her sailing qualities, or affect her should she take the ground or run foul of ropes, etc.; (7) should anything happen to the rudder, she can be steered with the turbine alone.

The action of the turbine will be at once understood by reference to our engravings. An inlet scoop is provided on the center line of the boat of sufficient area to admit of a very large quantity of water running freely into the turbine, the entrance to the scoop being protected by means of iron bars in the shape of a grating, which will prevent the passage of anything foreign of sufficient size to interfere with the working of the turbine. The water having passed round is discharged through the valves shown at either end, and, according to the position of these valves, either through the pipes leading forward or aft, as it may be desired to propel the boat in a direction ahead or astern. The working of these valves is in the control of the commander of the boat, who can manipulate them together or separately as he will. He can discharge through the pipe toward the bow, on the starboard side, and through that toward the stern on the port side, and so turn the boat round almost, if not quite, on her own center. He can discharge from both sides, astern, and propel his boat ahead at full speed, or he can allow a certain amount of water to pass through the pipes leading toward the stern, and so check her speed, or he can reverse altogether at his own will and without reference to any other soul on board, and all the time the engines are delivering water through the turbine at the rate of sixty tons a minute. The arrangement of inlet adopted effects a saving of power over an ordinary flush inlet in a ratio of 18 to 25. It is securely protected by—in addition to the grating before mentioned—an elm side keel on either side, which also serve the purpose of keeping the boat upright when she takes the ground.

This type of boat having been adopted, it only remained to fit the machinery into a vessel sufficiently strong, light, seaworthy, handy, and fast. Apparently neither time, nor pains, nor expense was spared in order to obtain a boat with the greatest possible strength compatible with lightness. The very best steel procurable was employed in her construction, having been submitted to the severest cold tests; indeed, so rigidly was this insisted upon, and so close was the inspection, that the hearts of the steel makers were nearly broken before material of a sufficiently excellent character was produced. The riveting is a special feature of the boat, being in excess of that usually employed in torpedo boats and similar vessels. Where a torpedo boat has double riveting, the lifeboat is triple riveted, and there is no single-riveted seam from stem to stern, either inboard or in the hull of the Duke of Northumberland. The strength and seaworthiness are still further amplified by a complete system of subdivision of longitudinal and transverse water-tight bulkheads, giving in all fifteen water-tight compartments, each of which can be rapidly drained by bilge pumps and steam ejectors.

Great attention was paid to insure stability, and several tests were made, one being of a highly practical nature. All the weights being placed on board, a heavy parbuckle was passed around the vessel. The end of this was fastened to a powerful steam crane furnished with a dynamometer, and the boat was then inclined until she lay completely on her beam ends. In this position lack of stability would have been apparent by her turning entirely over, which she was free to do, but so confident were the designers of the accuracy of their calculations—which showed righting powers up to 110°—that two members of the firm remained on board during the whole of the experiment. The final trials—official—to prove the boat's great handiness in maneuvering, sea qualities, speed, etc., took place on the river between Blackwall and Gravesend on July 24.

One of the greatest advantages of the boat is that it can be entirely maneuvered by one man, who has never to give an order to reverse his engines, and never to wait until that operation is completed before the vessel is again under his command. By merely turning the handles which control the delivery from the turbine he can go ahead or astern, slowly or at full speed, as he wishes, and as he can also steer his ship to a nicety, he is quite independent of a coxswain. Many times during the trial under notice was the service of a coxswain dispensed with, and the boat was freely maneuvered in and out amidst barges, boats, and steamers by turbine alone. The speed of the boat is sufficiently good, as under ordinary circumstances, and when not unduly pressed, she can do a good nine knots; but with a heavy forced draught pressure, when it is necessary to drive her, this can be considerably increased, as no doubt it would during a run out to a wreck. It is hardly necessary here to point out the great advantage the boat possesses in that she brings a perfectly fresh and unexhausted crew to a wreck, and is thereby enabled to render much more efficient service than could be expected from a crew much exhausted by hard rowing and severe buffeting about in an angry sea.

The boat was not run over the mile on the occasion of her trial under notice, but her maneuvering powers were severely tested. Going at full speed, she made with rudder a half circle in thirty-five seconds, and the full circle in fifty seconds. Going slowly with rudder and turbine, she made the full circle in forty seconds, and with turbine alone in fifty-two seconds. By working the turbine levers on deck, she was brought to a dead stop from full speed in thirty-two seconds, and from dead stop she attained full speed in four seconds. These tests were made several times, and always with the greatest accuracy, and they prove conclusively how entirely the vessel is under control of the officer on deck, without necessitating any communication with the engine room. The boat is also rigged for sailing, carrying a lug sail and jib, and no doubt can be sailed satisfactorily. Her mast is fitted into a tabernacle, and when not wanted can be lowered between the two funnels into a suitable iron crutch. Much attention has been devoted to the steering gear, which, for additional security, is twofold, viz., yoke lines, and a wheel in connection with a well arranged patent screw gear. The rudder is Hickman's patent, but for this particular boat it is constructed so that the lower part rises and falls automatically should it touch the bottom or any wreckage or other obstacle. The anchor is of the Institution's pattern. It is made fast to 120 fathoms of 5 in. manila, and is worked with a handy little cat davit.

