The use in computation of the equations I have given, whether to calculate the pressure from the temperature, or the temperature from the pressure, is rapid and easy. In Table II. they are recapitulated, and the values of the constants for different measures of pressure and temperature are stated.

In calculating the values of a the specific gravity of mercury has been taken as 13.596.

Temperatures measured by mercurial thermometers are, in all cases, to be reduced to the corresponding temperatures on the air thermometer, which may be done by means of the table given by M. Regnault in his memoir on that subject.

To be Continued.

For the Journal of the Franklin Institute.

On Smelting Magnetic Iron Ores. By MR. H. FAIRBAIRN.

Amongst the most interesting branches of observation which are presented to the view of the traveler, amongst the iron furnaces and through the iron ore regions of Pennsylvania, none is of more striking importance, in its probable ultimate revolutionary consequences on all the future iron manufacturing of Europe and of America, than the progress towards perfection in the yet imperfectly established system of smelting the magnetic iron ores of Pennsylvania, or those ores which abound in the primitive rocks in various parts of the State.

Although these iron ores have been hitherto known, in a manufacturing point of view, principally in New Jersey, or in Pennsylvania, and only in the region of the Lehigh river, yet the geology of this part of the continent of America displays, in the utmost distinctness, the continuation of the same rocks through a very wide range of country, from North to South,—from Connecticut through New Jersey, New York, Pennsylvania, Maryland, Virginia, South Carolina, and the South-Western States, under various local names. The mountains are of primitive formation, and they are universally non-volcanic,—the strata consequently continuous, and unbroken by the mechanical forces which have disturbed the stratification of so large a part of the European countries,—and the same iron ores may be reckoned upon as existing almost everywhere throughout the range of the primitive mountains of the United States.

The degradation of the mountains is various, as local circumstances may have produced aqueous decomposition in the varying degrees; but this has served the very useful purpose of laying open the deposits of iron in all the stages of geological formation, and it only remains for the manufacturer of iron to choose his location over hundreds of miles of country; or if fuel be absent from any part of the region where a particular iron ore be seen upon the surface, then to dig will be to find (in almost any other situation) the magnetic iron ores, at some depth, however various, between the surface and the granite foundation of the earth.

Scattered furnaces there are throughout Virginia, Maryland, South Carolina, and Alabama, and these furnaces are all engaged in the smelting of the magnetic ores of iron; but they are principally charcoal furnaces, on

the comparatively petty scale which is that of all iron furnaces dependent on wood for fuel, in this age of colossal competition for the manufacture of the iron of the world at large.

Through the circumstance of the existence of the anthracite coal fields in the State of Pennsylvania, and that all the ores of iron exist also in the nearest vicinity to coals and to limestone, it may be stated that the iron ores and the iron manufactures of Pennsylvania are substantially to be the future iron ores and manufactured iron of the United States. Time may develop other modes of smelting, in which coals may not be the all important consideration, but no extensive manufacture of iron can now exist at any considerable distance from the coal fields of Pennsylvania, however rich and abundant may be the magnetic iron ores of the more southern States. And although, in Pennsylvania, the circumstance of the greater accessibility of the magnetic iron ores in the region of the Lehigh river, has hitherto appeared to confine the smelting of these ores to that particular quarter of the State, yet throughout the whole of the region between the Lehigh and the Schuylkill, the same ores can be mined where a demand for iron ore exists; and either at Easton, on the Lehigh, or at Reading, on the Schuylkill, iron furnaces can be supplied in any quantities, however illimitable, of magnetic iron ores, at an average cost of three dollars per ton.

These ores are the richest of all the ores of iron,—not the most productive of iron in the greatest quantities only, but the iron is of the finest quality which is thus made from the magnetic ores of the United States. From the same oxides of iron is produced all the fine iron of Russia, Sweden, and Norway,—countries which are situated in similar primitive geological formations with a large portion of the State of Pennsylvania,—and whilst the search has been in vain for magnetic iron ores in England, yet in the return to the House of Commons of the importations of iron for the late years of 1848–9, which was made on the motion of Sir John Guest, there is an entry of “1340 tons of chromate of iron from Norway and the United States.” There is every variety of iron ore to be found in Pennsylvania, from the richest oxides of Russia to the leanest carbonates of Wales.

