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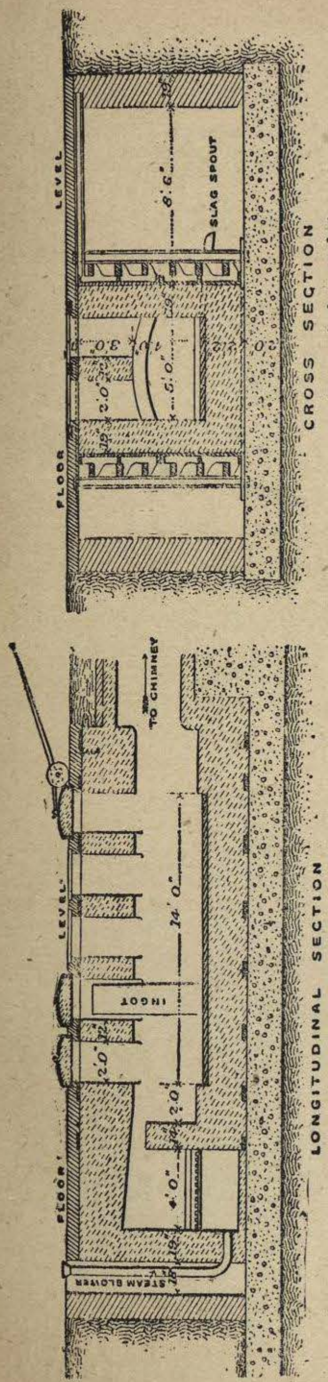
In works where they were making only one finished product, and that of a fairly large section, as, for instance, rails, these soaking pits gave good results; the chief objection was the difficulty of first heating the pits, which necessitated the transferring of several sets of ingots, which afterwards



Scale, 1 inch = 10 feet.
Fig. 314.

Scale, 1 inch = 10 feet.
Fig. 313.

English Vertical Coal-fired Ingot-heating Furnace.

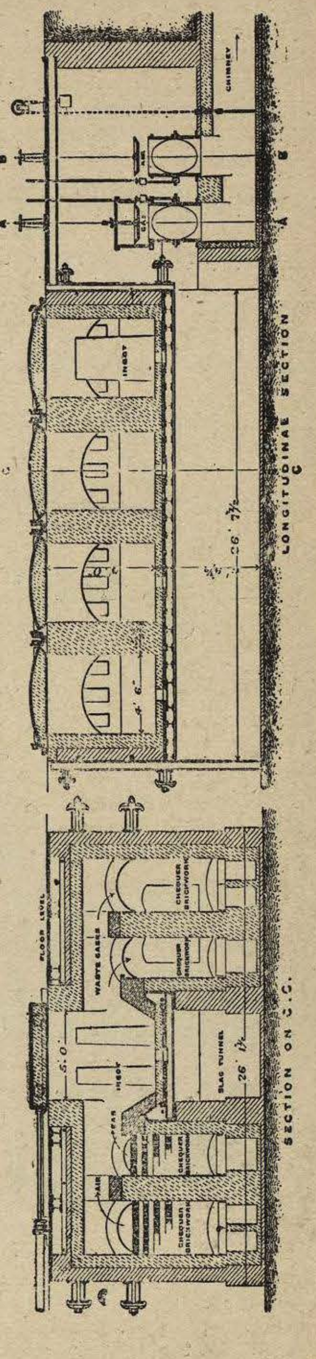


Fig. 316.

Fig. 315.

American Vertical Gas-fired Ingot-heating Furnace.

had to be reheated in a furnace, and the difficulty of keeping up the temperature for an hour or so, in the event of any delay due to a break-down at the mill or some similar cause. It was also not an easy matter to regulate exactly the supply of ingots from the steel department to the mills, so that ingots should not remain for too long or too short a time in the pits, and so necessitate the keeping back of some ingots, which would afterwards have to be reheated. In view of these practical difficulties, experience has shown that it is better to have the pits fired by gas through a series of flues, or by slack direct, so that they can be heated up before commencing to work, and the temperature can be increased when found necessary. The soaking pits thus become, practically, vertical gas reheating furnaces sunk in the ground, but owing to the small amount of heat lost by radiation, comparatively little subsidiary heating is required. Although soaking pits have given excellent results in rail mills, where all the ingots are practically of the same size, and where they are rolled direct to the finished section, they do not give such satisfactory results where smaller and variable sections are required; partly, no doubt, owing to the top end of the ingot being always slightly colder than other parts, but largely owing to the difficulty of regulating the supply of ingots to the requirements of the mill, which vary in accordance with the section being rolled.

