditions of thermal gradient and sampling rate can be determined. The geometry of this precipitator was found to permit a greater flow rate for a given thermal gradient than the other types of precipitators

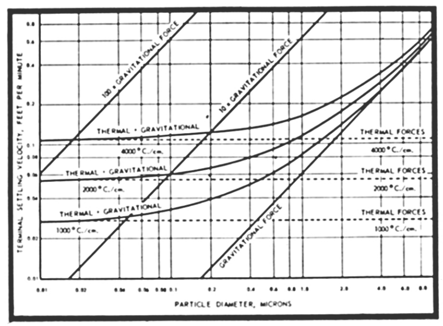

Figure 3. Gravitation forces acting on very small particles of aerosols are nearly negligible; however, thermal forces are essentially independent of particle size and are many times gravitational attraction for particles two microns or smaller.

which have been proposed. However, its application is limited in that a mere scaling up of its size will not increase its capacity. For use as a filter, several of these precipitators could be connected in parallel.

The Georgia Tech precipitator has been used, to a small extent, as a source of small quantities of filtered air in addition to its use in the study of bacterial and other types of aerosols.

Theory and General Observations

The currently accepted explanation for the motion of a suspended particle in a thermal field presumes that the fluid actually flows around the particle from the colder side to the warmer side. It is the reaction to this fluid creep which causes the motion of the particle toward the cooler region. Figure 3 gives a graphic comparison of the effects of gravitational and thermal fields of small water droplets.

For a more detailed explanation of the mechanism of thermal repulsion, the reader is referred to Saxton and Ranz's article.[3]

From theoretical considerations, we can make the following generalizations concerning the operation of thermal precipitators: (1) the gravitational force on a particle is negligible compared to the thermal force if the particle diameter is much less than one micron, (2) in the cases where gravitational forces can be neglected, the motion of a particle in a thermal field is independent of particle size, (3) the thermal force is negligible if the thermal gradient is less than about 750° C per centimeter, (4) the effects of thermal repulsion are greatly reduced for particles with high thermal conductivity (i.e., crystalline substances).

* * * * *

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AN OPPORTUNITY TO HELP

Continued from page 2

students in technical careers. Their plan includes dissemination of vocational guidance literature and sponsorship of job-opportunity seminars for the high school's councilors.

One of the most interesting activities of the Cleveland Council is a series of weekly television programs entitled "Adventures in Engineering." The programs consist of experimental demonstrations, talks, discussions and some films. At the end of each program a high school student is given the opportunity of quizzing a panel of practicing engineers. The Council believes that its program has played a very important part in the recent increased interest of Cleveland high schoolers in engineering professions.

Of course, Cleveland is a large, highly industrialized city with many resources for programs of the type described. In fact, the various societies of which the Cleveland Technical Societies Council is composed have a combined membership of approximately 10,000 engineers. Nevertheless, we see no reason why similar programs could not be taken up by technical people everywhere. In most cases the plans would, of necessity, be less ambitious, but they could still be very significant. We do not believe that it is necessary to point out the many possibilities here, but we do want to call attention to the nation's need and the opportunity, perhaps we should say obligation, of the engineers and scientists to help.