But the magnetic iron ores have yet been comparatively useless to the iron manufacturer of Pennsylvania, and Russian and Swedish iron continues to be imported into the United States, although made from the same ores which lie in whole millions of tons on the granite rocks of the Lehigh. The only instance in which the magnetic oxides have been smelted without admixture with hematite ores, is mentioned by Professor Walter R. Johnson, in favor of the Stanhope furnaces, in New Jersey; and though the work of Professor Johnson is now of some ten years in date, yet is there no furnace at this time on the Lehigh river where pig iron is produced with any regularity, unless with considerably more than one-half of the softer hematite ores. There are, occasionally, reports of extraordinary success in the attempts which may be made at particular furnaces to smelt the magnetic ores alone; and, for a short time, there is pig iron in the markets which sells at prices very far over the usual anthracite iron, of which there is an instance at this time of such pig iron being sent from a furnace on the Lehigh to Sheffield, in England, for the steel manufacture

of a place which depends almost entirely on Russia and Sweden for the raw material of steel. Yet this successful smelting of the magnetic iron ores never long fails to be followed by some important damage to the furnace; and it is generally considered that it is not practicable to smelt iron with profit to the manufacturer, when using the magnetic oxides of iron, unless with the admixture of considerably more than one-half of the inferior hematite ore.

But this admixture of inferior ore is fatal to the manufacture of iron, on the Lehigh, or elsewhere in Pennsylvania, in competition with the iron of Russia; for the quality of the metal is deteriorated, and the expense is increased, of manufacturing iron from hematite ores, which are usually brought from considerable distances to the furnaces on the river Lehigh. Great quantities of hematite ores are annually sent round from the Schuylkill river to the furnaces in New Jersey, and this ore is sold at an average of one dollar per ton above the magnetic ores, an expense which is most needlessly incurred, from a supposed impossibility that the magnetic ores can be smelted alone.

To overcome this difficulty in the reduction of the magnetic oxides of iron is, therefore, of the utmost importance in the anthracite iron manufacture of the United States. Certain it is, that iron equal to that of Russia can be produced from the magnetic ores of Pennsylvania,—for the Exhibition of the Franklin Institute exhibited such iron in the late year of 1849; whilst the steel manufactured at the Adirondac works, in New Jersey, is also from American iron, and the iron recently produced at the largest furnace on the Lehigh river, is reported from the rolling mills to be fully equal to Russian or to any other iron, with respect to malleability, but that, in the process of puddling, a considerable per centage of its weight has been found to be lost. This latter circumstance may probably lead to the better management of the process of smelting the magnetic iron ores of the United States.

For, against the alleged impossibility of smelting a hard magnetic oxide of iron, there is the refutation in the daily practice of the iron founder, who melts the pig metal itself, and it will not be said that there is any iron ore which is harder than the pig. The practice of the iron founder may, therefore, point to the true modes of smelting the magnetic ores of the United States.

It is the absence of the waste alone—of three-quarters of the coals, and the limestone—which enables the founder to reduce the metal itself, which yet cannot be produced by the smelter from the yet much more reducible form of the ore.

There is no iron foundry in which more than five cwt. of anthracite coal is used for the smelting of one ton of pig metal, and yet the cupola furnace is blown with cold air, and loses immensely more heat by radiation than is lost from a smelting furnace through walls of many feet in thickness. But the iron founder does not use his coal in enormous lumps, of which the greater part is useless in the smelting process and lost in the air. Were the cupola furnace filled with lump anthracite coal, two tons would equally be required for smelting a ton of pig iron, as a ton of iron from ores which are almost all iron, for there is frequently 90 per cent of iron contained in the magnetic ores.