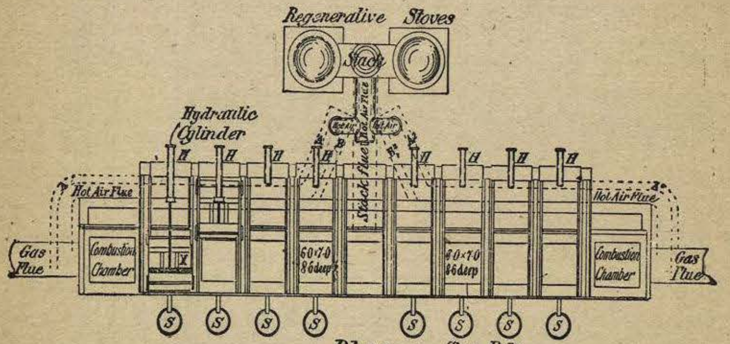


Fig. 317.

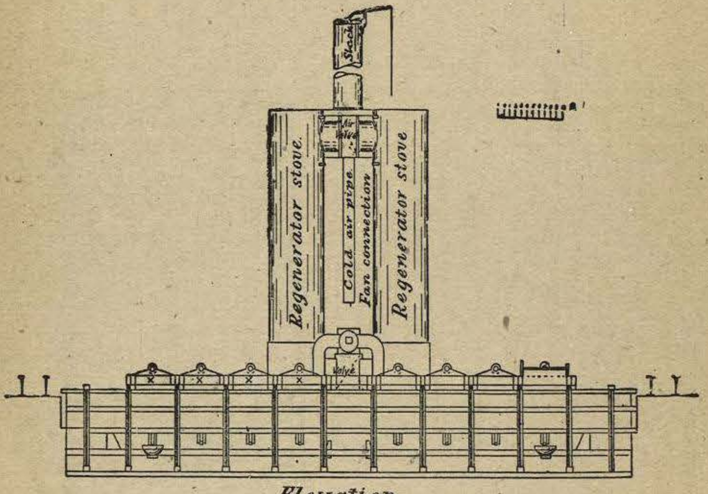


Fig. 318.—Talbot Regenerative Soaking Pit or Vertical Furnace.—$A^1 B^1$, $A^2 B^2$, walls of hot-air flue; X, movable cover over pits; H H H, hydraulic cylinders and rams for moving tops; S, slag pots. The direction of air and gas is reversed by valves in the usual way, through which they enter the combustion chamber at either end of the furnace, the gas direct from the producer, and the air from one of the regenerators. The products of combustion travel the length of the furnace, and then through the flue to the other regenerator on their way to the stack.

If the steel department makes more ingots than the mill can deal with, as sometimes is the case, some of these must be allowed to cool, and before they can be rolled will have to be reheated; for this purpose the soaking pit is useless, and some other form of furnace must be adopted, or some method of heating the ordinary soaking pits must be devised.

When an ingot is laid on its side before it is fully set, the cavity due to shrinkage may extend throughout nearly the whole length of the ingot, because the fluid interior naturally finds its own level; but, if kept in a vertical position, the pipe will be confined to the top end, which must be cut off in any case. So thoroughly is this recognised, that many American engineers specify that all large ingots are to be reheated in the vertical position. Again, in reheating ingots in a horizontal furnace, the sides exposed to the action of the flame, and especially the top side, is always hotter than the one resting on the bottom of the furnace. In the case of small ingots, this difficulty is met by turning them over, but this is a practical impossibility with large ones.

Figs. 313 and 314 show a vertical slack-fired reheating furnace in an English works, from which the cover is lifted by a crane, or by a wheeled lever called a ganger, each hole containing one ingot, while figs. 315 and 316 show a gas-fired American furnace; from each hole containing four ingots, the cover, which runs on rails, is drawn back by a hydraulic cylinder. Figs. 317 and 318 illustrate another gas-fired furnace, recently designed for an American works by Mr. Benjamin Talbot. The gas comes hot direct from the producer, and meets the air, which is forced by a fan through one or other of the vertical regenerators. The air and gas are admitted, first to the combustion chamber at one end of the furnace, and then to that at the other end.

Fig. 319 shows one by Mr. Frederick Siemens, to which is applied the principle of his New Form Siemens furnace.

The soaking pit is not applicable to ingots weighing much less than a ton each, and the best work is not obtained unless the ingots weigh 35 to 40 cwts. With ingots treated in soaking pits the loss need only be 1 per cent., of which about one-half is lost at the rolls. Daelen gives the loss as 1 per cent., and Mills as $\frac{3}{4}$ per cent.

