INCLINED RETORT COAL- AND COKE- HANDLING PLANT AT BRISTOL.

BY MR. WILLIAM STAGG, *Member*, OF BRISTOL.

It is estimated that fifteen million tons of coal are carbonized annually in gasworks in this country. It will be readily understood that the economical handling of this large quantity of material and of its principal by-product is of vital importance in gas undertakings, and it is hoped will afford a subject of interest to Members of the Institution. In Bristol, which was amongst the first of the provincial cities to light its streets by gas, last year nearly half-a-million tons of coal and coke were handled. The oldest works are at Avon Street, where there may still be seen a very interesting series of ten retort-houses built nearly a hundred years ago. In plan they present the form of a horse-shoe, with a large covered coal-store occupying a central position and opening into each of the retort-houses—all admirably adapted to the requirements of those days. They are a standing monument to the foresight and enterprise of the pioneers of the gas industry in Bristol.

For the greater part of the century that has passed since the introduction of gas-lighting, little was done to introduce strictly mechanical methods in the handling of materials. However, of late, various forms of machines for charging and discharging horizontal retorts, with their auxiliary coal- and coke-handling plants, have gradually come into use.

Charging and Discharging Machines.—The essential feature of the earlier charging machines is a long trough or scoop, which having been filled with coal is pushed into the retort, turned over and withdrawn; to put in the full charge the scoop makes two or more excursions into each retort. A machine is required on each side of the bench. The spent charges are withdrawn by separate machines which operate by means of either a rake or a ram; these stoking machines, as they are called, are operated either by hand, hydraulically, or by compressed air.

Projectors.—There are later types of machines which project the coal into the retort without any part of the apparatus entering the hot retort, and work from one side only of the bench.

In the De Brouwer projector, the machine is brought up to the front of the retort and the charge of coal allowed to fall upon a horizontal rubber-band moving rapidly towards the retort in the direction of its long axis; the coal is thrown off the band into the retort by its acquired momentum, the speed of the band being gradually reduced as the retort fills.

In West's projector machine the coal falls upon the blades of a revolving device and is projected into the retort by centrifugal force; the spent charges are pushed out by a ram, usually carried upon a separate frame.

Ram-Dischargers.—In these machines the ram consists of a cast-steel rack, in two or more sections, actuated by a sprocket-wheel. The first section to emerge beyond the frame of the machine is a rigid rack-bar; those that follow are flexible and held rigidly in a straight line by being sheathed in channel guides which telescope into each other; the flexible sections are constructed of short links.

In entering the retort, the head of the discharging ram slides along the floor of the retort, and when the first (rigid) section is fully extended it draws forward the next section, and this in turn the following section. In withdrawing the ram, the sheaths telescope into each other and the flexible tail of the rack coils back upon itself, in an easy curve, thus considerably economising space and

length of frame required. A constant stream of water is directed upon the ram to keep down the temperature of those parts entering the hot retort.

Combined Charging and Discharging Machine.—In the Fiddes-Aldridge machine, the two operations of charging and discharging are carried on simultaneously; the ram which removes the spent charge carries in the fresh charge of coal by the same movement.

Projectors, ram-dischargers, and the Fiddes-Aldridge machine are all electrically driven. The former may be seen at work at the Stapleton Road Works and the latter at the Canons' Marsh Works of the Bristol Gas Company.

Inclined Retorts.—Another method of charging and discharging retorts avails itself of the force of gravity. In this system, which is characterized by extreme simplicity, the retorts are inclined at an angle to the horizon, and the coal from continuous hoppers is dropped directly into the retorts through portable charging-shoots. The recent introduction of coal-projecting machines in conjunction with ram-dischargers has to a large extent checked the progress, for the time being, of the inclined-retort system, because with machines of this class retorts can be charged and discharged by the employment of a machine at one side only of the retort-house; this offers considerable advantage compared with the older forms of stoking machines, which work from both sides of the retort.

Inclined retorts were used at the beginning of last century by William Murdock, of Messrs. Boulton and Watt, Soho Foundry, Watt's right-hand man, as he has been called. An arrangement of inclined retorts was devised by Mons. André Cozè, in France, and worked on a small scale in Rheims about twenty years ago. In the French plan the retorts were arranged in pairs with a single cast-iron mouthpiece joining their upper ends buried in the brickwork of the setting. About 1889 the system was revived in England; even at Bristol there are memories at the Avon Street Works of a primitive installation of inclined retorts dating back fifty years. Here, in England, the single straight-through retort

was adopted, which immensely simplified the system, compared with the French plan, and assured its success.

Where the work is continuous, as in retort-houses, machines must be of the simplest, strongest and most durable character to avoid the risk of breakdowns, and considering the conditions prevailing in which they are expected to work—the great heat and the cutting action of coke upon wearing parts—it may be wondered why any other method than the inclined-retort system should be employed

FIG. 1.

Avon Street Gasworks, Bristol.