Accommodation for a shipwrecked crew is provided in a spacious well just abaft the engine room, which will carry about thirty passengers, and around which a comfortable and sheltered seat runs. This well is fitted with large valves, through which any water taken on board is freely discharged; and numerous scupper holes, with non-return flaps, are also fitted. The seat running round is formed of teak lockers, in which much can be stowed. Under the deck of the well are two tanks, capable of holding water equal in weight to that of a shipwrecked crew; and in order that the trim of the boat may be kept constant, these tanks are kept full when running out to a wreck, and only pumped out when the crew to be saved is on board. The remainder of the top of the boat is covered with "corticine," which gives a firm grip to the foot, and greatly reduces the danger of being thrown by heavy rolling.

The Royal National Lifeboat Institution was established in 1824, and from then until the end of 1889 it has the magnificent total of 34,670 lives saved placed to its credit, a fact which entitles it to the heartiest support from every soul in the three kingdoms who is connected, directly or indirectly, with those who go down to the sea in ships, and which ought to establish its claim to that voluntary contribution on which it depends for its very existence. It at present possesses a fleet of some 293 boats on the coast.—*The Engineer*.

(Continued from SUPPLEMENT, No. 769, page 12283.)

WORKING LOCOMOTIVES WITH PETROLEUM FUEL.*

By Mr. THOMAS URQUHART, Locomotive Superintendent, Grazi and Tsaritsin Railway, Southeast Russia.

Effect of Petroleum Fuel on Boilers.—Several slight casualties which took place when the author's coal-

engine and tender repairs per thousand axle miles of trucks, wagons, or carriages (not locomotives) during the twelve years 1876 to 1887, forming part of Table VI. and Fig. 31, and it is seen that in 1882, the last year in which coal was used alone, the repairs cost 4.7 shillings, while in 1887, when burning wholly petroleum refuse, the cost had fallen to 2.3 shillings, being a reduction of 51 per cent. The petroleum flame produces in reality no more detrimental effect on the fire box and tubes than a wood flame, owing to the protection afforded to the more important parts by the firebrick lining. Moreover, petroleum refuse does not contain any sulphur, which is so prevalent in all coals and so injurious to the metal of the fire box and tubes.

Plating up of Fire Door.—Since the discussion of his former paper the author has availed himself of a suggestion then made by Mr. Joseph Tomlinson (Proceedings 1884, page 299), that in a locomotive burning petroleum there need be no firing door whatever to the furnace.

Although adequate reasons were given at the time why it would not then have been expedient to do away with the firing door, Fig. 33, yet, now that the petroleum refuse promises to be the fuel of the future for many years to come, the author has already plated

RELATIVE EVAPORATIVE EFFICIENCY OF SEVERAL SECTIONS OF LOCOMOTIVE BOILER.

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burning locomotives were first fired with petroleum refuse led him to imagine that in consequence of the heat being so intense the cost for incessant repairs would be even greater than with coal. For instance, nuts screwed on the lower ends of the roof stay bolts dropped off, owing to the very intense heat. In order to insure perfect safety, these bolts are now made with solid heads, not welded on, but forged solid by upsetting the end of the bolt in forging.

In Fig. 32 are shown the Belpaire bolts so forged with a solid head, as used in the author's eight-wheeled locomotives. Five years' experience has shown that since the introduction of petroleum refuse as fuel the cost of repairs has been considerably diminished from what it was previously when firing with anthracite, which is particularly destructive to the fire boxes and tube ends. In Table V. and in diagram, Fig. 30 (page 12285 ante), is shown the comparative cost of

up the firing door both inside and outside, Fig. 34 thus adding 2½ square feet of very effective heating surface to the fire box, and obviating all possibility of leakage at the fire door ring, and making a neat job altogether. A sight-hole is made through a hollow stay bolt, as shown in Fig. 34, and a manhole in the bottom of the asphal affords access to the interior of the fire box for repairs and inspection.

Verderber Boiler.—With regard to the further suggestion made by Mr. Tomlinson and Mr. Tomkins (Proceedings 1884, pages 299 and 314), that a more special construction of boiler should be employed for petroleum firing, the author is of opinion that it would be difficult to mature a better design than the present locomotive boiler for working at high pressures and giving great power in a comparatively small space. By way of experiment, however, without discarding the old locomotive boilers, the author has lately adopted a construction of boiler devoid of any internal fire box, which was first introduced by Mr. Stephan Ver-

* Paper read before the Inst. of Mechanical Engineers.—*Engineering*.

derber in 1879 on the Hungarian State Railways. A somewhat similar arrangement had been introduced in 1827 on the St. Etienne and Lyons Railway in France by Mr. Marc Seguin.

