SCIENTIFIC AMERICAN SUPPLEMENT

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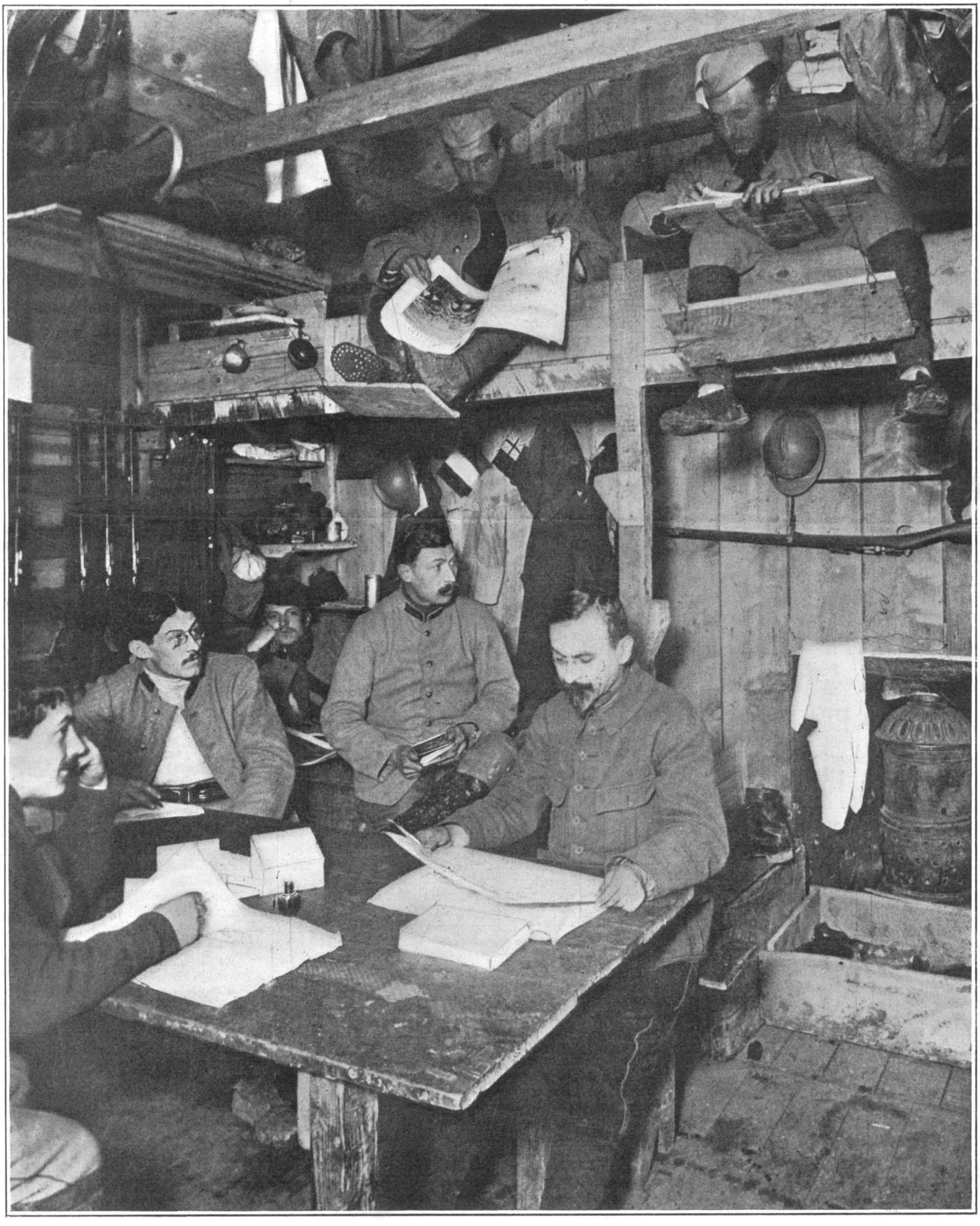
VOLUME LXXXII
NUMBER 2123

★ NEW YORK, SEPTEMBER 9, 1916 ★

10 CENTS A COPY
$5.00 A YEAR



Photograph from Underwood & Underwood

A lounging room, dug deep below the surface, in the trenches on the battle front in France.

UNDERGROUND HABITATIONS ON THE FIRING LINES.—[See page 168.]

Present-Day Knowledge of Metals and the Engineer

And Suggestions for a Systematic Course of Fundamental Instructions

By Clements E. Chase, Chief Inspector, Pittsburgh District, Modjeskki and Angler

A FEW years ago in a discussion before the American Society of Civil Engineers, Henry S. Prichard said:

"It would seem that all that is necessary is to commit to memory the theories, to ascertain the limits to elasticity of the materials of construction, and to take a course in mathematics; then structural engineering becomes a mere matter of computation. This is the conception which students in structural engineering are apt to derive from their text-books, and which some carry with them into their engineering practice."[1]

Under the knowledge of the materials of construction (speaking now particularly of the metals) available to our students of say ten years ago, there seemed to be but two possibilities. Either he could adopt this beautiful mathematical concept of an isotropic material that could be relied upon to obediently follow Hooke's law to a scheduled and unvarying elastic limit, or else he must memorize a vast array of unexplained and unconnected phenomena—the accumulation of three quarters of a century of tests on materials. With the former attitude toward structural materials one needs but a stress sheet, unit stresses from a text-book or specification, a manufacturer's hand-book for the grades of material; and the design is simple. The alternative course, though it can lead to mastery of the subject in the end, meant only confusion until time, experience and practice had sifted the unwieldy mass into some sort of rough order and empirical array. It is to be feared that too many structural engineers, graduates from American technical schools, have been content to take the easier road, unless thrown by chance into positions where the manipulation, testing or study of metals was part of their duty. In an editorial written soon after the Blackwell's Island Bridge fiasco had been heaped on the Quebec failure to the apparent discredit of our engineers, London *Engineering*[2] said:

"Whilst American and British bridge engineers hold widely divergent views as to criterions of safety, and as to good practice in bridge work, it is extremely remarkable that both here and at Quebec American engineers have blundered on the very points to which they attach, in English opinion, an exaggerated importance. If there was one thing more than another which American engineers agreed in emphasizing, it was the accurate calculation of the stresses in the different members of a bridge. . . . American bridge engineers, for the most part, we know, profess to disbelieve in fatigue, an incredibility due, in the main, to the fact that they are for the most part civil engineers or professors, and not mechanical engineers. They certainly appear to have much greater confidence in certain theories as to the resistance of materials than is usual here. Most of them definitely hold that the calculated stresses may safely approach the so-called elastic limit, and, on the other hand, not a few assert that material once strained beyond this limit is ruined."

Part of this can be charged off, of course, to the British viewpoint, but there yet remains something for us to think over. Their methods of training engineers do seem more likely to have resulted in men thoroughly familiar with the materials they work with, though on the other hand perhaps less skilled in handling new problems of design and in rational computation of stresses. The beginner usually apprenticed himself to an engineer or manufacturer and was put in position where the phenomena related to the manipulation, heat treatment and testing of materials were part of his daily routine and become thoroughly fixed in the fabric of his experience. We may think English methods of design a bit cumbersome and empirical, but we must respect the thorough knowledge of materials of construction usually displayed.

The text-books on materials familiar to Cornell men of former days were Johnson's and Thurston's treatises; but such accumulations of experiments, data and observations are truly formidable without the key to their understanding that has been supplied since. Their limitations are simply those of their time—a day when practically the only knowledge of the structure of metals was that afforded to the naked eye by fractures, and of their composition that supplied by ultimate chemical analysis. Many of the most carefully made tests of that day disregarded even chemical constitution of the material, it was "double refined iron," or "axle steel" or "mild steel" to the experimenter. The result was that none but the roughest and crudest laws could be established to tie together the observed facts, and there were so many apparent exceptions to these that the ultimate effect on the student was usually bewildering. It was in this day that the belief in the "fibrous" structure of certain metals, notably wrought iron, was taught, that men formed their convictions that metals "crystallized" in service, and that "annealing" might mean heating to any temperature in a range of a thousand degrees.

Looking back nowadays from the vantage point of our recently accumulated knowledge, it becomes plain that the two aids which have made that climb possible were: first, the application of the microscope to the examination of opaque metals and, second, the development of accurate methods of measuring high temperatures. Tucked away in the appendix of Johnson's "Materials of Construction," one finds a chapter by Arnold on the microstructure of iron and steel. It was hardly realized at the time that this was the beginning of a new branch of science that would revolutionize the study of metals.

In the manufacture of metals and metal products, the knowledge gained by scientists with the microscope and pyrometer has led to tremendous advances. In an older day these industries were often surrounded by a veil of mystery, their processes as much enveloped in secrecy as though Black Art were involved. Those in charge had acquired their store of knowledge in the painful and slow school of experience. If a new departure was essayed it could only be by the laborious methods of cut and try. Certain of the processes had come down through generations of workmen practically unchanged and with the causes and the principles involved as little known to the last as to the first. Metallography has changed all this. The microscope revealed the structure of metals, showed the various constituents and the effects of heat and work upon them, and dispelled the mystery surrounding such operations as case-hardening, malleableizing, and hardening and tempering. Microscope and pyrometer together established the laws of alloys and provided those "constitutional diagrams" of which the invaluable iron-carbon diagram is the most familiar example. In intelligent work-practice the pyrometer affords means for the control and check of every operation where heat is a factor, so that day after day, and in the hands of one workman or another, the same results may be obtained. If material proves defective, or a failure occurs, the microscope gives valuable aid in placing the blame; if a new alloy or process is to be developed, both tools are called to the aid of the investigator. There are still tremendous gaps in our knowledge of metals, but patient scientists and workers over the world toil ceaselessly to fill them in.

The idea that metals possessed "structure" had been developed from observation of fractured surfaces long before microscopic methods were known. The old Metcalf test is a rough study of the effect of heat treatment on the "grain" size of fractured steel, but of the nature of these grains very little was known. When Martens, the famous German authority on materials, first undertook to use the microscope in the study of metallic structure, he tried to examine fractured surfaces. This did not lead to success, for only extremely low power magnifications could be used. Later, it was found that by polishing a plane section of the metal, and then etching with acid, the structure of the metal, and the appearance of its constituents were revealed. The boundaries of the grains usually etch readily, so that simple or pure metals show a network pattern. The important fact then ascertained was that each of these grains was *crystalline*, that every minute element comprising each of them was arranged with geometric precision parallel to crystal axes. The orientation of each grain differs from that of its neighbors, but within itself it is a perfect crystal. The reason the grain boundaries usually do not show the straight lines and sharp angles commonly associated with crystals is that the grains in forming have interfered on every side with the growth to perfection of each other. Next it was observed that in metals containing more than one element, the grains were of various compositions, a section having a granite-like appearance. Great ingenuity was required to isolate these constituents, one by one, so that the chemical composition of each could be ascertained. Then, by a combination of physical tests and microsopic examination the effects of each constituent on the physical properties of the metal were learned. The effect of heat and work on grain size had been understood to a limited degree by the study of fractures, but the microscope added much, and in addition gave invaluable information on the changes in structure resulting from the hardening and tempering operations, information that (along with the pyrometric knowledge) has made heat treating an accurate art. These advances have marked the growth of the science of metallography as it is utilized in the industrial arts.

There is another phase of metallography, apparently little known generally on this side of the Atlantic, that has even greater importance to the engineers responsible for the design and construction of structures. This is the study of the effects of overstrain, or plastic deformation, on the microscopic structure. The pioneers were Englishmen, Rosenhain, Ewing and Humfrey, and the pioneer days were no longer than ten years ago. No one can read the papers[3] in which these men presented their work to the scientific world without a feeling of admiration for their accurate observation, logical reasoning and the ingenious check and countercheck on their theories. The basic fact which they discovered was that after the limit of elastic deformation in a metal under load has been reached, plastic deformation takes place by the *sliding* of the elements of the crystal grains past each other, the movement occurring along the cleavage planes of the grains. On a polished surface of metal under load these slippages are observed under the microscope to result in fine parallel lines across the face of each crystal grain, to which Ewing and Rosenhain gave the name of "slipbands." There is no opening up—or minute separation of the grains—as the elasic limit and yield point are passed, but simply a drawing out, or elongation, of each grain, the slippages taking place *inside* each grain. The result is that in severely cold worked ductile metals, like wire, for instance, the grains are greatly elongated in the direction of extension of the metal, but their crystalline internal arrangement is unimpaired and the grains are each joined firmly to the other at their boundaries. In fact, at rupture, in normal metal, it is found that the break passes *through* each grain, proving that the boundaries are stronger than the grains themselves.

Based on these and certain other observed phenomena, a satisfactory working theory has been gradually evolved which accounts quite completely for all the known facts regarding the action of metal under stress. It is briefly that on each of the surfaces of slip there is formed a thin layer of metal in a temporarily mobile (viscous) condition, but which soon hardens. When it hardens, however, it is thought not to adjust itself to the crystalline pattern of the grain in which it is formed, but to remain in an amorphous or non-crystalline state which there is reason to believe is characteristically very hard. It is interesting to ascertain by test how well this theory, or working hypothesis, explains the lowering of the limit of elasticity of an over-strained piece immediately after loading, its subsequent recovery or elasticity up to the point to which it was strained, the hardening of metal by strain and all the other observed effects of cold-work on metal.

Nowadays when the strength of metals is being taxed more and more by automobiles, high speed machinery, heavy locomotives, etc., the problem of the "fatigue" of metal is assuming an increasing importance. Popularly, it is believed that under protracted but fluctuating loading the metal "crystallizes," since, when the over-worked piece gives way, the fracture shows an apparently coarse crystalline structure. As a tension fracture of a chain, when new, will ordinarily appear fibrous, the erection foreman will tell you that its structure has changed from fibrous to crystalline when he picks up a link that has suddenly snapped apart under a load "smaller than he has lifted with the same chain every day." It is to Rosenhain and Humfrey that we are indebted for the first light on the true nature of the action involved in fatigue. They studied iron subjected to the Woehler test, under the microscope. With alternating stresses of but little over half the elastic limit they found that slip bands eventually occurred in the unfavorably lo-

[1]Discussion: Faults in the Theory of Flexure, Henry S. Prichard, *Trans. Am. Soc. C. E.*, Vol. LXXV, p, 966.

[2]*Engineering*, Editorial, November 27th, 1908.

[3]*Philosophical Transactions*, 1899, 193A; *Proc. Royal Society*, 1904, 74; *Phil. Trans.* 1902, 200A.

cated grains, and they watched these develop into cracks until finally the specimens ruptured without any extension, and showed the typical granular fracture of fatigued metal.

Attention is called to these applications of microscopic methods to show how profoundly our knowledge of metal is affected by this new science, and to point out the importance to every engineer who deals with structures and mechanisms of metal of being acquainted with the results of these investigations. To take the attitude that the engineer can simply specify the physical or chemical qualities he wants, and leave everything else to the metallurgist, is entirely wrong. In the first place, unless he understands the actual nature of metals, and the effects of heat and work and chemical composition, and the action under simple stress and repeated stress, the engineer cannot intelligently write his specification for the proper metal, in its proper condition, for any particular use. When it is said, "Leave it to the metallurgist," it is the manufacturer's expert who is referred to, and too often he is governed by commercial considerations, or has but a limited view of the factors affecting the problem or, occasionally, is expert only in name when it comes to knowing the right metal, in its right condition, for the right place.

One costly example of the risk attached to relying too much on the producer's knowledge is furnished by the experience of the engineers of the Board of Water Supply of the city of New York with the wrought and cast manganese brass used along the Catskill Aqueduct. A total of 3,000,000 pounds of such material was used at a cost of about $1,000,000. A great part of it has had to be replaced since with other materials, and the balance is under suspicion because of the development of "season cracking," a form of progressive failure associated with high internal stresses caused by improper methods of manufacture, or caused by subjection to high unit-stresses under corrosive conditions. Knowledge of the possibility of such trouble was not widespread, it is true, but among previous users of these materials, like ordnance officers, for instance, who had had experience with the cracking of brass cartridge cases, there was enough information on the subject to have warned against many of the bad mill and foundry practices that were permitted.

Another instance where greater familiarity with modern information on metals might have averted trouble is found in some expensive experience recently acquired by certain railroad engineers. It is hardly conceivable that anyone who thoroughly understood the structure of hyper-eutectoid (i. e. above 0.85 per cent carbon) steels, would have sanctioned the ordering of steel rails containing more than 0.85 per cent carbon. Yet this was done within recent years, and a disastrous crop of "transverse fissures" hammered the lesson home that these high carbon steels are not fit for use in railroad rails. Such instances might be multiplied to emphasize the point that the problems of the modern engineer demand a thorough acquaintance with metals.

Granted that familiarity with the real nature and property of metals is an essential part of the equipment of the engineer, the question remains as to what part of this knowledge can be supplied in the limited time available in college. It is the writer's opinion that in a properly balanced course in Materials of Construction there should be time to give the student thorough grounding in at least those phases of the science of "Physical Metallurgy"[4] which are essential to the engineer.

The study of the materials used in construction covers a wide field, with an infinite amount of detail that can only be retained by the mind properly when it is associated with practice, personal observation and slowly acquired experience. This should be recognized in a college course in the subject and every effort bent to trimming the subject matter down to the essentials, and to so impressing these fundamentals on the memory of the student that he will retain them to serve as the sound foundation for his future store of details. Most books on materials are too full of detail to make good textbooks; the very feature that makes them invaluable as reference books, or for study by the practicing graduate, presents a danger to the undergraduate. Unimportant and important facts are side by side with but little difference in emphasis; obsolete or little used materials or methods are presented along with the most important; details of apparatus and methods of manufacture are given at length when only the barest essentials can be retained in the absence of personal observation. Then a little while after graduation the engineer realizes (or worse, fails to realize) that all he retains is a vague smattering of many things and processes and names, and that he has no theory to guide his judgment and no outline of fundamentals to which to add his information.

With the inconsequent matter eliminated from the "Materials" course, room will be left for all that need be taught in school of the framework of the "new knowledge." The writer would develop the study of metals from the standpoint of *structure*, so that the mention of the name of any metal would not call to mind just its external appearance and popularly known properties, but rather a clear picture of its microscopic characteristics. To do this it would be necessary that considerable time be spent in laboratory periods in the examination under the microscope of previously prepared specimens. The work of polishing and etching is rather laborious and exacting, and would be a waste of the engineer-student's time, but the personal use of the microscope is indispensable. No amount of study of photomicrographs or hard labor at memorizing the constituents can do what a brief use of the microscope will accomplish in fixing the important characteristics in mind.

The first step, then, would be to impress the *crystalline* nature of all metals, the typical structure of pure metals and the broad theory of alloys, briefly. Taking up the metals one at a time, along with the method of manufacture of iron and steel, the structure of pure iron should be studied, then the manner of occurrence of slag in wrought iron and of carbon in normal steel. As soon as the microscopic appearance is familiar, the physical properties of the normal metal may become the subject of thorough laboratory experiments. Next, the iron-carbon diagram should be deeply impressed on the men as the key to all hardening, tempering and annealing operations. Following this, the effects of each of these operations on structure should be studied, along with their effect on the physical properties. When cast iron is taken up, the iron-carbon diagram, microscope, physical test and fracture should emphasize the distinctions between gray iron, white iron and malleable iron, and show which features of the process of manufacture are essential and which incidental.

