

quantity of heat above that temperature, the hyper-critical heat, and second another and larger quantity of heat below that temperature, the hypo-critical heat, the heat remaining when the temperature has sunk to the critical point. The hyper-critical heat is needed for certain work which can be done only at hyper-critical temperatures, the hypo-critical heat is available for work which can be done at hypo-critical temperatures; so that, just as we have hyper- and hypo-critical heat, so we have also hyper- and hypo-critical work.

FOR HEAT ECONOMY THE HYPER-CRITICAL HEAT SHOULD BE TO THE HYPO-CRITICAL AT LEAST AS THE HYPER-CRITICAL WORK IS TO THE HYPO-CRITICAL WORK. The proportion between the two evidently depends on the temperature reached by combustion itself. The higher this temperature, the higher proportion does the hyper-critical heat bear to the hypo-critical heat.

If the temperature developed by combustion is so low that the ratio of hyper- to hypo-critical heat is too low, is below the ratio of hyper- to hypo-critical work, then in generating enough hyper-critical heat to do the hyper-critical work we are forced to generate an excess of hypo-critical heat over and above the hypo-critical needs of the process, and this excess of hypo-critical heat is used to poor advantage or is wasted. If my ratio of iron work to accessories is too low, then in providing my building with enough iron work for forty stories I am forced to provide enough of these accessories for sixty stories, and the excess is left on my hands. And as a mere change in the ratio between iron work and accessories can enrich or ruin a builder, so a mere change in the ratio between hyper- and hypo-critical heat, induced by a change in combustion temperature, can lead to a wholly disproportionate change in the economy of our own vital processes or of the process of the blast furnace.

Thus it was with Neilson's introduction of the hot blast. Formerly blast furnaces were fed with cold air, with the result that, because of the low temperature of combustion, the proportion of hyper-critical to hypo-critical heat was far below the proportion of hyper- to hypo-critical work needing to be done, with the result that the burning of enough fuel to provide enough hyper-critical heat yielded a quantity of hypo-critical heat far in excess of the hypo-critical work to be done, and this excess was used to poor advantage or wasted. Hence raising the temperature of combustion by heating the blast led to a saving of fuel which, to those unable to think, was miraculous.

The degree of economy caused by blast-drying should vary from case to case with the initial lack of hyper-criticalness in the combustion temperature; and if there is no such lack initially, as may happen conceivably, then blast-drying should cause no economy.

Other means of adjusting the ratio of hyper- to hypo-critical heat suggest themselves, such as raising the temperature of combustion by further preheating the blast, by enriching it in oxygen, by removing part of the atmospheric nitrogen, or by electric induction at the very focus where the hyper-critical work goes on; and lowering the critical temperature by changes in the conduct of the process. We have not reached the end of knowledge in general, or of the improvement of the blast furnace process in particular. But the fact that blast-drying, in removing the effects of the fluctuations in the atmospheric moisture removes a serious cause of irregularity in the working of the furnace and in the quality of its product, gives it an administrative and commercial advantage over other means of raising the combustion temperature which may well be decisive.

The explanation which I have given you is not my own, and it may not be the only one or even the chief one. It is the only reasonable one which I have heard of the accomplished fact which it aims to explain, and it seems to me adequate.

The total quantity of pig iron made in the world in one year is some sixty-six million tons, consuming somewhere about sixty-six million tons of coke and its equivalents, and this in

turn represents about ninety-five million tons of coal. A 10 per cent. saving of fuel if applied to all the blast furnaces in the world would represent a saving of some nine and a half million tons of coal a year, or more than 40 per cent. of the coal production of so important a coal country as Belgium.

The scale is a large one. In how many of these furnaces such a saving can be made remains to be proved, but the results already reached lead us to expect that the total saving will be of very great importance.

The deliberation and caution, indeed the tardiness with which the iron trade has proceeded in adopting dry blast is referable to various reasons, such as hesitation to incur the certainly great expense of its installation, the competition of other devices for increasing earnings in other directions, the wish of each to get the benefit of the experience gained by its earlier adopters, uncertainty as to whether the saving found by John Doe will apply to the different conditions of Richard Roe's furnace, and the like.

But after all is said and done, that which interests us most is not the invention itself, important as that is, nor the great saving of fuel. The striking thing is the contrast between the mental attitude of the certainly very learned men of science who immediately stamped Mr. Gayley's claims as preposterous, and the attitude of this great captain of industry, who not only saw the saving to be effected but saw it so clearly that he was able to bring to pass the very costly experiments needed to prove his faith. Let us learn the lesson of humility. Natural human caution is likely to prevent the cautious from saying "I know that so and so can be done" unless they do know it; but such cases as this show that it does not prevent even the well qualified, the expert, and the prudent, from saying "So and so can not be done," though in fact it ought to prevent them, in view of the almost infinite excess of our ignorance over our knowledge.