The Verderber boiler, as shown in Figs. 35 and 36, consists of a cylindrical shell, forming the boiler proper, and of an external fire box or furnace lined inside with fire brick. The fire box is completely separated from the boiler proper, and the only way in which it contributes directly to the evaporation of the water is by its radiation of heat to the tube plate. The fire brick lining causes the whole fire box surface to par-

as rapidly upon the back ends of the tubes for one third of their length. And to facilitate its removal some of the bottom tubes are omitted and a mudhole is provided in the boiler near the fire box. As the water space in the Verderber boiler is considerably diminished by the removal of the internal fire box, it is requisite, in order to maintain the same rate of evaporation, that the feed should be effected continuously by an injector adjusted for the mean rate of evaporation, so as to prevent too sudden fluctuations of water level.

A lagging of 2 in. thickness of slag wool outside the

to maintain a regular temperature under irregularity of firing. The loss of heat by radiation from the furnace is decreased, in consequence of the fire brick lining, and of the fire door not having to be opened for firing. The increase in the number of tubes that can be got into the boiler, along with the extra heating surface due to the lengthening of the whole of the tubes by 2 ft. 1½ in. at the fire box end, more than compensates for the loss of fire box surface, although the latter surface is admittedly more profitable than that of the tubes for evaporation per square foot, as fully demonstrated by the experiments recorded by M.

WORKING LOCOMOTIVES WITH PETROLEUM FUEL.

take of the advantages of the fire brick arch already in general use in coal burning locomotives. The results of trials made with two locomotives, which differed only in one of them having the fire box thus modified, showed that there was an appreciable economy with the altered firebox, and that with the same combustion of coal the blast orifice must be closed more with the fire brick furnace, because the temperature in the furnace is some 630 deg. Fahr. higher, and consequently the volume of the gases passing through the tubes is increased nearly 35 per cent. The sediment ordinarily settling upon the fire box plates here settles

fire box shell keeps the heat in sufficiently to allow of holding the hand upon it. The fire brick furnace has run five months without any shaking, the boiler making steam as usual. When in the shops for repairs, the cost of altering an engine to this plan would be not more than 50%, whereas to renew a copper fire box in a large locomotive, with its multitude of stays and roof bolts and rivets, costs 250%, or five times as much.

The large extent of the fire brick lining, while preventing damage to the boiler plates, tends also to insure the complete combustion of the liquid fuel, and

Couche,* which are presented in a condensed form in Fig. 37.

Having occasion to renew some worn-out copper fire boxes, the author adopted a modification of the Verderber furnace for two locomotives, goods and passenger, fired with petroleum refuse, which have now been running over two years. From his own observations with these two locomotives he would have no hesitation in using the plan for all his boilers, as there is much about it which, in his opinion, recommends it for firing

* "Permanent Way, Rolling Stock, and Working of Railways," by Ch. Couche, vol. III.

with liquid fuel. In Figs. 38 to 41 is shown the furnace of the goods engine, and in Figs. 42 to 45 that of the passenger engine. It will be seen that the brick arch forming the roof of the Verderber furnace is here replaced by a crown sheet which not only increases the water space of the boiler and adds some very useful heating surface, but also appears to the author to be indispensable, for the two following reasons: First, there could be no guarantee that the brick roof of the Verderber furnace would not come down some time while running, and so bring the train to a premature stop on the line. Secondly, the crown sheet having water on the top of it carries the water level back again to the original back plate of the fire box, where all the water gauge fittings are ordinarily mounted. The consumption of fuel per train mile with these fire brick furnaces is no more than with ordinary locomotive boilers having internal fire boxes. And the author is indeed disposed to conclude that there is a decided economy in their favor on this score. In comparison with engines of the same class but with ordinary fire boxes, the mean of several trials made with the Verderber fire boxes gave an economy of eight per cent. in passenger engines and of four per cent. in goods engines, in saving of fuel per train mile.

For greater satisfaction these trials are to be continued for one year in the regular train service. But the greatest advantages of the fire brick furnaces are the reduction in first cost and in cost of maintenance, and the shorter time the engines have to stand in the repairing shop, inasmuch as the boiler repairs amount simply to changing the tubes and renewing the brick lining of the furnace. Even with coal, with which Mr. Verderber's experiments were made, the evaporation attained per pound of fuel was equal to that with the ordinary firebox. The object of his plan, however, was not to effect economy in fuel, but rather to obviate the incessant damage to fireboxes and the consequent stoppages, which were caused by rapid incrustation in the water spaces surrounding the firebox, from the very bad feed water he had to contend with; and this object he fully attained.

The six-wheel coupled goods locomotive, of which the furnace is shown in Figs. 38 to 41, was altered in August, 1885, and has been running ever since; it had previously, when burning coal, 151 tubes $2\frac{1}{2}$ in. in diameter, and a total heating surface of 1,248 square feet, including 82 square feet in the firebox; it has now 157 tubes of the same diameter, and 2 ft. $1\frac{1}{2}$ in. longer, which, with 13 square feet in the firebox roof, give a total heating surface of 1,410 square feet, or an increase of 162 square feet. As shown in Fig. 41, the firebrick lining is secured to the firebox shell by means of vertical angle irons riveted to the shell plates and embedded in the firebrick.