The same methods should be extended briefly to the non-ferrous metals and alloys and the effects of strain on metal can then be taken up in detail. The microscopic phenomena of plastic deformation should be made familiar, with emphasis on the part played by *crystalline* structure in it. Elastic limit and yield point will then be intelligible. The typical stress-strain diagrams for various metals under various conditions of loading should be impressed until they become part of the permanent working equipment of the young engineer, to be used constantly in forming his mental picture of the action of metal under load and overload.

With this foundation a rational study of fatigue can be made, familiarizing the student with the knowledge of its microscopic action. Segregation, slag inclusions and other common defects in steel will have a new meaning when their study is accompanied by microscopic examination.

It is the writer's belief that such a treatment of the subject would result in the graduate engineer possessing a real understanding of the subject and put him in a position to comprehend and add to his working knowledge the information constantly presented in his practice and reading.

[4] So named by Walter Rosenhain in his valuable book "Introduction to the Study of Physical Metallurgy."

Making Liquid Hydrocarbons from Naphthalene

By Dr. Wilhelm Schneider

In consequence of the war a great lemand has arisen for such liquid hydrocarbons as can be used for heating and lighting purposes and as driving power for motors. Such oils were amply available formerly in the raw petroleum—a mixture of liquid hydrocarbons—imported from foreign countries, and elaborated here in Germany after preliminary purification processes in the refineries by means of distillation into its technically important constituents, benzine, illuminating and lubricating oils.

As substitutes to furnish power and heat, the liquid hydrocarbons obtained by the distillation of coal-tar could be utilized in large measure immediately. It was, however, to the general interest not to rest content with this, but to institute experiments for deriving liquid hydrocarbons from chemically suitable solid products of coal-distillation, and to test the oils thus obtained with respect to their availability. Obviously only such substances were considered as were obtainable in large quantities and cheaply. These considerations lent promise to experiments with naphthalene. Such an investigation was recently the subject of a report by Dr. Franz Fischer, director of the Kaiser-Wilhelm-Institute for Coal Research, in Mülheim-Ruhr, who, with his assistants, manufactured liquid hydrocarbons from naphthalene by treating it with aluminium chloride under pressure.[1]

The naphthalene is obtained in large quantities by the distillation of the coal tar which is a by-product of coke ovens and gas works. The annual yield of recent years is about 80,000 tons. It is offered commercially as technically pure naphthalene, in a less pure form as warm pressed cakes, and as precipitated crude naphthalene. The price of the crude naphthalene is low.

By naphthalene the chemist understands a solid ring-formed hydrocarbon which becomes liquid at 80 deg. Cent. and boils at 218 deg. Cent. It is employed in dye works for making artificial indigo and many other dyes. It is often used as an addition to coal dust for making briquettes, as also for the preservation of skins, for impregnating wood, etc.

It has recently been made use of directly to furnish power in explosion motors. In this case, however, it is indispensable that it be previously warmed, so as to be supplied to the motor in a liquid state, which creates a necessity for special devices. Despite these manifold applications, the largest percentage of naphthalene has hitherto been burned, because of inability to obtain derivatives.

It is true that processes for transforming it into liquid products were known. This is done, for example, when heated hydrogen is allowed to act on naphthalene in the presence of catalyzers. The catalyzers employed, however, quickly lost their efficacy because of the unavoidable sulphur content of the so-called technically pure naphthalene. It was known also that liquid products were obtained when naphthalene was heated with aluminium chloride for several hours at ordinary pressure. But the quantity of oil obtained under these conditions was so small and the amount of aluminium chloride demanded for the operation was so considerable (25 to 40 per cent of the naphthalene treated) that this process was negligible practically.

The above mentioned recently published investigations now show that far better results can be obtained with ease if the action of the aluminium chloride on the naphthalene takes place at a higher pressure and higher temperature. Above all, this process is very rapid. The transformation is completed by the application of heat for 20 minutes. After the distillation of the oils obtained, and the freezing out and pressing off of the unaltered naphthalene, an oil is obtained which flows thin at ordinary temperatures, and is equal in amount to 40 per cent of the naphthalene employed. It is an especial advantage of this process that a very small amount of aluminium chloride is required (4 per cent).[2]

As concerns the applicability of the oil thus obtained, it corresponds in general to the requirements of oil used to generate heat or power, e. g., in Diesel motors. It is, of course, of peculiar interest to test the oil boiling between 150 and 300 degrees for availability as illuminating oil. The attempt to burn this oil in a lamp instead of petroleum showed that this was not possible in the ordinary lamp without the formation of soot. It requires an even greater supply of air than does Russian petroleum, which itself requires special burners because of its different chemical composition from American petroleum.

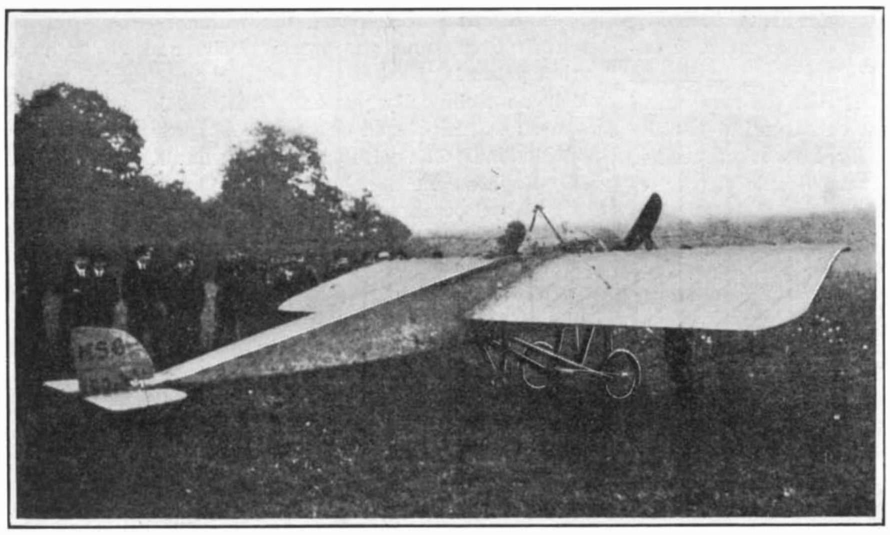
I have acceded to the wishes of *Die Umschau* to make a report upon the above investigation, although these are still in the process of development, since an idea is thus given of the manifold manner in which the science of chemistry strives to serve the general public.—*Die Umschau.* (*Censored in Frankfort.*)

[1] *Berichte der deutschen chemischen Gesellschaft,* Band 49, Seite 252.

Detection of Saccharin in Food

The sample is extracted with a mixture of ether and petroleum spirit, the extract evaporated, the residue boiled for a few minutes with 10 per cent hydrochloride acid, and the solution evaporated to dryness. If the presence of vanillin in the residue is indicated by the odor, it is removed by extraction with a mixture of ether and chloroform. A portion of the residue is treated with Nessler's reagent; if no reaction is obtained, saccharin is absent. If a positive result is obtained, the remainder of the residue is dissolved in phenol and the solution dropped on to phosphorus pentoxide in a porcelain crucible. If saccharin is present a red coloring matter is formed; this dissolves in the water to a yellow solution, which becomes blue on addition of alkali.—*M. Klostermann and K. Scholta. Z. Unters. Nahr. Gennusm. Z. angew. Chem. Abstract from Journal of the Soc. of Chem. Ind.*

[2] A dark brown crude oil is first obtained from the solid napthalene, and this shows no further separation even at lower temperatures. On distillation most of this passes over between 150 to 300 deg. Cent. The purified oil thus yielded is a clear, light brown liquid with an agreeable sweetish odor, and exhibits a bluish fluorescence. The heating index of the portion which passes over between 150 and 300 deg. Cent. is 9,932 cal. The viscosity in the Engler viscosimeter equals 1.16 at 20 degrees. It lies within the determined limits for various sorts of petroleum. The combustion point was found to be 70 degrees in the Pensky-Martens apparatus and 75 degrees in the open crucible.



A French Morane-Saulnier monoplane: type of 1913.

A German Fokker monoplane: type of 1915.

German Military Aeroplanes

The Fokker Type and Its French Prototype

Much has appeared in the daily press regarding a new German aeroplane, which is stated to be of such power and speed and climbing ability as to mark an epoch in aviation. It has been claimed that all the allied planes are hopelessly outclassed by this machine; that the latter possesses such new and revolutionary features that, in order to prevent the secrets of its construction from falling into the hands of the allies, the German aviators mounted on it are forbidden to venture behind the French lines.

Le Genie Civil, in an article whose significant features we reproduce herein, asserts that such estimates are entirely inaccurate, and presents detailed diagrams and descriptions to establish that the Fokker is an extraordinarily faithful reproduction of the Morane-Saulnier models, well known in France.

The first machines attempted by the Fokker concern appeared in 1912-13. They were complicated, and quite unlike any successful model. In 1914, however, after observing the success attained by the Morane-Saulnier planes, the Fokkers began the construction of identical machines, which they later furnished to the German ministry of war. Even before the war, these machines were being used by German army aviators. Since the outbreak of hostilities, their number has been greatly increased, and their makers have kept pace with the improvements effected in the Morane-Saulnier type.

The Fokker shops have produced two models of monoplane, a "single," accommodating the pilot only, and a "double," which carries one passenger. The general features of these machines are shown in the figures, which equally well illustrate the corresponding Morane-Saulnier machines. It will be observed that in most of its dimensions the latter is about 10 per cent larger than the former.

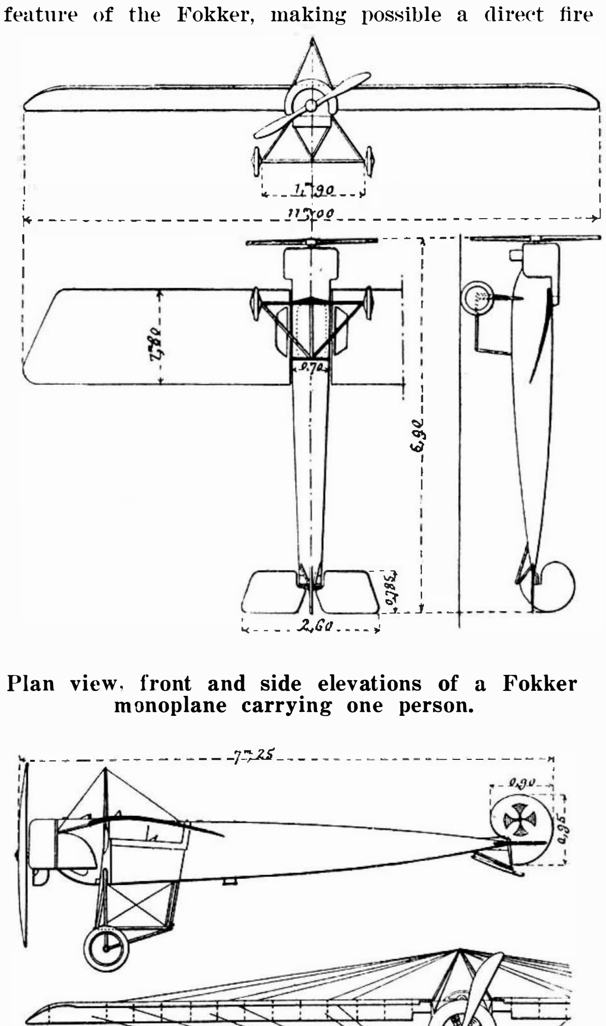
A noticeable feature of these machines is the apertures (in the single) or cut-away corners (in the double) in the wings, which make possible observation and bombardment of the country directly beneath the machine. In the double-seater, the passenger is mounted behind the pilot.

Noteworthy points of correspondence between these models and the Morane-Saulniers are the external curve of the wings, and the shape of the body. The surface curvature is slightly different, the crown of the wings being a bit farther forward in the German machine. The body is built of hollow metal rods covered with a sort of oil-cloth; the forward section has in addition protective plates of aluminium.

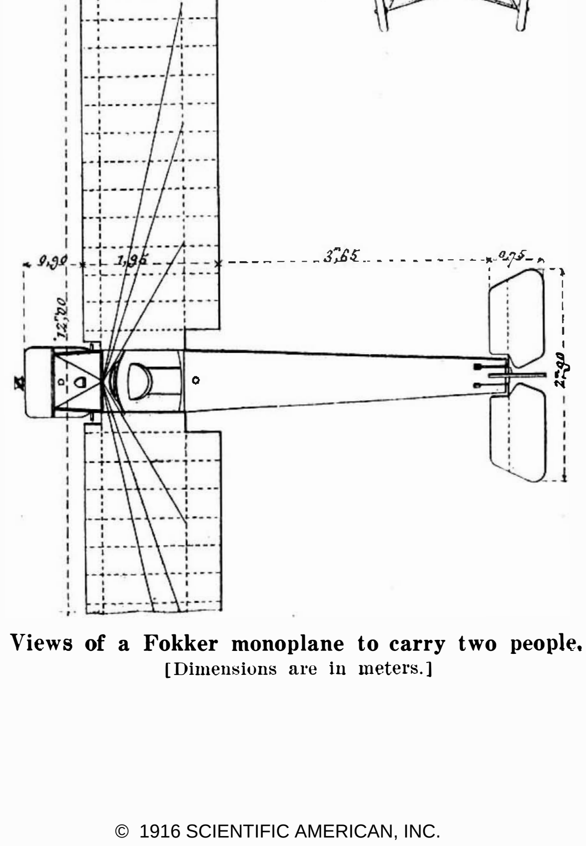
The horizontal rudder, it will be observed, is compensated, about one third of its surface being in front of the pivot. The vertical rudder, similarly compensated, has roughly the shape of two unequal circles joined along a common chord. The compensation feature is found in the Morane-Saulnier planes, but the curvilinear shape of the vertical rudder dates back to the earlier Nieuport monoplanes.

The motor used on the Fokker planes is of 80 horsepower or more, which is high, considering the size of the machine. This permits more rapid climbing than other machines of same class are capable of, and presumably explains the wild tales of the Fokker's prowess. In respect of general type and position of mounting the motor closely resembles that of the Morane-Saulnier.

Perhaps the most surprising statement made by our French authority is that the frontal mounting of the mitrailleuse, so graphically described as a very special feature of the Fokker, making possible a direct fire along the line of flight, not only is to be found in all the Morane-Saulnier planes, but is actually an invention of the well-known French aviator Garros.



Plan view, front and side elevations of a Fokker monoplane carrying one person.



Views of a Fokker monoplane to carry two people.
[Dimensions are in meters.]

It is of some significance to remark that the instance before us is not the first case of German plagiarism from foreign models. Our authority mentions the Gessellschaft Otto model Ago, and the Motorluftfahrzeug Gessellschaft model Parasol, as other Morane-Saulnier machines taken over bodily by the Teutons—in the latter case even to the name. In fact, it appears that German aviation as a unit has carefully followed the progress made in France, where almost every type of aeroplane now in actual war service has been created. It appears that the German is at least not bull-headed, and that he knows a good thing when he sees it.

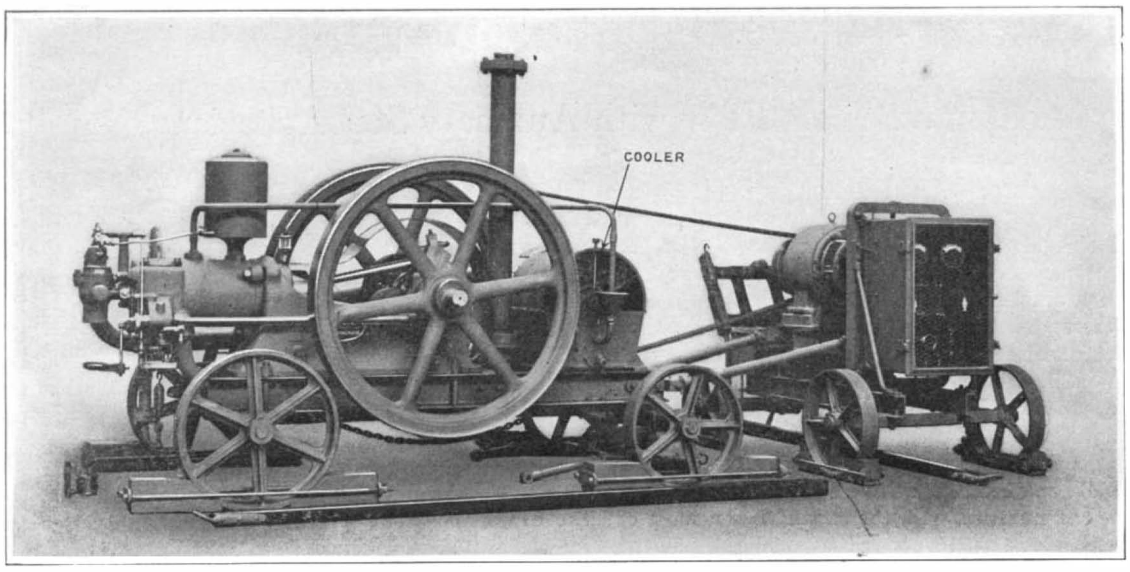
Nickel-Silver

An investigation into the properties of a number of the copper-zinc-nickel alloys known as nickel or German silver was described by Mr. F. C. Thompson, of Sheffield, in a paper read at the annual meeting of the Institute of Metals.

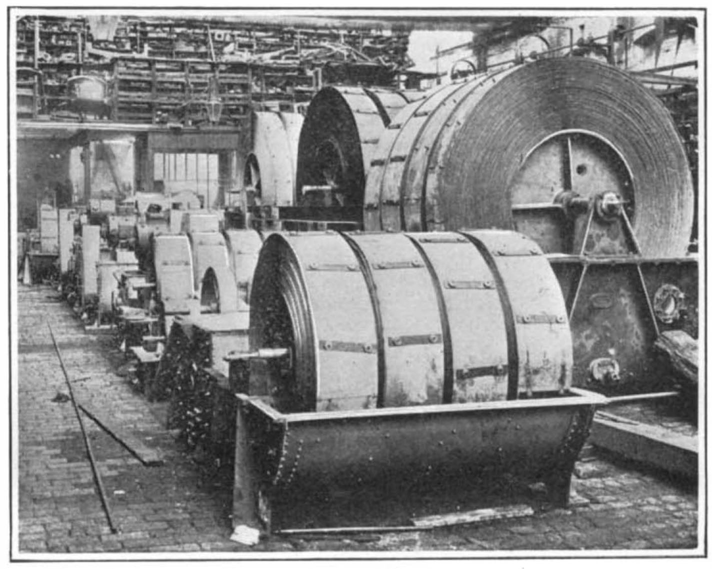
In summarizing his conclusions he said that tensile tests on the alloys containing from 7 to 28 per cent of nickel in the cast state show a distinct increase of strength as the nickel content is increased, without, however, appreciable change in the elongation or reduction of area. The results of compression tests are remarkably constant throughout the whole series of alloys tested, changes of the nickel content exerting in the cast state very little effect indeed. Deoxidation of the molten alloy with 0.25 per cent of manganese results in a marked improvement of the behavior of the material in rolls. As the nickel content of the alloy increases the specific volume is lessened, which is also the result of increasing the ratio of the copper to the zinc. The density is slightly greater in the work-hardened state than after annealing, and also in those alloys which have been deoxidized.