But though these ores are almost all iron, and the quantity of earthy adulterations less than in any other iron whatever, yet is there, in the iron furnaces on the Lehigh, no change or shadow of alteration from that everlasting "ton of limestone," which appears to be thrown into every iron furnace in every place and region in the United States. The founder uses only some small portion of lime, a few pounds of oyster shells being sometimes all that is used for melting a ton of pig metal of impure quality, but more frequently none whatever is used in the cupola furnace; and if the earthy ingredients in the ores be only 10 per cent., or 2 cwt. in the ton, then 1 cwt. of limestone is the true quantity to be used in the smelting furnace, the waste of limestone being one of the leading causes of the unsuccessful attempts to produce iron for steel from the magnetic ores of the Lehigh. The unusual waste of iron in the puddling furnace is owing only to the calcareous and carbonaceous concretions which remain from the excessive use of anthracite coals and of limestone in the smelting process, for the loss is not of metal, but of impurities which have been inserted in it, at a very considerable expense, and only to be again extracted by the further very heavy expense which attends all puddling of iron in the United States.

The chemistry of red short iron may not have been very clearly ascertained, and the phosphoretic substance which Bergman found on the analysis of one kind of iron, may not improbably be now sometimes mistaken for the metal of calcium, or of deoxydized lime, which may remain in the metal by the greater specific gravity which will cause its precipitation amongst the metal in the hearth; but certain it is, in all practical iron manufacturing, that pig iron is rendered the more brittle by the excessive use of lime, and this excess is most enormous throughout the iron manufacture of the United States.

In order to illustrate, from actual practice, the undoubted error of using this excessive and unvarying quantity of limestone in the American anthracite iron manufacture, it is here proposed to bring into notice the comparative quantities of limestone and other materials used, formerly and now, in Scotland, and under different temperatures of blast.

At the Clyde iron works, in 1831, the blast at 280° Fahr.

	tons.	cwt.
Coal for fusion, 1 ton;—18 cwt. of coke; in coal,	4	6
For the hot blast apparatus,	0	5
Blowing machine,	0	7
Limestone,	0	9

In 1833,—temperature of blast, 612°.

	tons.	cwt.
For fusion,	2	0
Hot air apparatus,	0	8
Blowing engine,	0	11
Limestone,	0	7

Here is seen a reduction of limestone to 7 cwt. per ton of pig iron, at a temperature of 612°, and this quantity is still in use very generally in Scotland, although the limestone of Scotland is only the mountain limestone which intervenes in the bituminous coal measures, and far inferior in quality to the transition limestone of the Schuylkill region, which approaches to almost perfect purity when taken from any low part of the stratum, and usually contains 94 per cent. of pure lime.

That the brittleness of anthracite iron is owing only to errors in its manufacture, is further rendered probable from everything that is known of the quality of the iron produced from hematite ores in other parts of the world. At Ulverstone, in England, iron is made with charcoal from hematite ores, and this iron possesses so nearly the soundness of the iron of Sweden as to be almost equally valuable in the market; nor has it even been doubted that hematite iron ore is second only in value to the magnetic oxides from a lower situation in the primitive rocks. The "ton of limestone" is the greatest misfortune that ever was imported into the manufacturing system of the United States.