#### DR. GAYLEY'S INTEREST IN EDUCATION<sup>1</sup>

By EDWARD HART

This is the second time I have participated in rejoicings in Dr. Gayley's honor. The first festival was held early in 1902, when we dedicated Gayley Hall to chemistry and metallurgy at Lafayette College. Then, too, Dr. Howe spoke, and many of those I see here to-night were present. Dr. Thomas M. Drown, Dr. Gayley's preceptor and mine, greatly beloved, now gone to the far-away country, spoke, and Dr. Ira Remsen. It was a great celebration. One of the college boys told me that never before had so many high hats been seen on that campus.

We dedicated then a new library as well—The Henry W. Oliver Chemical and Metallurgical Library of Lafayette College, endowed by Mr. Henry W. Oliver, one of Dr. Gayley's associates, long engaged in the iron and steel business. This gift was made at Mr. Gayley's suggestion.

Dr. Gayley is a working trustee of Lafayette College. He has given time and money to the College, not once, but many times. One of his recent tasks has been the erection of a new building for the Department of Mechanical Engineering. I have often been struck with the originality and keen intuition, which he shows here as elsewhere. One of his ideas is compulsory athletics for all students.

I went to Lafayette College in 1874 with Dr. Drown, as his assistant. I was nineteen years old and had never seen the inside of a college building. Gayley was then a junior and probably knew more about chemistry than I did. In his senior year I was in charge, during Dr. Drown's absences, of the quantitative laboratory where Gayley was working. I was never, therefore, in any proper sense Dr. Gayley's teacher.

Gayley is the son of a Presbyterian minister, not blessed with great wealth; like many poor boys he received help from

<sup>1</sup> Address delivered at the Perkin Medal Meeting, Society of Chemical Industry, Chemists' Club, New York, January 24, 1913.

the college funds. He was not much of a talker then, but had a keen sense of humor. At that time F. H. Daniels, of Worcester, Mass., was also an assistant in the laboratory. The boys called him Asenic, because that was the way he pronounced it. Daniels and I undertook to listen to the different preachers, and one Sunday evening visited the Presbyterian Church in Phillipsburg. Gayley and his friend Peacock were there too, and next morning we were accused of slipping over to P-burg on the sly to see the girls. What they were doing did not appear.

When he left college, Gayley became chemist for the Crane Iron Co. at Catsauqua. At that time a chemist was considered an ornament rather than a necessity, and his value was greatly increased if he were of economical habits. Mr. Frank Horn, of Catsauqua, thinks his salary was \$35 a month at the start and there is a tradition at Catsauqua that the Directors of the Crane Iron Co., upon one occasion, gravely discussed Mr. Gayley's petition that his compensation be increased from \$40 to \$45 and finally concluded that the additional expense was not warranted. The books of the company show that he was paid at the rate of \$500 a year in 1879. They also show that Mr. H. J. Seaman, who succeeded him, at one time received as much as \$100 a month. Perhaps this was the belated result of Gayley's persuasive work with the Directors.

Everyone who knew Jim Gayley at Catsauqua remembers him pleasantly. He likes to go back there where everyone calls him "Jim." While there he lectured on chemistry in the Presbyterian church and afterwards appeared as one of the "babes in the wood" in a church entertainment. I venture to predict that if Dr. Gayley ever has a return engagement in either of these rôles, no building in the Lehigh Valley will contain his audience.

While in Catsauqua he lived at the hotel kept by Captain Harte. He still holds in affectionate remembrance the pies Mrs. Harte used to bake. I can remember that when he came back to visit us at the college he told us that it cost less to run his laboratory than any other in the Lehigh Valley.

The major part of the education we receive is self-education. Some men have never had much beside self-education. When I remember what Mr. Gayley was then and see what he is now, I am thoroughly convinced of the fineness of his fiber. Every time I met him he showed evidence of improvement—of the working of that yeast with which only the great are infected.

After leaving college he often came back to commencement, and I saw him once or twice in Pittsburgh. I had been plugging away at chemistry in Jenks Hall, which was the chemical laboratory from about 1881 to 1902. I taught descriptive chemistry, analytical chemistry, organic chemistry, theoretical chemistry, chemical technology, assaying, blowpiping, metallurgy and scientific German. During the intervals I worked for a living. Our laboratory was poorly equipped and I was very short of books. One day Mr. Gayley came in and after some general talk suggested that I get up plans for a new laboratory. I had heard that sort of suggestion before from others and nothing had come of it. So I acquiesced, but did nothing. Some months afterward Mr. Gayley again suggested that I get up plans and said that he would pay for them. I consulted the President who told me that Gayley had made a lot of money and that he was probably in earnest. Then I consulted an architect and in a short time Gayley Hall was in full blast. Imagine my feelings. For 20 years I had labored with my college work as one almost without hope, when suddenly all my wishes were fulfilled and I found myself with a handsome, well-equipped laboratory, an endowed library and assistants enough to enable me to do really good work. I must leave some things unexpressed. I cannot possibly express my feeling for Dr. Gayley. On the return trip to New York, after the dedication of Gayley Hall, Dr. Drown, then president of Lehigh