A special form of boiler for petroleum firing, designed by Mr. Paschinin, which may be described as something like a Cornish boiler having a larger internal firebox with a flue extending thence along the bottom of the barrel to the smokebox, and with tubes added above the flue, appeared to the author at the time of its suggestion to involve the serious structural defect that the expansion and contraction of the long flue, which would be exposed to much greater heat than any other part, must tend to tear its end connections to pieces in the absence of any arrangement for taking up the expansion. This proved to be the case with a boiler so constructed for the Transcaucasian Railway at the Kolonna Locomotive Works, near Moscow. Besides presenting so dangerous a defect, the few trials made with the engine showed that this boiler consumed more fuel than an ordinary boiler of the same class of engine; and it is therefore looked upon as a complete failure, at least for locomotive purposes.

Blower for Air Supply to Furnace.—The suggestion made by Mr. Crampton (Proceedings, 1884, page 307), that the air should be absolutely injected with the steam and oil, and mixed with them in the exact proportion required for perfect combustion, has been carried out by the author by combining the spray injector with an induction air blower, as shown in Fig. 46. The spray injector itself is the same as that ordinarily used, with simply the addition of three concentric nozzles, fixed one in front of another, so that the steam jet passing through them draws along with it a supply of air entering through the annular spaces between the cones. In a less developed form this idea had indeed already been adopted in his first and subsequent practice; but with the blower shown in Fig. 46 sufficient air is supplied for a full fire, even if the ashpan doors are closed altogether. This blower was fitted to a six-wheeled compound goods engine which had been altered from an ordinary locomotive during the summer of 1887.

It is more especially necessary in a compound locomotive, because the blast in that case is very soft and makes only two beats per revolution instead of four, whence some difficulty was encountered in getting the adequate supply of air into the fire box by means merely of the draught produced by the exhaust. The blower was, therefore, resorted to, whereby the difficulty was fully solved. As, however, no appreciable advantage in fuel economy was found to result from its use, while at the same time it was terribly noisy in working, it has now been discarded.

Compressed Air for Spray Injector.—Experiments were also made on the use of compressed air instead of steam for the spray injector. An air pump was fitted on the front cylinder cover on the right-hand side of a goods locomotive, so as to be under the driver's eyes; it was worked by the tail end of the piston rod, which passed through the cover and was fitted with a piston 6 in. in diameter, making, of course, the same stroke as the steam piston. The air pump was single acting, and compressed the air up to six atmospheres into a receiver provided with a spring safety valve. Thence the compressed air was conducted through a coil of 2 in. piping inside the smoke box, thus picking up a good deal of waste heat, which it then returned through the spray injector into the fire box. With this arrangement the engine ran two months, but no appreciable reduction in consumption of fuel was noticed, while a good deal of the engine power was exerted in compressing the air; and the air pump being only on one side, its working tended to give the engine a lurch sideways, which was noticed when running slow. A more serious fault, however, of the arrangement was that, when the engine was running up an incline, and the speed was consequently

TABLE VII.—THEORETICAL EVAPORATIVE VALUE OF PETROLEUM FUEL AND OF COAL.

Fuel.	Specific Gravity at 32 deg. Fahr.	Chemical Composition.					Theoretical Evaporation.	
		Carbon.	Hydrogen.	Oxygen.	Sulphur.	Heating Power. British Thermal Units.	Pounds of Water per Pound of Fuel.	
							From and at 212 degrees Fahr.	At 8½ Atmo. Effective Pressure.
Pennsylvania heavy crude oil.....	S.G.	per cent.	per cent.	per cent.	per cent.	units.	lb.	lb.
Caucasian light crude oil.....	0.886	84.9	13.7	1.4	...	20,736	21.48	17.8
Caucasian heavy crude oil.....	0.884	86.3	13.6	0.1	...	22,127	22.79	18.9
Petroleum refuse.....	0.938	86.6	12.3	1.1	...	20,138	20.85	17.3
Good English coal (mean of ninety-eight samples).....	0.928	87.1	11.7	1.2	...	19,832	20.53	17.1
	1.380	80.0	5.0	8.0	1.25	14,112	14.61	12.16

slow, as low, indeed, as eight miles per hour, too little air was then pumped into the receiver, although it was just at this time that a strong fire was required for supplying the extra quantity of steam needed on the incline; whereas in running down an incline the opposite was the case, too much air being compressed when none at all was required, as the fire was stopped altogether and the brakes were applied. Even if this two-fold objection should be obviated, the author is of opinion, from what could be observed during the two months' trial, that the complication and cost of the extra gear would not be recouped by a sufficient economy in fuel consumption. The idea has, therefore, been completely abandoned, at least for locomotives, the boiler steam being found the most convenient agent for injecting the spray of petroleum refuse into the furnace.