According to Lantz[*] we must expect a loss of $1\frac{1}{2}$ to 2 per cent. if the pits are heated, and a consumption of fuel of $2\frac{1}{2}$ per cent. of the weight of the ingots ($\frac{1}{2}$ cwt. of fuel per ton).[†] Daelen puts the loss at $1\frac{1}{2}$ to $1\frac{3}{4}$ per cent.

In a very interesting paper on reheating furnaces by F. Mills,[‡] he states that the loss in coal-fired soaking pit furnaces ranges in different cases from $1\frac{3}{4}$ to $2\frac{1}{2}$ per cent. (one of the speakers in the discussion which followed the reading of the paper quoted, even contended for $\frac{1}{2}$ per cent.), while the fuel ranged from $1\frac{3}{4}$ to $2\frac{3}{4}$ cwts. per ton. He also instanced similar pits heated

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[*] *Stahl und Eisen*, vol. xviii., 1898.

[†] *Comite des Forges de France.* Bulletin No. 1445, p. 13.

[‡] *West of Scotland I. and S. Inst. Journ.*, 1897-8, vol. v., p. 80.

by gas, where the loss was 1 per cent., and the fuel consumption, which could only be estimated, was put at 1 and 1¼ cwts. per ton.

Ingots of 1 ton weight each require to remain in the pit about 30 minutes, 35-cwt. ingots 45 minutes, and 45-cwt. ingots about one hour, before their heat is sufficiently uniform throughout, to permit of their being rolled. One hundred tons of ingots is easily passed through a 10-cell pit per shift of twelve hours; as much as 2,500 tons of 20-cwt., and 3,000 tons of 30-cwt. ingots have been passed through three such pits in a week's working.

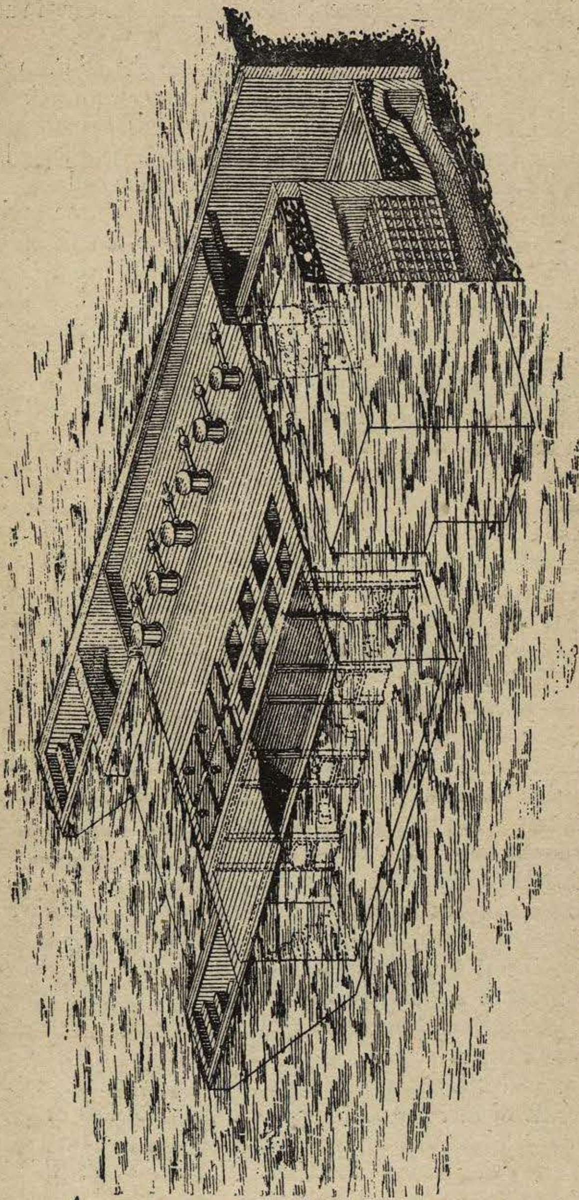

Fig. 319.—New Form Siemens Vertical Underground Furnace for Heating Steel Ingots.

Materials Used for Constructing Reheating Furnaces.—For this purpose it is not necessary to use Silica bricks, those made from infusible fireclays being sufficiently refractory in many cases.

The following analyses of high-class fire-bricks made in different parts of England have been kindly sent us by our friend Mr. J. E. Stead. It is very important that the alkalies should be as low as possible, preferably under 1·00 per cent., and never exceeding 2·5 per cent., as they greatly increase the fusibility of a fire-brick :—

Analyses of Fire-bricks.

