CHAPTER X.

BOILER SMOKE.

In the defence of boiler smoke cases in court a statement has been made many times to the effect that it is impossible for a chimney to emit 30 or 35 minutes of black smoke in one hour. Such a statement is a positive proof that the speaker knows nothing at all about either the production or prevention of boiler smoke, for frequently boiler chimneys have emitted 40, 50, and even 60 minutes of smoke, and recently a chimney serving 9 boilers was observed by the author to emit black smoke for 70 consecutive minutes.

There is no necessity for 95 per cent. of the smoke made by boilers, whether Lancashire, Yorkshire, Cornish, Tubular, Marine, Loco., Steam Wagon, Vertical, or any other type, when working under normal conditions, for during the last 35 years its practical and profitable prevention has been demonstrated thousands of times, and should be undertaken by manufacturers if only from the point of view of economy.

Smoke Limits.—The boiler smoke limits should be reduced to the following :—

1 boiler 1 minute of black smoke in the hour.
2 boilers 2 minutes ,, ,,
3 boilers 3 ,, ,, ,,
4 and more boilers 4 minutes of black smoke in the hour.
1 boiler, 1 or more furnaces served by the same chimney, 4 minutes in the hour.

And the above limits need not be exceeded when the boilers are working under normal conditions.

Boiler Power.—Sufficient boiler power for the maximum load, even when using somewhat inferior fuel, contributes to the prevention of the formation of smoke, for sufficient time can be allowed for the complete combustion of the fuel, and does not necessitate the forcing of the fires. Many manufacturers put down barely sufficient boiler power for their requirements and when trade increases they add machine after machine, increasing the load on the boilers and but rarely increase their boiler power. The fireman has to force unduly the fires to try and make the required steam. If he fails to make the steam he never fails in making smoke and in the end the fuel thus wasted costs more than the necessary extra boiler power would have done. Such a policy is penny wise and pound foolish.

Also, boilers should be of the most modern type, properly set, and be cleaned at short intervals to produce the maximum efficiency.

Natural Boiler Draught.—Boilers would be useless without the requisite draught. The chimney is employed for the purpose of maintaining a draught of air through the body of burning fuel in the furnace. Its effectiveness is due to the quality which it possesses of maintaining an unbalanced pressure between the interior, or combustion, chamber of the furnace and the atmospheric pressure without.

Furnace draught is caused by the difference in weight, or pressure of the column of cold air outside the chimney, and the weight of the column of heated gases within it. Air and gas when heated expand in volume and become less dense than at equal volume at a lower temperature. This difference in density is the draught-producing quality of heated gases. The unbalanced pressure originates in the fact that hot gases occupy a larger volume for a given weight than cold gases. As there is no exit for the hot gases generated in the furnace except through the chimney a current is at once established in that direction. By reason of the height of the chimney above the furnace, and the fact that it is filled with gases of higher temperature, and consequently of less density, than the air outside the chimney, an upward current of hot gases will be maintained so long as any unbalanced pressure exists between the outside and inside of the chimney.

Mechanical Draught.—This name is applied to any system of pressure or exhaust fans driven by a separate mechanism by which, in the case of a blower, a current of air is forced through the fire, or by exhaustion of the products of combustion by means of a vacuum created by a revolving fan placed beyond the uptake, or in the breaching leading to the chimney. In either case the air needed for combustion is supplied to the fire through mechanical means and not by natural draught.

Forced Draught is secured by means of a centrifugal fan, or fan blower by which the air needed for combustion is forced through the fire. The air supply in stationary boiler practice is usually forced into an airtight ashpit, and as there is no other means of escape it is forced through the fuel. Another method, frequently employed on steamships, is to make the fire room airtight and force the air into it at such pressure and in such volume as may be needed for the combustion of the fuel. An objection to the direct introduction of air under pressure by means of a pipe in the bottom of, or through one side of, a closed ashpit is found in the failure properly to distribute the air in the ashpit, resulting in unequal combustion, localising the heat in certain portions of the grate, and producing blowholes in others. The air pressure in the ashpit being in excess of that of the atmosphere necessitates keeping the ashpit doors closed. This pressure also causes all leakage to be outward. The tendency is therefore to blow the ashes out of the ashpit and the flame and smoke and fuel out of the fire doors.

Induced Draught.—The induced, suction, or vacuum method for obtaining a suitable draught for furnace combustion, consists in the introduction of an exhausting fan in the place of a chimney. The fan serves to maintain the vacuum which would exist if a chimney were employed, and its capacity can be made such as to handle the gases which result from the processes of combustion. As the draught is thus rendered practically independent of all conditions except the speed of the fan, it is necessary to provide only a short outlet pipe to carry the gases to a height sufficient to permit of their harmless discharge to the atmosphere. In practice the capacity of an induced draught fan, as measured by the weight of air or gases moved, necessarily varies with the temperature of the gases it is designed to handle. Therefore the density which varies inversely as the absolute temperature should enter as a factor in all such calculations.