Evaporative Value of Petroleum Fuel.—In Table VII., which is a slightly modified reproduction of one given in the former paper (Proceedings, 1884, page 274), is shown the theoretical evaporative value of petroleum fuel in comparison with that of coal, as determined by Messrs. Favre and Silbermann. At an effective pressure of $8\frac{1}{2}$ atmospheres or 125 lb. per square inch, the highest evaporative duty of the petroleum refuse used in the author's locomotives on the Grazi and Tsaritsin Railway has been 14 lb. of water per pound of fuel; in comparison with the theoretical evaporative value given in Table VII. of 17.1 lb., the actual efficiency of the fuel is, therefore, nearly 82 per cent. The only way of increasing the efficiency of liquid fuel appears to the author to be to make it into crude gas and work it on the regenerative principle; but such a plan, however successful it might be in metallurgical furnaces or indeed for stationary boilers, is quite inapplicable to locomotives.

Copper Tubes.—By way of experiment, with a view to raising the efficiency of petroleum fuel, the author fitted two locomotive boilers with solid drawn copper tubes of 2 mm. (0.079 in.) thickness and $2\frac{1}{2}$ in. diameter, having thick copper ferrules brazed on the ends next the fire. With these tubes steam is made very readily, so much so that the blast pipe had to be increased in area. As these engines have only recently commenced running, the economy in fuel has not yet been ascertained; but the author has no doubt the copper tubes will produce an appreciable economy, and he will be happy to communicate the results as soon as they are fully known.

Lubrication.—The petroleum refuse burnt in the locomotives is also found to make an excellent lubricant, and for some years past nothing else has been used for the wagons and tenders, thus reducing expenditure considerably. The only thing necessary is to get it pure, without sand or grit; and, fortunately, this can readily be managed by skimming the cream off the top of the reservoirs in summer after they have stood some time for settling. In this way a very pure oil is obtained for lubrication, although black in color.

From laboratory experiments made at Borisoglebsk on the comparative qualities of petroleum refuse as a lubricant under varying conditions of temperature, it was found that in summer it can be used by itself as a lubricant for carriages, trucks, and tenders, and also for all pumping engines and other rough machinery. As cold sets in, it is indispensable to add to the petroleum refuse from 30 to 50 per cent. of solar oil, a mineral oil which is one of the products of distillation from crude petroleum, and has a specific gravity of 0.860 to 0.870 and a flashing point of 100° Cent. or 212° Fahr. As petroleum refuse by itself becomes in cold weather too thick to rise through a wick by capillary attraction, solar oil is added in proportion to the coldness of the atmosphere, so as to preserve the necessary fluidity.

In place of the usual plan of testing the value of a lubricating oil by measuring the external friction of rubbing surfaces lubricated therewith, the novel idea occurred to Prof. N. P. Peteroff, professor of mechanics in the Technological Institute, St. Petersburg, of measuring the internal friction among the molecules of the oil itself. For this purpose a sample of the oil to be measured is passed with a definite pressure through a glass tube of $1\frac{1}{2}$ mm. = 0.06 in. bore and 505 mm. = 20 in. length, which is immersed in a water bath kept at various temperatures; and the friction is determined by the time required for passing a measured quantity of oil through the tube. The results, expressed originally in milligrammes of pressure per square millimeter of bore of the glass tube, are represented by the curves plotted in the diagram, Fig. 47, in which the scale of pressure has been converted to hundredths of a pound per square inch of bore.

As a standard for comparison the friction of rape oil is taken, which is represented by the curve R R. Petroleum refuse used by itself, without admixture, gives the two curves, A and B, of which A represents the petroleum refuse used by the author in February, 1886, having a specific gravity of 0.904 at 20° C. or 68° F.; and B represents that used in July, 1885, having a specific gravity of 0.895 at the same temperature. The three curves, C, D, E, correspond respectively with admixtures of 30, 40, and 50 per cent. of solar oil; the two higher percentages are employed in very cold weather, while 30 per cent. is the admixture used in spring and autumn.

At temperatures of from 40° to 45° C., or 104° to 113° F., it will be noticed that the friction of petroleum refuse by itself in the line, B B, approaches pretty near that of rape oil in the line, R R; while the addition of

30 per cent. of solar oil, as shown by the line, C C, reduces the friction to the same as with rape oil at the above temperature, thus rendering the train resistance consequently the same. Similarly, the lines, D D and E E, show respectively the same friction as rape oil at the lower temperatures of about 32° and 18° C., or 90° and 64° F.

Now that petroleum seems destined to occupy a prominent place in India as well as in many other parts of the world, these results in regard to its value as a lubricant can hardly fail to be of interest to engineers, irrespective of its use as a fuel.

ADDENDUM TO SUPPLEMENTARY PAPER ON THE USE OF PETROLEUM REFUSE AS FUEL IN LOCOMOTIVE ENGINES.

Scrap-welding Furnaces.—In Figs. 48 and 49 are shown a longitudinal section and end elevation of the larger of two scrap-welding furnaces, fired with petroleum refuse, which have been in daily use for about three years at the Borisoglebsk works, and are giving perfect satisfaction. The body of the furnace is of the usual reverberatory form, and in place of a fire grate it has three air spray injectors at the firing end, which are placed almost on a level with the bridge. Through these three blast injectors the whole of the air required for combustion is supplied. As no unconsumable particles exist in the fuel, no ash pit is required, and no cleaning is necessary during the working; hence the furnace can work continuously so long as the roof does not get burned out.