University, was one of the party, and Mr. Gayley offered him \$5000 for the University, which Dr. Drown accepted. This was used by Dr. Drown as a part of the fund for the erection and equipment of a Mechanical Laboratory at Lehigh. I think this gift was prompted more by his love for Dr. Drown than for any other reason. Lafayette and Lehigh are athletic rivals and it is necessary for Lafayette men to practice a certain amount of discretion in confessing fondness for Lehigh. If Mr. Gayley is to be convicted of love for Lehigh, he must himself confess it. I know, however, that many Lehigh men are fond of him, for Dr. Drinker is my authority; the best evidence of this is the honorary degree which Lehigh gave him last June.

About this time Mr. Gayley gave \$5000 to Dr. J. A. Brashear, of the Allegheny Observatory. This gift may also have been a personal one, prompted by the love which Mr. Gayley felt for him: a feeling shared by all Brashear's acquaintances.

Sometimes Gayley was willing to educate the older generation. There is a story going the rounds, unverified, that shortly after he assumed charge at Birdsboro, the furnace began to give trouble. Of course, Mr. Brooke was greatly interested and asked many questions. Finally Gayley could endure this no longer. He told Brooke not to bother any more, the furnace would come around all right and when it did he would send for him.

My friend, Dr. J. W. Richards, says that he once asked Gayley what his calculations showed in calories with dry air as compared with natural air. Gayley replied that he didn't know nor give a whoop about the calories; what he was interested in was the pounds of coke saved per ton of iron.

When Gayley Hall was about completed he came over from New York to look at it. I found him standing out in the quadrangle looking up. "That's a fine building," he said. Then we went in and stopped a moment in the hallway. "My! that's a fine building," said Gayley. When we went into a laboratory, plain, unadorned, modeled after the laboratory of a steel works; "By God, that's a fine laboratory," said Gayley.

I have had the good fortune to know a good many men whom I consider really great men—and by the way, have you ever noticed how prolific our country is of such men? Most of them are, of course, chemists. Without being invidious, I may mention such shining examples as Dr. Drown, Dr. Raymond, Dr. Howe, Dr. Chandler, Dr. Nichols, Dr. Morley, Dr. Acheson, Dr. Remsen, Dr. Wiley, Dr. Smith of the University of Pennsylvania—one must particularize when speaking of Smiths—and Dr. Loeb, just departed, and I have noticed one characteristic common to them all—very prominent in all of them. I mean their great consideration for other folks' feelings. Mr. Gayley belongs in this class. When pleased he expresses himself fully, when not pleased—silence. Consideration for others is so natural to Jim Gayley that I don't believe he half realizes what a good fellow he is.

In essentials he seems to me very like my dear friend and preceptor Tommy Drown, whom, as his assistant for many years, I knew well. Surely, I may praise the dead whom I loved and whose memory is dear; sympathetic in all that was good and true, aspiring, just—no, generous, always fair, carefully concealing a heart of pure gold. It is a privilege to have associated with such men.

Mr. Harold Chidsey, who is one of the instructors at the Tome School for Boys at Port Deposit, Maryland, speaks in the warmest terms of Mr. Gayley's work there. In Mr. Chidsey's words, "He is a live trustee." I am quite sure this is true, for Dr. Gayley has often spoken to me about the school; about their high ideals and the wonderful work they were doing. He was particularly anxious that at Lafayette our work should be of the same high order.

What may we not hope to accomplish at Lafayette College with such leadership? I confess to the belief in a great future.

Away from the hurricanes which rage in the cañons of lower Manhattan, the effete civilization of Wall street, and the lures of Broadway, we must endeavor to build up a sacred city dedicated to the purity of truth.

### THE NEW AGE<sup>1</sup>

By ROSSITER W. RAYMOND

There is no possibility of denying that we live in a new age. I know that this has been said, and I suspect that it has been true, of every age since Lamech handed the administration over to Tubal Cain; but that does not prevent its being true to-day—more truly true than anything previously declared, because it is true for us. People do not agree as to the exact particulars of this novelty, or their exact value, or the spirit in which they are to be received. Enthusiastic voices of youth, shouting the war-cry "Whatever is, is wrong!" rejoice in every change as a step of victorious progress. Deprecatory voices of age declare that they recognize, in many of these changes, old errors, which, once exposed by experience and killed after long struggle, are not entitled to a resurrection; and that progress backwards is not real progress at all. Yet, after all, for good or evil or (as usual) both, it is a new age. Let us see whether we cannot point out some features in it, concerning which all parties can agree. Before engaging in this perilous attempt, permit me to remind you of the universal proposition that science is quantitative. No enumeration of facts, causes and factors can constitute a science until it begins, at least, to weigh and measure them, and to determine their relative effect and importance. It is for this reason that political science, as a body of laws deduced from established facts, and universally accepted by competent investigators, does not yet exist. It presents, in lieu of well established facts, ardent assertions, supported by statistics, more or less carefully compiled, and more or less intelligently interpreted; and the laws of a science cannot be derived by induction from such inexact and disputable data, to which, even if they be unassailably true, no relative value has been quantitatively assigned.