The simplest arrangement for an ordinary boiler plant consists in placing the fan immediately above the boiler, leading the smoke flue directly to the fan-inlet connection, and discharging the gases upward through a short pipe extending just above the boiler-house roof.

The induced draught system is on the whole better subject to control than the other systems, its leakage is always inward, avoiding inconvenience from flame and smoke at the fire doors, it lends itself readily to control by the dampers which may be introduced for the purpose.

Mechanical draught can be adapted to a variety of conditions, such as accommodation to restricted space, or it may be placed in any convenient location, and not necessarily in the fire or engine rooms. Perfect control may always be maintained over the action of mechanical draught. With a chimney the intensity of the draught is least when the fire is low, with the fan it is possible to produce instantly the maximum draught under these conditions. Climatic conditions do not affect mechanical

Kent's Table of Size of Chimneys for Steam Boilers.

Formula: H.P. = 3·33 (A − 0·6 $\sqrt{A}$) $\sqrt{H}$. (Assuming 1 H.P. = 5 lbs. of coal burned per hour.)

Diameter. Inches.	Area A Sq. Feet.	Effective Area, E=A−06. $\sqrt{A}$ Sq. Feet.	Height of Chimney. — Commercial Horse-Power of Boiler. 50 ft	60 ft	70 ft	80 ft	90 ft	100 ft	110 ft	125 ft	150 ft	175 ft	200 ft	225 ft	250 ft	300 ft	Equivalent Square Chimney. Side of Square, $\sqrt{E}+4$ in.
18	1·77	·97	23	25	27	29	..	..	..	..	..	..	..	..	..	..	16
21	2·41	1·47	35	38	41	44	..	..	..	..	..	..	..	..	..	..	19
24	3·14	2·08	49	54	58	62	66	..	..	..	..	..	..	..	..	..	22
27	3·98	2·78	65	72	78	83	88	..	..	..	..	..	..	..	..	..	24
30	4·91	3·58	84	92	100	107	113	119	..	..	..	..	..	..	..	..	27
33	5·94	4·48	..	115	125	133	141	149	156	..	..	..	..	..	..	..	30
36	7·07	5·47	..	141	152	163	173	182	191	204	..	..	..	..	..	..	32
39	8·30	6·57	..	..	183	196	208	219	229	245	..	..	..	..	..	..	35
42	9·62	7·76	..	..	216	231	245	258	271	289	316	..	..	..	..	..	38
48	12·57	10·44	..	..	..	311	330	348	365	389	426	..	..	..	..	..	43
54	15·90	13·51	..	..	..	..	427	449	472	503	551	595	..	..	..	..	48
60	19·64	16·98	..	..	..	..	536	565	593	632	692	748	..	..	..	..	54
66	23·76	20·83	..	..	..	..	..	694	728	776	849	918	981	..	..	..	59
72	28·27	25·08	..	..	..	..	..	835	876	934	1023	1105	1181	1253	..	..	64
78	33·18	29·73	..	..	..	..	..	..	1038	1107	1212	1310	1400	1485	1565	..	70
84	33·48	34·76	..	..	..	..	..	..	1214	1294	1418	1531	1637	1736	1830	2005	75
90	44·18	40·19	..	..	..	..	..	..	..	1496	1639	1770	1893	2008	2116	2318	80
96	50·27	49·01	..	..	..	..	..	..	..	1712	1876	2027	2167	2298	2423	2654	86
102	56·75	52·23	..	..	..	..	..	..	..	1944	2130	2300	2459	2609	2750	3012	91
108	63·62	58·83	..	..	..	..	..	..	..	2090	2399	2592	2771	2939	3098	3393	96
114	70·88	65·83	..	..	..	..	..	..	..	..	2685	2900	3100	3288	3466	3797	101
120	78·54	73·22	..	..	..	..	..	..	..	..	2986	3226	3448	3657	3855	4223	107
132	95·03	89·18	..	..	..	..	..	..	..	..	3637	3929	4200	4455	4696	5144	117
144	113·10	106·72	..	..	..	..	..	..	..	..	4352	4701	5026	5331	5618	6155	128

For pounds of coal burned per hour for any given size of chimney, multiply the figures in the table by 5.

draught, it can be made as strong in summer as in winter, and on a muggy day as on one that is bright and clear. Increased rates of combustion are readily produced, and the capacity of a boiler largely increased at any time to suit temporary or permanent conditions. The burning of cheap and low-grade fuels is accomplished best by means of mechanical draught.

In mechanical draught boilers, to prevent a nuisance, it is necessary to have the uptake or iron chimney high enough to discharge the combustible and non-combustible gases above the surrounding workshops or dwelling-houses. Also when using low-grade small fuels, the draught must not be more than necessary to produce complete combustion of the fuel, or tons of grit will be discharged from the chimney, and will prove to be a greater nuisance than the smoke, making the disadvantages of mechanical draught greater than the advantages. Where such conditions have prevailed, it has been necessary, in order to abate the grit nuisance, to reduce the draught (say to $2\frac{1}{2}$ to $1\frac{1}{4}$ inch of water), burn a better class of fuel, and raise the chimneys to a reasonable height.