Front Elevation of Buildings showing the two Coal-Elevators.

for charging retorts. However, greater care is necessary in the selection of suitable coal, and the success of the system depends, in a measure, upon the type of coals from day to day being fairly uniform. Some gas-coals have a tendency to slip during the earlier stages of carbonization in inclined retorts, and in doing so, a downward creeping movement readily sets in, leading to a thickening of the charge of coal at the lower end of the retort, thus rendering efficient carbonization difficult. Avoiding these slipping coals, the system is as near perfection as can be attained by any method. The slipping is due to the coal swelling during the earlier stages of carbonization.

An Installation of Inclined Retorts at Avon Street Works, Figs. 1-4, and Plate 15.—On the "New Side" of the works at Avon Street three very substantial retort-houses adjacent to the harbour were erected in 1860. In order to make the most of these buildings it was decided in 1900 to raise the roofs; the height of the walls was doubled and by this means accommodation afforded for inclined retorts. The dimensions of the houses and the general surroundings lend themselves admirably to this method of carbonization. The work was designed and carried out by, and under the personal superintendence of, the Company's Chief Engineer, Mr. Daniel Irving, and the work executed by the Gas Company's own staff and workmen. The coal can be lifted from the hold of the steamboat lying alongside the Quay, weighed, broken, elevated, conveyed to any part of either three retort-houses, charged into the retorts, and when carbonized discharged from the retorts directly on to coke-conveyors, cooled, conveyed into the yard, screened, stored, and loaded into carts or trucks without the material being once handled.

The plant is divided into two sections—for coal-handling and for coke. The power required is supplied by gas-engines provided in duplicate for each section. The coal-breakers and elevators are also provided in duplicate, and the coal can be placed in any part of the coal-hoppers of the three retort-houses from either breaker. The coal-handling plant is designed to do its work, as far as possible, during the hours of daylight, 300 tons per day being required of it.

Inclination of the Retort.—The determination of the angle of the retort, as might be expected, is a critical question. The ideal coal for working with is "Nuts," such as will pass through a screen of 1½-inch mesh; compared with this "lively type," small coal requires a steeper angle, especially if damp, and larger coal a less angle. An angle that would serve well in a newly-built bench would be less suitable as the retorts become worn, in consequence of the formation in the retorts of irregularities in the inner surface and of ridges at the joints, which impede the descent of the coal; and generally a steeper angle might be employed for discharging than would be suitable for charging. For a slipping coal, a less angle would be more

FIG. 2.
Cross-Section of No. 3
Inclined-Retort House.

serviceable. Lastly, the amount of vertical drop of the coal from the measuring chamber to the charging mouthpiece of the retort varies for each horizontal line of retorts, and introduces another disturbing factor, which requires some compensation and which is provided for by introducing baffles and checks in the charging-shoot. Obviously then, a compromise in the angle is necessary to satisfy these conflicting claims, and the angle decided upon is 31° .

Fig. 2 (page 570) shows a cross-section of the retort-house; it will be noticed that the charging floor is placed upon a higher level than the discharging floor, allowing of this angle of 31° as the inclination of the retorts. High up over the retort mouthpieces on the charging side is a continuous coal-hopper A, supported partly from the bracing of the retort bench and on cross-joists resting on the walls of the retort-house: over each vertical line of four retorts a measuring chamber B, for the charge of coal, depends from the hoppers—twenty in all. These measuring chambers are shown in detail, Fig. 3 (page 572); there is a slide at the top for filling it from the hopper and another at the bottom for discharging, each worked from the charging floor of the retort-house by a separate lever. The full capacity of the chamber is 7 cwt. This may be reduced by pushing in a flap-plate, which hangs hinged inside the chamber, held in position by a quadrant which passes through the back of the chamber, and fixed by a pin. The weight of the charge of coal can by this means be adjusted to suit the prevailing conditions.

The method of charging the retorts is as follows:—A portable stop-plate C, Fig. 2 (page 570), is placed in the retort at its bottom end in order to prevent the charge of coal from resting upon the relatively cold iron mouthpiece and from pressing against the retort lid; this remains in the retort during the period of carbonization. On the charging side are four shoots D, one for each horizontal line of retorts; the lower hinged end of one of these shoots is placed in a retort, and the contents of the measuring chamber are discharged into it by pulling a lever, Fig. 5, Plate 15, the coal forming an even layer along the bottom of the retort about 6 inches thick from the stop-plate to the upper end of the retort. These charging shoots, Fig. 4 (page 573), are provided with adjustable baffles

FIG. 3.—Measuring Chamber for Coal.

FIG. 4.
Shoot for Charging Coal.

A, and in the longer shoots fixed baffles also BB, for regulating the speed of the descent of the charge of coal, thus aiding the operator who has the chief control. The weight of the charge is from $6\frac{1}{2}$ to 7 cwts., and twenty retorts can be drawn and charged in twenty-five minutes.

The retort-lids and the face against which they close are machined, the retort being sealed by pressure from a lever with an eccentric shank.