	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Potash.	Soda
	SiO_2. Per cent.	Al_2O_3. Per cent.	Fe_2O_3. Per cent.	CaO. Per cent.	MgO. Per cent.	K_2O. Per cent.	Na_2O. Per cent.
Wortley, Leeds,	72·65	23·75	1·75	0·30	0·36	0·81	0·29
Stourbridge, . .	69·00	27·30	1·86	0·27	0·32	0·65	0·26
Glenboig, . .	63·00	32·00	2·85	0·79	0·36	0·74	0·20
Newcastle, . .	60·10	34·65	1·89	0·52	0·38	2·05	0·35
Durham (Newfield),	65·40	27·56	2·00	1·12	0·72	2·12	0·34
Derbyshire calcined fireclay, .	68·05	27·50	2·01	0·35	0·68	1·08	0·34

Temperature for Reheating.—The temperature to which any particular class of steel should be reheated, previously to rolling or forging, depends largely upon the percentage of Carbon it contains. The higher the Carbon, the lower should be the reheating temperature. High Carbon steels not only have to be worked at a lower temperature than mild or low Carbon steels, but they require much greater care in reheating, which should be done slowly, the precaution being taken to maintain in the furnace an atmosphere as reducing as possible, to prevent the Carbon being removed by oxidation. The correct temperature is a matter of considerable importance, now receiving much attention. There seems little doubt that there is a fairly definite temperature which gives the best results for any particular grade of steel, but it is extremely difficult to determine exactly what this is, and so to arrange working conditions, when dealing with large quantities of material, that this temperature can be regularly maintained over any required period.

Furnace Bottoms.—Owing to the great weight concentrated on such a comparatively small bearing surface, heavy ingots, particularly when heated in the vertical position, are apt to sink into a common sand bottom, with the result that much metal is wasted by the formation of siliceous cinder. If a hard infusible neutral or basic material is employed, such as hematite ore, hammer and roll scale, non-silicious flue cinder, or other pure Oxide of Iron, and the bottom is well-made and glazed, comparatively little trouble is experienced.

One of the best materials for the purpose is basic slag, first used by Mr. A. E. Tucker and Mr. F. W. Harbord. Bottoms made of this material have been largely used for ingot and slab heating furnaces, with most satisfactory results. This bottom is made by filling in the hearth to a depth of 10 or 12 inches with basic slag, or the bottoms of old basic Siemens furnaces or of Bessemer converters, either alone, or mixed with Dolomite. The material is broken up into pieces about the size of walnuts, and the hearth then covered with finely-ground slag, or a mixture of finely-ground slag and magnesian limestone, and the whole surface glazed. When the hearth has once firmly set, it remains perfectly hard, and requires only the slightest of repairs, which are effected by spreading a little of the slag and Dolomite mixture over any part that is worn away, when it rapidly glazes on to the bottom.

For the bottoms of continuous furnaces, along which billets are pushed after they have left the pipe skids, Mr. Morgan uses Magnesite bricks.

Determining the Heating Value of the Fuel.—The heating power of a fuel can be determined in the laboratory with great exactitude by means of a calorimeter, of which there are several patterns on the market, all working on much the same principle. A small accurately weighed sample of the fuel to be tested is enclosed in a vessel or bomb, in which it is burned, either in a current of Oxygen, or intimately mixed with some body which will give up Oxygen when the mixture is fired. The vessel is entirely surrounded with a known weight of water, and the rise in the temperature of this water, due to the combustion, is read on the thermometer. Knowing the relative weight of the fuel and the water, and the rise in the temperature of the latter, and making certain necessary corrections, the number of thermal units set free by the combustion of a given quantity of the fuel tested is exactly known. The operation is a simple one, requiring only ordinary care and precautions, and there is generally no reason to doubt the substantial accuracy of the results obtained.

Determining the Efficiency of the Furnace.—The calibration and reading of pyrometers, when dealing with very high temperatures, present considerable difficulties, and our knowledge of the specific heat of metals and gases at such temperatures is not as exact as could be desired. The heating power of the fuel is consequently much more accurately determinable than is the amount of its heat which is imparted to the steel.

As previously pointed out, when dealing with the subject of Soaking Pits, less than half a cwt. of good coal, when burned under laboratory testing conditions, sets free, during its combustion, as much heat as would suffice to raise a ton of steel from 50° F. to 2,000° F. There are, however, a great variety of circumstances which combine to render any approach to such results altogether unattainable in actual practice.