Boiler flues must also be large, with no leakages but air proof, and they must be cleaned at reasonable intervals, to prevent reduction of draught.

Air Admission.—Air plays a principal part in the combustion of coal, but if insufficient, or excess, is supplied, it is almost impossible to secure complete combustion. The troubles that follow the too rapid cooling of the plant when air is admitted in excess—leakage in tubes and such—have led to the adoption of methods calculated to deprive the furnace of the requisite air.

The fires often are allowed to run too long without cleaning—the dirt and clinker prevent the necessary air going through the fire. After stoking the furnace doors are closed, the grids put on the doors for the purpose of air admission are closed also, and in affect a good attempt is made to keep out the air, with the result—black smoke for long periods.

Grate Bars.—The grate bars should be kept fairly free from clinker and dirt to permit the unobstructed passage of air between the bars, and through the mass of incandescent fuel. Steam jets are put in the ashpit, the ashpit is closed to increase the pressure to blow up the fire, increase the consumption of fuel, and the evaporation of water.

Furnace Doors.—Furnace doors are provided with grids, vertical and circular, which should be opened to let air into the furnace for the required period after a charge of coal. Louvres are fitted on the doors and are closed automatically after 1, 2, or 3 minutes as the fuel requires. A supplementary supply of air is provided for the boiler, by a Hollow Bridge, with a door in the ashpit at the back of the furnace, which admits air through the bridge door into the tube, beyond the furnace. These mix with the unconsumed gases leaving the furnace and the latter are ignited and consumed. But judgment must be exercised in opening and closing the hollow bridge door, or too much air will go through (taking the line of least resistance), and too little through the furnace, the result will be incomplete combustion.

Insufficient Air.—The effect of the admission of insufficient air is a very serious one. One pound of carbon combining with two pounds of oxygen results in perfect combustion, the product being carbonic acid gas, CO_2, with the development of 14,500 heat units, but, as previously explained, if insufficient air (which means too little oxygen) is present, carbon monoxide, CO, will be formed, and developing only 4,450 heat units, or 10,050 less than the first combination. This represents a loss approximately of 69 per cent. of the fuel merely as a result of insufficient air in the fire at the right time and place.

Heated Air.—A direct economical effect of heating the air is that of raising the intensity of furnace combustion, and this may be explained on the probable hypothesis that the chemical affinity of heated air for carbon is much greater than that of cold air. One consequence of this is that when it is employed, it is deprived of its oxygen within a very short time, and the combustion is thereby more concentrated and localised at the point where the heat has to be applied. This is favourable to the economy of fuel, for combustion and high temperature beyond the point at which the heat has to be applied, are useless.

It is known that 1 lb. of carbon with $2\frac{2}{3}$ lbs. of oxygen will develop 14,500 heat units. This will require under theoretical conditions 12 lbs. of air, and to place it under ordinary conditions say 24 lbs. of air. We have then 25 lbs. of gaseous product of which $3\frac{2}{3}$ lbs. will be carbonic acid gas, and $21\frac{1}{3}$ lbs. of inert waste gas. The more nitrogen there happens to be mingled with the oxygen the greater the weight of matter that will have to be uselessly heated, also the greater its capacity for absorbing heat, the greater its specific heat, and the greater the amount of heat that would be taken up.

Quantity of Air.—The exact quantity of air required for complete combustion depends on the class of coal, the amount of coal put on the fire, atmospheric conditions, etc. In the general working of boilers, air cannot be scientifically measured, but it may be approximately ascertained. And to do this the stoker must be able to see the top of the chimney from the boiler front, either through a glass roof or reflected through a mirror placed in the right position. After stoking the boiler the stoker must look at the top of the chimney, and if black or dense smoke is being emitted he then has positive proof that there is either too little or too much air being admitted, and it must be regulated at the furnace door, bars or bridge to procure complete combustion. An intelligent and industrious stoker who takes an interest in his work can very quickly find out the exact quantity of air the different grades of coal require, and so admit that amount, with smokelessness and economy.

Boiler, Furnace, and Copper Smoke.—In Sheffield there is a large number of what are called combination chimneys because each chimney serves one or more boilers, furnaces, and brewing coppers. A few chimneys serve from 10 to 20 furnaces in addition to boilers. It is considerably less of a nuisance to discharge furnace smoke from a boiler chimney, say 120 feet high, than from 10 to 20 iron pipes 25 feet high. The furnace draught can be regulated satisfactorily according to furnace requirements by the damper, and the efficiency of the furnace is increased. When a combination chimney emits excessive smoke it is impossible, when outside the works making the observation, to determine the proportion of the smoke made by the boilers and furnaces. But immediately after the observation, when the works are visited, the boiler fireman invariably says the smoke was from the furnaces and the position of being able to blame the furnaces for his boiler smoke conduces to carelessness. Furnace firemen having other work to do are often guilty of careless stoking, but by inspecting the working conditions of both boilers and furnaces, it is often found that most of the smoke complained of is from the boilers. But before convictions can be obtained for smoke from combination chimneys it is necessary to satisfy the magistrates that the smoke from both boilers and furnaces complained of is not necessary and that it is practicable to prevent it.