The retorts are tapered, increasing in width towards the bottom end, to facilitate the discharge of the coke. In this installation they are arranged in sets of eight, two vertical lines of four retorts under each of the ten arches, each set being independently heated by producer-gas on the regenerative system. A fraction of the hot coke as it is discharged from the top line of retorts is directed through a portable shoot hung on rails, into the producer E, Fig. 2 (page 570), the only manual labour necessary being to push it back in order to maintain an even thickness in the depth of the fire, Fig. 6, Plate 15. The clinkering is done from the ground-floor stage below. Owing to the regular heating possible in this system, the life of the retorts and of the setting is prolonged. A bench is still in action at the Avon Street Works in which the heats have not been once let down since August 1904, having done continuous work for nearly four years.

Coal Plant.—Water-borne coal is unloaded by means of a steam-crane and a Hone's grab. The grab of 15-cwt. capacity discharges into a hopper weighing-machine, in which the weight of the coal is indicated by a pointer on a scale of hundredweights. This arrangement permits of rapid weighings, as the shifting of the counterpoise is unnecessary. From the weighing-machine it is discharged by a lever into the hopper of the breaker, together with coal received by cartage, and there reduced to a uniform and suitable size.

The breaker A, Fig. 8 (page 577), is a powerful machine, capable of dealing with 30 tons of Cannel per hour, Cannel being the hardest variety of coal carbonized. The coal is fed in automatically by a shuffle-plate to two double lines of steel claws on square shafts,

suitably enclosed. The breaking is done in two stages; the coal falls from the second pair of claws into the boot of the elevator. During its six-and-a-half years' continuous work it has dealt with 360,000 tons of coal without having been once taken apart for repairs, notwithstanding the rough usage it has sustained from stray tram-coupling links, axle-bearings, and stones which occasionally find their way in with the coal.

The steel elevators, Figs. 7 and 8 (pages 576-577), are constructed of a central roller-chain upon which buckets of 28 lbs. capacity are fixed, 18 inches apart. They are driven from the top end by a sprocket-wheel which engages the connecting-chain. Projecting arms, fixed on each side of the buckets, slide on angle-iron bars which serve as guides. The coal is elevated to the full height of the lofty retort-house walls, a total lift of 70 feet, and there delivered into the conveyors for distribution.

The general arrangement of coal-conveyors A is shown on Fig. 9 (page 578) and details on Fig. 10 (page 579), from which it will be seen that each of the three retort-benches is served by its own conveyor, fixed on cross-joists above the continuous hopper, and a fourth conveyor at right angles to these stretches from one elevator head to the other; this cross-conveyor is fitted with reversing gear and clutches, Fig. 11 (page 580), and so arranged that coal from either elevator can be delivered on to each of the hopper-conveyors, and thus serve all three benches in turn. These conveyors are driven from the elevator head by chain-drives; the coal from the elevator is directed by a shoot into the trough of one of the conveyors; along this the coal is swept by a continuous chain of push-plates to the first open slide, where it falls either into the cross-conveyor or into one of the compartments of the coal-hopper.

Referring to Fig. 12 (page 581), it will be noticed that the section of the trough of one of the conveyors is semi-elliptical. In this conveyor every third push-plate is provided with wheels and axle, and the whole connected up by a chain of the roller type, driven by a sprocket-wheel at one end, which engages the rollers on the links of this chain; at the opposite end of the conveyor, a screw tension-gear is provided which acts through a second sprocket-wheel. The

(Continued on page 582.)

FIG. 7.—Upper End of Coal-Elevator.

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FIG. 9.

General Arrangement showing Hot Coke-Conveyors and Hoppers.

FIG. 10.—Longitudinal Coal-Conveyor.

FIG. 11.—Cross Coal-Conveyor.
ELEVATION.

Section through Gangway.

End Elevation
of Bridge over
Longitudinal
Conveyor.

Section of
Conveyor.

FIG. 12.

Section of Semi-elliptical Coal-Conveyor.

wheels carrying the push-plates run upon angle-irons fixed at each side of the trough. A more efficient conveyor could scarcely be devised; it requires very little attention, and owing to the slippery character of the coal requires very little lubrication. During its six years' work it has transported 220,000 tons of coal. Such ample bearing surfaces have been provided, that, excepting the bottom of the trough where the coal falls upon it, the amount of wear is proved to be insignificant.

In all the other conveyors the section of the trough is rectangular, and every push-plate provided with its wheels and axle, Fig. 11 (page 580). The coal moves along at the rate of 100 feet per minute. To drive the whole plant—2 breakers, 2 elevators, 2 hopper-conveyors and 1 cross-conveyor—when running light requires 35·89 I.H.P., and 35 per cent. more when dealing with coal, nearly 50 I.H.P.