The electrical resistivities of the alloys after being re-heated at increasing temperatures reveal a well-marked transition between 300 and 400 deg. Cent., which is shown also by thermo-electric curves, but not by inverse-rate heating or cooling curves. The specific resistance of the alloy is determined chiefly by the nickel present. With the exception of the alloy containing only 7 per cent of nickel the resistance is practically the same in the hard drawn and in the annealed states. The temperature at which annealing starts is shown well by the torsion and hardness tests; it increases as the nickel content is raised, from 370 deg. Cent. with 7 per cent, to 600 degrees at 28.6 per cent. The hardness results show a sharply localized peak about 320 degrees. The influence of time on the temperature at which annealing begins is negligible, though the temperature of the critical point is slightly lowered with "soaking."

Tests of the Brinell hardness and the resistance to alternating stress (Arnold) made on commercial samples indicate that the impurities usually present are practically without effect on the properties, at the temperature of annealing. The results indicate that the tendency of such alloys to "burn" is increased (a) by increasing the nickel content; (b) as the ratio of zinc to copper is increased; and (c) with the amount of the impurities present.



Cooler used in connection with a portable electric outfit.



Coolers under construction.

A Novel Cooler for Internal Combustion Engines

An Efficient Device for Use Where Water Is Scarce

There are many localities where economy is necessary in the use of water for cooling internal combustion motors, either on account of its scarcity of cars, or where the apparatus hitherto used would occupy too much valuable space. To meet these conditions a novel device has been produced in England which appears to be remarkably compact and efficient, and for which a number of advantages are claimed.

This cooler was designed for the efficient and rapid transference of heat between two fluids, one of which (usually air) is in the gaseous and the other in the liquid state. The liquid may be water, oil, brine or some other fluid. The liquid to be cooled is contained in a tank in which a number of cooling cylinders revolve. These cylinders are built of galvanized steel sheeting wound in the form of a spiral, the whole forming an enormous cooling surface in a very small space. The lower portion of the cylinders dip in the tank containing the liquid to be cooled, and air is passed through the annular spaces of the upper half.

The cylinders revolve at a slow rate and are thus continually bringing fresh supplies of the liquid into intimate contact with the air. The cooling is effected partly by conduction of heat between the liquid and the air, and also, in most cases, by evaporation. In cases where the liquid to be cooled is water, a small portion of the water which is picked up by the steel plate in the form of a film, is evaporated, and the latent heat required for this purpose is extracted from the metal contained in the cooling cylinders and hence from the liquid in the tank.

It should be noted that the liquid is spread over galvanized steel sheets in the form of a thin film and is not broken up into drops or globules. This means that there is no possibility of a portion of the liquid being carried away from the machine in the form of loose moisture. The loss by evaporation is, therefore, the minimum possible by which the cooling effect can be produced.

For the purpose of passing air through the machine a fan is used which may be of the propeller or centrifugal type, according to the size and type of machine. The machines are usually driven by belt on to the fan spindle, the drums being revolved by suitable reduction gearing between the fan and drum shafts. As the cylinders are mounted on ball bearings, they offer practically no resistance, and as the fans are of a highly efficient design and construction, the power required to drive these coolers is very small, indeed, and is practically negligible.

As illustrated this cooler has been applied with great success for dealing with the circulating water of all types of internal combustion engines. Briefly, the advantages of the machine for this purpose are as follows: The machine is positive in its action. It possesses a definite amount of cooling surface, a certain fixed volume of air is passed through the machine per minute and, therefore, a constant cooling effect is produced. It is practically independent of climatic conditions and for this reason is altogether different in its action from cooling towers, tanks and other systems. It follows from the above that the best running conditions for the engine can be provided at all times. The heat generated by the engine is dissipated by the cooler just as quickly as it is produced.

There is no question of any heat being stored up as is the case when tanks are used. Further, even under extreme conditions, as prevailing in the tropics, the machine may be relied upon to provide entirely satisfactory running conditions. Engine makers and users are well acquainted with the great importance of an ample supply of cooling water at a proper temperature, and it is hardly necessary to say that an engine which is efficiently cooled runs much more satisfactorily in every way than one which suffers through overheated circulating water.

It is claimed that the space taken up by this cooler is very much less than that taken up by any other system. Where tanks are installed with an engine of any size, the space occupied by the necessary number of tanks is often very considerable, and greatly in excess of that required by the coolers. This is especially the case where engines have to run continuously day and night and no time is available for cooling down all the water in the tanks. Water is economized by the use of these machines. The water lost is the minimum possible amount required to provide the cooling effect. Where towers are installed a considerable amount of water is often lost in the form of spray, and with the tank system the whole of the water has in many cases to be run away periodically, especially where the engine works continuously.

This cooler may be arranged to ventilate the engine room, that is, air may be taken from the engine room and discharged to outside atmosphere. This is a great advantage, especially under tropical conditions where the atmosphere of the engine room is often extremely oppressive.

In plants ranging up to 200 B. H. P. this English cooler is arranged so that the pump delivers cooled water direct into the engine jackets, after leaving which, the water returns direct to the cast iron inlet funnel fitted on the water cooler. The water then flows through the cooler by gravity and is passed by the circulating pump back to the engines. The loss of water by evaporation is made up by means of a float valve fixed in a small galvanized iron tank fitted at the side of the cooler. In stationary plants this float valve being connected up to the town's main or other source of supply and with plants of larger sizes, it is desirable to provide a small storage, in the form of a tank or sump let into the ground. Some engineers prefer a small overhead storage tank in order to provide a steady head on the engine jackets. As a rule, this tank or sump has a capacity of a few hundred gallons of water, and its purpose is to counteract any unsteadiness of the circulating system at starting up, due to the comparatively small quantity of water in circulation. When this system is used the float valve for making up the loss of water by evaporation should be fixed in the tank or sump.

When a sump is provided, the pump is arranged to deliver the water from the sump to the engine jackets, and thence by gravity through the water cooler back again to the sump. If an overhead tank is provided the water should flow direct to the engine jackets, and through the water cooler be returned by the pump to the tank.

Essential Oils and Immunity

From very ancient times various aromatic and pungent substances have been regarded as possessing prophylactic powers in some measure. It is curiously interesting, therefore, to learn that modern bacteriologists have discovered that in certain cases of infectious disease some of the essential oils, such as those of cinnamon, cloves, mustard, garlic, thyme, and marjoram, not only possess bactericidal power, but may even be made to confer immunity when injected like serums. Certain investigations of this highly complex subject recently made by Mr. F. d'Herelle of the Pasteur Institute are reported in the *Bibliothèque Universelle* (Lausanne) for June. He said:

"There is a bacillus belonging to the group of the paratyphics, the *bacillus typhi murium*, which is naturally pathogenic for white mice. Many attempts have been made to render it inoffensive for these little creatures by vaccinating them with a product containing dead bacilli; but the project has always failed though attacked in the most various fashion.

"Mr. d'Herelle then asked himself whether this failure was not due to the manner in which the bacilli had been killed, and therefore sought some new method. In the course of his investigations it occurred to him to kill the bacilli meant to serve as a vaccine by means of essences (essential oils), as had been done by Mr. E. Roux. This process has the advantage, according to the eminent bacteriologist, of not altering the albuminoid matters and the disastases contained in the substance of the microbes. . . . No attempt had hitherto been made to prepare vaccines with bacilli killed by essences. Mr. d'Herelle found by experiment that vaccines thus prepared from the essences of cinnamon, garlic, thyme, marjoram, cloves, and mustard were active in certain conditions.

"Thus a white mouse into which is injected a vaccine containing from 500,000 to 10,000,000 corpses of bacilli slain by the essence of mustard is immunized against mortal, and even very 'super-mortal' doses of the living bacilli. But these limits must be maintained with great care in order to obtain immunity, and care must be taken to give a stronger dose to a young mouse than to an adult. For if the dose of 10,000,000 be surpassed, the immunity obtained is very feeble, with little resisting power, and the more the dose is surpassed the weaker the immunity, apparently. On the other hand, the dose must consist of not less than half a million; thus a dose of 150,000 bacilli confers no immunity. It is also useless to try to obtain immunity with a number of successive doses, superior to 10,000,000; the result is *nil*, as if one had done nothing. To resume, the essence of mustard gives a very active vaccine, in this particular case, against hundreds of mortal doses of virus, provided the immunizing doses are confined within the given limits."

The Status of Water-Power Development*

Economic Advantages of Utilizing Maximum Stream Flow with Auxiliary Steam Stations

By H. W. Buck

The development of the use of steam-power by Watt and others, and the resulting availability of the steam engine for application in all kinds of industrial work, caused an increase of demand for power at a cumulative rate, and all industry became dependent upon power of a magnitude far beyond the potentialities of human muscles or animal horse-power. The steam engine of that time was, however, very inefficient mechanically and from the standpoint of thermodynamics, and fuels were expensive and not easily available. A search was consequently stimulated among engineers for a method of producing power on a large scale by means more economical than the steam engine.

The energy of falling water was the most obvious alternative, and the engineers of the day devoted their attention to the development of means of utilizing water-power commercially. The early efforts were principally along the lines of the well-known undershot and overshot wheels, now looked upon with considerable humor as relics of more or less prehistoric times.

EARLY COMPETITION BETWEEN WATER-POWER AND STEAM.

The contest for supremacy then began between the two classes of prime movers, water and steam, which has continued to this day with increasing vigor, the relative advantage alternating between the one and the other from period to period. The popular notion that water-power is and always has been more advantageous than steam-power is not in accordance with the records of engineering.

In the United States, New England and its vicinity contained many river situations which could easily be developed by the early methods prevailing in water-power engineering, and as a result that section of this country underwent a rapid expansion in industrial development during the nineteenth century, beginning about 1825. The steam engine of that period could not compete with the New England water-powers, and consequently the New England district held a commanding position for many years in industrial progress. Industrial communities grew up around all of the waterfalls of reasonably large volume and moderate head.

The next change in conditions which came about was in favor of steam-power. Economical methods of coal mining were developed, and railroad systems for the distribution of coal grew up, so that coal supplies in volume sufficient for power purposes became available at many new centers of industry. Furthermore, new and radical improvements in steam-engine design were introduced, as exemplified by the relatively large engine units of the Corliss type. Water-powers no longer controlled industry, and industrial centers grew up in Pennsylvania, Ohio and elsewhere where cheap coal of good quality could be obtained in large quantities.

About the year 1875 the development of the gas engine as a commercial source of power began as a further competitor of water-power. In large stationary power units, however, the gas engine has been disappointing and has not proved the universal prime mover which it was at first expected to become. Its field has been confined largely to the smaller units.

The steam engine, the gas engine and the waterwheel then became the three great sources of power, each having advantages under particular conditions. The relative advantages, however, of water-power became less and less as the steam engine and the gas and oil engine were improved.

In the old-fashioned mill town, where the presence of a water-power constituted the reason for the existence of the town, it was necessary, in order that all of the mills might utilize the water-power, to group them close together about some strategic location where a canal or headrace could be favorably constructed. The water from such canal was, as a rule, fed through the various mills, which discharged the water thus supplied through their own individual waterwheels to the lower levels. Sometimes several levels were employed, the water passing in series through the mills from one level to another.

When the water-power development at Niagara Falls was at first proposed, before electric transmission was definitely established, the distribution of water to various manufacturing plants to be established in the vicinity by means of an extensive system of radial canals was seriously considered. Customers were to purchase water and not power from the company and use it to operate their own individual waterwheels. All of the proposed consumers were to discharge their water into a common tailrace tunnel at the lower level.

All of these general schemes of utilizing water-power were inefficient and expensive. Since the headrace canal systems were limited necessarily in extent, the industrial development in a water-power community resulted in a huddled mass of factory buildings, jammed in together as closely as they could be constructed, with the whole zone honeycombed with shafts, tunnels, etc.

In these communities, with the expanding business of the various factories, more power was required than the water system could supply. Consequently, the water-power system was usually outgrown, and it became necessary to supplement the water-power with a steam auxiliary. Such steam plants were enlarged from time to time, and ultimately have become the chief source of power in those communities, with the water-power only as an auxiliary. Many of the old mill towns which are popularly regarded as dependent upon water-power have long since outgrown the underlying water-power and are to-day essentially steam-driven.

HYDROELECTRIC DEVELOPMENT AND ELECTRIC TRANSMISSION.

A change and a new era in water-power application began in the year 1892, when power to the extent of 300 horse-power was first transmitted on a semi-commercial scale from Lauffen to Frankfort in Germany, a distance of 100 miles, at about 30,000 volts, and the commercial success of high-tension electric transmission was demonstrated. It proved that power could be generated in one place and transmitted efficiently by alternating electric current to points many miles away. At the same time evolution had taken place in alternating-current electric motors, so that the transmitted power could be utilized efficiently at the point of delivery

This immediately relieved the congestion of the old water-power towns and made it possible to make hydroelectric developments of water-power sites, regardless of any consideration of industrial plants to be located in the immediate neighborhood, and transmit the power output. In other words, the power could be taken to the consumer instead of having to bring the consumer to the power.

Electric transmission from central water-power stations on a large scale began in this country about the year 1895 with the great enterprise at Niagara Falls. In Europe plants of considerable size were built at an earlier date. The voltage limit for transmission at that time was about 10,000, and the transmission distance limit was about 20 miles. Since that time an extraordinary evolution has taken place, so that voltages of transmission are now commercially as high as 150,000 and lines up to 250 miles in length are in operation.

This development and change in methods has opened up an entirely new group of water-powers which were too remote from suitable manufacturing and railroad centers to consider as sites under the old hydraulic scheme of application of water-power. As a rule, water-powers are situated in mountainous regions where the topography is too rough for the satisfactory layout of an industrial town and yet well suited for the construction of a modern hydroelectric plant.

Under this new method of using water-power for industrial purposes its utilization has received a tremendous stimulus. During the past fifteen years many water-powers have been able to show a good margin of saving over the best steam costs, and numerous large central hydroelectric stations have been constructed. The margin of saving in water-power operation since the year 1870 has not, however, been sufficient to prevent a far greater expansion in steam-power for manufacturing purposes than in water-power, and the following table will give an idea of the relative growth of the two as given in the United States Census report:

	Total Steam-Power, Horse-Power.	Total Horse-Power, Water-Power.
1869	1,215,711	1,130,431
1879	2,185,458	1,225,379
1889	4,581,305	1,255,045
1899	8,139,579	1,454,112
1904	10,825,348	1,641,949
1909	14,199,339	1,807,439

The above figures do not include the large central stations generating power by either steam or water-power. Including these, it is estimated that the total water-power developed at the present time is about 6,000,000 horse-power and the total steam-power about 27,000,000 horse-power.

ADVENT OF STEAM TURBINE.

The modern development of the commercial steam turbine dates from about the year 1900. This has accomplished for the extension of steam-power use as much as electric transmission has done for water-power. The evolution has been rapid and is still continuing. During the past fifteen years it has resulted in reducing the capital coast of central steam-power houses from more than $100 per horse-power to about $40 per horse-power, and has reduced the consumption of coal from 3 pounds to 4 pounds per kilowatt-hour down to a coal rate of about 1.5 pounds under favorable conditions at the present time. The steam turbine has so much reduced the size and complexity of the steam plant that the operating expense and maintenance are much lower than before.

All of this has caused a serious setback to the expansion of water-power development. It has brought about conditions that make it now usually a serious question, where an average water-power is under consideration, whether the water-power can produce the power as cheaply as the modern steam plant. Water-powers are often situated many miles from the community where the power is wanted for use, which necessitates the transmitting of the water-generated power over a long line. Such electric transmission not only operates to increase the cost of construction of the water-power plant as a whole, and consequently the fixed charges against the power, but also increases the operating expense in line patrol and maintenance. Furthermore, not less than 15 per cent of the power is usually lost in the long-distance transmission, which raises the cost proportionately at the point of delivery.

Where a steam turbine is the prime mover it can in most cases be installed at or near the consumer's premises. This may give the steam plant the controlling advantage.

COST OF GENERATING SYSTEM.

A water-power transmission system of average merit may range in cost at the present time, including transmission, from $150 to $300 per horse-power of rating. A steam-turbine plant, if it can be established at the center of use where a long transmission will not be required, and if of fairly large size, will not cost over $50 per horse-power. The capital charges, therefore, in favor of the steam plant will be in the ratio of from three to six to one. The water-power plant must therefore have a low annual operating and transmission expense in order to overcome the financial advantage of the steam plant.

There are, of course, a few water-powers in the United States and Canada, such as Niagara Falls, Shawinigan Falls and others which have been developed, that can produce power at an exceptionally low cost, with which steam cannot possibly compete. It is such plants that have led to the remarkable growth of the electrochemical industry, which cannot operate except at the extremely low energy cost of from 2 mills to 3 mills per kilowatt-hour.

There are very few water-power sites, however, on this continent which could afford to sell energy for such low rates where continuous twenty-four-hour power is required at a constant rate throughout the year. The only possible way to obtain low kilowatt-hour cost for electrochemical processes from most of our rivers is to develop the water-power for the maximum flow of the stream for, say, three months of the year, and then operate for the rest of the year at reduced output.

It is probable that the electrochemical industries could adapt their process of operation to monthly variations in power delivery without material inconvenience and certainly with great reduction in cost of energy.

A scheme of power supply where there is a considerable variation in the water flow would not, of course, be applicable to an ordinary manufacturing establishment, where constant production throughout the year is required, but as a rule there is not the extreme necessity in such cases for power at low cost. In an electrochemical process the power item is generally a large part of the total cost of manufacture.

Within the range of feasible development at a cost of construction which would make the cost of such power about equal to that of steam power, it is esti-

*From a paper presented at Pan-American Scientific Congress, Washington, D. C. Reprinted from *Electrical World*.

mated that there is still undeveloped in the streams of the United States about 35,000,000 horse-power.

It is a popular misconception that, owing to a diminishing coal supply, the cost of steam-power is constantly rising, so that water-powers are becoming more and more in control of the power situation. The fact is exactly the reverse. Methods of deriving the energy of the coal are constantly improving in efficiency, and even if the cost of coal should rise it would in all probability be more than offset by the increased economy of use. There is nothing to indicate that the limit to the reduction in cost of steam-power has been reached or is in sight, inasmuch as the best type of steam-electric plants to-day utilize only about 20 per cent of the total energy of the coal. Water-power plants are at present, however, about as efficient as can be hoped for, with 93 per cent efficiency for water turbines and 98 per cent for electric generators.

As the cost of steam-power falls, the total water-power of the country susceptible of profitable commercial development continually shrinks, and many water-powers which a few years ago could have successfully competed with steam plants and might have been developed, will not be developed to-day on account of steam-turbine competition. The proposed taxation of water-powers and other legislative restrictions will increase the list of water-powers that cannot be developed with a profit.

Even California and other Western States, where a few years ago the high price of coal gave water-power a practical monopoly in the power field, no longer hold this position, on account of the development of the local oil fields, which makes fuel available at a cost low enough for successful exploitation of the steam turbine where long transmissions are required from the competing water-power plant and where the hydraulic development is not of exceptionally low cost.

In South America there are apparently numerous water-powers which could be economically developed. The present high cost there of coal and oil should give water-power development a great economic advantage in the South American countries. The same is true of Canada to a great extent, where there are a large number of exceptionally favorable water-power sites and where coal and oil are in each case relatively high in price.

Where a water-power plant is required to deliver a practically uniform daily load throughout the year, which is generally necessary on a miscellaneous power distribution system, and where seasonable variations in load are not permissible, the deficiency at low water flow must be made up either by storage of water or by steam. Usually both are required.