It also slags very freely, thus proving that quite sufficient heat is available for all practical purposes. The blast used is cold and from the ordinary smithy main. It was at one time contemplated to heat the air by the waste heat from the furnace itself; but being short of boiler power, the author had to utilize the waste heat from both these welding furnaces for heating a large elephant boiler erected close by, which now supplies almost sufficient steam for the steam hammers and rolling mill. The petroleum reservoir, R, is placed right above the larger furnace, in order that during winter the refuse may be kept in a liquid state by the heat radiating from the furnace; it supplies both furnaces through a separate pipe to each. Besides a main cock, M, on the pipe to each furnace, there are also three half-inch cocks, C C C, for regulating minutely the supply of fuel to the three spray injectors of the larger furnace.

The liquid trickling from these cocks spreads into a thin film upon an inclined shoot cast in one piece with the blast pipe, which terminates at the furnace end in a wide, flat tuyere, as shown full size in Fig. 50. The blast issuing from this broad rectangular orifice carries with it in the form of spray the thin flat film of petroleum dropping from the orifice above; and the jet striking against the low bridge, half a brick high, produces a thorough mixture of air and gas, the proportions of which are so accurately regulated that a perfect white welding heat is maintained in the furnace without any smoke being emitted. The larger furnace has three blast injectors, while the smaller requires only two. The same construction of blast injector is now used also in the tire fires, in place of the circular tuyere nozzles previously employed (Proceedings, 1884, Plate 59).

The great simplicity of the appliances for thoroughly utilizing liquid fuel for metallurgical purposes, even for forgings of the largest size, commends itself in any country where this fuel can be had at a cheap rate.

As no trace of sulphur exists in petroleum refuse, no deteriorating effect can take place upon the iron. With coal, especially Russian bituminous from the Donetz coal basin in South Russia, which is rich in sulphur, it is impossible to get iron of first-rate quality. In tests made on iron rolled from poor unwashed scrap welded with liquid fuel it was invariably found that a very homogeneous ductile metal of high quality was produced. As compared with coal, a saving is effected of 40 per cent. in weight of fuel, besides the output being considerably increased.

On Monday mornings three and a half hours are required for heating the larger furnace up to a white heat, with a total consumption of 540 lb. of petroleum refuse. On all other days in the week one and three hours are required, with a consumption of 125 lb. To make one ton of blooms in the larger furnace alone, from small unwashed scrap three times welded, requires a consumption of 17 cwt. of petroleum, with a loss of iron of from 18 to 20 per cent. In practice, however, both furnaces are at work at the same time, and the blooms are passed from one to the other when being hammered, thus keeping the heat up in blooms and furnaces and reducing the consumption of petroleum to 13 cwt. per ton of rolled bars of light sections.

Brass-melting Fires.—In Figs. 51 and 52 are shown a plan and vertical section of the two brass-melting furnaces using liquid fuel, which the author has also had in daily work now about three years with entire satisfaction. The same fires were formerly used with coke as fuel. They are of the well known make having drop bottoms, which, however, are not now used, as no unconsumed residue remains in the furnace. The same blast tuyere is used here as in the welding furnaces and tire fires. One is quite sufficient for each brass fire, and is set tangentially to it, as shown in the plan, thereby giving a whirling motion to the flame,

which, coming in contact with the white-hot fire brick lining, insures complete combustion of all the particles it contains. The blast used is cold, and supplied with an ordinary fan. Besides occasioning a much cleaner foundry, free from sulphurous fumes, the adoption of petroleum in place of coke has resulted in a sensible economy in fuel, as well as a saving of time in melting.

The results are as follows:

With coke, 40 lb. of brass castings were made with 35 lb. of fuel and 10 per cent. loss of metal, while with petroleum refuse 40 lb. of brass castings are made with 18 lb. of fuel, and only 6 to 7 per cent. loss of metal, and with 25 per cent. saving in time.

It is, of course, quite possible that a better arrangement could be made for this purpose. But, as in the case of locomotives, the plan here shown is the simplest and most direct way of applying the liquid fuel under existing circumstances, and the author has been so satisfied with the results that he has not seen any necessity for further experimenting.

THE ROCHE-SUR-YON COVERED MARKET.

IN the spring of 1886 the city of Roche-sur-Yon put up for competition a project for a covered market. It addressed the principal builders who were specialists in the matter, asking them to present both a project and a specification. As a result of this competition, and upon the report of the committee appointed by the municipal council to examine the work of the competitors, the project presented by Mr. Michelin, of Paris, obtained the majority of votes, and its author was charged with the carrying of it out. The work was pushed forward rapidly, and the market was recently inaugurated.

This market consists of a rectangular hall with a frontage of 98 and a depth of 130 feet. It is flanked by two lateral awnings 16 feet in width, giving a total superficies of 17,200 square feet of earth covered.

THE ROCHE-SUR-YON COVERED MARKET.

