air on plant life and human lungs, also often attributed to preventible smoke, are in like manner due to this non- preventible sulphuric acid. The great gain in cleanliness, however, that would follow the abolition of smoke cannot be overrated.

The methods that have been suggested for the abolition of smoke may be divided into two great classes, viz., those that seek to attain this end by improving the appliances for the burning of bituminous coal, and those that propose to abolish its use and substitute for it some other kind of fuel. The proposals of the first class may be divided into those applicable to domestic purposes and those applicable to boiler fires and other large-scale operations. Those of the second class may be divided according to the nature of the fuel which they suggest. The innumerable inventions of the first class depend for their success (so far as they are successful) on the attention bestowed on the scientific requisites for complete combustion, viz., a sufficient but not too great supply of air, the thorough admixture of this air with the products of the destructive distillation of the coal, and the maintenance of a high temperature within the fire. In our old and crude methods the facts which most militate against the attainment of these desiderata are—(l)that large masses of fresh fuel are continually being thrown on at the top, which cool down the fire just at that point where highest temperature is required ; (2) that the products of the distillation of this fresh fuel, heated from below, do not get properly mixed with air till they have been drawn up the chimney; (3) that unduly large volumes of cold air are continually being sucked up through the fire, cooling it and carrying its heat away from where it is wanted, and yet without remedying the second evil. In the improved methods regularity of supply of both fuel and air is sought so as to maintain a steady evolution of distillation products, a steady temperature, and a steady and complete combustion. In many cases it is sought to warm fresh air before it enters the room by a regenerative system, the heat being taken from the escaping gases which would otherwise carry it up the chimney; and in some cases the air which feeds the fire is heated in the same way.

We cannot here discuss the merits of individual inven­tions ; but we may summarize the chief results of the tests applied at the South Kensington Exhibition. These tests, for domestic grates and stoves, included a chemical ex­amination of the chimney gases, observations of the “smoke-shade” as indicating the proportion of unburnt carbon, and a record of the amount of coal burnt, of the rise of temperature produced, of the radiation, and of the amount of heat lost by being carried away through the chimney. Domestic grates and stoves were divided into six classes as follows :—(1) open grates having ordinary bottom grids and upward draught ; (2) open grates having solid floors (adapted for “ slow combustion ”) and upward draught; (3) open grates fed from below,—supplied with fresh fuel beneath the incandescent fuel ; (4) open grates fed from the back or from the sides or from hoppers ; (5) open grates having downward or backward or lateral draught ; (6) close stoves. Each of these classes was sub­divided according as the apparatus was “ air-heating ” or “ non-air-heating, ” *i.e.,* according as an attempt was or was not made to save heat on the regenerative principle. This attempt does not appear to have been distinctly successful in any class except the fifth ; indeed the evidence of the tests as a whole is rather against the air-heating principle. The following table gives the average results of tests for each class and sub-class as regards general rise of tempera­ture and radiation per pound of coal and smoke-shade. The figures under the last head refer to a standard of shades ranging from 0 (smoke imperceptible) to 10 (black and dense). It was found in practice that the results of

this smoke-shade test were in general accord with those of the chemical examination of the chimney gases. The letters “ a ” and “ n ” in the first column signify air-heating and non-air-heating respectively, the average results for the whole class being given before those for each sub-class. All the experiments were made with Wallsend coal, a fair representative of the bituminous coals.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Class. | No, of appli­ances tested. | Average rise of temp. per lb of coal per hour, in degrees Fahr. | Average radia­tion per lb of coal per hour,  in degrees Fahr. | Average  smoke-shade. |
| 1 | 19 | 2∙88 | 3∙58 | 3∙01 |
| ,, a | 9 | 3∙37 | 2∙88 | 3∙22 |
| ,, n | 10 | 2∙45 | 4∙21 | 2∙78 |
| 2 | 12 | 2∙99 | 4∙07 | 3∙23 |
| ,, a | 2 | 2∙81 | 3∙93 | 4∙11 |
| ,, n | 10 | 3∙02 | 4∙09 | 3∙09 |
| 3 n | 5 | 3∙81 | 3∙61 | 2∙82 |
| ,, a | none | ... | ... | ... |
| 4 | 6 | 3∙05 | 3∙14 | 2∙66 |
| ,, a | 2 | 2∙41 | 2∙42 | 2∙23 |
| ,, n | 4 | 3∙37 | 3∙50 | 2∙88 |
| 5 | 18 | 3∙38 | 3∙70 | 2∙73 |
| ,, a | 11 | 3∙45 | 4∙00 | 2∙29 |
| ,, n | 7 | 3∙28 | 3∙22 | 3∙21 |
| 6 | 10 | 4∙14 | 1∙66 | 2∙11 |
| ,, a | 2 | 3∙79 | 1∙78 | 1∙58 |
| ,, n | 8 | 4∙23 | 1∙64 | 2∙25 |
| 1-5 (total average). | 60 | 3∙22 | 3∙62 | 2∙89 |

From this table the following facts, among others, may be deduced :—(*a*) the air-heating principle has not been applied with success except in class 5 ; (*b*) close stoves (class 6) are superior to open grates (total average of classes 1-5) in respect of freedom from smoke and of general heating effect, but they are greatly inferior in radiating power,—a deficiency which partly explains their unpopularity in the United Kingdom ; (*c*) the “slow-com- bustion ” principle gives a high radiation factor, but is otherwise not successful ; (*d*) the class of air-heating grates with downward, backward, or lateral draughts is, on the whole, most efficient.

Much attention has been devoted for many years to the question of how to work boiler fires, both for locomotives and for fixed appliances, with the least possible production of smoke and the greatest possible evaporative power. Here the desiderata are essentially the same as in the case of domestic fires, viz., adequate admixture of the com­bustible vapours given off by the coal with the necessary air and the maintenance of a high temperature ; and the principles involved are consequently also the same, though the appliances are necessarily different. These improve­ments may be all classed under one or other of two heads, according as the mode of supplying the fuel or the mode of supplying the air is the subject of the improvement. These two kinds of improvement may of course be com­bined. The article Furnace may be consulted ; see also Steam-Engine, sect. “Boilers.”

In the old forms of furnace fresh fuel, as it is wanted, is supplied by hand labour, the furnace doors being opened and large quantities of coal thrown in. One result of this is the inrush of great volumes of cold air, which, aided by the equally cold fuel, lowers the general temperature of the furnace. Mechanical stokers meet this difficulty by supplying the coal regularly in small quantities at a time. They may be divided into those which deliver the coal at the front and gradually push it backward, those which scatter it generally over the surface of the grate, and those which raise it from below so that the products of its dis­tillation pass through the already incandescent fuel. The mechanism by which these results are attained is often of a complex nature.

It is generally recognized that air cannot be efficiently