In the absence of the means of such scientific induction, there is sometimes at command a short method, which roughly checks the conflicting claims of theorists and reformers. The Egyptian King, when his engineers differed violently as to the grade of an irrigating ditch—each party producing the notes of its survey to support its assertion—turned water into the ditch, and decided the question-at-issue by observing which way the water ran. In like manner, when we are shown conclusively that the conditions of labor in this country are worse than in other lands, we look at the statistics of immigration, and finding a mighty current, running only one way, we form our general working hypothesis accordingly.

It is by this method that I ask you to consider our new age, as indicated not in this country alone, but throughout the civilized world, and to recognize certain world-wide facts.

1. In the first place, the old world, after many centuries, during which it barely succeeded in feeding and clothing itself, is at last growing rich. Up to, say, fifty years ago, how beggarly was the surplus—a few hundred palaces, a few thousand pictures and statues, a few millions of accumulated gold, silver and jewels. In these respects, fifty years of to-day are more than a cycle of yesterday.

2. What has been the chief cause of this change? Not government, not commerce, not war, not social reform, except so far as these contribute to the fundamental condition. For the phenomenon is the ability of the world to feed and clothe and shelter its population, and still have labor to spare for industries not directly productive; and the cause must be the greater productivity of the individual man.

<sup>1</sup> Address delivered at the Perkin Medal Meeting, Society of Chemical Industry, Chemists' Club, New York, January 24, 1913.

3. This has been achieved, first, by increasing the equipment of the man by means of knowledge, and then by his use of that knowledge in summoning and controlling the powers of nature, to reinforce his own. In short, applied science, under and before all other causes, has transformed human life.

In connection with the first point—the increase of individual knowledge, permit me to repeat a statement, uttered by me ten years ago, in an address on the Dynamics and Ethics of Engineering. It is so delightful to be able to reiterate without change an opinion ten years old!

"What is Engineering? The control of nature by man. Its motto is the primal one—'Replenish the earth and subdue it'—not merely depend upon it, like a stationary plant or roaming beast, or hunting savage, taking what it gives—but change it by creative work, and use it with sovereign skill. Is there a barren desert—irrigate it; is there a mountain barrier—pierce it; is there a rushing torrent—harness it. Bridge the rivers; sail the seas; apply the force by which all things fall, so that it shall *lift* things. Recover the solar energy long stored in black darkness to reinforce the sunshine of to-day with heat and light and power. Nay, be 'more than conqueror,' as he is more who does not merely slay or capture, but makes loyal allies of those whom he has overcome! Appropriate, annex, absorb, the powers of physical nature into human nature!

"In the execution of this primal command, the use of machinery has been the factor and measure of progress. It is a truism of to-day that the most civilized nation is the one which uses the most coal. Probably that will not always remain as accurate a test as now. Regions which have no coal may come to utilize water power, and its transmission by means of the electric current, so as to realize something of the benefits of modern engineering. So I will not say that it will always be the country that uses the most coal, but I think it will always be true that the nation which is foremost in the utilization of some natural power will be also foremost in every branch of human progress.

"For what is the species which we seek to perpetuate? Not an animal form merely, which can eat, fight or hide, or run away, nurse children, and die. No! the species is *progressive man*, linked in his origin with the grass and the beast, but in his destiny with the universe and its Creator.

"For we have to consider now not merely the descent, but also the ascent of man—a nobler evolution, which I have attempted to describe in modest verse.

### THE ASCENT OF MAN

He stood upon the earth, and turned  
To gaze on sky and land and sea,  
While in his ear the whisper burned,  
'Behold, these all belong to thee!'

O wondrous call to conquests new!  
O thrill of blood! O joy of soul!  
O peaks with ever-widening view!  
O race, with still-receding goal!

He heard; he followed, evermore  
Stumbling and falling, wandering far,  
Yet still advancing, while before  
His footsteps shone the guiding star.

He cleft the seas; the torrent loud  
He harnessed to his need or whim;  
He bade the lightning of the cloud  
Run with his words, and toil for him.

He pierced the rock; he scaled the steep;  
Destroyed; created; brought to light  
The secrets of the deepest deep,  
The glories of the highest height!