When a chimney serves in addition to boilers, 1 or more *Brewing Coppers*, there need not be excessive smoke if care is exercised when lighting up the copper and during the two hours or so when the liquer must be kept on the boil. There is a greater liability of excessive smoke from coppers than boilers, because the copper fire is lighted and let out after each boiling. But when lighting up the copper fire, with care there need not be excessive smoke, for the best coal is generally used, modern appliances attached, and the stokers have generally nothing else to do but burn the coal.

Penalties of £20 and upwards have been imposed for excessive smoke from combination chimneys.

Auxiliary Appliances.—The appliances for which is claimed the prevention of smoke and economy of fuel and which have been patented are legion. There are various types of mechanical Stokers, Mechanical Draught Automatic Doors, Bridges, Bars, and every device imaginable, but the most practically perfect cannot dispense with the human element, for it largely depends on the latter whether the best of appliances is a success or failure. Also the substitution of Gas Engines and Electric Motors for Steam has done much to reduce the nuisance.

Boiler Stoking.—There are owners of boilers to-day who believe that the only qualifications necessary for boiler stoking is to be strong in the arm (no matter if weak in the head), to be able to use a shovel, and to land the coal in the fire box. Such a belief is most fallacious, and evidence of little, if any, knowledge about either boilers or the stoking of them. Everybody knows that boilers are for the generation of steam, and they must be stoked with combustible matter, producing the necessary heat to generate the steam. If boilers are stoked with coal containing a large percentage of dirt the fires soon become dirty, the temperature of the furnace falls, and it is difficult when using dirty fuel (without frequent cleaning of the fires) to prevent making a large quantity of black smoke. If the coal is clean or only contains a small percentage of dirt, whether small or large, if a large quantity of coal is put on the fire (more than reasonable and necessary) then the furnace is choked, the excessive raw coal causes the temperature of the furnace to fall, the solid fuel is distilled, and most of it discharged from the chimney, unconsumed.

Such firing of boilers is not infrequent. It is unscientific and wasteful. It requires no intelligence or skill merely to fill the fire box with raw coal, shut the door, exclude the necessary air for combustion, sit down and watch the chimney emit 10 or more minutes of black smoke. But to fire boilers economically and smokelessly, utilising the whole of the calorific value of the coals, requires the exercise of much intelligence and skill. And this can be accomplished by firing the boiler furnace lightly, and frequently, either by hand or machine.

i. By *spreading* or *sprinkling* a little coal over the whole area of the grate (to prevent air holes) which will ignite quickly, burn the gas and prevent the formation of smoke.

ii. The same result can be achieved by the *Coking Process*. Dumping the coal down at the front of the furnace, when incandescent, or the volatile gases consumed, then pushed back, always keeping a hot thicker fire at the back of the furnace to consume the gases as they pass over, after liberated at the front of the furnace by the coking process.

iii. But the easiest and most economical system of hand stoking is the *alternate side firing principle*. Firing the right-hand side of the tube first, and in 5 minutes or so when the gases are consumed and the fire incandescent, then fire the left-hand side of the tube (keeping the bars covered with fuel), and the gases from the left side firing will quickly be consumed by the incandescent fire on the right-hand side of the tube, and so continue firing first one side of the tube and then the other.

Firing on this principle is the easiest and most satisfactory system of hand firing, no dragging or raking of the fires is necessary even with small coal, less unnecessary air is admitted to the furnace and the latter being always at a high temperature practically complete combustion is

secured, producing the maximum amount of steam, least waste, least coal consumption, and practically no smoke.

Stoking is Skilled Work.—From the foregoing it will be seen that the burning of coal under boilers economically and smokelessly requires great skill, an intelligence above the average, and great industry as well.

There are different grades of coal to burn, each requiring a different quantity of air, the regulation of the draught must receive attention, the right quantity of coal must be put in at each stoking ; care taken to meet the frequently irregular steam demands ; the working level of the water must be attended to, the cleaning of the fires (with dirty coal at short intervals), and in addition to evaporate the maximum amount of water per pound of coal.

Stoking, then, is not only skilled work, but work of great responsibility, and it must be remembered that in a measure the finances of an undertaking are much in the hands of the stoker as also is life, seeing that neglect may lead to explosion and disaster.