Coke Plant.—The coke-handling plant is shown in Fig. 9 (page 578). Along the front of the retort-bench, below the bottom line of retorts and below floor-level, is a rectangular trough F, Fig. 2 (page 570), constructed of steel plates and angles, with cast-iron renewable bottom wearing plates. This trough F is covered down with $\frac{3}{8}$ -inch plates with a hinged section G in front of each vertical line of retorts. The plates serve to confine the heat and steam to the trough as the coke is conveyed through the house, and when raised for discharging the retorts they serve as shields to protect the workmen from the falling hot coke. Beyond the house, the conveyor-trough is bent upwards at a considerable angle, becoming an elevator; this portion being entirely enclosed acts as a flue and draws the steam from the retort-house, discharging it at the top end, entirely clear of all workmen. Along the walls of the retort-house a line of wrought-iron gratings takes the place of the ordinary brick floor, allowing a plentiful circulation of cool air in the retort-house.

The coke and breeze storage-hoppers rest upon pillars, and are raised sufficiently to allow carts to stand underneath the hoppers, Fig. 9 (page 578). They are divided into sections by bulkhead

plates, corresponding with the screens, and below each pair of screens the hopper is partitioned off for breeze. Above and along the entire length of the hoppers, carried upon a lattice framing, there is a conveyor for distributing the coke. As the coke leaves the retort-house it is quenched, and on reaching the top of the coke-elevator it is discharged into the trough of the distributing or hopper-conveyor, and either falls directly on to screens through the open slide beneath, or is carried to the next set of screens, where the coke is separated from the breeze, and each falls into the section of the hopper set apart for it. To save the coke from

FIG. 13.—Hot Coke Chain-Conveyor (De Brouwer).

breakage in falling into the hoppers, portable shoots are placed when required at the foot of the screens. The carts are filled by operating a lever from the ground-level.

The form of conveyor chain adopted for the coke plant is the De Brouwer, Fig. 13 (above), which resembles a flexible ladder with cross-bars of round and flat steel. M. De Brouwer is the engineer of the gasworks at Bruges, where it was first used towards the end of 1895. The whole of it consists of mild forgings stamped to shape under a drop-hammer. All parts are machined and the rivet-holes are rimmed, the rivets being driven in cold and riveted cold. Where the coke has to be

taken up inclines, flat bars are introduced at regular intervals in place of the round bar. The conveyor when new moves along at the rate of 50 feet per minute. This speed is increased as the wear of the chain necessitates an increase in the diameter of the pitch circle of the driving sprockets.

In discharging the retort, the coke slides down the inclined retort into the trough in front of the bench and is carried forward,

FIG. 14.—Sprocket-Wheel for Hot Coke Chain-Conveyor (De Brouwer).

sliding along the bottom plates. A little water lies in the bottom of the trough to keep things cool, and this helps to quench the coke as it travels along. In spite of the trying conditions under which it has to work, and of the cutting and grinding action of coke, a chain may be made to last more than three years, working day and night, and to transport 70,000 tons of coke during its life. The new chain weighs 50 lbs. per yard; an old one removed to the scrap heap weighs 32 lbs. per yard, showing a loss in wear of 36 per cent. by weight.

The chain of the conveyor is driven by a pair of sprocket-wheels, Fig. 14, engaged for ninety degrees of the pitch circle; the slack chain is payed directly on to guide-wheels which maintain it in constant tension by a balance-weight B, Fig. 9 (page 578). The chain of the hopper distributing-conveyor is kept taut by tension screws instead of the usual balance-weight arrangement, which cannot be well applied where the conveyor has to be reversed; in this case the chain has a trick of increasing in length more on one side than on the other; sections of the chain have frequently to be turned over to counteract this unequal wear and consequent difference in the pitch of the two sides. Judging from what takes place at the Avon Street Works one would be inclined to think that the introduction of a balance-weight in place of the tension-screw would overcome the difficulty, but the experience at other works renders this doubtful.

It will be noticed that, as the parts wear, the pitch of the chain increases and demands a readjustment of the pitch of the sprockets; this is met by increasing the radius of the pitch circle, the sprockets being drawn further out from the centre of the sprocket-wheel as the wear increases. This extension of the length of the chain is considerable, and where in a new chain the pitch is $8\frac{1}{2}$ inches, when nearly worn out it is found to have increased to nearly $9\frac{1}{2}$ inches, equivalent to an extension of 10 per cent. in the pitch of the chain.

The amount of power required for these conveyors is surprisingly small, and is supplied by a gas-engine. 1,540 feet of conveyor-chain requires, when light, only 25.16 I.H.P., including two line-shafts, belts, and driving-gear, and 12 per cent. more when fully loaded. So thoroughly reliable are gas-engines that for nearly three years work was proceeding day and night, year in and year out, with a single gas-engine. The rapidity and ease with which hot coke is removed from the retort-house by conveyors adds much to the convenience and comfort of the workmen and to the general economy of the system.

The Paper is illustrated by Plate 15 and 12 Figs. in the letterpress.

Discussion.

On the motion of the PRESIDENT, a hearty vote of thanks was accorded to Mr. Stagg for his interesting Paper.

