South Kensington. At the close of the exhibition a national smoke abatement institution, with offices in London, was formed.

In the United Kingdom the subject takes an important place in the programme of the Royal Sanitary Institute, whilst the Coal Smoke Abatement Society is devoted to improving the prevailing conditions, especially in the Metropolis, and has organized a number of exhibitions and conferences on the subject. Several smoke abatement committees exist in the provinces.

A knowledge of the nature of coal and of its combustion is essential for an understanding of the smoke problem. For the purposes of this article coals may be classified as smoke-producing or bituminous, and smokeless, the former including all those varieties most commonly used as fuel. The elementary constituents of such coals are carbon (generally about 8o%), hydrogen, nitrogen, oxygen and sulphur, and they also contain a varying quantity of earthy impurity or ash. The process which occurs in a coal fire consists of two distinct operations. The first, which requires a comparatively low tempera­ture and is independent of the presence of air, is one of destructive distillation, similar to that which occurs in the retorts of gasworks. It results in the decomposition of the coal, and the formation of the following substances:—(1) hydrogen, marsh-gas, carbon monoxide, ethylene, benzene, other hydrocarbons of the paraffin and benzenoid series, water—all of which are either gaseous at the temperature at which they are formed or capable of being converted into gas at some­what higher temperatures, and all of which are combustible except the water; (2) ammonia and other nitrogenous compounds and certain compounds of sulphur, which are also volatile and com­bustible; (3) coke, which consists of carbon (and ash) and is non­volatile but combustible. It is these products of distillation, not the coal itself, that burn, in the strict sense of the word; and this second process requires the presence of air and also a much higher tempera­ture than the first. If the combustion is perfect, the only products are (1) water-vapour, (2) carbon dioxide, (3) nitrogen and (4) sulphur dioxide, the first of which contains all the hydrogen originally present in the coal, the second all the carbon, the fourth all the sulphur, while the nitrogen is liberated as such together with the very much larger volumes of nitrogen derived from the air which has supplied the necessary oxygen. These products are discharged through the chimney.

Two things are necessary for ensuring such complete combustion, viz. an adequate, but not too large, supply of air, properly ad­ministered, and the maintenance of the requisite temperature. In practice, however, these conditions are never perfectly fulfilled, and consequently the combustion of coal is always more or less imperfect and gives rise to a complex mixture of vapours. This mixture con­tains not only the combustion products already mentioned, but also the following unburnt or partly burnt distillation products:—(5) hydrogen, (6) hydrocarbons, (7) carbon monoxide, (8) unburnt carbon in a very finely divided state, and also considerable volumes of unused air.

Usually the name “ smoke ” is applied to this vaporous mixture discharged from a chimney only when it contains a sufficient amount of finely divided carbon to render it dark­coloured and distinctly visible. The quantity, however, of this particular ingredient is apt to be overrated. It always bears an extremely small proportion to the vast volumes of water-vapour, carbon dioxide and nitrogen with which it is mixed; it probably never amounts, even in the worst cases, to 3% of the weight of the coal from which it is formed; and its importance, reckoned in terms of so much fuel wasted, is certainly not greater than that of the unburnt hydrogen and hydrocarbons. It is perhaps best to use the name “ smoke ” for all the products of imperfect combustion (5 to 8) which are avoidable, as contrasted with the necessary and unavoidable ingredients (1 to 4). The problem of smoke abatement is thus seen to resolve itself into the problem of the production of perfect combustion.

The solution of this problem would lead to an important saving in fuel. It has been calculated that at least twice as much coal is used in boiler fires and six times as much in domestic fires as is theoretically required for the production of the effects obtained. A considerable portion of this loss is certainly un­avoidable; nevertheless, much of this enormous waste could be prevented by improved methods of combustion. Another advantage is the gain in cleanliness and public convenience; not only would there be an end to sooty chimneys, but the atmosphere of towns would no longer be polluted by unburnt carbon, whose total quantity is enormous, though the amount contained in any given puff of smoke is very small. The “ London ” or “ pea-soup" fog would be avoided, not because fogs would become any less frequent than now in London and other large cities, but because they would lose their distinctive grimy opacity.

An investigation of London fogs was made in 1901-1903 by the Meteorological Council with the assistance of the London County Council, from which it appeared that 20% of fogs were entirely due to smoke, and that in every case the density and duration of fogs was enormously added to by smoke.

It is often stated that these fogs are *caused* by the smoke that blackens them; but this is an error. The combustion of coal is certainly responsible for their existence, but it is the sulphur of the coal (oxidized ultimately to sulphuric acid), and not the carbon, that is the active agent. So long as coal is burnt at all this manu­facture of sulphuric acid and of fogs must continue; it is not to be got rid of by improved methods of combustion, though the character of the fogs may be materially improved. The evil effects of town air on plant life and human lungs, also often attributed to preventible smoke, are in like manner due to this non-preventible sulphuric acid. Sixteen million tons of coal are annually used in London for heating purposes, and it has been shown by Dr Rideal that, as the sulphur content of this coal ranges from 1 to 2%, there is diffused in the air of the metropolis from half a million to a million tons of sulphuric acid every year. The extent to which smoke and fog affect life and injure property is, perhaps, a matter of opinion. It has, however, been proved that the death-rate enormously expands in foggy weather, and the Hon. Rollo Russell has made a careful calculation showing the extra cost which the smoke nuisance annually imposes upon London. The figure at which he has arrived is £5,470,000, including damage to buildings, fabrics and works of art.

The amount of coal consumed each year in the country was calculated by the Royal Commission on coal supplies to amount to 160,000,000 tons, of which 36,000,000 or 19∙2% are consumed for domestic purposes, and 53,000,000 tons are used in ordinary factories. Thirteen million tons are taken by railways, 15,000,000 by gasworks and 28,000,000 tons by the iron and steel industries.

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 the old and crude methods the facts which most militate against the attainment of these desiderata are—(1) that large masses of fresh fuel are thrown on at the top, which cool down the fire where the 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.

Tests applied at the South Kensington Exhibition of 1882 and in recent years by the Coal Smoke Abatement Society acting in con­junction with the Office of Works, for domestic grates and stoves, have 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 are divided into six classes :—(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 is subdivided according as the apparatus is “ air-heating ” or “ non-air-heating,” *i.e.* according as an attempt is or is not made to save heat on the regenerative principle. The following conclusions, among others, have been arrived at:—(a) the air-heating principle has not been applied with success except in class 5; (&) 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