Natural Limitations to Efficiency of Furnaces.—In the first place, the temperature generated in the furnace must be greater than that to be imparted to the metal, for if the heat of the flame were no greater than that required in the metal there could be no flow of heat from the one to the other. The difference must be considerable, because the rate of transfer of heat falls off very rapidly as the temperature of the metal approaches that of the flame. And so, not only the steel, but also the mass of brickwork surrounding it, must be maintained at a temperature considerably above that to be imparted to the metal.

In addition to the heat requisite for the performance of the work, some must also be generated to secure rapidity of action, which is essential, apart altogether from commercial considerations. The external surface of the furnace, from which heat is continually escaping by radiation and conduction, is always inevitably much greater than that of the steel inside it which receives the heat, and the difference between the temperature of the interior of the furnace and that of the external air is always greater than the difference in temperature between the flame and the average heat of the steel.

Generally more heat is dissipated to the external air, by conduction and radiation from the exterior of the furnace, than is imparted to the steel within. This form of loss would greatly increase, if the furnace were worked more slowly.

Next, to obtain the maximum heat which the fuel is capable of giving out, combustion must be perfect. This involves the supply of nothing but Oxygen, and only such an amount of that as is theoretically necessary; any excess would merely pass through the furnace unconsumed, and, having been raised to the same temperature as the rest of the waste gases, must have absorbed some of the heat produced, and so lowered the flame temperature. But, seeing that no such supply of oxygen is available, we must use atmospheric air, of which only about 23 per cent. is active Oxygen; the remainder consisting of inert Nitrogen, or other incombustible gases, is raised to the temperature of the active Oxygen at its expense, while it merely serves to dilute it. It is the same with producer gas; less than 30 per cent. of it is combustible, the rest consisting of the inert diluting gases N and CO.

Though the use of atmospheric air and comparatively poor gas involves a loss of efficiency from a purely theoretical and thermodynamic point of view, it by no means follows that undiluted Oxygen and very rich gas, even if obtainable, would be commercially preferable. The oxidation of the steel and the wear and tear of the furnace would be very much greater, and with a rich gas combustion is so localised that the uniform heating of a large space presents considerable difficulties. An instance in point is the failure of water gas, when applied to open hearth melting furnaces, where a diffused heat is required, and its success for welding, where local heat of great intensity is needed. The long smoky flame obtained with producer gas is full of minute particles of glowing Carbon, which are excellent radiators of heat, and compensate largely for the loss due to imperfect combustion.

A further inevitable cause of loss is that, whatever precautions are taken to mix the air and gas together, it is found necessary in actual practice, if some of the gas is not to pass away unconsumed, to supply more air than is theoretically necessary for perfect combustion—rarely less than 20 per cent. in excess, even in the case of gas firing—rising sometimes to as much as 100 per cent. in excess, when solid fuel is burnt direct on the old form of fire-grate.

The result then is that, for every pound of coal burnt, at least 11 lbs. of waste gases must leave the furnace. During the process of combustion these gases have been inevitably raised from the temperature of the atmosphere, which we may call 50° F., to the temperature of combustion, which is about 2,500° F. As the specific heat of the waste gases is somewhere about 0·24, or one and a-half times as great as that of the steel heated by them, it is easy to see what an enormous quantity of heat passes away to waste, when they are rejected at so high a temperature. Sir William Siemens in 1873 pointed out that the useful work done in a Sheffield crucible steel melting furnace represented only $\frac{1}{70}$ of the heat given out by the combustion of the coke, and the actual efficiency of an ordinary puddling furnace is under 3 per cent.

Nor, in actual practice, is it possible even to attempt to recover the whole of this waste heat, because the column of gases in the chimney must remain sufficiently hot to provide the chimney draught required to carry off the products of combustion. Of the heat generated in any furnace, the less the proportion which is rejected by the chimney the larger is that which has been utilised in the furnace. A low chimney temperature is, therefore, the best proof of the efficiency of the working of the furnace—provided always that this reduction is not due to leakage of cold air into the furnace or chimney. The temperature in the chimney should, therefore, be no more than is needed to produce the requisite draught with sufficient margin to allow for contingencies—in practice generally between 300° and 700° F.

The heat passing off in this way is a source of loss which it is impossible to avoid, but throwing away the heat between the temperature of the furnace and that of the chimney is a serious loss, which can be avoided by methods to be discussed later.