Nearly all water-powers are subject to a period of low water for at least two or three months in the year, and in order to utilize the energy available during the high-water months a combination of steam and water-power is necessary and profitable. The two together will be found in most cases to give a lower cost of annual output than either one or the other alone.

A steam auxiliary is an important and necessary part of a water-power development. This steam-generated power can either be secured by operating occasionally the old steam plants of power customers which have been shut down by purchase of power from a water-power company or by constructing new steam-turbine plants as part of the water-power system.

Where steam-power is to be supplied to make up the deficiency in the water-generated power it is important to operate the steam plant, when running, in the most economical way. The lowest labor and fuel cost will be obtained per kilowatt-hour when the steam plant is operating at practically constant load throughout the day. The operating expense and efficiency of a water-power plant is not so dependent upon constant output, so that it can be operated in the combination at a lower load-factor, taking the peaks of the load.

The outlook for the future development of water-powers appears, therefors, to be largely in the line either of power plants exclusively driven by water-power for seasonable variation in output, or for constant output developments, where steam storage and water-power are combined, each contributing to the economy of the joint operation.

Extension of the Spectrum Beyond the Schumann Region—II*

Difficulties Encountered and Methods of Procedure Followed

By Theodore Lyman, of the Jefferson Laboratory, Cambridge

Concluded from Scientific American Supplement No. 2122, Page 147, September 2, 1916

The electrodeless discharge is easily dismissed; no radiation on the more refrangible side of λ 800 has been obtained with it. The arc discharge in quartz, both when calcium electrodes were used and when magnesium was employed, showed no lines more refrangible than λ 1000 which could be certainly attributed to these metals. The spectra in both case consisted mainly of secondary hydrogen lines; the primary lines at λ 1216 and λ 1026 were, however, quite strong. The spectrum, which is intense, terminates near λ 905.

The absence of metallic lines in this region is also confirmed by experiments with the spark-discharge at reduced pressures. Pointed terminals of both aluminium and iron, about 1 centimeter apart, were arranged in a small globular vessel communicating directly with the spectroscope. A spark-gap in air, in series with the terminals, insured the disruptive nature of the discharge. At a pressure of about 1 centimeter of hydrogen the spectra obtained with both metals were characteristic of the gas-filling. They contained no lines which could be ascribed with certainty to either aluminium or iron. The spectra terminated near λ 1030. The amount of gas present in the light-path was about equivalent to that in a column of hydrogen at atmospheric pressure 2.5 centimeters long. The experiment, therefore, is of some interest as giving an idea of the order of transparency of hydrogen for these short wave-lengths.

The relation between the spectra of helium and of hydrogen forms a fascinating subject for speculation, and the spectral region now under consideration is an excellent field for the test of hypotheses. However, as has already been pointed out, the data at hand cannot be made to yield conclusive answers to the questions involved. The difficulty is inherent in the nature of the problem since the type of the apparatus which must be employed, if the region in question is to be studied at all, precludes the separation of the effects of absorption from those produced by radiation, and at the same time renders the elimination of traces of hydrogen from an atmosphere of helium extremely difficult. In considering the spectra obtained from the discharge tube, therefore, it must suffice for the present at least, to confine the attention to their general character.

On comparing the spectra obtained from hydrogen excited with and without capacity, it becomes evident that when the lines obtained in the latter case are subtracted from those produced with a disruptive discharge, some seventeen strong lines remain. Of these, λλ 1216, 1026, and 972 form the Balmer analogue predicted by Ritz; λ 1216 is one of the strongest lines in the spectrum: the second member, however, is so feeble as to be hardly visible in spectrum *a*, Plate III, but it is easily seen in spectrum *d*. This illustrates the curious fact, to which reference has been already made, namely, that the extreme lines of the Ritz series appear to be produced more strongly in helium with a non-disruptive discharge than in hydrogen when a condenser and spark-gap are employed. The line λ 972 is not visible in spectrum *a*, but may be seen quite clearly on the original negative from which spectrum *d* was taken. In connection with Bohr's speculations it is important to observe that λ 1216, which forms the first member of the Ritz series, occupies exactly the same position when obtained from helium as when it is produced in hydrogen.

The striking pair of strong lines near λ 1086 and the wider pair near λ 992 have already been attributed to an impurity. They occur in both quartz and glass discharge tubes and their appearance is independent of the nature of the electrodes. They occur very strongly in nitrogen and may perhaps be attributed to this gas, though not with perfect certainty. They may possibly be produced by an oxide of carbon, a trace of which has been occasionally detected in the visible spectrum of helium and which probably takes its origin from the wax used to seal the spectroscope. An inspection of spectra *a* and *b* will show that these lines are less intense in helium than in hydrogen; they cannot, therefore, be ascribed to helium, though Bohr has hinted that they belong to this gas.[13] The line at λ 1176 is perhaps the strongest in the whole hydrogen spectrum; it is equally strong in helium and is very strong in nitrogen; of its origin nothing positive can be said. All the remaining lines to λ 977 are stronger in nitrogen than in either helium or hydrogen; all occur in argon. From λ 997 to λ 904 all the lines, with one exception, occur in hydrogen, helium, and argon, but with relative intensities depending on the gas in which they are produced. All the lines on the more refrangible side of λ 900 are obtained only when helium is employed, with the exception of λ 833 which occurs in argon. The strength of the pair near λ 835 is striking. An examination of the print from which Plate III was made showed in spectrum *b*, if a magnifying glass was used, the extreme line near λ 600 *A*; however, this line is probably lost in the reproduction.

Nitrogen yields a few strong lines with a disruptive discharge besides those which it appears to contribute to the hydrogen spectra; with a non-disruptive discharge it yields but two or three weak lines near λ 1200. As its spectrum does not extend beyond λ 977, I have been chiefly interested in the gas in its character of an impurity and have made no measurements upon its lines.

As has been mentioned already, argon gives a spectrum containing many lines terminating only near λ 800, but here, again, I have not delayed the progress of this research in order to make measurements. A careful study of the argon spectrum in the future, however, will probably well repay the trouble.

The wave-lengths which are to be found in Table I were obtained by the two-slit method which I have frequently employed.[14] They rest on the hydrogen line λ 1216.0 and upon the shifted spectra of iron and aluminium. They make no claim to extreme accuracy, but I hope that, when standard wave-lengths shall have been established in this region, the values given in the table will not be found to depart from the standards by more than one unit.

The numbers in the first column indicate the intensities of the lines as they occur in helium.

It must be remembered that λλ 1216, 1026, and 972 represent the only strong radiations on the less refrangible side of λ 900 which can be attributed to helium or to hydrogen with any degree of certainty. Even the extreme lines produced in helium alone may owe their appearance on the photographic plate to the superior transparency of the gas and may be produced by some subtle impurity.

TABLE I.

STRONG LINES IN THE EXTREME ULTRA-VIOLET.

Intensity in Helium	λ	Intensity in Helium	λ
1	590.0	3	992.0
1	643.7	4	1010.6
2	702.4	4	1026.0
3	703.5	5	1037.0
5	718.2	2	1084.9
2	796.8	5	1081.1
8	833.4	1	1134.7
7	834.8	8	1175.5
4	904.6	10	1176.3
2	916.7	5	1199.8
1	972.7	10	1216.0
2	976.8	1	1236.0
6	977.6	5	1247.9
1	990.2		

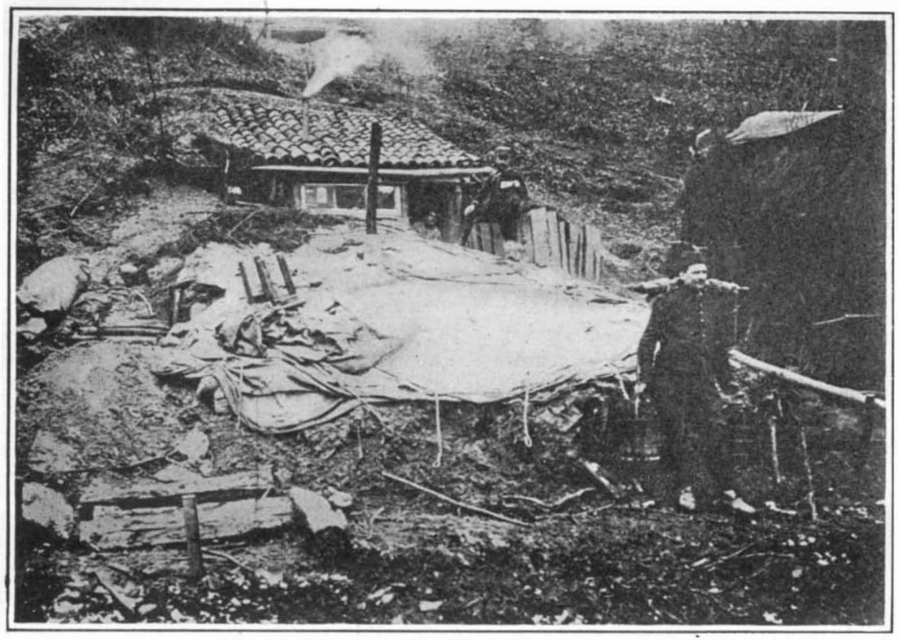
The result of this investigation is easily stated; the spectrum has been extended to λ 600 A.

I cannot conclude this article without expressing my appreciation of the skill and patience which my assistant, Dr. Paul Sabine, has shown during the whole course of this research.

*The Astrophysical Journal.

[13] *Philosophical Magazine*, 30, 401, 1915, note.

[14] Lyman, op. cit., p. 45.



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Quarters of an artillery officer at Beausejour.

Photo by Meurisse.

Headquarters of a French division in Alscoe.

Underground Habitations on the Firing Line

Comforts and Conveniences Improved Under Adverse Conditions

THAT the trench, hastily excavated in the soft earth, has superseded the massive masonry, and even armored fortress of a past generation, is well known, for it has developed that the effects of one of the monster shells thrown by modern guns is by no means as far-reaching on defensive works constructed of earth as on the apparently more substantial structures. In the case of the armored turrets, so confidently relied on in Belgium before the war, their weakness was not so much in the quality of the armor as in the concrete or masonry foundations upon which they must be built, and in the vulnerability of the operative machinery, to disturb which direct hits are not necessary, and, like the chain, the fortress is no stronger than its weakest part.

Another reason for the disappearance of the permanent fortification, and the universal adoption of the trench, is the immobility of the former, while an efficient defensive trench may be thrown up in a few hours wherever the necessities of constantly shifting military strategy may indicate, and may be readily developed in magnitude to meet the particular requirements of the locality. As a matter of fact, at many points on the German front the trenches that were at first constructed with a view to temporary defense have been developed into what may be regarded as permanent works, as is evidenced by some of the positions recently captured by the British, which were found to have been very elaborate structures, heavily walled and reinforced by masses of concrete, only to be shattered by the heavy guns unexpectedly brought out by the allies.

Elaborations of the simple trench is to be found along the lines of the allies as well, but in these cases no attempts at permanency were apparently made, but merely an increase of conveniences for living quarters, where the men at the front could be better sheltered from the elements and have a place for rest and recuperation during their trying terms of duty.

These living quarters, made desirable by the long wait while the allies perfected their supplies of guns, munitions and other supplies for an active campaign, were usually burrowed out far below the surface of the ground, sometimes thirty feet deep, so as to have a protective roof that should be fairly proof against the shells of the ordinary field gun; and many of these habitations were quite commodious and elaborate, as may be judged by the illustration on the front page of this issue of the SUPPLEMENT, which shows a corner of an officers' dug-out on the French front. It will be noted that here provision is made not only for conducting the official business of the post, but for living and sleeping quarters as well, all of which are warm and comfortable, although crude and homely.

Photo by Meurisse

A shelter on the first line.

Other illustrations show the exteriors of commodious quarters at various points, some constructed in hillsides, and others in the embankments of fighting trenches; while one view shows the entrance to a large cavern in a bluff at Soisson, with sculptured decorations wrought by the soldiers in their idle moments. At several points on the French front there are large caves of this description, some of them the remains of quarries, which are commodious enough to accommodate large troops of men, and in at least one case a troop of cavalry has been comfortably housed.

Many of the German dug-out habitations are more elaborate than anything attempted by the allies, for some of the retreats uncovered in the recent advances of the allies have been found to be equipped with electric lights. In one case an automobile had been established in one of these underground abodes to furnish power for the lights. In the recent advances of the allies in France some of the more substantial of these German subterranean retreats escaped destruction by the shell fire, and into these the Germans retreated, carrying with them their machine guns, to emerge and open fire on the attacking forces from behind, after they had passed the trenches where these concealed refuges were located.

It is not alone on the fighting lines that subterranean retreats have been utilized, for we read of the inhabitants of Brussels, and other Belgian cities that were bombarded by the Germans, taking refuge in wine vaults, and the deep cellars beneath cathedrals and churches from the bursting shells, wantonly thrown among these non-combatants; and even now these places are being utilized for schools, where the large number of children can continue their education in comparative safety.

What the ultimate development of the trench, with its accompanying subterranean habitations, may lead to is difficult to foresee, but undoubtedly it will continue to be a prominent feature in future wars, as it has so thoroughly proved its efficiency and adaptability in both defensive and offensive operations that it will always hold a prominent place in the studies of military tacticians throughout the world.

The Study of Hereditary Eye Defects

By C. H. Danforth, Ph.D.*

THE eye has furnished one of the most fertile fields for the study of human heredity. No better illustration for the unit factor hypothesis is to be found than that afforded by the heredity of pigmentation in the normal iris. Likewise in the transmission of abnormalities, both structural and functional, the eye offers many striking examples, and in consequence of this fact some of the most important papers relating to the heredity of abnormal conditions have been written by ophthalmologists.

For the student of heredity the chief interest in eye defects has been, in the past, to learn whether or not the general laws that have been derived from the results of controlled breeding of lower animals apply with equal force to the human being. In general, as is well known, there has been found to be a rather striking similarity between the mode of inheritance in man and the lower animals. It may not be out of place to review briefly a few points of importance in this connection.

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Cytological evidence has furnished a strong presumption in favor of the idea that the truly heritable characteristics of an animal owe their existence to some peculiarity in the chromatin of the germ cells, and this view is still further strengthened by the results of immense number of breeding experiments. In the case of the fruit fly (Drosophila ampelophila), Morgan and his collaborators[1] in what is probably the most elaborate series of experiments of this sort that have ever been undertaken, are able to refer the determiners for certain eye peculiarities, not merely to certain chromasoms, but actually to definite loci within the chromosomes. The method of analysis in this case is comparable to that employed by the physico-chemist in determining the constitution of molecules, and the conclusions likewise may be tested in an analogous manner.

[1]The observations on Drosophila are summarized in *"The Mechanism of Mendelian Heredity,"* by T. H. Morgan, et. al., New York, 1915.

The results of these studies on Drosophila and of many other investigations that point in the same direction have led to a wide acceptance of the unit factor hypothesis, which is in reality an elaboration of the original Mendelian conception. According to this view certain heritable peculiarities are due to what might be called positive variations in the determiners while others are due to negative departures. When an individual showing the positive variation is mated to a normal, the offspring tend to show the characteristic (dominant), whereas in the other case the offspring are *apparently* normal, since the defect in the one parent is compensated by the normal condition of the other. Such apparently normal young, however, may be capable of transmitting the defect to their descendants. In the first case we have the *direct* form of heredity, in the second the *indirect* and the *collateral.*

In the peculiarities of the human eye numerous cases are found where the heredity of the defect is clearly of one of these types. The extensive family histories that have been published seem to show, for instance,

Photo by Meurisse

Small shelters thrown up near Dixmude.

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Caves carved in the bluffs at Soisson.

that stationary night blindness behaves as a dominant characteristic, whereas retinitis pigmentosa behaves as a recessive.[2] An interesting special form of recessive characteristic is illustrated by peculiarities that behave in heredity like color blindness. Here in the vast majority of cases it is the male that is affected, the affection being transmitted from affected father through normal daughter to grandson. Such a characteristic is called *sex-linked*, and in the eyes of Drosophila several such peculiarities have been found. Detailed study of these characters has shown that the determiner for these sex-linked peculiarities, such as "eosin eyes," are located in the sex chromosome, of which the male has 1, the female 2. The character is so much more unusual in the female then for the reason that the chances that her 2 sex chromosomes will *both* be defective are much less than that the single sex chromosome of the male will be defective. That the same chromosomal relations between the two sexes obtains in man has been reported by several cytologists; and since the parallelism in heredity is also complete, there is good reason to believe that color blindness in man and the sex-linked eye defects of Drosophila are capable of the same explanation.

There are abundant data to show that many other eye defects of man are heritable in the same way as the peculiarities of lower animals; and it is of great importance for the advancement of our knowledge of human heredity to extend, so far as possible, the comparison between observations on family histories and the data obtained from experimental breeding.

But there is no reason why the study of human heredity should be confined, as it has so largely been in the past, to fitting data from human sources to the rules that are derived from investigations in other fields. The fact does not seem to be generally appreciated that for the study of certain problems in heredity man himself furnishes the best available material. No mammal is so well known, and few, if any, are more variable. His environmental influences are diverse and the methods for accurately recording his varying bodily conditions have been developed to a high degree. From the point of view of the geneticist the study of such an organism would seem to offer unusual opportunities. A few of the general questions that might be attacked by a study of human eye defects may be discussed briefly.

The question that arises in connection with any abnormality of the eye is whether or not it really is hereditary. This is not always easily answered. The mere presence of the same defect in the eyes of several children of the same family or even of parent and child is not necessarily proof that the defect is hereditary; for, among other things, we always have to reckon with chance as a possible factor. For this reason it is important to know the normal incidence of the character in the general population. The higher the incidence the more difficult it is to prove the existence of an hereditary tendency; for if the chances that an individual picked at random will show a peculiarity are high, then the probability that several members of the same family will also show it is also relatively high. For instance, the chances that a child will be a boy are about even. Consequently in families of 4 children there is mathematical probability that 2 of them will be boys in 11 cases out of 16. It is the high incidence of senile cataract that has made it difficult to demonstrate its hereditary nature. In the case of congenital cataract, on the other hand, assuming that the incidence is as high as 1 in 5,000, the probability on a purely chance basis that a parent and 2 of his 4 children will show the defect is less than one in a million. Since congenital cataracts are not distributed according to the laws of chance, but are commonly grouped among members of certain families, there is good presumptive evidence that this form of eye defect is hereditary.

But it does not necessarily follow from this that all cases of congenital cataract are hereditary. This brings us to a very important and difficult aspect of the study of heredity, namely, the question of the interrelation of environmental and germinal factors.

Writers have frequently failed to recognize that these two sets of factors are not mutually exclusive, as will appear from a review of the literature. The study of a large number of reported cases, however, will probably convince the reader that the same eye defect may be due primarily to hereditary factors in some cases and to environmental factors in other cases. The occurrence of cataracts other than congenital illustrates this point. What the result of these factors acting together or in opposition to each other may be the opthalmologist is in a peculiarly favorable position to answer.

Some slight investigation of this problem has been undertaken in comparative lines. For example, in the studies on Drosophila, already referred to, it was discovered, apparently by accident, that in a given environment a certain peculiarity was inherited according to the regular rules; but when the environment was altered the proportions were changed, and frequently no abnormal young were produced. When, however, these normal appearing individuals were returned to the former environment, the original Mendelian proportion of defectives reappeared. Here, then, is a case in which the environmental factor is stronger than the hereditary.