Mr. W. H. ATHERTON, in opening the discussion, remarked that the author pointed out (page 567) that the introduction of coal-projecting machines and ram-dischargers had checked the progress of the inclined-retort system, because they enabled retorts to be charged and discharged by machinery working on one side only of the retort house. While that was true enough, it was not the sole reason why projectors had come so much to the fore in recent years. It must be remembered that most gasworks of moderate size were already equipped with hand-charged horizontal retorts, and the adoption of projectors enabled the old settings to be utilised, thus permitting the introduction of labour-saving appliances at a minimum of first cost and without interruption of working. Their use also permitted a rather freer hand in the choice of coal, as was pointed out on page 568. It must be admitted, however, that projectors were very dirty machines in operation, clouds of coal dust and thick smoke being evolved from the retorts during the process of charging. In this respect the Fiddes-Aldridge machine was an improvement, but smaller charges had to be used than were possible with projectors for a given size of retort. In the course of another decade he was hopeful of seeing both horizontal and inclined retorts displaced by vertical retorts.

He hoped the author would favour the members with a rough idea of the comparative cost of two new retort-houses of equal capacity, the one being equipped with inclined and the other with horizontal retorts, and the usual labour-saving machines. He did not ask for actual, but only relative costs. The author gave high praise to the inclined retorts in saying (page 568) that "The system is as near perfection as can be attained by any method." The ideal system in principle, though not yet in practice, seemed to be the vertical retort, as in the Woodall-Duckham system, where

the coal was fed by a conveyor continuously into the top of the retorts and discharged either continuously or intermittently at the bottom, precautions being taken to seal both ends. That system was being tried on a small scale at three English gasworks, though a full measure of success had not yet been achieved. In Germany he understood that "Dessau" vertical retorts, fed and discharged intermittently, were in successful operation on a large scale.

With regard to the details of the coal-handling plant, he noticed that the receiving hopper below the ground level was shown in Fig. 8 (page 577) unusually shallow, the inclination of the sides being about 35° only. Did the author find that the coal flowed freely from that hopper without hanging up at the sides? The method of feeding the coal-breaker by means of a jigger or reciprocating shoot was certainly an improvement on the ordinary sliding door, and ought to be adopted generally, in spite of the extra first cost and space occupied. Only in that way could a regular feed be obtained with variable and lumpy material, without the necessity of frequent adjustment by hand. Apparently the small coal fell through holes in the bottom of the jigger, and was by-passed to the elevator boot without passing through the breaker.

Roller chains were successful if kept lubricated, but, as that was hardly feasible in elevator work, it was found in practice that better results were obtained by the use of a rollerless chain of the Ley type, with a hardened steel renewable bush, the latter being subjected to external wear by the action of the sprocket-wheel teeth, as well as to internal wear due to the pull of the pins. The elevator top shaft in Fig. 7 (page 576) was shown driven through two pairs of bevel wheels and a side shaft. Personally, he preferred a chain drive, which was more flexible and required fewer bearings. In large elevators the top shaft was commonly driven through a pair of spur wheels and a short countershaft, itself chain-driven. In light elevators the countershaft could be dispensed with and a direct chain-drive used. In the case of an elevator to handle 50 tons of coal per hour now being made for a retort-house by the Chain-Belt Engineering Co., Derby, he had ventured to adopt a frictional or grip chain-drive, by which a large reduction ratio could be

(Mr. W. H. Atherton.)

conveniently realised, even with short centres. In that case the driving sprocket-wheel was about 12 inches diameter, and the driven wheel keyed to the top shaft was 60 inches diameter with a plain grooved rim, thus avoiding all trouble due to variation of chain pitch. Owing to the wedge action of the grip chain on the tapered sides of the groove, the drive was more positive than a belt, while in case of a total jam there was still the possibility of slipping. In that 50-ton coal elevator the top shaft was carried on roller bearings. The buckets were also fitted with bushed rollers, and were bolted to a chain of the Ley bushed type.

FIG. 15.—*Section of Scraper Conveyor Trough.*

The three types of coal conveyor used in retort-houses were the scraper or push plate, the rubber and canvas band, and the gravity or tipping bucket. Each of those types was capable of good service. Probably the scraper type (page 579) was the most convenient and durable form for retort-house duty, where coal was required to be deposited at a large number of points. The particular design shown in the Paper was capable of improvement, the projection of the acting edge of the scrapers beyond the rollers being too great, and thus the head room required by the conveyor was excessive. A convenient form of section he had used with success was indicated in Fig. 15. The bottom of the trough was fitted with renewable lining plates, and the rollers were bushed.

Mr. J. HERBERT CANNING, of Newport (Mon.) Gas Works, most heartily congratulated the author upon his comprehensive and detailed Paper. He was specially interested in it, because a few years ago through the kindness of Mr. Daniel Irving he had the opportunity of seeing the excellent installation in operation at the Avon Street Works, and nothing could exceed the smoothness and efficiency with which every department worked. The portion of the Paper which interested him particularly was that dealing with the coke-handling plant. At the gas works with which he had the honour of being connected, the directors some years ago decided to carry out a considerable installation for the mechanical handling of the coal and coke. For that purpose they used gas-engines as prime movers; and he could bear witness to what the author said, that nothing could exceed the excellence with which those engines had worked under trying conditions. At Newport the work was spread over a considerable area, and in consequence an electrical system of distributing the power was installed, which had worked very efficiently. They had capstans and a tipping crane at the sidings which were elevated about 25 feet above the yard level. The coal was tipped from the wagons into a hopper, which discharged into a breaker, the remainder of the coal-handling installation being very similar to that described by the author, with the exception that horizontal (not inclined) retort benches were used.