Practically the whole of the heat generated in a bomb calorimeter passes through its metal walls into the water which surrounds it. Fortunately brickwork is about 400 times a worse conductor of heat than metal, and air is only $\frac{1}{770}$ the weight of water, and possesses much less power of absorbing heat, its specific heat being less than one-fourth that of water. Nevertheless, a great deal of heat escapes through the walls of the furnace, and constitutes the next most important source of loss. Much of this is inevitable, because the brickwork forming the roof and ports of furnaces working at high temperatures must be kept cool on the outer side, or the cost and trouble of frequent renewals will more than offset any saving in fuel.

If the pressure within the furnace is not the same as that outside, hot gases must rush out or cold air rush in, whenever the doors are opened to charge or withdraw material, in either case involving a loss of heat. If the flames rush out the workmen are likely to be injured, and to avoid this the damper is adjusted so as to maintain a pressure within the furnace as little below that of the surrounding atmosphere as possible. By inattention to this a careless furnaceman may admit so much cold air into the furnace as to cause very serious loss.

These are the chief reasons why the steel in the furnace can never absorb anything like the same proportion of the heat yielded by the fuel as is absorbed by the water surrounding the calorimeter, but there are other minor sources of inevitable loss. H, when burned with O, forms water vapour, which is cooled down in the calorimeter to a temperature little above that of the atmosphere, and thus the latent heat in the steam is transferred to the water, a condition quite impossible in a furnace discharging its products of combustion at a temperature above 212° F. Fuel which falls through the grate incompletely burnt is another form of loss which sometimes is very considerable; and the heat contained in the ashes removed from the grate cannot be recovered.

Recovering Waste Heat.—The main source of loss, which is moreover largely avoidable, consists in throwing away the heat contained in the waste products between the furnace and the chimney.

There are three distinctly different methods of utilising this. First, it may be used to preheat the cold steel; secondly, to preheat the air used for combustion, in both cases returning to the furnace heat which would otherwise be lost; and thirdly, it may be used to heat something entirely independent of the furnace itself.

In the first case, the steel does not enter the combustion chamber until it has been heated by the waste products very nearly to its full temperature. By thus reducing the work to be done in the combustion chamber, a much greater quantity of steel can be heated in it in a given time, and the weight of gases leaving the furnace per ton of steel heated is, therefore, much decreased, and, incidentally, their temperature is sufficiently reduced before they reach the chimney. This transfer of heat directly to the steel is theoretically correct, and its efficiency is proved by the previously quoted low consumption of fuel obtained in a continuous furnace. Unfortunately, the principle is not easily applied when pieces of varying size and weight have to be heated.

The second method, transfer of waste heat to the cold air, may be effected through the walls of tubes or passages of metal or fire-brick, the waste products being on one side and the air on the other side of a partition. As far as practicable, the two streams should flow in contrary directions, so that the coldest air may receive its heat from the coolest portion of the waste gases, and leave the hottest portions to heat the already partly heated air. The air and gas flow continuously each in its own direction. Provided only moderate heat is required in the furnace, this form of construction is cheap and simple, but when the waste gases are at a high temperature the life of the walls of the "recuperator" pipes is very short, sometimes only a few weeks, and the "regenerator," as introduced by Sir William Siemens, and already described, is almost a necessity.

As the heat in any recuperator or regenerator has to be communicated from the waste gases to the fire-brick, and from that back again to the air, and as the brickwork which is used to receive and give out the heat can never attain to the full heat of the gases, or the air to that of the brick, there is a double loss in the transfer, which does not occur when the gases can be used to heat the steel directly; steel moreover is a vastly better conductor of heat than brick.

The only way of applying the third method of recovering the waste heat —that is, its utilisation for some purpose outside the furnace itself—which is at all practicable in a steel works, is to absorb it by means of a boiler placed between the furnace and the chimney. The specific heat of water is the highest of any known substance except Hydrogen—about six times that of steel. It does not require to be raised to more than the comparatively very moderate temperature of high pressure steam—less than 400° F.—a temperature often below that of the chimney. The difference of temperature between the waste gases and the material to be heated by them is, therefore, considerable, and the rate of transfer may be proportionately rapid. Between the hot gases and the water to be heated by them there is interposed only a thin plate of steel, which is a good conductor of heat, while the circulation of the water within the boiler ensures the rapid and continuous removal of the heated water, and the replacement by that which is colder.