We have not as yet the data for drawing final conclusions in regard to this matter; but it would seem that the various observations might be harmoniously interpreted on some such basis as the following, in which we may use for an example the case of cataracts which are not congenital.

There is much evidence to indicate that such cataracts are often of an hereditary nature. There is also abundant evidence that they may be produced by diseased bodily conditions or by purely external agents. There is probably no one in whom a cataract of some form could not be induced to develop, and it is possible that were the ætiology better understood there would be no one in whom the formation of a cataract could not be prevented. Thus it may be that the likelihood of a cataract being formed is only a relative matter depending on the interaction of both hereditary and environmental factors.[3]

That the hereditary tendency in certain cases is very strong cannot, I think, be denied. Just what the physical basis of such a tendency is it is difficult to say, but some recent work on the heredity of pigmentation in the rabbit may throw a little light on this question. It was found[4] that in certain areas of the skin in a race of spotted rabbits an antiferment develops which prevents the oxidation of the pigment forming substance. The presence or absence of this antiferment, as determined by chemical tests, is inherited according to the strict Mendelian ratios. It is conceivable that a disposition to produce some substance that will act unfavorably upon the lens at some period of its existence may likewise be inherited in man. Whatever the predisposing factor may be, it is of interest to geneticists to know whether or not it occurs in varying grades of intensity, and whether there are to be found families in which a slight inherent tendency is seemingly present but manifests itself only under special conditions. Existing statistics do not seem sufficiently adequate to settle this point.

Another point which ophthalmologists are in a position to elucidate concerns the question of the degree of fluctuation that a unit character may show within the limits of a single family. According to the pure line conception, developed in connection with animal and plant breeding, the individuals of a strain may fluctuate rather widely, whereas their germplasm varies not at all. If this is true of man, the children of a slightly affected individual have no better chances than those of his markedly affected brother. The evidence bearing on this question is at present conflicting.

Closely related is the problem of the first origin of defects. There is a suggestion in this connection from the work of Stockard[5] with alcoholized guinea pigs, where it is found that there may be artificially produced in the germ cells defects which are transmitted through several generations. Can the environment produce upon human germplasm variations which will make themselves felt in succeeding generations in the form of eye defects? If the germplasm can be thus affected, is the alteration permanent or, after a few generations, will the normal equilibrium gradually be restored? These are questions of the greatest importance, both practically and theoretically, and for their solution the study of the histories of human eye defects seems to be a most promising point of attack.

The one real difficulty in the study of all these questions is in getting adequate data from which to draw conclusions. If one might judge of a profession by its literature, it would seem that ophthalmologists as a class appreciate the importance of heredity better than almost any other group of physicians. But even among ophthalmologists there is a tendency to report only the striking cases and to overlook or disregard the supposedly normal relatives of an affected patient. This is very natural, and it is not surprising that the active practitioner often does not feel justified in taking the pains to look up a family which promises no special evidence or whose history might not seem particularly worth publishing if worked out. But such histories are important if we are really to understand the workings of heredity, and some method should be found for making the data available.

If the writer might venture a suggestion in this connection, it would be that in a center of population such, for example, as St. Louis, the local ophthalmologists report all cases of the eye defects whose heredity it is desired to study, to a secretary or other person who should correlate such reports and keep them open for consultation by members of the porfession. Then whenever even a small amount of additional information might be gathered, instead of being laid aside or forgotten, it could be turned in with the feeling that it would be a real contribution toward a knowledge of the conditions that actually obtain in this community. Such records would increase in value as time goes on, and they would ultimately furnish the material for an intensive study of a definite region, a study which would have far greater importance than one based on the many data gathered at random from a variety of sources.

[2]Summarized by Bateson in *"Mendel's Principles of Heredity,"* Cambridge, 1909. See also Usher: "On Inheritance of Retinitis Pigmentosa, with Notes on Cases," Roy. Lon. Ophthal. Hosp. Reports, No. 19, 1914.

[3]Many of the ophthalmologists whose views are reported by Zydek (translation in this Journal, vol. 32, pp. 235-247), seems to hint at some such idea. Somewhat similar views in relation to the heredity of cancer in mice are expressed by L. Loeb—*Science*, New Series, vol. XLIII, No. 1105, 1916.

[4]H. Onslow: "A Contribution to our Knowledge of Coat-Color in Animals and of Dominant and Recessive Whiteness." *Proceedings of the Royal Society, Series B.*, vol. LXXXIX. pp. 36-58, July, 1915.

[5]Stockard and papenicolaou: "A Further Analysis of Hereditary Transmission of Degeneracy and Deformities by the Descent of Alcoholized Mammals." *American Naturalist*, vol. L, pp. 65-88, 144-177, 1916.

The Plains of Northern India*

And Their Relationship to the Himalaya Mountains

By Sir Sidney Burrard, F. R. S.

A HUNDRED years ago the accepted idea was that mountain ranges were due to the upward pressure of liquid lava, and that their elevation had been caused by volcanic forces. But when geologists began to study the structure of rocks, they found that mountains had suffered from horizontal compression, which was evident from the folding of strata. This discovery led to the idea that mountains had been elevated, not by vertical forces, but by horizontal forces, which squeezed the rock upward. The wrinkling of the earth's crust into mountains by horizontal forces was explained by the cooling of the earth: this is the well-known contraction theory; the earth's interior is held to cool and to contract, and the outer crust is supposed to get too large for the shrinking core and to wrinkle.

About 1860 the observations of the plumb-line brought to light a most important and totally unexpected fact, namely, that the Himalaya were not exercising an attraction at all commensurate with their bulk.

The plumb-line was observed at Kaliana, 60 miles from the foot of the mountains; the observers found that the Himalaya were exercising no appreciable attraction. By the theory of gravitation the plumb-line ought to be deflected at Kaliana 58 seconds toward the hills. It is not deflected at all; it hangs vertically. This discovery was the first contribution made by geodesy to the study of mountains. The discovery was this, that the Himalaya behaved as if they had no mass, as if they were an empty eggshell; they seemed to be made of rock, and yet they exercised no more attraction than air. From the Kaliana observations Pratt deduced his famous theory of mountain compensation; he explained the Kaliana mystery by assuming that the rocks underlying the mountains must be lighter and less dense than those underlying plains and oceans. The visible mountain masses, he said, are compensated by deficiencies of rock underneath them. This is the theory of mountain compensation. The compensation of the Himalaya is not believed now to be exactly complete and perfect; they seem to be compensated to the extent of about 80 per cent; their total resultant mass is thus about one fifth only of their visible mass standing above sea-level. The discovery of mountain compensation struck a blow at all theories which attributed the elevation of mountains to any additional masses that had been pushed in from the sides. The elevation of mountains by subterranean lava squeezed in from the side had to be rejected because it gave to mountains additional mass; the wrinkling of the earth's surface by lateral horizontal forces had to be rejected because it gave to mountains additional mass pushed in from the sides. As the Himalaya possess only one fifth of their apparent visible mass, I am led to suggest that the principal cause of their elevation has been the vertical expansion of the rocks underlying them, vertical expansion due to physical or chemical change.

MOUNTAINS ORIGINATE AT GREAT DEPTHS.

A very important work has been that of Mr. Hayford, who has recently discussed the result of the plumb-line at a large number of stations in America. He has confirmed Pratt. Hayford has investigated the depth to which the deficiency or density underlying mountains goes down, and he has found that that depth is between 60 and 90 miles. That is to say, he has shown that the depth of subterranean compensation is very great compared with the height of mountains. The discovery that mountains originate from the great depth of 60 to 90 miles is the second important contribution of geodesy to this study. The first was compensation, the second is great depth.

SOUTHERLY DEFLECTIONS PREVAIL OVER THE GANGES PLAINS.

Now let me tell you of the third discovery due to this plumb-line. The survey found that at 60 miles from the hills this plumb-line hung vertically, and Pratt deduced the theory of mountain compensation. But when the survey began to extend their operations, a new phenomenon came to light, which caused great surprise. All over northern India at distances exceeding 70 miles from the hills, this plumb-line was found to hang decisively away from the mountains; here at Lucknow it is deflected 9 seconds to the south. If the Himalaya were simply compensated, this plumb-line should be hanging at Lucknow exactly vertical; if the mountains were not compensated, it should be deflected here about 50 seconds toward the north. But it is deflected 9 seconds toward the south. The observers were astonished to find that at places in sight of Himalayan peaks the plumb-line turned away from the mountain mass; that at Amritsar, in sight of the Dhauladhar snows, it was deflected toward the low Punjab plains; at Bombay it was deflected seaward away from the Western Ghats; on the east coast of India it was deflected seaward away from the Eastern Ghats.

The new lesson to be learnt from the plumb-line is this: a hidden subterranean channel of deficient density must be skirting the mountains of India. Here in North India is a wide zone of deficient density, of crustal attenuation; it is the presence of this zone of deficiency that accounts for the southerly deflection of the plumb-line. What is the meaning of this zone? How has is come into existence?

If you look at this section, the earth's crust in these outer Himalaya has been compressed laterally: of this there is no doubt. The area between the snowy range and the foothills is a zone of crustal compression. And I suggest for your consideration that the Gangetic trough, this zone of deficiency, is a zone of tension in the crust. The crust has been stretched here and attenuated. Here you have compression, and alongside is the tension. The tension is the complement of the compression. I have pointed out that the Himalaya mountains are largely, but not completely, compensated by their underlying deficiencies of density; their compensation is, however, rendered complete by the presence of the Ganges trough; if the Himalayan compression and the Gangetic tension are considered together, it will be found that there is no extra mass.

HYPOTHESIS OF A RIFT.

I showed you on the evidence of the plumb-line that the Gangetic trough was a zone of crustal attenuation, a zone in which the earth's crust was deficient in density. I then took one step forward and suggested that it was a zone of tension. I will now take another step forward and suggest to you that there has occurred an actual opening in the subcrust, and that the outer crust has fallen in owing to the failure of its foundations. I suggest that the Ganges plains cover a great rift in the earth's crust.

The earth is a cooling globe; an increase of temperature occurs as we descend into mines; and this temperature gradient is a proof that the earth is losing heat by conduction outward. The discovery of radium has not affected the argument.

The rock composing the crust and subcrust is, however, a bad conductor, and the interior of the earth will not shrink away from its crust, as has been assumed in the contraction theory. The inner core of the earth is, in fact, not losing heat appreciably. The outer shell was the first to lose its heat, then the shell below it, and the subcrust is now losing its heat more quickly than the interior core. As the outer shells contract from cooling they become too small for the core, and they crack. Supposing we had here a great globe of rock, red-hot throughout; how would it cool? Can you imagine it cooling in such a way that the core became too small for the outer shell, and the outer shell became wrinkled? No; the outer shell would cool first, and would crack.

The outer shell of the earth was the first to crack millions of years ago; now a lower shell, the subcrustal shell, is cracking. When a crack occurs in the subcrust, parts of the upper crust fall in.

You will see that this Indus-Ganges trough has the appearance of a crack. And there are reasons for believing that these Himalaya have been split off from this ancient table-land, and have been moved northward and crumpled up into mountains.

FROM THE BAY OF BENGAL TO THE MEDITERRANEAN.

Geologists have discovered that the ancient table-land of the Vindhyas and Deccan is a remnant of a much greater table-land that in very early ages included Africa and Arabia. Africa and Arabia and the Deccan table-land are, in fact, fragments of one extensive and ancient continent.

To the west of Karachi we see the Persian Gulf and the plains of the Tigris-Euphrates. The plains of the Tigris-Euphrates are very similar to those of the Ganges: they consist of mud, sand, and sediment lying in a long trough between the ancient table-land of Arabia and the mountains of Persia.

Farther west we find the Euphrates trough is continued by the Mediterranean Sea, and the Mediterranean is bounded on the north by the Taurus mountains, by the Balkans, Carpathians, Apennines, and Alps.

Throughout the whole distance from Calcutta to Sicily we see that the old table-land, India-Arabia-Africa, is bounded on the north by a long trough, and that this trough is, in its turn, bounded by the younger mountain ranges from the Himalaya to the Alps. Geologists have discovered that all these mountain ranges were elevated in the same era; they are all the same age.

I submit for your consideration that the Ganges-Indus-Euphrates-Mediterranean trough is an indication at the earth's surface of a rift in the subcrust.

The whole zone from Java to Sicily has been visited by earthquakes throughout the historic period. And the recent earthquakes in Shilong, Dharmsala, and Messina show that seismic activity is continuing in our time. This is, in fact, one of the zones of the earth along which earthquakes occur most frequently.

THE BOMBAY COAST.

I must now invite you attention to the Bombay coast. From the Tapti to Cape Comorin runs the range of mountains known as the Western Ghats. This range is parallel to the coast of India and about 40 miles inland; it rises suddenly with a steep scarp. The strata are almost as horizontal as when first laid down; they have never been compressed or folded.

The survey has observed the plumb-line at different points along this coast; it is always deflected strongly toward the sea. To the west of Bombay and Mangalore there is the deep sea; and to the east there is a massive range more than 4,000 feet high; yet the plumb-line will hang seaward. If the Western Ghats possessed the mass which they appear to possess, and which the Suess school ascribes to them, then the Bombay plumb-line should be deflected 15 seconds toward them. If, on the other hand, the Western Ghats are compensated by deficiencies of mass underlying them in accordance with the compensation theories of Pratt and Hayford, then the plumb-line should hang vertically at Bombay. But the plumb-line takes neither of these courses; it hangs toward the sea, We have been puzzled for years by the plumb-line at Bombay; we used to think that the rock under the ocean must be so dense and heavy that it was able to pull the plumb-lines toward the sea. Major Cowie, however, observed in the south of Kathiawar, and found that the plumb-line here had a strong landward deflection. The seaward deflections occur throughout the Bombay coast, but not round Kathiawar. It is only quite recently that we have realized we have at Bombay the same phenomenon as at Lucknow.

In northern India the plumb-line will persist in hanging away from the visible mountains, and at Bombay it takes the same course, and when I consider its constant seaward deflection I can only suggest to you that a crack in the subcrust has extended from Cape Comorin to Cambay, and that as this crack has occurred the Western Ghats have been elevated. The crack has been filled by masses of fallen rock and by alluvial deposits brought down by rivers.

Geologists have shown that this range consists, from latitude 20 degrees to 16 degrees, of the lavas of the Deccan, comparatively recent rocks, while from latitude 16 degrees to 8 degrees the range consists of ancient metamorphic rocks. The rocks of the northern part of the range are of a dfferent age and structure and origin from those of the southern.

Nevertheless, geodesists contend that this is one and the same range; the rocks composing it have had nothing to do with its elevation. The Western Ghats have been elevated, after the Deccan lavas had become solidified, into surface rocks. Their elevation took place in the Tertiary age.

THE DEPTH OF THE GANGETIC RIFT.

In considering the depth of the Gangetic rift we must appeal, first, to geodesy, and then to seismology. Now geodesy tells us that the compensation of the Himalaya (i. e. the root of the Himalaya) extends downward

*Abridged from an address to the Indian Science Congress at Lucknow by the president. Reprinted from *Nature*.

to a great depth. I regard the Gangetic plains and the Himalayan range to be the two parts of one whole; I believe that they have originated together, and if the depth of Himalayan compensation extends down to 60 miles, then I think that the Gangetic rift may extend down to that depth also.

Now let us turn to seismology; seismologists are able to form rough estimates of the depths of earthquakes. In the Dharmsala earthquake Middlemiss estimated its depth to be between 12 and 40 miles. Middlemiss's maximum value is not very different from the geodetic value.

It is an interesting question to consider whether a fissure in rocks could extend downward to a great depth. From a place near the Indus in Kashmir it is possible to see a continous wall of rock 4 miles in height, on the flank of Nanga Parbat. Mount Everest stands erect five and one-half miles above sea-level; its summit stands firm and rigid 11 miles above the depths of the Bay of Bengal. We have, therefore, evidence that the materials of the crust are strong enough to admit of the continued existence of great differences in altitude.

But Mount Everest is standing in air, whereas a crack in the subcrust becomes filled with rocks falling in and with fluid rock magma from below; and the walls of the crack thus get a support that Mount Everest does not possess. It seems to me quite possible that a crack such as I have described may have extended down to a depth of 60 miles by successive fractures at increasing depths, the opening being filled by falling material.

INTERNAL CAUSES OF MOUNTAIN ELEVATION.

I have shown you how zones of substance in the crust are bordered by mountains, and I have now to discuss the relationship of subsidence to elevation, of troughs to mountains. The Red Sea is a zone of fracture, and it is bordered on each side by a zone of elevation. But along the Bombay coast the zone of subsidence is bordered only on the one side by a zone of elevation. The subcrustal crack from Surat to Cape Comorin has been accompanied by a vertical uplift of the Ghats, and I suggest for your consideration that the vertical force which elevated the Ghats was the expansion of the underlying rock due to physical or chemical change.

Mr. Hayden informs me that the specific gravity of the rock composing the Neiligherries varies from 2.67 to 3.03—that is, 14 per cent—and that the rock of the Hazaribagh plateau varies from 2.5 to 3.1—24 per cent.

The Western Ghats appear to have risen about 4,000 feet. Now we know that the Western Ghats are largely compensated by underlying deficiency of density; if the compensation of the Western Ghats extends downward to a depth of 60 miles, then an expansion of 2 per cent would be more than sufficient to account for the elevation of the Ghats. Mr. Hayden finds variations of 14 and 24 per cent in the densities of surface rocks, and yet an expansion of only 2 per cent would account for both the elevation and the compensation of the Ghats.

The heterogeneous rocks composing the earth's crust are continually undergoing changes of structure, known to geologists as metamorphism. At a depth of 30 miles the temperature is sufficiently high to melt all known rocks; but increase of pressure raises the melting point, and the increase of pressure underground may be sufficiently great to counteract the effects of the increase of temperature. So that at a depth of even 60 miles rocks may still be solid and rigid, as geodesy leads us to believe they are.

The main ranges of the Himalaya are composed of granite; this granite has protruded upward from below. I suggest that the protrusion of granite is due to expansion of rocks in the subcrust. The great Himalayan range is 5 miles high, and the compensation of this range—that is, its underlying deficiency of density—is estimated to extend downward to a depth of perhaps 75 miles. An underground expansion of 7 per cent would be sufficient to account for the elevation of the Himalaya.

Many of the faults which intersect the Himalaya may, I think, be ascribed to the shearing which must have ensued when certain areas of the crust were forced vertically upward by the metamorphism of subcrustal rock. Many distortions of surface strata may be ascribed to local variations in the vertical expansion of deep-seated rocks.

The peculiar sinuous curve of the Northern Tibetan border, concave on the east, convex on the west, is reproduced in the north of Persia, and again in the Carpathians. The Persian ranges all have a trend from south-east to north-west, except that the Caspian subsidence seems to have pushed rudely in from the north and forced the northern range into a sinuous curve. It is significant that at the point of the Caspian push stands the peak of Demavend, the highest point in all Persia. *Elevation is the companion of subsidence.*

The conclusions which I have ventured to submit to this meeting may be summarized as follows:

1. The fundamental cause of both elevation and subsidence is the occurrence of a crack in the subcrust.
2. Mountains are compensated by underlying deficiencies of matter.
3. Mountains have risen out of the crust from a great depth, possibly 60 miles.
4. Mountains owe their elevation mainly to the vertical expansion of subjacent rock.