Skilled Workers' Wages.—Such skilled and responsible work should not only demand, but receive skilled workers' wages, instead of wages not equal to those of, say, a street sweeper, which requires very little skill or intelligence. The difference between unskilled and skilled stoking is at least a saving of 15 per cent. of coal. If a man firing 2 boilers (which is now the rule) burns about 20 lbs. of coal per square foot of grate bar per hour, working 8 hours per day, and saves say, 15 per cent., this means about £4 saving per week in coal—sufficient to pay him a wage commensurate with the work done. In addition, by burning the gas instead of discharging it from the chimney, he is a benefactor to the public. So from a purely selfish policy alone, the skilled stoker receiving a skilled worker's wage is a far more profitable servant to the manufacturer than the unskilled stoker with a less wage.

There are a large number of skilled scientific stokers, who are contributing their share toward practical and profitable smoke prevention. The smoke nuisance is bad enough now, but it would be considerably worse if it were not for industrious and conscientious stokers. Many of them have other work to do, they look after engines, pumps, repairs, etc., at a distance from the boilers, necessitating too long a time between the stokings, hence the fires get too low, and the prevention of smoke is impossible for a period of time. To compel a stoker to do other work, and neglect the stoking is an injustice to the stoker, is not a paying policy for the owner, and the public suffer also. Very few of the most skilled stokers know much of the theory of combustion, but they are most expert in practice, and an ounce of that is worth a ton of theory.

Semi-Skilled Stokers.—There are too many "semi-skilled stokers" as is conclusively proved by coal consumption as compared with that of skilled stoking. Naturally as a consequence they are paid less wages, which produces discontent. Some of them are a little below the average in intelligence, not over industrious, often careless and slipshod, taking little or no interest in their work, because of wage discontent. Some object strongly to appliances which are put on the boilers to assist them in smoke prevention, and in coal economy, regarding them as no good ; often by the treatment they receive at their hands the best appliances *are* of little use, which is grossly unjust to the patentee and the purchaser. When the Inspector visits the works to complain of unnecessary smoke, such men often resent any suggestions for its prevention.

The manufacturers, who are the aggrieved parties, complain that they have spent large sums of money on bringing plants up-to-date, and putting on the best considered smoke preventers, but that the stokers will not do their best to assist, with the result that they are

prosecuted and have to pay the penalties, which they consider a great injustice, and that the stokers should pay when it is their fault, so that it would make them do their duty. The manufacturers know they are responsible by law for the actions of their servants, but consider that the law ought to be altered to punish the guilty and not the innocent. It is true the men can be discharged, but it is probable that men engaged to take their place would prove worse.

Unskilled Stokers.—There are many unskilled stokers —men and youths—who know which is the firing end of the boiler, how to fill the fire box with coal, how to put the water in the boiler, and that they must, if possible, keep up a certain pressure of steam, and their knowledge ends there. They have received no training, it is not the work they wanted, but that which they have been put to do and which they are unfitted for. In such cases the management is to blame and the engineer also, for not giving them a little instruction.

The Training of Stokers.—There is provided by educational authorities training almost in everything, for everybody, except in stoking, which is as important from all points of view as anything else, for unskilled and inefficient stoking is largely responsible for the smoke nuisance. A few educational authorities and societies have provided classes for stokers, and after a course of lectures have granted certificates of efficiency. They have not been a conspicuous success, for the stokers who need most theoretical instruction concerning their work will not attend the classes on the ground that they know more about stoking than the lecturers.

It is the duty of manufacturers (1) To recognise universally that stoking is skilled work, and (2) To be prepared to pay a skilled wage, and (3) To demand that educational or other authorities provide the necessary training for stokers which will produce the skilled type of man that is required.

Twenty years ago the German Government set aside annually thousands of pounds for salaries and expenses of *Practical Smoke Prevention Demonstrators*. Each demonstrator had a district and visited the works therein to instruct firemen and others, and to demonstrate specially the production and profitable prevention of smoke.

Our Government could not do better than follow the excellent example and appoint Demonstrators to visit the works to give the necessary practical training in smoke prevention and coal economy.

Such training should be the best that could possibly be provided, and in a very short period of time by such instruction the semi-skilled and also the unskilled stokers would become skilled, would be granted a certificate of competency and would receive a skilled wage agreed upon by the Government, Masters, and Men. If such a practical course of training were adopted there would be no difficulty in raising the necessary army of skilled stokers, for young men would be anxious to take the training, and they would be trained by the certificated stokers, and when certificated they would receive the standard rate of wages, and the discontent which now exists amongst this class with respect to wages would disappear.

With the disappearance of discontent, and the possession by the stokers of the necessary expert knowledge, they would assist in the prevention of damage to property, would contribute to improved public health and to the reduction of mortality. If the Government is not prepared to find the money for Demonstrators (who would save in coal a thousand times more than their salary), surely the manufacturers should be able and willing to bear the cost.

The Grit Nuisance.—Very many complaints were received by a corporation, with regard to a grit nuisance, from people who daily passed their electric power station

and who demanded that the corporation should stop the nuisance.