With regard to the power required to drive a coal breaker, at Newport this was driven by a separate motor; and as it was driven electrically one was enabled to measure the varying load with some approach to accuracy. The variations in load were somewhat extraordinary and were very sudden, and there was a continual variation due to the size and hardness of the coal. Tests which he had made indicated that, using ordinary coal, the power required was from 8 to 12 E.H.P. A deduction would have to be made from that for the efficiency of the motor; those were gross figures. Occasionally, however, a momentary rise to 20 E.H.P. was obtained. The diagram, Fig. 16, Plate 15, from a recording ammeter gave some idea of the variations in the load.

(Mr. J. Herbert Canning.)

In breaking Cannel coal, which was much harder, the usual load was from 9 to 15 E.H.P., with sudden momentary rises to as high as 23 E.H.P., and 30 tons could be broken per hour. Owing to that variation in load, he considered a gas-engine was admirably adapted for the purpose of driving such a plant.

With regard to coke-handling, the conditions at Newport being different, a coke conveyor of the type used at the Avon Street Works, Bristol, had not been installed. It was necessary at Newport, owing to the height of the sidings above the yard level, to instal a coke-handling plant which at one and the same time would either deliver the coke at the yard and stack it, or load the coke into wagons on the sidings. For that purpose a telpherage system was put in. The telpher ran upon an elevated track, with an up gradient of about 1 in 22, and at the siding end it was about 40 feet above the yard level. The coke was dropped from the retorts into openwork wagons, specially devised to prevent the buckling of the wagons by the expansion and contraction caused by the hot coke. For that purpose the bars of which the wagons were built were riveted at one end only, and were free to expand and contract at the other end. The wagons were taken from the retort house, elevated by the telpher and carried to the point in the coke heap, or to the wagon on the siding where they were to be discharged and tipped. The telpher elevated a ton of coke in each wagon at the rate of 60 feet per minute, and travelled along the track at 200 feet per minute. The power absorbed was very slight. Hoisting the empty tram only absorbed about 3 E.H.P.; hoisting a full tram absorbed about 7 E.H.P.; running light upon the gradient took $4\frac{1}{2}$ E.H.P.; and running full $7\frac{1}{2}$ E.H.P. There was a considerable advantage also in the use of a telpher, in that there was no portion of the machinery which came into actual frictional contact with the coke. Some transformation took place in the carbon of coal when it was converted into coke, which changed it from what might be called the graphitoid state in which it existed in the coal, into a hard, gritty substance, having very much the same effect as emery upon everything with which it came in contact, so that there was a great deal of advantage in a machine which obviated frictional contact with such a material.

It was mentioned in the Paper that the total extension of the chain of the coke-conveyor amounted to about 10 per cent., but the author did not mention whether that was due to wearing at the joints entirely, or to absolute extension of the links under tensional stress, or to both causes combined. It would be of interest if the author would state which cause produced the effect.

Mr. DANIEL IRVING said he thought nothing indicated more clearly the progress mechanical engineering was making, not only in the gas industry but generally, than the fact that the plant, which the author had so ably described in his Paper, had practically in eight years become antiquated. Mr. Atherton had contrasted the carbonising of coal in what was known as the inclined-retort system with that of the horizontal, or the old-fashioned system. There could be no doubt that the projector machine lent itself very readily to existing old-fashioned retort-houses, and enabled the work to be done with great economy. The tendency of gasworks practice was still further to incline the retort. Instead of an angle of 31° , 45° had been adopted; and the angle had even been abandoned altogether, and the retort set upon end. The vertical retort was now being generally used in Germany. The most advanced and complete vertical system at present in use was at Bournemouth, namely, the Woodall-Duckham system, where the coal was continuously and automatically fed in at the top of the retort, and the coke periodically removed from the bottom of a vertical retort. All practical men would at once see that this arrangement must result in great economy in the handling of coal for gas-making.

He hesitated in giving figures with regard to his own works; but he might state for the information of members that the labour costs had practically been reduced to nearly one-third. On the old system it practically cost 5*d.* per ton to place the coal in the retort house; at the present time the cost of handling coal with the plant that had been described was something under 1*d.* per ton. With the old arrangements coke cost practically 5*d.* per ton of coal for wheeling, cooling and stocking, while the labour involved in doing the same work with this plant was something under $1\frac{3}{4}$ *d.* Coke was a much

(Mr. Daniel Irving.)

more difficult article to deal with than coal. The plant the author had described had worked remarkably well, and the whole system had worked very smoothly ever since it was introduced; the fact that Mr. Stagg, who had the most intimate knowledge of the plant of any member of the staff, was the most enthusiastic with regard to it, spoke greatly in its favour. The cost of maintenance had not in any case exceeded the original estimate. The system had been of great help to the men employed, and the work was much easier and more comfortable. He did not for one moment suggest that the plant was introduced simply to lighten the labour of the work; it was introduced by the directors to enable them to meet their great responsibility in providing light and power in the important city of Bristol at the least possible cost, and so far there was every reason to be well satisfied with the results that had been secured.