I have now had the great privilege of placing certain problems before you. My endeavor has been to point out to this congress, and especially to its younger members, the many scientific secrets that are lying hidden under the plains of Northern India.

The Modern Boiler-House*

THE main object in the design of a modern boiler-house has come to be to have the maximum of steaming capacity in the minimum of space. Twenty years ago 1 horse-power per square foot of engine-room floor space was an average figure. As a rule the boiler-house was a one-story building, and an evaporation of 14 pounds of steam per square foot of boiler-house floor space, or 42 pounds per square foot of boiler-floor space, represented good average steaming capacity. A few years later when larger stations were being erected the power per square foot of engine-room space was not seriously increased, as condensing engines were installed and the space required for condensers increased the size of the engine-room and the total space occupied by the steam-using plant. Larger boilers were used, but economizers were installed—as a rule on the boiler-house floor level—and the evaporation per square foot of boiler-house space was not much altered.

INFLUENCE OF THE TURBINE.

The introduction of the steam turbine for driving generators about 1904 brought about a distinct change in the relative space required for engine-room and boiler-house plant. The turbine-room came to consist of a two-story building, with the condensers on the ground or basement floor and the turbo-generators above. There are to-day turbine-rooms with 5 horse-power per square foot, and in designs for new power stations, using 15,000 to 30,000. kilowatt sets, this figure may go up to 20 horse-power per square foot. Changes in boiler-house design thus become imperative, particularly in the layout of the boilers, else the space occupied by the boiler-house will be out of all proportion to that allotted to the turbine-room. It is now recognized that when very large turbo-generators are in use every pair of such sets requires a separate boiler-house. While the engine-room and boiler-house floor spaces were about equal 20 years ago and remained so for even 10 years thereafter, in a large modern generating station the boiler-house occupies a space from 1½ to 2½ times greater than that of the turbine-room.

The first consideration is to insure the maximum grate area per square foot of boiler-house floor space, and it is now recognized that there should be three stories at least, the basement or ground floor containing ash-handling plant, the second the boilers proper, and the third economizers and coal-conveying machinery and probably coal storage in the form of overhead hoppers above the boilers. In stations with boilers of 50,000-pound capacity a separate chimney must be erected for each boiler or each pair, and it becomes practically compulsory to adopt steel in preference to brick chimneys, since the former can be erected from the third floor, whereas brick chimneys must be built up from foundations on the lowest floor.

The necessity for concentration of power has made the water-tube boiler indispensable for the modern power-house, but even with this type of plant the assembling of the heating surface over the grate area is undergoing modifications in order that the highest possible evaporation per square foot of ground space may be obtained. The space actually occupied by boilers at present, with the necessary furnaces between, does not as a rule exceed 33 per cent of the total boiler-house floor space, and of this 33 per cent the grate area accounts for only one half.

Increasing the size of the boiler unit will not of itself seriously increase the power per square foot of floor space. Twenty years ago water-tube boilers of 4,000 to 6,000 square feet of heating surface were considered large, whereas they are now made with 10,000 to 20,000 square feet. At Detroit five boilers, each with over 20,000 square feet, are in use. There is still a tendency to make the combustion chambers of boilers much too small. The older ones had 2 to 2½ cubic feet of combustion chamber per square foot of grate area, whereas to-day similar boilers have 5 cubic feet. The boilers at Detroit have 9 cubic feet, and it is generally conceded that this fact is largely responsible for their high efficiency at widely varying loads.

FUEL HANDLING AND STORAGE.

A station of 50,000-kilowatt capacity and burning 200,000 tons of coal per annum requires facilities for handling 1,000 tons of coal a day, together with 100 tons of ashes. This means a railway siding capable of holding from 100 to 120 full trucks, and probably another siding of equal dimensions to hold the empty trucks. The provision of an adequate railway siding is therefore a costly adjunct in the layout of a large power-house, owing to the serious addition to the site which it entails. The length of railway sidings for a 50,000-kilowatt station would not be less than half a mile, or an addition to the site equivalent to 4,400 square yards. The wagons have to be tipped and coal-conveying plant has to be provided capable of handling 100 tons per hour. Coal-breaking machinery should be installed, for, while in the past it has been customary to use small coal, circumstances may in the near future render it economical to buy and break larger coal.

Large coal storage accommodation is advisable and will prove economical. Not less than from two to four months' fuel supply should be retained. This marginal stock enables coal to be delivered in fairly regular quantities throughout the year and may result in lowering coal prices. The height or depth at which coal can be stored depends upon the class of coal; the best method of storing coal is still undecided.

The cost of lifting coal from canal barges or from trucks, and placing it overhead in coal hoppers or in the coal store, is a small item in the total price of coal. In one Glasgow station there is a coal transporter fitted with a 1-ton grab. It cost £2,600 and handles coal at the rate of 40 tons an hour, and the cost of energy, labor, and repairs on it brings the cost of handling coal in this way to just under 1d. a ton. In another station truck loads of coal are elevated 30 feet at one end of the coal store to an overhead platform, whence the coal is tipped into an overhead hopper or to the coal store, and the empty trucks lowered by a second elevator at the other end of the coal store. These two elevators, complete with electrically-operated capstans, cost £2,000. The inclusive cost of handling coal in this way is 3¼d. per ton, the higher cost being due to the amount of labor necessary for handling the trucks. These figures are conclusively in favor of the grab and transporter. Where coal has to be carried a short distance from coal store to boiler-house, bucket or tray conveyers appear to be the right thing. On the other hand, for longer distances, the telpherage system works out slightly cheaper, although the human element, with its attendant problems, enters more largely into it.

FUEL.

It is now almost universal practice to buy fuel on a calorific basis, but it must always be remembered that along with calorific value and analysis there are physical properties to be taken into account. Two samples of coal may show an approximately similar calorific value figure and yet present wide differences of behavior in the furnace. Actual boiler tests must therefore be made with sample truckloads of coal if the best and most economical selection is to be made. In the Glasgow Corporation Electricity Department the calorific value of the different kinds of coal offered is judged by the previous year's experience, and if any particular kind of coal as delivered is below the previous year's experience then it has a decreased figure of value allotted to it against the time when it will be again offered.

*From a paper read by W. W. Lackie at the annual convention of the Incorporated Municipal Electric Association, at London, and reported in *The Engineering Supplement of the London Times.*

Immersion for Microscopic Object-Glasses

MICROSCOPISTS should know that it is now almost impossible to procure proper immersion oil for microscope object-glasses. The proper fluid was invented by Prof. Abbe, and has been sold only by the firms of Winkel and Zeiss. The "cedar oil" as commonly sold, and also the immersion fluid of Leitz, have not the requisite optical properties, therefore objectives immersed with them do not yield their best results. Prof. Abbe experimented with a large number of substances, and devised several immersion fluids. The following is the formula of the one he adopted. He has now been dead some years, and I do not know if any alteration has since been made in this fluid except in its price, for the amount one now gets for 1s. is about one-third of what could be purchased formerly. This is Abbe's formula: The ingredients are three, viz.: 1. White oily *tacamaque* of Guibourt. 2. Oil of cedar (*Juniperus virginiana*). 3. Castor oil. The proportions are: 29 grammes of *tacamaque* dissolved in 22 cubic centimeters of *cedar oil*, to which is added 14 cubic centimeters of *castor oil*.—*Edward M. Nelson in the English Mechanic.*

Internal Combustion Engine Cycles—I*

Possibilities of the Constant Pressure Cycle

By Arthur B. Browne and Herbert Chase

HAVE not engines designed to operate on the Otto or constant volume cycle reached a state of development such that but little further progress of moment is to be expected in the art of their construction, save perhaps in refinement of mechanical detail? Or, to put the question in another form, are not the limitations of the Otto cycle as now applied, notably its poor thermal efficiency under the average low compression pressures realized in practice, such as to force the automobile engineer to consider carefully the possibilities of other cycles, if the art of motor-car construction is to progress as rapidly in the future as in the past?

These are fair questions and must in the opinion of the authors be answered in the affirmative. Having so concluded we have given much thought and study to the subject of this paper and have found it to embrace possibilities which we believe are certain to have far-reaching effects in the entire field of the engineering of internal combustion prime movers.

Before considering the possibilities of the constant pressure cycle it will be well to consider, for purposes of contrast and comparison, the advantages and disadvantages of engines operating on other cycles.

The thermal efficiency of any cycle is dependent in large part upon the conditions under which combustion takes place. Since these conditions vary greatly as between cycles it is most important to have clearly in mind, when making a comparison, the factors conducive to maximum combustion efficiency.

COMBUSTION EFFICIENCY AND CLASSIFICATION.

The liberation of heat energy in a gas engine depends for its efficiency upon several conditions that may exist prior to ignition and during the combustion period. The efficiency is a maximum when the following conditions obtain:

(a) The density or compression of the charge is the greatest possible.

(b) The temperature prior to ignition is the highest possible.

(c) Oxygen is present in quantities just sufficient for complete combustion.

(d) The admixture of fuel with the necessary oxygen is perfect, that is, when the charge is absolutely homogeneous.

(e) Inert and diluting gases are absent.

Combustion may be divided into three main classes.

In *Class A* all the oxygen is furnished by the supporting atmosphere without admixture prior to combustion. An illustration of this is the luminous gas flame, in which gas issuing from an orifice finally comes in contact with the oxygen of the air and burns with a luminous flame of low thermal efficiency. It will be noted that Class A fulfills none of the conditions previously enumerated as making for efficiency because: (a) Both gas and air are at atmospheric pressure; (b) the temperature prior to ignition is low; (c) much more oxygen is present adjacent to the combustion zone than is necessary and this excess is heated without useful purpose; and (d) there is no intimacy of the mixture, the gas molecules being forced to "seek" their proportions of oxygen before combustion can occur. Hence in the luminous gas burner the gas is caused to issue in a thin sheet, whereby its surface is made as great as possible in proportion to its volume.

In *Class B* part of the oxygen is mixed with the fuel, the remainder being furnished by the supporting atmosphere. This class is illustrated by the Bunsen burner and its thermal efficiency is, obviously, far greater than that of Class A. In this case the first three conditions are not complied with, the increased efficiency being clearly due to a partial compliance with condition (d).

The change in efficiency obtainable as the other conditions are complied with is illustrated by the blowpipe, where the pressure on or density of the charge is increased and a marked increase in efficiency of combustion results, while with the superheating air coil

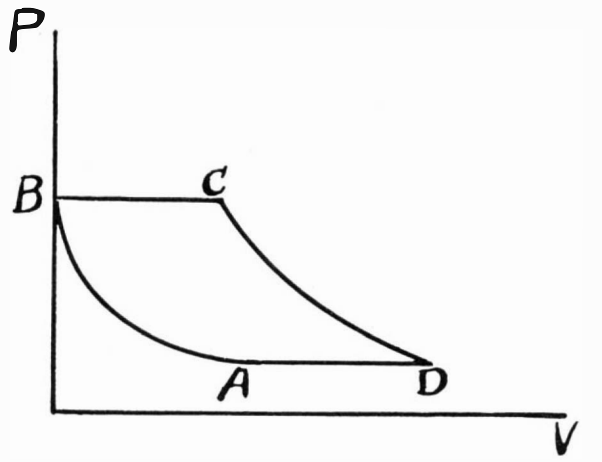

Fig. 1.—Theoretical card for constant pressure cycle.

sometimes used in connection with the blowpipe, the use of which tends to comply with condition (b), still higher efficiencies are obtained. It is probable, however, that the combustion in the case of the blowpipe can be considered in some measure as falling under Class C.

In *Class C* fuel and air are mixed in such proportions that there is just sufficient and no excess of oxygen, so that combustion ensues without regard to the gaseous medium in which it takes place. This is sometimes called "flameless" combustion, from the fact that the combustion is so rapid and so thorough that it takes place by concussive propagation between the molecules, in a very limited zone, almost a sheet, which is termed the "flame cap."

The term "surface combustion" is sometimes used interchangeably with "flameless combustion." In the opinion of the authors all combustion under Classes A and B is "surface" combustion; that is, the reactions take place only on the *surface* of the gas, when it meets the necessary oxygen.

Class C, however, embraces combustion within the mass—a true molecular interchange confined to the sheet of flame cap only because at that point alone the rate of propagation between the molecules exactly balances the rate of flow.

In the case of flameless combustion there is no dilution of the unburned gases by the burned. The mixture of gas and air approaches the flame cap, complete and instantaneous combustion takes place and the products of combustion move away. Thus the surface on which combustion takes place is the dividing point between burned and unburned gas. The process is orderly and efficient to the highest degree.

If a mixture of combustible gas and air in correct proportions is subjected to compression and heated prior to ignition the first four conditions (a, b, c and d) are present and combustion of the highest efficiency obtainable, in the presence of an inert gas, such as nitrogen, ensues.

COMPARISON OF ENGINE CYCLES.

Internal combustion engines may be classified as follows:

Class I.—Engines operating on constant volume cycle.

Class II.—Engines operating on constant temperature cycle.

Class III.—Engines operating on constant pressure cycle.

The Otto Cycle.

To the first class belongs the Otto cycle, applied universally at the present time for internal-combustion automobile engines. Its chief advantages are its flexibility and adaptability to relatively light-weight and therefore to easily portable units. Its disadvantages are many and include the following:

(1) Poor thermal efficiency under the average condition of low compression pressure, which results from throttling of the charge and which (at maximum) must be relatively low to prevent self-ignition when a fuel rich in hydrogen (such as gasoline) is used.

(2) High explosion pressures occurring so suddenly as to deliver what practically amounts to a hammer blow on the piston head. To meet this condition the parts must be much stronger (and heavier) than they would otherwise need be to accommodate the relatively low mean effective pressure produced.

(3) Large clearance space required to admit of the low compression pressures necessary with rich and volatile petroleum fuels, which are practically the only fuels commercially available that will give reliable operation under varying load conditions. This clearance space is always filled with burnt gases, which dilute the incoming charge of unburnt gas.

(4) Impracticability (especially in light high-speed units) in cases where only heavy or relatively non-volatile fuels are available. This applies only to oil; that is, not to gas engines.

Combustion in the Otto cycle is superior by reason of its partial compliance with conditions (a, b, c and d) above. Combustion in this cycle clearly falls under Class C and would be highly efficient were it not for unavoidable losses and inherent limitations. But under condition (a) we find the density of the charge is limited by liability to pre-ignition, and under (b) the same limitation is placed on the pre-ignition temperature; as to (c) and (d) it is to be noted that the proportions and intimate admixture of the fuel and air depend on the efficiency of the carbureting device used. This is never perfect and is usually far from ideal. From condition (e) it is evident that the presence of burned gases in the charge not only serves to lessen the unit weight, but entails a direct loss because of the heat delivered to these products of combustion.

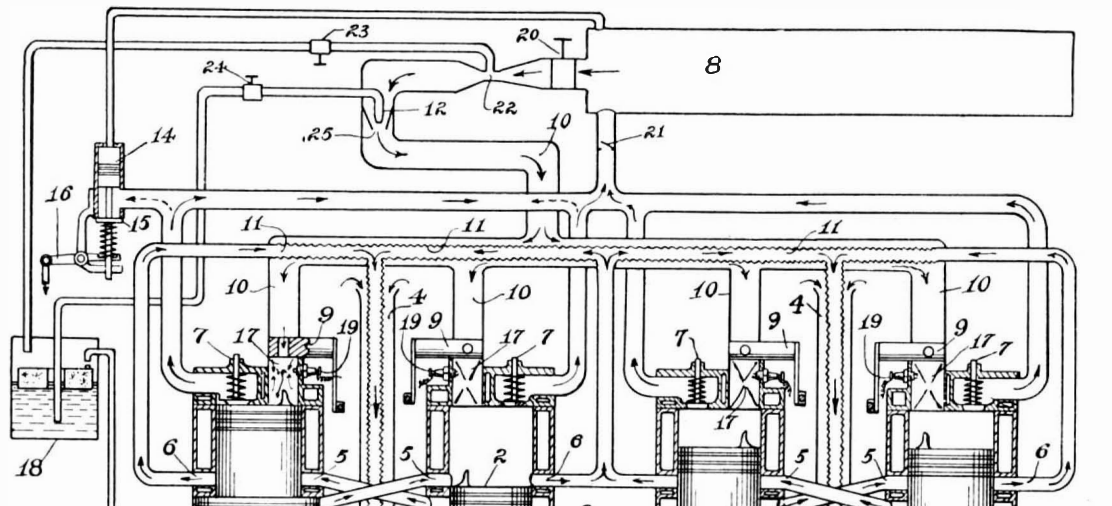

Fig. 2.—Diagrammatic representation of a four-cycle engine operating on proposed cycle.

*A paper presented at the Semi-Annual Meeting of the Society of Automobile Engineers. Republished from the *Bulletin* of the Society.

The Constant Temperature Cycle.

No engines practicable for motor vehicles have ever been developed using this cycle (Class II). Engines operating on the Diesel cycle were originally intended to operate on a constant temperature cycle, in fact, the Diesel patents so stipulated. In practice, however, it was found that Diesel engines operate more nearly on the constant-pressure than on the constant-temperature cycle.

The Diesel Cycle.

The Diesel cycle has several inherent advantages. High thermal efficiency, adaptability to use of heavy oils, variable cut-off (within certain limits) and high compression temperatures, making ignition devices unnecessary, are foremost among these. Its disadvantages, on the other hand, are quite as numerous and in some cases insurmountable where small light-weight units are required. These disadvantages have to do largely with the high pressures encountered and include the following: (1) High compression and explosion pressures making necessary heavy and close-fitting parts, difficult to keep tight (engine may become inoperative if not tight); (2) necessity for high pressure fuel injection pump, and separate air compressor; (3) mechanical difficulties in regulating the minute quantities of fuel discharged by the pump to accommodate different loads; (4) fuel admission line limited by the relatively small volume (entailed by the high compression necessary) to be heated by combustion; (5) difficulties in starting with resultant complication; and (6) low mechanical efficiency owing to close fitting parts (especially piston rings).

The combustion conditions applying in the Diesel cycle, as exemplified in modern practice, approximate closely those of Class B. The latest practice in this cycle is to atomize and inject fuel by highly compressed air; hence combustion is dependent only in part upon the compressed air within the cylinder. The high combustion efficiency of this cycle is, however, due largely to compliance with condition (a) and to the partial fulfillment of condition (d).

The Semi-Diesel Cycle.

The hot-bulb or so-called semi-Diesel engines possess most of the advantages of the Diesel type, although they are less efficient because of the lower compression pressure employed. They are limited as to power output per unit of weight on account of disadvantages similar to those of the Diesel cycle. This alone would preclude their adoption for motor vehicles.

As compared to the Diesel type the decrease in thermal efficiency and the fact that some form of ignition device must be provided are offset by lower compression pressure and the attendant advantages of somewhat lighter parts, and less expensive machine work. The thermal efficiency of the semi-Diesel engines is higher than that of the Otto cycle engines, but this efficiency is obtained at the expense of heavier parts made necessary by the higher mean pressure encountered. Largely because of this fact and of difficulties and complications incident to the problem of starting (such as preheating of the bulb), the semi-Diesel type of engine has never as yet been applied commercially in motor-vehicle construction.

