

Bessemer could blow air through molten metal in a pot and demonstrate the value of the pneumatic process, but it would have been of no value to build a small plant to refrigerate a part of the air; nothing conclusive would have been gained. Nor would it have been of any value to treat the whole air supply of a diminutive or toy furnace. To efficiently demonstrate its value, it had to be applied to a furnace that was equipped and operated according to the most advanced state of the art, and not only was it essential that the whole air supply should be treated, but that the method and means of treatment should measure up in capacity and efficiency, and operate as continuously as any of the other accessories of a modern blast furnace.

This, in brief, is the story of the dry air blast.

### THE VALUE OF EXPERT OPINIONS<sup>1</sup>

By HENRY M. HOWE

Interesting as are the other aspects of the Gayley process its greatest interest lies, I think, in the light which it throws on the nature of expert evidence and on the value of expert opinion.

What is this process? It is simply drying the air used for burning the fuel in the iron blast furnace—apparently a rather simple matter. To refresh your memory, the blast furnace is a huge vertical firebrick cylinder, roughly speaking. In it iron ore, which is essentially iron oxide, is converted into cast iron or pig iron by prolonged exposure to coke or its equivalent, in an atmosphere of mixed carbonic oxide, carbonic acid, and nitrogen, which results from burning this coke by means of atmospheric air forced in through appropriate openings near the bottom of the furnace, and called "the blast." The furnace is full from top to bottom of an intimate mixture of this coke and ore, together with limestone added for the purpose of forming with the barren mineral matter of the ore and with the ash of the coke a fusible silicate or slag, and for other purposes into which we need not enter here. These three solid materials collectively are called "the stock."

The burning of the coke generates at the bottom of the furnace a temperature so high as to melt away the bottom of this column of stock, or mixed coke ore and limestone, of which the last two have, by this time, been converted locally into metallic iron and lime, and as the column thus descends it is renewed at its top by adding more of this same mixture so as to keep the furnace continuously full.

There are, as it were, two rivers passing through this great cylinder in opposite directions, a sluggish river of solid stock which descends as its bottom is melted away, and a swift river of ascending gases resulting from the burning of the coke by the injected air or blast. The former traverses the length of the furnace in from 12 to 15 hours, the latter in a very few seconds. These rivers interact as they interpenetrate and flow past each other, the rising gaseous column progressively giving up its heat to the solid column and taking from that solid column the oxygen of its iron oxide, so that the gaseous stream as it emerges from the top of the furnace has taken from the descending ore all the oxygen that it is capable of removing, and has delivered over to that ore and its accompanying coke and limestone all the heat that they are capable of taking from it.

So much for the blast-furnace process, which, like every mundane process that seems simple, is in fact of a complexity so overwhelming that the human mind is inherently and incurably impotent to grasp it. We rub our eyes and, seeing as far as the ends of our noses, assume that we see to the end of the universe.

As a heat engine the blast furnace was known to be extremely efficient, as human heat engines go. Nevertheless, by the

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extremely simple step of drying the blast Mr. Gayley made a further important saving of fuel amounting in some cases to 20 per cent., and according to our present evidences to about 10 per cent. on an average, for usual American conditions. To those who had taken up the logical stick by the wrong end, such a saving by thus drying the blast seemed simply preposterous, as preposterous as talking a thousand miles through an iron wire, or waving a message to Europe without any wire, or as any invention is till you understand it.

Its preposterousness was promptly and convincingly exposed by the public-spirited experts whose geographical misfortune prevented their knowing Mr. Gayley's character, though those of us more favored geographically followed "Br'er Fox" till our question "Why and how?" could be answered.

The heat required for heating and dissociating the moisture of the blast is a small fraction of the total heat requirement of the blast-furnace process; how then dare we say that the removal of this heat requirement may save 10 or even 20 per cent. of the fuel?

Not a few of us had grown so used to calculating the heat needed for a given chemical and physical work like that of the blast furnace, and the heat evolved by the combustion of a given weight of fuel under known conditions, and to calculating thus the thermal balance, that we had lost sight of the supreme importance of temperature.

The atmospheric moisture, calorimetrically considered, is indeed slight, but thermometrically considered it is sometimes of overwhelming importance. As to its effect on climate Tyndall says: "To say that on a day of average humidity in England, the atmospheric vapor exerts 100 times the action of the air itself, would certainly be an under-statement of the fact."

Those who have felt the physical and mental exhilaration which a ten-mile trip from Cairo out into the desert creates by the sudden substitution of a drier for a moister climate; those whose legs would fain leap when the "wild west wind, thou breath of Autumn's being" suddenly dries our air, might well listen to the claim that a like drying of the air affects the blast-furnace process as it affects our own vital processes.

The sum and substance of it is that the blast-furnace process has, among its various duties, to supply a certain quantity of heat at or above a certain high temperature, which for brevity we may call the critical temperature, while shamefacedly confessing that we are further overworking an already grossly overworked word. No quantity of heat offered at any lower temperature will do this work. All the heat in all the suns of the milky way if offered at a temperature of 50° C., could not boil one egg.

Drying the blast saves fuel by improving the temperature-distribution of the heat generated.

Perhaps this is more readily understood if we consider an imaginary case. Suppose that matters were so ordained that he who wished to build an iron building was obliged to take, along with his iron work, a certain fixed proportion of accessories, windows, flooring, tiling, etc., the proportion fitted for a ten-story building. That would be all well enough for those who build nine- ten- or eleven-story buildings; but for the builder of a forty-story building it would be most uneconomical, because whereas the quantity of accessories, windows, flooring, tiling, etc., increases directly as the height of the building, the iron work needed increases in a higher ratio; so that, in order to get enough iron work for his forty-story building he might have to get enough accessories for a sixty-story building, and the excess would be left on his hands. This is because of bad proportioning of his supplies. A mere change in the proportion between iron work and accessories would cause a great saving.

It is somewhat so with a thermal process like that of the iron blast furnace. When combustion has raised the temperature above the critical point there is available first a certain

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

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