Besides the loss of anthracite coal, and of limestone, with all the injurious effects upon the metal which so arise from their use in excess, there would seem to be another important error in the filling of the furnaces with the magnetic oxides of iron, in an insufficiently reduced state. This variety of iron ore of a specific gravity proportioned to its great content of pure iron,—probably three times heavier than anthracite coal or limestone, or more than double the weight of the hematite or argillaceous iron ore with which it is intermixed so universally at the furnaces on the river Lehigh. The magnetic iron ore will therefore tend to fall, by its greater gravity, through and below the coals, the limestone, and the other ores in the furnace at the same time, lying impressed against the boshes, obstructing the blast, impeding its own reduction, and causing much of the superincumbent coal to be lost to the process of smelting and wasted at the tunnel head. The continual "chills" which occur at the furnaces which use any important quantity of magnetic iron ores, are probably to be much traced to that merely mechanical cause. The remedy for this obstruction is very easily to be found by reducing the magnetic ores to the smallest size,—as in Sweden the ores are always broken to about the dimensions of an ordinary egg,—and by filling also the furnace with the ores more intimately mixed with the limestone and the coals. The expense of the reduction of these magnetic ores to even very minute dimensions, by stamping machinery, would be amply repaid by the facility with which they would be smelted, with the greater quantity of iron which a furnace would produce, and the greater duration of the brickwork of the walls.

The internal form of the furnaces on the Lehigh, which are universally cylindrical, must be viewed as another impediment to the successful smelting of these heavy magnetic iron ores, which will press with increased force, by their greater weight, against the walls of a furnace with an imperfect internal curve. A chill of very great consequential damage has occurred recently at the furnace which was becoming known for the production of iron selling readily for \$26 per ton, against the iron of neighboring anthracite furnaces at \$19 per ton, and the furnace in question is of the cylindrical internal form. On the other hand, the Stanhope furnaces are true circles, according to Prof. Johnson; and he mentions, as with exultation, that these furnaces had reduced the magnetic ores without mixture with ores of any inferior kind.

These are the undoubted causes of the unsuccessful attempts to smelt the most valuable of all the ores of iron—the magnetic oxides of the Lehigh region; nor is there any truth whatever in the usual reasoning of the proprietors of iron works, that the use of the hot blast is the cause of the

difficulty in the production of iron for the purposes of steel. It has been settled long since, not more, theoretically, by the extensive series of experiments which were made by Messrs. Fairbairn and Hodgkinson, for the British Association for the Advancement of Science, than by the daily subsequent experience at all the principal iron works in Scotland, that there is no difference in the quality of iron made by hot air or by cold, or that the difference has been in favor of the hot blast system of smelting, a much larger increase of No. 1 iron having been produced at the Clyde iron works, by the same furnace and from the same materials, after the change to the use of heated air. The opinion that hot blast iron is inferior in quality has long since been exploded at all the iron furnaces of Great Britain, and the hot blast is assuredly not the cause of the inferiority of the great bulk of the anthracite iron of the production of the United States.

By the abandonment of the present very rude and unreasoning modes of building, of filling, and of blowing the iron furnaces of Pennsylvania, it would very soon cease to belong to the serfs of Russia to supply the finest of iron from underneath the snows of the Ural mountains, to all the rest of the nations of the modern world. This occupation is very clearly destined to belong to the people of the United States, for all the rarest of the oxides of iron are to be found in the primitive mountains of the Atlantic States, and to use these treasures on some system approaching to the resemblance of mechanical and chemical science, is all that would appear to be required to the early and entire ascendancy of the iron and steel manufacture of this quarter of the world,—for there would be no difficulty in smelting magnetic iron ores were the process conducted on any reasonable plan, and when not pig iron only, by the founder, but Russian and Swedish bars, by the manufacturer of steel, and even cobalt, is reduced daily, (although this is amongst the most refractory of all the metals,) it follows that there is no iron ore whatever which cannot be reduced with the greatest comparative ease.

On the supposition that the magnetic ores have only been neglected or disused from causes which the improvement of the general iron manufacture may cause to pass away, then as the deposits of magnetic ores are shown to be boundless for any possible requirement for future manufacturing purposes, a chain of remarkable consequences may be seen to follow the establishment of iron and steel manufactures in the regions of these ores; for not only may the finest of iron be made in any possible quantities in Pennsylvania, but the most valuable of all the varieties of iron may come to be made at a less expense than the worst. One ton of magnetic iron ore will produce more metal than two tons of ordinary hematite, or than three tons of carbonate of iron, whilst the expense of mining the richest will not be greater than the leanest of the ores; and thus may all other smelting become unprofitable in any other regions but those which contain the ores of the original rocks. Russians, Norwegians, and Swedes would then cease to be the sellers of all but inferior iron to such nations as Great Britain and the United States; and as the British islands possess a geology not within the probabilities of any deposits of iron ore of a class superior to the hematites, the State of Pennsylvania and its anthracite coal regions would appear to be destined to take a very high rank in the future manufacture of iron for the world at large.