Mr. F. G. WRIGHT, after asking the author if he could give the members any information with regard to vertical retorts, said he happened to be a director of the gasworks at Swindon; and was interested in the subject. The Great Western Railway Co. had gasworks, and any of the members who intended visiting Swindon by the Institution Excursion on the Friday would be welcome to inspect the works there, which were of a modern nature, although not so large as those connected with Bristol.

Mr. A. T. TANNETT-WALKER, Vice-President, thanked the author for his able Paper and for calling attention to the fact that William Murdock, who was the inventor of the slide-valve, was the first to use inclined retorts in this country. Under the heading of coal plant (page 574) the author said that "water-borne coal is unloaded by means of a steam-crane and a Hone's grab." His own experience, which was a fairly considerable one, was entirely in favour of unloading coal from boats by means of cranes and grabs, and he had been present at tests when as much as 70 tons of coal were pulled out of a boat in an hour at, he should think, 200 per cent. less cost in mechanical work compared with the previous plant. From actual experience he knew that the grab was a cheap, economical, and

simple means of unloading coal from a boat. His firm had a problem to deal with at the present time which related to the handling of something like a million tons of coal per year. The coal was sea-borne; and after experience on the River Thames and in various other places, where marvellous results had been obtained so far as simplicity and economy were concerned, they had decided to adopt grabs. The ingenious sprocket pulley-chain depicted in Fig. 14 (page 584) was invented by a Welshman, who ought to receive every credit for his work. It was a wonderful contrivance, and the French honoured the country to this day by calling it "Chaine de Galles," which showed that they admitted that the chain was invented in Wales. It was of interest to have new things brought before their notice, and he was therefore much indebted to the author for his description of the De Brouwer wheel.

Mr. CHARLES HAWKSLEY said it had been foreshadowed that certain particulars would be given with regard to costs, and he therefore wished to utter the warning that costs were very illusory unless they included every item, that is, the capital cost, and the cost of up-keep, including replacement so as to maintain the machine or structure in perpetuity. Then, on the other hand, in arriving at the cost of labour it was amongst other things necessary to remember the expense of ensuring the workmen against accidents. All items of whatever kind ought to be brought into account before comparing the cost of handling coal or other articles by one method with the cost by another method. He therefore hoped that, in any costs which might be given, everything of that kind would be included.

Mr. ALFRED SAXON, in referring to the question of the lengthening of the pitch of the chain, said it was his experience that driving chains for motors lengthened somewhat under ordinary working conditions in addition to the wear in the holes and the pins, and he thought it not unlikely in the particular case under discussion that, owing to the heat under which the chains worked, they had also stretched as well as worn.

Mr. WILLIAM STAGG, in reply to Mr. Atherton's request for particulars of costs, desired to refer the answer to that request to Mr. Irving. Mr. Atherton also referred to the angle of the slope of the breaker being too flat. As a matter of fact the coal fell down almost vertically on to the lines of steel claws. There was a by-pass for coal which did not require breaking, but he was bound to admit it was not working well, and was really out of use, so that its angle did not matter under those circumstances. With regard to the chain-drive at the elevator head, a chain driven from the elevator head was used to drive the conveyor itself, and he had nothing to complain of whatever in the vertical shaft for the main drive. There was less friction with a pair of wheels than with a chain-drive. Mr. Atherton illustrated a section of the coal-conveyor he favoured. If a reference were made to the two sections given in the Paper, it would be seen that one was semi-elliptical and the other rectangular, and the one Mr. Atherton sketched was exactly like the rectangular section shown in the Paper. From practical experience in working, he preferred the semi-elliptical pattern as shown in Fig. 12 (page 581), the wear and tear being much less than with the rectangular form. The rectangular coal-conveyor referred to by Mr. Atherton was also in the Paper, and was shown on page 580.

Reference had been made by Mr. Canning (page 589) to the amount of electrical power required for driving a plant. There was no electrical installation at the Avon Street Works, although there was at Stapleton and Canon's Marsh, where all the work was driven electrically. He was very interested in the statements of the variation of power required for breaking, and they quite bore out his own estimates. There must be a great variation, owing to varieties in the hardness of the coal, the foreign matter which inevitably got in, and the small coal jamming itself. He was afraid he could not give the information asked for with regard to vertical retorts; he had given in the Paper the result of first hand experience. Grabs were splendid things for small coal, but they were of no use for large coal.

Mr. A. T. TANNETT-WALKER, Vice-President, stated that his firm used the grabs for large coal.