Also many complaints came from the people who lived within a quarter of a mile of the station, who stated that the grit was worse than the smoke and smuts which were bad enough. The writer received instructions from the corporation to take the necessary steps to abate the nuisance as far as practicable without stopping the station. In the station, which was situated in the centre of the very congested city, there were large marine boilers served by 4 iron chimneys, not more than 35 feet high. The draught was induced, produced by fans speeded up to create an abnormal draught (water gauge from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches) equal to that which a chimney 300 feet high would produce. This was done to force the fires, owing to shortage of boiler power, and the coal was very small slack—smudge. The result was that from such working conditions, nearly half the fuel put on the fire was not consumed but was forced out of the chimneys and consisted of grit, smoke, and smuts. This is not a matter for wonder, for the pull on the fires was almost strong enough to pull the firemen into the furnace. In a very short time the grit covered the station roof, filling eaves and gutters, which had to be frequently cleared, and shopkeepers and occupiers of dwelling-houses surrounding the station had daily to clear away the dirt. To cope with the nuisance, the draught was greatly reduced, a rougher coal was used, grit arresters were put in the chimneys, and the boilers were not unduly forced, with the result that the grit emissions were greatly reduced. To end the nuisance entirely would have necessitated a very large expenditure. The plant being somewhat out of date, the station neither large enough nor conveniently situated, the corporation did the best thing possible—built a larger power station near the city boundary, a considerable distance from dwelling-houses, and fitted up with the most modern boilers, mechanical stokers, and every other appliance to prevent as far as practicable both grit, smoke and smuts. When the new station was opened the old one was closed.

Pulverised Fuel.—In firing boilers with pulverised fuel, fed under steam pressure, great care and judgment must be exercised to procure complete combustion, or 10, 20 or even more per cent. of ash and gritty matter, plus smoke, will be discharged from the chimneys, creating thereby an intolerable nuisance.

HIGHWAYS LOCOMOTIVES.

HIGHWAYS AND LOCOMOTIVES (AMENDMENT) ACT, 1878.

Section 30.—Any person using any locomotive on any highway; not (P) constructed on the principle of consuming its own smoke or not consuming as far as practicable its own smoke, shall be liable to a fine not exceeding five pounds for every day during which such locomotive is used on any such highway.

LOCOMOTIVES ON HIGHWAYS ACT, 1896.

Section 1.—(I) Shall not apply to any vehicle propelled by mechanical power, if it is under (O) three tons in weight unladen, and is not used for the purpose of drawing more than one vehicle, such vehicle with its locomotive not to exceed in weight unladen (O) four tons, and is so constructed that no smoke or visible vapour is emitted therefrom except from temporary or accidental cause; vehicles so exempted, whether locomotives or drawn by locomotives, are in the Act referred to as light locomotives.

HEAVY MOTOR CAR ORDER, 1904.

Article iii.—Notwithstanding anything in the Motor Acts of 1896 and 1903, and except as is otherwise provided in the regulations, a heavy motor car may be used on a highway if the weight of the heavy motor car unladen does not exceed five tons, or if the weight of the heavy motor car unladen with the weight of an unladen vehicle drawn by it does not exceed six and a half tons.

Steam Wagons.—In (comparatively) a very short space of time there were hundreds of steam wagons working on the roads. The unladen weight of the wagons (exclusive of water, fuel or accumulators) was from 4 tons 10 cwts. to 4 tons 19 cwts. Front axle weight 4 tons, and Back Axle weight 8 tons, engine and wagon combined. There are the Foden, Garrett, Clayton, Yorkshire, Sentinel and other wagons, and the speed is from 6 to 12 miles an hour.

No sane person will dispute for a moment the statement that it was by special design for the unladen weight of the said wagons to be under five tons, to enable them to claim exemption under the Heavy Motor Car Orders of 1904—from action under the Highways and Locomotives (Amendment) Act, 1878, Section 30—for not consuming the smoke as far as practicable.

Assuming that the 1878 Act was a dead letter so far as their wagons were concerned, and with this feeling of immunity from interference or prosecution by the Local Authority they filled the streets with smoke, and making vehicular and pedestrian traffic most dangerous, in fact many times cars and even carts have had to stand for safety until the smoke had cleared away.

A number of owners and drivers of steam wagons were summoned for not causing their smoke to be consumed as far as practicable. The defending solicitors claimed exemption under Order 1904, Article iii., and the magistrates dismissed the cases with costs.

In 1908, however, an interesting case was heard in the King's Bench Division.

The appellants had been summoned under *Section* 30 of the Highways and Locomotives (Amendment) Act, 1878, for respectively using on a highway two motor engines which did not so far as practicable consume their own smoke. It was proved that on the highway the motor engines had emitted an excessive quantity of smoke and steam while they were respectively in charge of the appellants. Evidence was given on behalf of the appellants that the engines were so constructed that no smoke or visible vapour was emitted therefrom, except from some temporary or accidental cause. This evidence was not contradicted on the part of the respondent.