The interior arrangement is such as to meet the requirements and usages of the locality. There are 99 stalls, distributed as follows:

- 19 for butchers,
- 10 for fish dealers,
- 30 for fruit dealers,
- 40 for dealers in various provisions.

The awnings are designed especially for sheltering small country dealers—peasants who come quite irregularly. These arrive in crowds on market days in order to sell their commodities, fowl, butter, eggs, etc., and find a shelter under these awnings, which, on ordinary days, are used by the peddlers and itinerant merchants who travel about the city.

Spacious cellars situated under the extreme bays are used by the merchants as store rooms. These cellars are provided with compartments formed of iron lattice work. The floor is covered with Portland cement in order to facilitate washing.

The establishment of this market cost \$40,328.—*Le Genie Civil*.

[Continued from SUPPLEMENT, No. 769, page 12287.]

REFRACTORY MATERIALS.*

By T. EGLESTON, Ph.D.

MIXTURES AND TREATMENT.

THE clay, when mined, is left exposed to the air under sheds, and is cleaned and carefully dried, and is afterward mixed with the substances with which it is to be incorporated, which are classified by numbers, varying according to the size of the sieve holes through which they will pass. The quantity and quality of the mixture will determine the refractory nature of the material to be produced. A friable paste with large grains, and quite porous, resists a great heat. One with fine grains, close and compact, splits at a high

heat, especially if it is not homogeneous. The manner in which the mixture is made also influences the quality of the brick quite as much as the material. In some works in Belgium, after taking all the ordinary precautions to make the mixture perfect, it is submitted to a succession of shocks continued for some time, until it is found by experiment that the materials are perfectly mixed. It has been found by long experience that the bricks so made keep their form perfectly, while others made of exactly the same mixture in the ordinary way contract. The quantity and size of the mixture depend upon the size of the article to be manufactured. When coarse grains are used, greater thickness must be given to the sides of the articles if they are hollow, and they must be made larger if they are solid, thus giving a mechanical cohesion where a chemical one is wanting. The usual quantities of the mixture for bricks are three-fifths to two-thirds of the substances added to two-fifths to one-third of the clay, these quantities being determined by volume and not by weight. When coke dust is used, it does not seem to have any decided effect beyond one-tenth. The action of coke or graphite is to decompose the metallic oxides as they form, and thus prevent their union with the material of the crucible. Coke may be profitably used in the place of graphite when the ash is in small quantity, free from iron and highly aluminous. Beyond two to three per cent. of graphite cannot be profitably used, as it weakens the article and renders it liable to break. The mixture which gives the very best results for small articles is, however, worthless for large. It will generally be found that the pieces which crack up and down in drying have had too much material mixed with the clay, and those which crack laterally have had too much clay.

The very greatest importance is attached in some industries to not having a mixture made by a machine. In most places even to this day the inhuman method of heel treading is used, because more care is then exercised, or because, smaller quantities being mixed at

once, better results are obtained. The more the operations of mixing are repeated, the better the material, and it is undoubtedly true that with mechanical means such a homogeneous paste is not produced as can be made by human labor, because the whole object of the machine is to operate on large quantities at a time.

TEMPERING.

The paste made, and the article completed, it must be dried or "tempered." This is commenced in the open air, and, if possible, out of the draught. If the draught cannot be excluded, the place where the drying takes place is slightly heated, commencing at a temperature from 60 deg. to 70 deg. F., and keeping it up from twenty-five to thirty days, then increasing it from 80 deg. to 100 deg., leaving the article as long as possible, with an active ventilation, but the same temperature being kept up. The article should remain in a temperature of from 150 deg. to 180 deg. for at least six weeks. Bricks do not generally require so much care, but crucibles and retorts do. Long experience has proved that there is a great economy in conducting this process of tempering as slowly as possible, and that it influences materially the refractory nature of the article. It is found by actual experiment in crucible works that those crucibles made from the same mixture, tempered during six to eight months, last more than three times as long as those which had been tempered only two; so that in general, the older the article before being burned, the better. This desiccation, while, perhaps, it is the most important part of this manufacture, is undoubtedly the one most neglected. A poor article well tempered is often better than the best which has been hastily dried. By working rapidly, and filling up cracks as they form in a too rapidly heated drying house, with a very liquid material, in order to secure complete penetration, both time and money are lost. The material never lasts nearly so long as when slowly dried.

In the works at Andenne, in Belgium, large pieces, like glass house pots, are kept six months in the drying house before they are burned, and during this time the greatest care is taken to prevent draughts, so that no air colder than the drying room shall strike them. Leaving the door of the drying furnace open has been known to crack the pieces, which had been up to this point most carefully prepared and tempered.

EXPANSION AND CONTRACTION.