Combustion in the semi-Diesel cycle falls under Class A. Fuel is injected into compressed air and each molecule must separately seek its individual quota of oxygen. Intimate admixture, condition (c), is impossible, and carbon deposits are the result. But since the temperature and density of the charge are high, the thermal efficiency is better than that of the Otto cycle.

The Constant Pressure Cycle.

Let us now consider engines belonging to Class III. The advantages of this type are numerous and the disadvantages encountered in the past have had to do almost entirely with constructional difficulties. While the former have long been appreciated, not to say regarded as ideal, the latter have stood in the way of progress and have operated against the development of any commercially practicable[1] engine applying the principle of this cycle—this excluding, of course, engines operating on the Diesel or semi-Diesel cycles as not, strictly speaking, belonging to the constant pressure cycle class (see previous reference to Diesel cycle engines, under heading "Constant Temperature Cycle."

In order to have in mind exactly what is meant by the constant pressure cycle let us first consider the succession of events. A theoretical card for this cycle is shown in Fig. 1, in which *AB* represents adiabatic compression from atmospheric to maximum pressure; *BC*, addition of heat isopiestically; *CD*, adiabatic expansion from maximum pressure to atmospheric pressure; *DA*, cooling at atmospheric pressure. Note that heating is effected at constant pressure, and that this pressure is the maximum pressure of the cycle. There is no sudden rise in pressure at ignition as in the Otto cycle.

ADVANTAGES OF THE CONSTANT PRESSURE CYCLE.

High Mean Effective Pressure With Low Maximum Pressure.

(1) Inspection of the card given in Fig. 1 at once makes evident the two cardinal advantages of the cycle; (a) the large area indicating high mean effective pressure and (b) the low maximum pressure. In practice these are factors of utmost importance. They result in high and relatively uniform torque, large power output per unit of displacement and relatively low maximum bearing pressure and unit stresses on parts, with consequent light weight and length of life.

Variable Cut-Off With Constant Compression Pressure.

(2) The possibility of varying the point of cut-off is practically the same as that in the ordinary steam engine. The variation can be made through such a wide range that the engine accommodates itself to most if not all variation in load. This fact is of utmost importance, since it operates to make the cycle practically as efficient at part load as it is at full load. No corresponding variation to meet changes in load is possible in the Otto cycle unless with "hit or miss" governing, which of course is not feasible for motor-car engines. Variations in load are taken care of as a rule by throttling of the charge with consequent decrease in compression pressure. The thermal efficiency in any cycle falls rapidly with a decrease in compression pressure. In the automobile engine, for example, a maximum thermal efficiency of about 20 per cent is obtainable under full load conditions; the thermal efficiency can fall as low as 2 or 3 per cent under light load when the charge is throttled and the compression pressure correspondingly reduced. Since automobile engines run throttled during a large part of the time their thermal efficiency is necessarily low. Inspection of the card of the constant pressure cycle, Fig. 1, shows the feasibility of making the admission line *BC* so short (by means of an early cut-off) as to cause the expansion line *CD* to fall practically on the compression line *AB*. By this means it is probable that the lightest loads can be carried at the maximum pressure of the cycle with practically the same fuel efficiency as at full load. This being the case, throttling of the charge would take place only in starting.

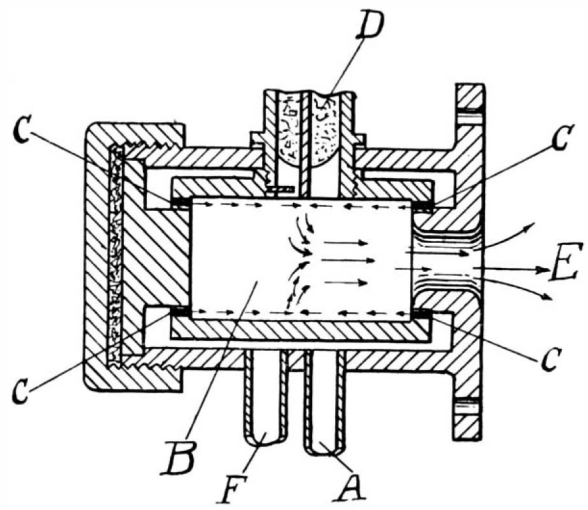

Fig. 3.—Representation of construction of burner.

Adaptability to Use of Low Grade Liquid Fuel.

(3) The importance of this factor in view of the constantly advancing price of highly refined petroleum distillates is readily apparent. The method by which low grade fuel can be utilized will be outlined later. But engines of this type can be made to run on quite as heavy an oil as can be utilized in any Diesel engine and with far better combustion conditions than are possible in the Diesel type. Self-contained constant pressure engines can therefore be expected to replace those of the constant volume type in the small size light weight class as rapidly as the Diesel engine has replaced the Otto cycle engine in the heavy weight class, where fuel cost is much in favor of the former. It is not at all unlikely that even the highly efficient Diesel engine will give place to the constant pressure type of engine when its advantages over the Diesel type are fully realized.

Excellent Scavenging Properties.

(4) The scavenging in a four-stroke constant volume engine is never complete because of the large clearance space required. This results in several drawbacks, among which is a loss in volumetric efficiency and a dilution of the incoming charge with inert gases. These faults are not present in constant pressure engines, because an excess of air can be forced through the cylider while the piston is at or near the lower dead-center.

(5) *Volumetric Efficiency.*—In the constant pressure engine using the working cylinder for a compressor, losses from decreased volumetric efficiency are precluded by the nature of the cycle. The air that may be normally pumped is in excess of the requirements of the working stroke on account of the subsequent expansion by heat. Hence there is always an excess of compressed air from which to draw on the working stroke. The piston cannot move until the volume behind it is sufficient to afford the necessary pressure. For peak loads the normal maximum pressure can even be temporarily increased, so that volumetric losses do not exist. This is in marked contrast to the constant volume cycle, in which the volumetric efficiency is not high, even at low speeds, and usually decreases as the speed increases.

Adaptability to Operation on the Two-Stroke Cycle.

(6) Constant pressure engines will operate much more satisfactorily on the two-stroke cycle than will engines of the constant volume cycle, because scavenging in the former can be more nearly perfect, through the use of an excess of air to remove the products of combustion, whereas unless fuel injection with its inherent difficulties is resorted to, engines of the constant volume two-stroke type must depend upon the incoming charge to scavenge the combustion chamber. This inevitably results in a loss of fuel. Under these circumstances not only is a four-stroke cycle unnecessary in a constant pressure engine but all the advantages of the two-stroke cycle without any of its disadvantages are realized. The four-stroke cycle with its two idle strokes is an engineering anomaly that need be no longer tolerated when the constant pressure cycle is employed.

Low Operating Temperatures.

(7) The specific heat of air at constant pressure is 0.2375, while at constant volume it is 0.1689. If a given weight of fuel containing a certain number of heat units be mixed with a sufficient weight of air for complete combustion, and the fuel ignited, the temperature attained will be much higher if heating takes place at constant volume than if the volume be allowed to increase at such a rate as to hold the pressure constant, although the work that can be done in either case is the same since the energy liberated is the same in both cases. In practice, however, it is probable that the longer continuance of the lower temperature of the constant pressure cycle will offset the higher temperatures of short duration and the greater flame-swept area in the constant volume cycle so that the heat losses through the cylinder walls will be approximately the same. The temperature of the exhaust gases in the constant volume engine will also be higher at the same exhaust pressures and this will represent a greater *total* heat loss than that resulting in the constant pressure engine.

No Fuel Injection Pump Necessary.

(8) The operation of engines of the constant pressure cycle is not dependent upon any fuel injection pump as is that of engines of the Diesel and semi-Diesel type. Aside from the purely mechanical difficulties and complications of such pumps, the metering of the fuel for varying loads presents some exceptional difficulties, especially in small units. From all such difficulties the constant pressure engine is free, an advantage worthy of special mention in comparing the strictly constant pressure engine with one of the Diesel or semi-Diesel type.

No Starter Necessary.

(9) In practically all types of Diesel engines some form of high compression air starter is necessary on account of the high compression pressures attained. No such complication is necesary in the constant pressure engine. A small quantity of air under a pressure of perhaps one to five pounds will be sufficient to start the engine. When once started the engine will quickly pump air up the predetermined maximum of the cycle and the pressure will then remain constant.

COMBUSTION IN THE CONSTANT PRESSURE CYCLE.

The constant pressure cycle comes closest to fulfilling all the conditions for efficient combustion. Combustion takes place under Class C conditions. It is highly efficient because: (a) The density of the charge is limited by structural considerations only; (b) it is possible to raise the temperature of the compressed air to a high degree, prior to the introduction of fuel, by utilizing the exhaust heat (which is commonly wasted); (c) the proper proportions of fuel and air can be automatically maintained without mechanical complications; (d) on account of the appreciable time that elapses between the entrance of the fuel and its final combustion, its complete vaporization and diffusion,

[1]Messrs. Carpenter and Diederichs state in their book on the Internal Combustion Engine that the Brayton oil engine was a thoroughly practical engine and saw wide application. This was true in its day but the engine has long since been abandoned, partly because of its inefficiency as compared to the modern Diesel types, but more especially because of cumbersome design and failure of its inventor to grasp certain important details of construction that will be treated of later.

even though it be of low grade, is assured by its introduction into the highly heated air, noted in (b) above; and (e) as was seen under heading of "scavenging properties" little if any dilution is due to presence of burnt gas in the mixture so that except for the presence of atmospheric nitrogen, which of course cannot be excluded, dilution is at a minimum.

REASONS FOR SLOW DEVELOPMENT OF CONSTANT PRESSURE ENGINES.

Consideration of the numerous advantages of the constant pressure cycle immediately raises the question "Why has not the cycle seen a wider practical application?" The answer to this question can be found in the circumstances given in the following paragraphs:

During the period 1872-77 Brayton produced the first commercially successful constant pressure engines. These were built early in the art and were extremely inefficient, as judged by modern standards, both mechanically and thermally. They were used to some extent, but were replaced by engines of the Otto cycle after the year 1877, when Otto took out his American patents. The greater efficiency of this type *as then constructed* reacted against the Brayton engine, which would, if better understood and designed, have readily held its own or displaced the Otto engine. Brayton's engine was cumbersome and so designed as to require a separate compressor. This resulted in low mechanical efficiency and complication, which could have been avoided entirely, as will be seen later.

The advent of the Diesel engine, which proved to be much more efficient thermally than the Otto engine, was another element in diverting attention from engines of the strictly constant pressure type. Under present circumstances there appears to be no reason why an engine much more efficient than those of the Otto type and lighter than those of the Diesel and semi-Diesel types should not be readily produced. A *purely diagrammatic* representation of such an engine is shown in Fig. 2. This should *not* in any case be considered as indicating *actual* or *recommended construction* except as to *general principles* involved.

PROPOSED CONSTANT PRESSURE ENGINE.

The cylinders *1* serve as both the compression and working cylinders in which move the differential piston *2*. Air first enters the compression spaces *3* of the larger diameter of the pistons through pipe *4* on the in-stroke and is compressed on the out-stroke. This air need never be raised to more than five-pound pressure, and this may be accomplished by other means than a differential piston if more desirable. The air thus compressed serves to scavenge the adjacent cylinder, entering the latter *via* port *5*. The products of combustion leave the cylinder through port *6* (unless some other valve be provided in or near the cylinder head as a better means of exit). As the pistons move on the outward stroke, ports *5* and *6* are closed and the air remaining in the cylinders is compressed and discharged through the valves *7* into the receiver *8*.

Since the clearance space between piston and cylinder head is practically zero, substantially all the air is expelled on the out-stroke. Just as the crank passes top-center the admission valve *9* is opened and the mixture is admitted to the burner through piping *10* (where its temperature has been raised by contact with the hot inner piping *11* through which the exhaust gas, discharged after the previous working strokes, has passed). The mixture, still under high pressure, passes into the burners *17*, which are in reality a part of the combustion spaces, as the pistons are forced downward. In the burners (the construction of which will be fully described later) ignition by spark from plugs *19* occurs and *complete combustion at constant pressure* ensues until the mixture is cut off as a result of closing the admission valves *9*.

During the admission period the heat gradually liberated as a result of combustion enables the products of combustion to expand *without loss of pressure* and thus do work on the piston. After cut-off the hot gases expand, with decreasing pressure, and continue to do work until the exhaust port opens. The burned gases, still at high temperature, then pass through the pipes *11* provided for this purpose, and give up to the walls of these pipes and the compressed air surrounding them a large portion of their heat before escaping to the atmosphere. Thus there is saved to the succeeding cycle much heat that would otherwise be entirely lost, as it is in most if not all other types of internal combustion engines. Furthermore, the addition of heat to the air in the piping *10* takes place *after* the air has been compressed. Thus its temperature is raised with corresponding increase in ability to do work.

Suppose now the compression pressure decided upon as most desirable be assumed, for the moment, to be one hundred and fifty pounds. Even at normal full load with cut-off at say one third stroke it is evident that all the air compressed in the working cylinder cannot be utilized. Hence the pressure in the receiver will build up rapidly unless some relief valve be provided. To put this on the receiver would, of course, mean the loss of much of the work of compression. Hence a single unloading valve *15*, operated by piston *14*, is provided. When the pressure in the receiver rises above the one hundred and fifty pounds desired, the valve *15* is forced open against its spring and the air in the cylinder is simply discharged to atmosphere with only slight loss of power.

If for any reason a momentary overload is to be carried by the engine some device such as *16* for increasing the tension on the spring that normally holds the unloading valve closed, can be brought into play. In the case of a motor-car engine such a device could be operated by a simple dash control.

Fuel is supplied to the engine as follows: The pump *13*, positively driven from the engine, draws the fuel from the main supply tank and delivers it to the reservoir *18* in which a float or some other device maintains a constant level. Any surplus fuel pumped is by-passed or returned to the main supply tank. The small tank *18* is maintained at a pressure somewhat less than receiver pressure, depending upon the air velocity through the restricted area *22*. From this tank the fuel is drawn through the spray nozzle *12* by the injector action of the air passing the nozzle. The flow of fuel will of course cease immediately when the air flow ceases on account of the closure of the admission valves *9*. A correct proportioning of fuel to air may be accomplished by proper adjustment of the regulating valves *23* and *24*, Fig. 2. As the velocity through the atomizer *25* increases the natural tendency toward over-richness is counteracted by the proportionately diminished pressure in the restricted area at *22*.

The admission valves *9* can be made of the Corliss, slide or poppet type, as proves most desirable, and be operated by any conventional cut-off device such as, for example, is used in steam engine practice. In the case of a motor-car engine the point of cut-off would be varied by a device operated in precisely the same manner as is the throttle on an ordinary Otto cycle engine. The throttle valve *20* shown in Fig. 2 would be used only in starting.

The check valve *21* prevents air in the receiver escaping to atmosphere when unloading valve *15* is open. The admission valve can, if desired, be left open during practically full stroke when a heavy torque is required. The card would then be practically square and resemble closely a card from a steam pump. Under this condition the fuel consumption would of course be much increased because the gases would not be allowed to do work in expanding after cut-off. The periods when such a late cut-off might be used would be short in an engine properly proportioned to the load.

The striking similiarity of the constant pressure cycle to that of a steam engine is at once apparent. But while the results are equal in every way to those accomplished with the steam engine, the engine is self-contained and does not require the boiler, condenser and other elaborate external apparatus necessary in the case of the steam engine. An engine operating on the proposed cycle has all the advantages of the steam engine without any of its disadvantages and at the same time possesses characteristics that should render it much more efficient and practicable for motor vehicles and many other types of service than is any type of internal combustion engine now in use.

(To be continued.)

Why Small Farm Engines Are Failures

THERE lies ahead a future, a prosperous and golden future, for the engineer who will grasp the many possibilities attaching to the design of a really adaptable internal-combustion engine of small and medium power for estate and farm service.

The failing of most existing farm engines of this description is their utter lack of adaptability—this and the complicated nature of many of their primary movements. Let us glance for a moment at their duties. They are manifold and diverse. They are asked one day to drive a threshing machine or winnow grain, the next day to cut chaff, grind and crush corn or break cake. Then they are put to pulp roots, saw wood, pump water, separate cream and churn butter, or generate electricity—each and every one of which operation demands some variation in power, or a change of speed. Of course these demands could each be met quite easily provided the engine was a fixture, and the various machines grouped together under one roof and driven from a line or lines of shafting But then it would lose its portability—its most useful feature—and become at once a fixed power plant.

Gasoline and oil engines of the type specially designed for farm work have invariably but a single driving pulley. And as their rated power is usually based upon full speed conditions, which may be anything from 400 to 800 revolutions per minute, it follows that any reduction of speed is synonymous with an equivalent loss of power. Now it often happens that a user requires a relatively low speed and full power, or inversely a high rotative speed with a minimum of power. But can he obtain these conditions direct off his engine?

The portable farm engine of the future will have to be considerably changed from that of the present. We have seen that their portability is a *sine quâ non.* But this does not imply mere portability on wheels. A farm engine needs to be so adapted that when required for indoor work it can, if desired, be lifted clear of the traveling carriage and set down anywhere on the floor in a self-contained condition, ready for instant service.

Then as to adaptability the single driving pulley should be substituted by a graduated speed-driving device, having a range in convenient steps of, say, from a 33-inch diameter pulley down to a 6-inch, the change of speed being easily and readily controllable at will by means of suitable change-gearing, and without any trouble further than operating a conveniently placed lever or clutch. Thus any accommodation of power, with its concomitant change of pully speed, would meet the variations imposed by the necessities of the moment. For example, the top speed may be conveniently used for threshing or driving a dynamo, or sawing, the lowest speed for pumping, pulping, cake grinding or churning; the speed of the engine being uniform throughout and whatever power required maintained.

Much of the complicated character of an engine could be obviated and a distinct advantage thereby gained if the movements and adjusting mechanism were not so closely crowded together. The aim of engine designers would appear to be a reduction of overall dimensions to the last degree of possibility; and for what purpose? There can be but one reason, and that is for the sake of appearance. Surely a most absurd one when an extra foot one way or the other would mean ease and comfort when dismantling or any adjustment is found necessary. And an extra foot in occupied floor space would be unnoticed in a ten-acre field or on a barn floor.

Many of the cylinder troubles usually associated with this class of engine have been found by the present writer to proceed from defective jacket-water circulation: either insufficient tank capacity or the connections between jacket and tank so restricted in area or of such formation structurally as to impede circulation. It is not at all uncommon to find engine troubles to proceed from carbonization, directly due to intensely high cylinder temperatures. This, again, is a detail well worthy of a maker's closer attention.

Complete automatic lubrication is another point to be insisted upon. True, some of the more important points are so safeguarded on a few of the farm engines of to-day, but certainly not all, and its development might with very great advantage be in all cases so extended as to embrace practically all possible wearing movements.