The justices were of opinion that the emission of smoke and steam were due not only to the carelessness of the appellants but also to the fact that on the occasion in question the engines did not so far as practicable consume their own smoke, and they were not satisfied that the emission was due to a temporary or accidental cause within the meaning of *Section* 1 of the Locomotives on Highways Act, 1896. They therefore convicted the appellants.

The appeal, however, was dismissed, and the King's Bench decision was most decisive, *e.g.*, that all Locomotives on the Highway, irrespective of unladen weight, must as far as practicable consume their own smoke. Such a decision is most just to all parties concerned.

Since this decision, solicitors in Sheffield defending owners and drivers of steam wagons (which have not consumed their smoke as far as practicable) have claimed exemption, stating the smoke was temporary and accidental, but the magistrates have convicted, imposing penalties.

Temporary or Accidental Cause is smoke, the result of an accident which cannot be practically prevented and only of short duration, caused by tubes leaking, something going wrong with the fire box, bars, engine, or such unpreventable cause. Smoke made under such conditions would not be a nuisance within the meaning of the Act.

Smoke Constituting a Nuisance is smoke of any colour or density, or duration which it is, with care, practicable to prevent in the ordinary working of the steam wagon, and not necessary either when running or standing. To prevent the smoke, as far as practicable, the fire must be fed lightly with either good or bad coal, and the necessary air admitted to the furnace to burn all the gases and prevent the formation of smoke, thus utilising all the heat value of the coal. There will be no leaking of the tubes if only the required air is admitted to the furnace and the result will be little if any smoke, accompanied by an economy of fuel.

These excellent results can be obtained when using a bituminous coal if care is exercised in handling it. Anthracite is better, but coke is the best, as has been proved by the good results obtained from many wagons in which the fire box is specially designed for the burning of coke.

Many wagons make most smoke when standing, and this can be prevented easily, if, when it is necessary to fire the furnace, a *light* charge is put on, and also the steam jet in the uptake be turned on to produce the necessary draught, and so heat, to consume the gases. But the driver has the greatest antipathy to the jet and rarely, if ever, uses it, under the impression that if used it will cause the tubes to leak, which, of course, it will not, if used judiciously.

Extent of the Steam Wagon Nuisance.—There are over 500 steam wagons running daily in Sheffield streets alone, and upwards of 10,000 throughout the country. The numbers are increasing yearly and the nuisance is correspondingly great.

Railway Locomotives.—The railway smoke nuisance can be almost if not wholly abated by simply exercising proper care and judgment in firing, by reducing the coal to small sizes, using no large lumps, and firing in what is known as the *simple shovelful method.* The practical working of this method of firing locomotives burning bituminous coal, without any specially contrived fire box, or fixtures (except the ordinary brick arch), can be operated in any service, quite as smokelessly as if anthracite were used.

This method of firing now permits passenger trains to be run comfortably with the windows open. Further, an economy of about one-sixth of the money formerly paid for coal is now saved to the company, the engines steam much more freely than under the old method of heavy intermittent firing, the annoyance of leaky tubes has almost ceased, there is no filling up of smoke boxes with cinders, and there has been a decided reduction in the work of the boiler maker, and last, but not least, the fireman has had less work to do.

To secure these results it was necessary first to equip the engines with brick arches, and four holes are on each side of the fire box, for the purpose of admitting air. Four tubes run through the arch and the outside air passing through these tubes is heated to a high temperature. This heated air supplies oxygen to the unconsumed gases and produces complete combustion. The four holes on each side of the fire box are located twelve inches above the grates, and into these holes are inserted deflecting air tubes conveying the air to the fire.

After firing each shovelful of coal, the door must be left open one or two inches for a few seconds, admitting enough air to produce complete combustion of the gases driven off from the coal. Care must be taken not to leave the door open longer than necessary to consume the gases. Firemen must learn to work with as light a fire as possible.

Before starting, the blower must be put on and a sufficient supply of coal put into the fire box to ensure a good solid fire. After the coal has been put in, the door must be left partly open by placing the latch on the first notch of the catch, so to remain until the smoke entirely disappears, when the door must be closed. On approaching tunnels the fire must be replenished in ample time, obtaining sufficient fire to carry the train through the tunnel without smoke, the door to be kept closed while passing through tunnels. Firemen must pay particular attention to the manner in which the driver works the injector and handles the engine, in order to regulate the fire accordingly. A good fireman can prevent railway smoke economically when using soft coal without any special device, and produce better results than can be obtained by any of the mechanical devices if badly managed.

Steamship Smoke.—Steamships are (as strikingly shown by the illustration) among the greatest of smoke makers.

Owners of steamships hold that smoke is no nuisance to anybody when at sea, but it *is* to the passengers, and their convenience and comfort ought to be considered, even if the owners can afford to waste coal and yet pay big dividends. Such being the fact, passengers should demand its stoppage. Then it would be stopped, and perhaps the money saved utilised in the reduction of fares.