Mr. STAGG, continuing, said that the sprocket-wheel which was referred to was designed by Mr. W. J. Jenkins, of Retford. After seven years' experience of the plant, he would not go back to the old style of work. It was quite likely, as had been suggested by Mr. Saxon (page 593), that the links of the coke-conveyor chains stretched slightly, but the great wear was in the joints. The coke grit got in the joints and the chains became very slack. A hole that might be 1 inch in diameter was enlarged by wear to nearly 2 inches before the chain was thrown away.

Communications.

Mr. FREDERICK BERRY wrote that he wished to call attention to the power required by the conveyors used. The author stated (page 585) that "the amount of power required for these conveyors is surprisingly small, and is supplied by a gas-engine. 1,540 feet of conveyor-chain requires, when light, only 25·16 I.H.P., including two line-shafts, belts, and driving-gear, and 12 per cent. more when fully loaded." Now 12 per cent. of 25 H.P. was only 3 H.P., and therefore the total power at full load was 28 H.P. The writer inferred therefore that 28 H.P. was absorbed in giving out a useful output of 3 H.P. only, that is, the difference between full load and light load. This meant an efficiency of only 10·7 per cent., or a wasteful expenditure of power in friction, &c., of nearly 90 per cent. It appeared to him that the power necessary to work these conveyors was rather high, and not "surprisingly small."

Mr. J. R. WILLIAMS wrote that the author stated (page 571) that the measuring chamber was discharged by pulling a lever connected to a slide, and in Fig. 3 (page 572) a section of the measuring chamber was shown. He would like to ask, if any difficulty were found in actuating these slides? If no difficulty were found and they worked easily, he would like to know the nature of the metal

(Mr. J. R. Williams.)

used. At the Tramway Power Station in Sheffield great difficulty had been found in actuating slides, even when using gun-metal; the levers broke off repeatedly and had to be replaced with a rack and pinion fitted with chain and chain-wheel. They also found it difficult to close the slide tight, owing to its not having a clear way through the trunk; whilst if a way were cut through the trunk, it allowed small coal to fall upon the floor. They intended to try toothing the front edge of the slide, about $\frac{3}{4}$ -inch deep; when tried experimentally this had overcome the difficulty.

A sketch was shown (page 583) of a chain conveyor, which was riveted up; the writer's experience of riveted-up chains had not been a fortunate one, and in the conveyor in use at Sheffield, which was of the gravity-bucket type, the links were originally riveted up; but the difficulties of repair were so great, that when the chain was renewed, they fitted it with straight steel pins washered at each end and simply fastened with split pins. Their reason for using the straight pins was cheapness of first cost, as these pins could be cut cold from the rolled steel bars and simply required the pin holes to be drilled. The writer now found that any repairs or alterations that might be required, such as fitting new pins, links, &c., or changing over the chain, owing to the unequal stretching, were much more rapidly completed. Instead of having to chip off the rivet-heads, they simply drew out the split pin, and drove out the coupling-pin.

They had also found difficulties due to the unequal stretching of the chain, the usual result being that, the longer chain ran out of the groove in the guide wheel; and this riding tended to stretch the longer chain still further. This defect could be partly remedied by opening out the grooves in the guide-wheel, the sides of the groove being turned at an angle, and also by carrying the leading on guide rail as close to the wheel as possible.

Mr. STAGG wrote, in further reply to Mr. Atherton's question relating to the possibility of coal hanging up at the sides of the hopper (page 587), that no inconvenience arose from this cause, and in practice the angle of the hopper, 35° , had proved itself to be

sufficiently steep. The reply given during the discussion referred to the inclination of the surfaces below the shuffler.

With regard to Mr. Herbert Canning's and Mr. Alfred Saxon's enquiries as to whether the lengthening of the chain was in part due to the stretching of the links under tensional stress, careful measurements, since made, of new links and of those worn out showed that the links did not stretch, and therefore the whole of the wear occurred at the joints.

In regard to Mr. F. Berry's communication, the author quite agreed that the mechanical efficiency of the conveyor was low.

In reply to Mr. Williams, no difficulty was experienced in actuating the coal slides of the measuring chambers. These and their guides were of steel. Occasionally coal dust settled in the grooves in sufficient quantity to cause the slide to jam. But with 120 slides in operation they did not get a jam more frequently than once a month. The slide had a clear way through, and a little coal fell in consequence.

The riveting of the coke-conveyor chain-links (De Brouwer) had proved to be a wholly satisfactory method of connecting the links, and no other method could be so well applied to this type of chain.

COAL- AND COKE-HANDLING PLANT. Plate 15.

Fig. 5. Charging Floor of Retort-House.
Operation of Filling a Retort.

Fig. 6. Discharging Floor of Retort-House.
Operation of Filling a Producer Fire.

(Mr. J. Herbert Canning's remarks.)

Fig. 16. Diagram showing additions to the load upon a Dynamo
caused by four periods of driving a Coal Breaker. 16th Jan. 1908.

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