There is also usually a lamentable lack of provision for taking up normal wear, this referring particularly to main bearings; a split bush or adjustable brasses being infinitely more desirable from an economic point of view than those of solid form.—*F. R. Parsons, in The Engineer.*

Utilizing Straw

IN European countries the greatest care is given to the feeding of all straws and other farm roughages. Frequently the straws are choped up and mixed with other feeds such as beets, mangels, silage, etc., so as to make the straw more palatable. Some farmers are so careful in the preservation of straw that after it has been used for bedding, and latter distributed over their fields, it is raked up and again used for bedding, after lying on the ground until it has become clean and free from manure. There are no signs of such thrift in this country. In certain sections opportunity is not even given the cattle to consume the straw and fodder, for in some States almost the entire crop is burned. Fifteen per cent of the straw produced in the United States, as shown by the Bureau of Crop Estimates, is burned, and probably as much as this is otherwise wasted. Of course in some of the sections of the United States where straw is burned there are few cattle, and the material consequently has little or no value because of the distance from market; nevertheless some provision should be made for its utilization. If this straw were combined with some of the home-grown concentrates, not only would the feed yield a profit in return for beef, but the manure would have great value in building up the soil.—*Report No. 112, U. S. Dept. of Agriculture.*

Fuel Economy*

And the Proper Utilization of Coal

NOTWITHSTANDING the fact that we are raising annually in the United Kingdom—according to the official estimate for 1913—287 million tons of coal, of which 189 million tons (or, say, 4 tons per head of the population) were consumed at home, more or less wastefully, it is indeed surprising how little has been done, or is being done, by the scientific community to impress upon the government and the public generally the importance of establishing some systematic control or investigation of fuel consumption in all large industrial areas. Deputations have waited upon the government about the question of reviving our languishing coal-tar color industry, so that in future we may be independent of Germany for the supply of the £2,000,000 of dye-stuffs required by our textile industries, and already a state-aided organization with an advisory scientific committee has sprung into existence to achieve this desirable result. But no organized body of scientific men, so far as I know, has ever thought it important, or worth while, to take an active interest in the vastly greater subject of fuel economy and the proper utilization of coal, upon which the dyeing industry depends for its raw material.

It is unnecessary for me to remind you that the contending armies in this Armageddon of the nations depend upon certain distillation products of coal for their supplies of high explosives; and there is little doubt in my mind but that Germany's violation of the neutrality of Belgium, and her subsequent seizure of that country and of a large tract of Northern France, had more than a purely political or strategic significance. She, doubtless, wanted also to seize for herself (and at the same time to deprive her enemies of) coalfields lying just beyond her own borders, which are capable of furnishing abundant supplies of coal admirably adapted for yielding the raw materials for the manufacture of high explosives. A country in which all metallurgical coke has for years past been manufactured under chemical supervision in by-product coking-ovens, with recovery of ammonia, tar, and benzol, and in which the wasteful beehive coking-ovens have long ago ceased to exist, was hardly likely to overlook the military importance of the Belgium coalfield, with its many by-product coking plants. And, moreover, but for German commercial acumen and enterprise, for many years, our own by-product industry would not have attained even to its present respectable dimensions. Certainly it owes very little to the interest or attention of British chemists, most of whom are unfortunately but little aware of its circumstances and conditions, and seem to care even less for its particular problems. And yet, in proportion to the capital outlaid upon it, it is one of the most profitable of all our chemical industries, coal-tar colors not excepted.

Fuel economy, and the proper utilization of coal, whether in connection with manufacturing operations or domestic heating, will become one of the most important national questions during the trying years that will follow hard upon this war, because of all directions in which national economy can be most healthfully and advantageously exercised, this is perhaps the most obvious and prolific. For it is tolerably certain that, with an efficient and systematic public supervision of fuel consumption, we ought to be able, even with existing appliances, to save many millions of pounds of our annual coal bill, and with improved appliances still more millions—a saving which would in the long run redeem a considerable amount of the war loan which has been much more easily raised than it will be repaid.

Now, I fear that not only are chemists for the most part lamentably ignorant of the nature of coal, and of modern fuel technology, but they have been for many years past so indifferent about such questions that they have been content to leave them almost entirely to engineers, who, as a body, are notoriously deficient in chemical sense and experience. The engineer has indeed not usurped the place of the chemist, but has had to do his best to fill the position long since abdicated by the chemist.

This indeed seems strange when we remember that the foundations of modern chemistry were deeply laid by investigators who were, above all things, "fire worshipers." But, judging from most chemical text-books, nearly all that the modern student of chemistry is taught in our academies about combustion was known to Lavoisier; and I question whether in the majority of our university laboratories any investigation on coal or combustion is ever undertaken. And yet the subject is full of most fascinating and fundamental theoretical problems—for the most part unsolved—and the nation consumes every week as much coal as could be exchanged for the whole quantity of aniline dyes used by its textile industries in a year.

Moreover, such advances as have been made during recent years, and they are by no means inconsiderable, have nearly all been in the direction of the wider applications of gaseous fuels. Yet in how many of our university laboratories is even gas analysis taught, or how many of our schools of chemistry provide systematic courses in the chemistry and manipulation of gases, without which no professional training of industrial chemists, however much "research work" it may include, ought to be considered satisfactory? It is my opinion that this important branch of our chemical craft and science has not, for many years past, been accorded its proper place and share of attention in the ordinary curriculum of the majority of our academic institutions.

Of the 189 million tons of coal consumed in the United Kingdom in the year 1913, about 40 million tons, or say approximately one fifth of the whole, were carbonized either in gasworks, primarily for the manufacture of town's gas, or in coke-ovens for the manufacture of metallurgical coke in practically equal proportions. Two thirds of the latter was carbonized in by-product recovery plants; the remainder in the old wasteful beehive ovens. So that, roughly speaking, we have:

Total coal carbonized = 40,000,000 tons.		
In Gas Works.	In By-Product Coke-Ovens.	In Beehive Coke-Ovens.
20	13.5	6.5

At present there are 8,297 by-product coke-ovens built in this country, of which 6,678 are fitted with benzol recovery arrangements, capable of producing something like 10,000,000 tons of coke per annum.

The yields of the various by-products obtainable on such coke-oven installations naturally vary with the locality and character of the coal seam; but they probably average from 20 to 35 pounds of ammonium sulphate, from 56 to 112 pounds of tar, and from 2 to 3½ gallons of crude benzol, etc., for each ton of dry coal carbonized—according to the locality. About 65 to 70 per cent of the crude benzol is obtained as finished products—benzene, toluene, solvent and heavy naphthas.

How rapid has been the development of the by-product coking industry in this country during recent years may be judged from the following official returns of the quantities of ammonium sulphate annually made by such plants, as compared with the corresponding quantities produced in gasworks.

TONS OF AMMONIUM SULPHATE PRODUCED IN—

Year.	By Product Coke-Oven Plants.	Gasworks.
1903	17,435	149,489
1908	64,227	165,218
1913	133,816	182,180

In the natural course of events, the final disappearance of the wasteful beehive coking-oven from this country is now only a matter of a few years; but I venture to suggest that public interest would justify the government fixing by law a reasonable time limit beyond which no beehive coke-oven would be allowed to remain in operation, except by expressed sanction of the state, and then only on special circumstances being proved.

There is also much need of a better and more systematic chemical control, in the public interest, of by-product coking plants. At present, in far too many cases, the chemists employed in coke-oven laboratories are men that have practically no chemical training other than that obtained in evening classes. And with few exceptions the chemist, however competent he may be, is entirely subordinated to the directing engineer, and regarded as a mere routine analyst. I can say, from personal knowledge, that plants which are managed and controlled by experienced chemists of broad training, combined with force of character, yield much better results than those which are controlled by men without such qualifications.

And even in this crisis when so much depends on plants working not only at their maximum output capacities but also, chemically speaking, under conditions calculated to ensure the highest yields of benzol and toluol, with a proper selection of coal, I doubt whether the measures which have been taken to advise and supervise the coke-oven industry are really adequate from the point of view of chemical control. I do know, for instance, that the experience and resources of the majority of our University Departments of Applied Chemistry which specialize on fuel technology and cognate matters have not been as fully utilized as they might have been in this connection. I cannot for one moment imagine a similar state of things being permitted in Germany, where we may be sure that nothing is being left undone in the way of fully utilizing all the available expert chemical and engineering knowledge which can be brought to bear on this important aspect of war munitions, and I venture to say that, whatever may be the case in this country, in Germany at least the staff and resources of no publicly maintained Department of Fuel Technology will not be fully employed on war problems.

The coal-gas industry, which deals with some 20,000,000 tons of coal per annum, has, especially within recent years, shown a growing appreciation of the aid of chemical science, in regard not only to the actual manufacture but also to the domestic and industrial uses of coal-gas. The endowment by the industry in 1910 of a Special Chair at the Leeds University, in memory of the late Sir George Livesey (of which I had the honor and pleasure of being the first occupant) was a sure sign of the faith of its leaders in the value of scientific research into its special problems; and from personal knowledge and intercourse with gas engineers, I can assure my chemical colleagues that any serious interest taken by scientific chemists in these problems, or in training men to tackle them, will be welcomed by the industry, no matter from what quarter such help or interest may come. For although the carbonization of coal in gas-works is efficiently carried out, no one in the industry supposes that finality has been reached, or that existing methods and conditions cannot be improved under better chemical control.

And, moreover, the gas industry has just recently given a striking example of the public benefit which may accrue from the whole-hearted co-operation of the chemist and engineer in the new nickel-catalytic process for the removal of carbon bisulphide from coal-gas, which has been worked out, and brought to a successful issue, by the combined skill and efforts of Mr. Charles Carpenter, D.Sc., Mr. W. Doig Gibbs, and Mr. E. V. Evans, of the South Metropolitan Gas Company. They have shown that sulphur content (as CS_2) of London coal-gas can be reduced on a large scale, in regular day to day working, from nearly 40 to about 8 grains per 100 cubic feet, without in any way deteriorating the quality of the gas, at a cost (including interest and depreciation) of 0.299 d. per 1,000 cubic feet. Such a striking success was, as Mr. Carpenter acknowledges, only achieved "because of the unrestricted and unreserved collaboration of the chemist and the engineer." Incidentally the gas industry is to be congratulated on this tacit abandonment of the old contention that coal-gas was either none the worse for the presence in it of a certain amount of sulphur compound or (alternatively), if worse, that a minute amount of sulphur dioxide in the atmosphere of a living room is so rapidly absorbed by the ceiling that its harmful effects are nullified.

As the outcome largely of the work of the Joint Committee appointed in 1907 by the Institution of Gas Engineers and the University of Leeds (of which I was a member) to investigate gas-fire problems, the manufacturers of these appliances have paid much more attention than formerly to the scientific aspects of construction, so far as to ensure the best combination of radiant and ventilating effects, and nearly all the larger firms have now their scientific staffs busily employed in making further advances. Prominent among the pioneers in scientific gas-fire construction has been Mr. H. James Yates, who will enlighten you as to some of the most recent improvements. I can, however, from personal knowledge, testify to the enterprise shown by most of the leading manufacturers, and that their combined efforts have resulted in a very efficient and perfectly hygienic domestic gas-fire. A committee appointed by the Institution of Gas Engineers, upon which scientific men are largely represented, is now considering the adoption of a standard method of testing the radiant efficiencies of gas-fires. Thus no one can say that the gas industry is not making every effort to put its affairs upon a thoroughly scientific basis.

Passing on to the metallurgical and allied industries (which, of course, are large consumers of fuel), there is much here to be done in improving the construction and operation of furnaces in order to check the waste of fuel. But of these details there is no time to treat; and one instance of the possibilities of very large economies as the result of scientific control must suffice.

It is perhaps common knowledge that the most econ-

* From an address to the Chemical Section of the British Association. By Prof. W. A. Bone, D.Sc., F.R.S.

omical arrangement of plant for the manufacture of iron and steel is one in which by-product coke-ovens, blast-furnaces, steel furnaces, and rolling mills are brought together on one site and under one organizing direction, so that the surplus gases from the coke ovens, and blast-furnaces may be utilized to the fullest extent. Mr. T. C. Hutchinson of the Skinningrove Iron Company, who has devoted many years of anxious thought and practical study to this important problem, ventured some few years ago to predict that—with the most approved type and arrangement of plant, working under strict scientific control by competent chemists—it would soon be possible to make finished steel rails or girders from Cleveland ironstone with no further consumption of coal than is charged into the by-product coke-ovens for the production of the coke required for the blast-furnace, and all subsequent experience at Skinningrove has fully demonstrated that his prophecy can be fulfilled in every-day practice. Of course, it means a constant watchful control by a well-paid and competent scientific staff.

It is perhaps unnecessary, even had time permitted, for me to multiply instances of possible economies in other important directions—such, for instance, as power production and the heating of domestic apartments. There is probably no direction in which equally good results would not accrue with proper scientific application and control as those already cited as having been reached in the direction of carbonization, or in the iron and steel industry. We are to discuss the important subject of smoke prevention, in which many Manchester public men are showing an active interest; so that there will be some further opportunity of referring to the matter.

But may I, in conclusion, appeal in all seriousness to chemists and scientific men generally to take up this important matter effectively as a public duty at this crisis in the country's affairs? I would suggest that the government be memorialized with a view to the establishment of a central organization for the supervision of fuel consumption and the utilization of coal somewhat on the lines of the existing alkali works inspection, which has been so beneficial to chemical industry. And in connection with such an organization there might be undertaken a much-needed systematic chemical survey of British coal fields, as well as experimental trial of new inventions for fuel economies. There would certainly be no lack of important work for such a properly organized department of the State, and there can be no doubt at all that the results of its activities would be not only a very large direct saving in our colossal annual coal bill, but also a purer atmosphere and healthier conditions generally in all our large industrial areas.

The Pyranometer: An Instrument for Measuring Sky Radiation*

By C. G. Abbot and L. B. Aldrich

THIS instrument, as its name (from the Greek πῦρ, fire, ἀνά, up, μέτρον, a measure), indicates, is intended to measure the heat equivalent of radiation received from or going out toward the complete hemisphere above the plane of the measuring surface. We have devised two satisfactory types of the instrument, both derived in principle from the electrical compensation radiation instruments of the late K. Angström. The full description of the instruments and tests of them will be found in a paper now being published in the *Smithsonian Institution Miscellaneous Collections*. The instruments are adapted to measure direct solar radiation, the total radiation of the sun and sky combined, that of the sky alone, and nocturnal radiation. It is possible to employ screens of selective transmission and thus to limit the measurements to selected spectrum regions. The instruments are of primary standard type, but have been compared with the standardized pyrheliometers of the Smithsonian Institution and found accordant. No auxiliary apparatus other than that employed with the Angström pyrheliometer is required, and the observations are easy to make.

The simpler form of pyranometer comprises a single blackened manganin strip, 3 mm. wide, 6 mm. long, placed centrally in the plane of the upper surface of a nickel-plated copper disk 75 mm. in diameter. Copper blocks insulated from the rest of the disk, but continuous with it in surface, serve to connect the insulated manganin strip with an electric heating current of adjustable strength. A sensitive thermo-electric couple fastened by means of thin waxed paper to the rear surface of the manganin strip, and embedded at the other end in a recess of the copper disk, serves to indicate changes of temperature of the strip. Concentric with the strip in a hollow hemispherical screen of ultra-violet crown glass, 26 mm. in outer diameter and 2 mm. thick. Its purpose is to admit rays of shorter wave-lengths, such as form essentially the whole strength of the direct and scattered solar rays, but to cut off rays of great wave-length proper to the emission of a body at ordinary temperatures. During measurements of nocturnal radiation this glass screen is removed. A nickel-plated hemispherical shell of polished nickel-plated copper encloses this glass, and is removable at pleasure.

If now the shutter is opened diffuse sky-radiation falls upon the strip and warms it, producing a deflection of a moving-coil galvanometer in the circuit of the thermo-couple. The shutter being then closed, an equal deflection may be produced by the electric heating current. As corrected to allow for losses by reflection of the glass and their imperfect absorption by lampblack, the energy dissipated in the strip by the heating current measures the energy of radiation. As constructed the sensitiveness of this instrument is so great that it proves convenient to balance the deflection to zero by means of a potentiometer current in the galvanometer circuit, and so to reduce the operations to the zero method. A defect of this simple form of pyranometer is found to be caused by the slow warming of the glass-covered portion of the copper disk when the shutter is opened, which at other times shades that area of the surface. This warming induces a secondary deflection, because it affects the two differently situated ends of the thermo-couple differently. Experiments have shown, however, that practically the full deflection due to direct heating of the strip occurs in 20 seconds, and that the secondary deflection begins to be sensible after 20 seconds. Accordingly the error is eliminated by balancing the primary deflection by the potentiometer current after exactly 20 seconds, then closing the shutter and waiting two minutes for the secondary heating to subside, before adjusting the heating current.

Fearing that this defect might prove more serious in nocturnal radiation work, we devised a second form of pyranometer. In this form there are *two* blackened manganin strips side by side, each 2 mm. wide, 6 mm. long, separated by a nickel-plated copper bar 2 mm. wide, and both insulated as in the simple form by vertical mica strips coming exactly to the surface of the plate. Thermo-couples connect the two strips at the back, the hot junction behind one strip, the cold junction behind the other. As the two strips absorb radiation equally, there would be an equal rise of temperature, if it were not that one strip is 10 times as thick as the other. Owing to this the conduction to the ends is so much greater for the thick strip that a difference of temperature arises, and a deflection of the galvanometer ensues. The heating current is divided between the two strips, and by suitable resistance coils the circuit is adjusted once for all so that whatever the strength of the heating current it produces equal dissipation of energy in the two strips. If now after closing the shutter the heating current is graduated until the deflection formerly produced by radiation is reproduced by electrical heating, the energy dissipated in either strip is the measure of the absorbed radiation. In the two strip pyranometer the secondary deflection by indirect heating is unimportant, because of the symmetry of the arrangement. However, to avoid this source of error altogether the exposure is limited to 30 seconds, and a full minute is allowed to elapse before introducing electric heating.

Numerous measurements of the sky-radiation have been made from the North Tower of the Smithsonian Institution. On fine days the sky-radiation alone received on a horizontal surface ranges from 0.07 to 0.13 calories per square centimeter per minute. On cloudy days, not thick enough for rain, the values run from 0.20 to 0.30 calories according to the kind of cloudiness prevailing. Measurements were made on the reflection from new fallen snow, and for total solar and sky radiation this proved to be 70 per cent

In the simpler form the instrument is so sensitive that it could be used in the deep shade of a forest, or with screens of selective transmission, so that it would be suited to botanical as well as meteorological investigations. As in the case of the silver disk pyrheliometer, the Smithsonian Institution may undertake to prepare pyranometers at cost (approximately $150) where valuable investigations may be promoted thereby.

*Proceedings of the National Academy of Sciences.

Detections of Ions in the Atmosphere

THE May issue of Section A of the Proceedings of the Royal Irish Academy contains three papers by Prof. McClelland and his assistants which deal with methods of production and detection of ions in the atmosphere. In the first of the series it is shown that leaves exposed to the ultra-violet light of an electric spark between aluminium electrodes show the photoelectric effect to an extent which in some cases is a tenth of that shown in the same circumstances by copper. A cold-water extract from the leaves may show an activity a third of that of copper, while an acetone extract shows no activity. A few drops of the acetone solution will, however, render a large volume of water strongly active. The other papers relate to the ions produced when water is sprayed into air or air bubbled through mercury. In both cases the saturation curves of the air show that there are four or five kinds of ions present in it with mobilities which vary from those of the large Langevin ions to those of the ordinary small ions, while there appear to be present in addition at least two types of ions with still greater mobilities.—*Nature.*

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, SEPTEMBER 9th, 1916

Published weekly by Munn & Company, Incorporated

Charles Allen Munn, President; Frederick Converse Beach, Secretary; Orson D. Munn, Treasurer; all at 233 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) . . . . " 3.00

The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application
Remit by postal or express money order, bank draft or check

Munn & Co., Inc., 233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

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