All these circumstances conduce to the efficient absorption of the heat, as is proved by the fact that ordinary steam boilers, when fired direct, will absorb 50 to 75 per cent. of the heat generated by the combustion of the fuel. The consumption of fuel by reheating furnaces fitted with steam boilers, when the waste heat is utilised in this manner, as will be seen from the figures previously given, prove that the furnace and boiler taken together are a more efficient means of utilising the heat given out from the coal than a regenerative furnace, and almost as efficient as a continuous one. The drawback to the arrangement is that the boiler and furnace are thrown out of use, if one of them needs repair, and the repairs to such boilers, owing to the high heats in the furnace, are usually heavy, and the boiler requires a man to watch the water supply.

There are considerable practical inconveniences in having boilers dotted about in various situations wherever a furnace is wanted, instead of all being arranged in one battery under the charge of one man responsible for the whole, while the additional steam and feed pipes needed are a source of trouble and loss of steam. It is these considerations, rather than any lack of thermal efficiency, which are responsible for the gradual abandonment of furnace-fired boilers.

Experiments to Determine the Efficiency of Furnaces.—While it is possible to measure directly with more or less accuracy the quantity of heat absorbed by the metal, and rejected by the chimney, the extent of the other respective sources of loss has usually to be approximated by lengthy calculations, and the date on which these are founded are not free from doubt. The difference between the sum of all the figures found, and that which the fuel is theoretically capable of furnishing, is regarded as lost by radiation and conduction.

M. Kraus[*] arrived at the conclusion, from experiments made at the Sougland Iron Works, on a Siemens reheating furnace, that the distribution of heat was as follows :—

Conversion of fuel into gas, ...	31·7	per cent.
Absorbed by the charge, ...	16·5	„
Lost by the chimney, ...	7·7	„
Lost through the walls of the regenerator, . .	8·6	„
Lost by radiation and conduction from furnace, .	35·5	„
	100·0	„

D. K. Clark[†] came to the conclusion that the distribution of heat in an ordinary reheating furnace heating iron piles and fitted with a boiler to recover the waste heat was—

Absorbed by the iron, ...	9·5	per cent.
Retrieved by generating steam, ...	33·0	„
Lost by the chimney, ...	38·0	„
Lost by radiation and conduction, . . .	19·5	„
	100·0	„

If more modern figures for the specific heats, &c., were employed, the efficiency of both these furnaces would be very materially reduced.

So little has been done in the direction of determining experimentally the efficiency of reheating furnaces that we are driven to infer what is their actual efficiency by examining the figures obtained by other furnaces of somewhat similar types.

Major Cubillo,[‡] experimenting with a puddling furnace, which does not differ materially from the old-fashioned reheating furnace, fitted with a modified form of Boetius gas producer, and using air slightly warmed before use, arrived at the following figures :—

Heating and fusion of iron, ...	2·90	per cent.
Fusion of slag and absorbed in other necessary chemical changes, ...	6·10	„
Heat in ashes, ...	1·11	„
Lost in the chimney gases, ...	42·14	„
Radiation and conduction, ...	47·70	„
	99·95	„

Campbell,[§] comparing one experiment made by Von Jupner on a Siemens melting furnace, with two experiments made by himself on other Siemens furnaces used for the same purpose, arrives at conclusions which may be stated in the following form :—

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[*] *Annales du Génie Civil*, 1874.

[†] "Fuel, its Combustion and Economy," p. 262.

[‡] *Iron and Steel Inst. Journ.*, vol. i., 1892, p. 245.

[§] *The Manufacture and Properties of Iron and Steel*, Campbell (1907 edition), p. 149.

	Von Jupner.	Campbell.	
		No. 1.	No. 2.
Lost as Carbon in ash, ...	25·9	5·6	2·1
Lost in producing the gas, ...	23·4	27·6	19·5
Absorbed by the charge, ...	11·7	11·5	19·4
Lost by the chimney, ...	14·4	12·1	20·5
Lost by radiation and conduction, . . .	24·6	43·2	38·5
	100·0	100·0	100·0

It should be understood that the heat lost in the formation of the gas is not peculiar to gas firing. Most of it represents the heat absorbed in producing the change of state in the fuel from the solid to the gaseous form, and would occur if the fuel were burned direct, but could not then be separately stated. Whatever method of firing is employed, the fuel must be converted into gas during combustion.