Also, pressure should be put upon owners of steamships to prevent all unnecessary smoke when raising steam and especially when lighting up the boilers when in dock. Visitors to seaside resorts who spend their money to procure pure air and sunshine, should give Local authorities no peace until they stop the nuisance from pleasure boats, etc., when arriving, standing by, and leaving the piers.

Oil *versus* Coal.—A steamship company a few years ago made some tests with one of their vessels, burning coal and oil on different occasions.

The actual cost of fuel consumed on these voyages was practically the same. When using fuel oil, as against coal, the average speed of the vessel was increased almost

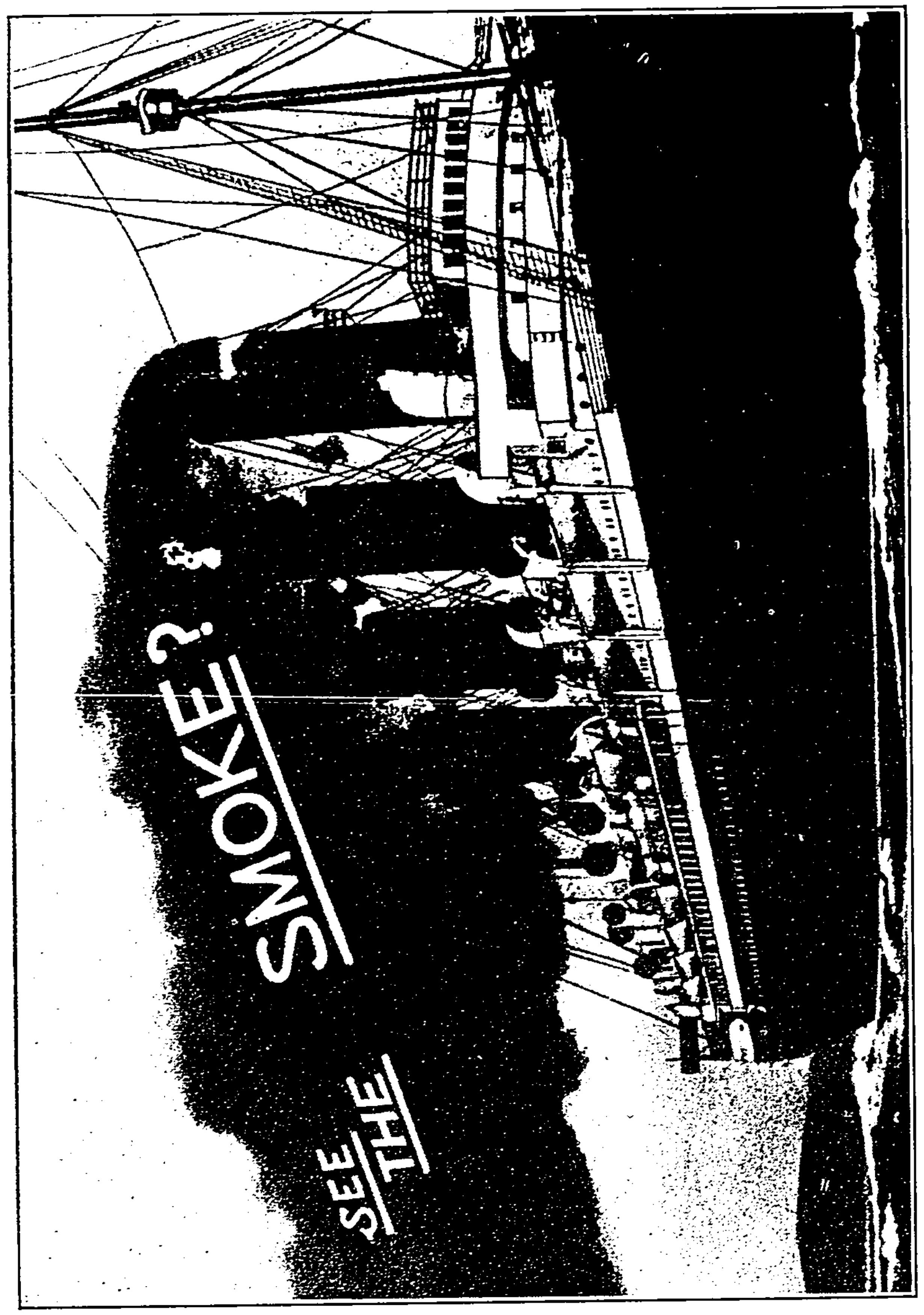

Fig. 28.

by one knot per hour, and 25 days were saved on the round voyage, 18 days owing to the increased speed, and 7 days owing to reduction in time of fueling oil as against coal. The saving in victualling, manning, and also

the increased freight earnings, etc., together with the days saved per round voyage amounted to approximately £4,000 per trip.

With fuel oil, there need not be any smoke nuisance, if the necessary care is exercised in the burning of the oil.