But this only can be the result of the most economical use of the iron ores of the finest quality, since the difference is daily becoming less in favor of any particular nation in any particular pursuit of manufactures or of foreign trade. Navigation is cheapened and more expeditious from year to year, and the freight of commodities is daily lessened over the sea. The difference in favor of the American iron manufacturer would be only the expense of conveying magnetic iron ore from the Lehigh to Scotland or to Wales, as the chromate of iron is now taken to Great Britain from Maryland at Havre de Grace, and the cost of the freight is comparatively less, the more valuable may be the ores which may yet come to light from the primitive mountains of the new world. Specimens of both meteoric iron and of specular iron ore were recently shown to the writer of these observations, by proprietors of iron furnaces on the Lehigh river, and when the non-volcanic character of the region is preserved in view, and reflecting that the specular iron ore is in entire hills in the Island of Elba, in the Mediterranean Sea, that the laws of comparative geology render probable the existence of the same ore in continuity of deposit in the places where it has been found at all, consequently that hills of specular iron ore may be found in the regions of the Schuylkill, the Susquehanna, the Lehigh, or any other part of the long line of country which is traversed by the primitive mountains of the United States; and that in the present wasteful use of anthracite coal, and of limestone, it might be considerably less expensive to carry the specular iron ore to Scotland than the coals from Pottsville to Reading or the Lehigh. Such considerations render indispensable an equality in the art of smelting iron, in order to the preservation of the local advantage of the possession of the finest of ores. As Scotland, with advantages so inferior, still continues so strangely to supply the lower qualities of pig iron, so will it be not any very long time before the same people will be in possession of the manufacture of the higher varieties of iron, unless upon the rise of a more formidable opposition than any which yet can be discovered in the science of the iron manufacture of the United States. There is no mode of now maintaining an ascendancy but by the skill and enterprise of nations. Geology, chemistry, and mechanical science are rapidly assisting many nations to become rich from resources which were not formerly supposed to have an existence; and though the position of Pennsylvania is that of so undoubted an apparent magnificence, amidst the mineral deposits of so many valuable kinds, yet, without more rapid improvements in their use, neither the magnetic iron ores nor the anthracite coal fields appear to be destined to increase very materially the wealth and the commercial ascendancy of the Republic of the United States.

For the Journal of the Franklin Institute.

Fresh Water in Marine Boilers.

Much time and money have been wasted in vain attempts to perfect, for marine engines, a condenser that, while it would maintain a good vacuum, would also allow the condensed steam to be returned to the boilers as pure as it came from them. Of all those which have as yet been offered

to the public, that of Hall has met with the most success, or has at least been practically introduced into several steamers in England, where it was thought it would work a revolution in the economy of the marine engine. But although at first it gave much satisfaction, it was soon found to have defects which became of such a serious character as, in a short time, to almost, if not entirely, prevent its use. It was very expensive in its first cost, and, after short use, the tubes would leak and cause the water in the boilers to become salt; and, in addition to this, the tubes being vertical, the water from the steam first condensed was obliged to pass through the whole length of them, and as it adhered to their surface on its passage, their conducting power was much injured.

Since then, Mr. Howard, of England, has brought forward a refrigerator for cooling the injection water. By his arrangement the steam was condensed by a jet as usual, and then the condensed steam and water of condensation were made to flow through a large number of small horizontal tubes, having a current of cold water on their external surface. By this means the injection water was sufficiently cooled down to be again used. Although the arrangement possessed considerable merit, still it failed to succeed, probably from the liability of the tubes to leak from their constant contraction and expansion.