Comparison of the Various Systems.—Nothing perhaps is more difficult than to make accurate comparisons of the work done by reheating furnaces. It is not even possible to compare the results obtained with the same furnace in different works, because the work done is hardly ever identical in any two instances, and when the comparison has to be made between furnaces working with fuel obtained from localities widely separated, no definite conclusions can be expected. Many of the most startling and confusing discrepancies are no doubt due to the care and skill, or want thereof, displayed by the furnacemen, which, particularly in the case of direct fired furnaces, may vitiate any results. Experiments of short duration will undoubtedly show what a furnace can be made to do, but as such experiments are usually undertaken by the inventor of the furnace to show what it can accomplish, he naturally makes the trial when the furnace is in the best possible condition, and the results so obtained are no criterion of what the same furnace would do when worn, even in his own hands; much less is it any evidence of what it may be expected to do in daily work in the hands of men who are deficient in the knowledge which a highly skilled experimenter possesses. Again, should the proprietor or manager of the works, for any reason, take an exceptional interest in the working of the furnace, or indeed of any other particular portion of the plant, he will concentrate his attention on that special item, often to the extent of ignoring how the increased efficiency of the particular appliance in question, may be more than neutralised by loss in other directions. For this reason, a mere statement of fuel consumption at the furnace may be exceedingly misleading, as it is quite possible to lose more by broken rolls, or the exertion of unnecessary power in rolling, with its attendant waste of steam and wear and tear of machinery, that the saving of the whole of the fuel burned at the furnace could justify; the expenditure of a little more fuel in reheating may often prove a sound economy in the end.

Nevertheless, it is possible to draw certain broad conclusions from the frequently contradictory returns.

1. Intercepting the heat carried up the chimney, whether done by boilers in direct fired furnaces, or by regenerators or recuperators in gas furnaces, will always afford an economy of 40 to 60 per cent.

2. The poorer the fuel the more necessary it is to gasify it before use, hence doubtless the greater popularity of gas-fired furnaces on the Continent.

3. It is much easier to make use of the waste heat in gas furnaces, both for heating the air for the producer and for combustion.

4. Gas-fired furnaces are more easily managed than direct fired ones, give a more uniform heat, and, owing to the possibility of working with a less oxidising flame, cause 1 to 1½ per cent. less loss of the steel heated.

5. This reduction in furnace waste will usually pay for the additional interest charges on the more costly gas furnace, because its repairs are usually less expensive, the temperature being more uniform. It is to be remembered that the value per ton of the steel heated is generally eight to twelve times that of the fuel used to heat it, so that a saving in furnace waste of 1 per cent. is often worth as much as 1½ to 2½ cwts. of slack.

6. Where a low temperature only is required, as, for instance, in the direct firing of boilers, there is not sufficient saving to justify the employment of costly gas-making appliances.

As regards the choice of any particular form of furnace, it is generally more a matter of convenience than economy. Unfired soaking pits, if used at all, are most suitable for Bessemer works, where the casts are made at very regular intervals; but at open hearth plants, where furnaces "come on," and require tapping at very irregular intervals, so that the supply of ingots is not regular, the pits usually require to be heated: as a battery of gas producers already exists for working the melting furnaces, it is convenient in that case to take gas from them to heat the pits. Ingots having flat bottoms on which to stand, are in any case best heated vertically, because slag and scale run off, and do not remain on the underside to be rolled in, as is the case where they are laid horizontally on a furnace bed; moreover, there is no cold side to the ingot to cause trouble. Slabs and billets having sheared ends, not being able to stand on end, must naturally be laid flat, and be charged horizontally through doors on the side of the furnace, unless the roof is raised, as in the case of the Moor furnace. For heating pieces of varying weight, a reversing gas furnace is most convenient, but if the pieces are all precisely alike, the inclined furnace is a very suitable means of ensuring that every one shall be similarly heated. Indeed, Mr. Morgan contends that a continuous mill cannot be properly worked, unless a continuous furnace is employed for heating the material.

Whatever furnace is used it must bring the material up to the right temperature, and must heat it uniformly, this being of vastly greater moment than a few pounds more or less of fuel. If one side of a piece is colder than the other, it will not extend so much when in the rolls, and the bar will leave the mill crooked, causing much trouble in turning it over and handling it. Nor must the outside only be hot, so that it rolls, as the men say, "like as it had a bone in it." The rolls always spring, and the housings stretch appreciably, so that if one end of the piece rolled is much colder, it will be thicker than the other, when it leaves the mill; this is a constant source of trouble with wire rods, and thin strip, which cool so rapidly that the last end is always colder, and therefore thicker, than the first.

Finally, the question of getting the material into and out of the furnace has an important influence in deciding the type of furnace to be adopted, the charging and drawing often costing more than the fuel used in heating, the invention of the soaking pit being in this respect an important step, as it enabled the vertical furnaces to be easily charged and drawn with existing ingot cranes. The charging and drawing are fully dealt with in the following chapter.

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