In reviewing the effects which the different elements which constitute refractory materials have, we find that the same element often produces exactly contrary effects, according to the proportion in which it is present, and that there is nothing anomalous in effects being so produced. Silica causes expansion when highly heated, so that the moulds in which the bricks are made must be smaller than the brick is to be. Every mixture has its own peculiar rate of expansion and contraction. This expansion not only takes place when the bricks are made, but if when used they are submitted to a higher degree of heat, they expand still further, and contract again on cooling to such an extent that at Dowlais the tie rods of the steel furnace are slackened when the furnace is getting into heat, and are tightened again as it cools. At Creusot the furnace casing is made so strong as to resist the pressure, so that the roof arch must rise and fall to allow for the expansion and contraction. When neutral brick must be had for any reason, it is mixed with just enough clay and burned brick to make it keep its form, and such a brick is generally less fusible, the less silica it contains.

FLUXES.

Alumina alone, or with silica in the proportion of thirty to thirty-eight per cent., is very refractory; but three per cent. of it in a silica brick makes it fusible. In clay, or pure, it tends to contract, and this tendency is greater as the alumina is in greater quantity, and the heat of manufacture has been low, but when it has been very highly heated at first, it afterward undergoes but little change. Though both silica and alumina affect each other so unfavorably, Bischoff found that four of alumina to one of silica, or two to one, or one to one, only sintered before the oxyhydrogen blowpipe, making masses with a granular fracture. One of alumina to two of silica was fusible like porcelain, but still somewhat granular. One of alumina to four of silica and one of alumina to six of silica melted like a thick enamel, which shows that the acid silicates of alumina are much more fusible than the basic. He also found that a mechanical admixture of alumina and silica was less fusible than the same amount in a natural combination, and that, in general, silicates already formed are more fusible than a mixture of their constituents. The general property of alumina, when mixed with other substances, is to bind them together. When combined with iron or other bases alone, it makes infusible aluminates; but if silica is present, it fuses more or less easily. It is generally conceded that the proportion of alumina in a brick should be between 10-20 and 25 per cent.

The alkalis in small quantity make a brick fusible. There is a great difference of opinion among those who have studied this subject with regard to the quantity. Mr. Snelus states positively that one per cent. of alkalis in an otherwise good material makes it too fusible to withstand high temperatures. Mr. Riley states, with equal positiveness, that he has found brick containing 2-73 per cent. of potash to resist the greatest heat of a Siemens-Martin furnace. It is probable that both are right, and that in the special cases alluded to the peculiarities were owing to the association of elements. In any case, a material with a very small percentage of alkalis cannot be used.

Lime alone is completely infusible; but in very small quantities in a clay it makes a brick fusible at high temperatures. Two per cent. of it with silica makes the most infusible brick known.

Magnesia in small quantities makes the clay fusible. In very large quantities it is very refractory. Alone, it is entirely infusible.

Oxide of iron, in the absence of alkalis, may be present in small quantities without seriously affecting a clay, unless it is to be used for melting steel. If alkalis are present, any proportion of iron would make such a clay worthless. If no silica at all is present, 5 or 6 per cent. may not damage it. In a silica brick 2 to 3 per cent. of iron makes the brick worthless. If the iron was always certain to remain in the state of a sesquioxide, its compounds would be much more infusible, and a large percentage would do no injury; but some of the sesquioxide is certain to become reduced to protoxide in the presence of reducing gases, and the result is a very fusible compound in the presence of silica. There is a still more deleterious and dangerous effect of iron in firebrick, because its effects are produced, not at a high heat, but at a comparatively low temperature. It is well known, from the researches of Bell and others, that when a brick containing iron is exposed, even at a low temperature, to gases containing carbon, part of this carbon is deposited near the iron; this has often not only caused the brick to lose its cohesion, but has even burst it, so as to throw down the in-walls of furnaces and the linings of flues. The presence of iron is, therefore, doubly to be dreaded, as in the presence of reducing gases it is quite as deleterious at low temperatures as at high.

As much as 1 per cent. of titanium has been found in some clays. Little is known about it, but it appears to act like silica.

Bischoff found that 20 per cent. of magnesia, 28 of lime, 47-1 of potash, or 40 of iron had exactly the same effect in making the clays fusible, and that when 4 and 2 of the different bases were used, the relation was striking, and in about the same order. The quantity of other substances necessary to make a compound fusible depends upon the quantity of silica present—the more silica, the less of the other substances. It will thus be seen that while the predominance of any one element will materially affect the nature of the materials, it is more the way in which the different ingredients are grouped together than their individual percentages which affects the nature of the brick, and frequently, above all these, the mechanical and molecular arrangement of the particles which determines its commercial value.

ESSENTIAL QUALITIES OF GOOD FIRE BRICKS, ETC.

The essential qualities of a good brick may be stated as follows: First, infusibility; second, regularity of shape and the power to retain it under all circumstances, which involves perfect uniformity of composition; third, strength to resist the different pressures required under different circumstances; and fourth, its cheap price.

* This article was written at the suggestion of the Committee on Refractory Materials of the American Institute of Mining Engineers, with a view of calling attention to the anomalies and difficulties of the subject. It was hoped that its discussion would eventually lead to the appointment of a commission, by the great metallurgical interests of the United States, to investigate the whole subject, since it is believed that a better and cheaper artificial product can be made than any now in use, and that many other important incidental results would be accomplished by such an investigation.—*Brickmaker*.