Several persons, in this country and in Europe, have brought forward fresh water condensers, but most of them have been modifications of Howard's arrangement, although they condense the steam, while he cooled the water, yet, in construction, they are the same or nearly so. They all have defects, or at least all that have yet been publicly tested have. The objections are, liability to leak, and by that means destroy not only their efficiency as fresh water condensers, but also to affect the vacuum. The requisites of a good condenser of this kind are, first, instant condensation, so that the ordinary vacuum may be maintained; second, impossibility of derangement, or as much security as the ordinary condenser allows.

The advantage of such an apparatus would soon be appreciated and generally adopted, but until it has been put successfully in practice, few if any of our steamers would venture to use it. With them success is of great importance, and, rather than risk partial failure, they will adhere to the old and well-tried condenser of Watt. But when at least 10 per cent. in fuel, besides the wear of boilers, may be saved by an apparatus that will answer the requirements above stated, I hope some of your numerous readers will take the subject in hand.

Z.

For the Journal of the Franklin Institute.

Improvements in Sugar.

We were shown, a few days since, some samples of sugar made on the plantation of Messrs. Benjamin & Packwood, near New Orleans. These gentlemen have one of Rillieux's Patent Three-Pan Sugar Boiling Apparatus, and the sugar is made directly from the cane. Two of the samples were of white sugar, *crushed* and *flour*, and the third of molasses sugar. Their white sugar will compare favorably with that from our northern refineries, and has been pronounced by Professor McCulloch, in his report,

as equal in chemical purity to Lovering's single refined. From 12,000 to 15,000 lbs., of the white is produced daily, besides working over the molasses, which produces a sugar but little inferior to the best. We are also informed by Messrs. Merrick & Son, who are the agents for the apparatus, that, in consequence of its success, they have recently shipped one to the Island of Cuba, and are now building two for Mexico, the largest of which is a duplicate of that used by Benjamin & Packwood. In consequence of the quiet state of affairs in Mexico, several gentlemen there are turning their attention to the cultivation of sugar cane for home consumption, as the very expensive land carriage will prevent exportation.

B.

For the Journal of the Franklin Institute.

Economy of the Steam Engine.

The great expense of steam power is the cost of fuel, and although we cannot reduce the price per ton, which is regulated by its market value, we can readily reduce the number of tons used, by paying proper attention to the following items of loss.

1st, Insufficiency of power produced by having an engine too small for the work to be done, or boilers too small for the engine, but generally from both these causes combined.

2d, Imperfect setting of the boilers.

3d, By radiation: the tops of the boilers often being uncovered, and the steam pipes and cylinder nearly always so.

4th, By ignorance: the persons who have charge of many of our stationary engines being entirely unfit (by their want of knowledge of the principles of the engine) to keep all the parts properly adjusted.

The above are the principal causes of loss, and I shall, in your next, show the remedy, and adduce examples to prove the truth of my remarks.

W.

*Means of Preventing Boiler Explosions. By A. C. JONES, Esq., Civ. Eng.**

The recent explosions of steam boilers in this vicinity have brought out many contrivances, and revivals of old plans to *prevent* explosions. After it was *conceded* that high pressure steam boilers could be worked safely with proper care, then came various plans to make them *safer*. First on the list was lead plugs, riveted into holes made in the boiler sheet above the fire surface; next came fusible alloys, which would melt at a slight increase of temperature above that equivalent to the pressure of the steam in the boiler. Fusible alloys have entered into a large variety of arrangements for preventing explosions, by the order of the French Government; and also by the Committee on Explosions of the Franklin Institute, numerous experiments were made with alloys. We have had advocates for "Floats," "Balance Valves"—using the expansion of mercury, and rods of copper, arranged so as to open valves to permit the steam or water to

* From the New Orleans Daily Crescent, November 22, 1849.