furnaces. That good progress has been made in this direction may be judged from the fact that on the Continent of Europe, where most attention has been given to this subject, they are building gas engines of from 500 to 2000 horse-power.

The demand on coal next in importance is made for the purposes of steam-raising and power-production, including that used by steamers at sea and factories generally. For these purposes there is used about one-fourth of the total quantity. Economy in the utilisation of coal for power production may be divided into two parts, viz., the economical production of steam, and the economical use thereof. They may, therefore, be referred to separately. It would be a difficult task to try and enumerate the various types of steam boilers, fuel economisers, and other devices which have from time to time been brought forward or proposed as a means of obtaining the highest economy in the use of coal for the production of steam. It may, however, be safely said that there is no particular type of boiler which is intrinsically better than all other types, each type possessing advantages and disadvantages the relative importance of which depends on the conditions under which the boiler has to work.

In Mr. Bryan Donkins' work, "The Heat Efficiency of Steam Boilers," and in Mr. George Barrus' work, "On Boiler Tests," the results of about 530 tests are recorded, and go to show that the efficiency of the different varieties of boilers varies greatly, ranging in some instances from 79.5 per cent. down to 42.1 per cent. with the same type of boiler. These wide variations can only be accounted for by improper firing or some other unfavourable condition. In round numbers, it may be safely said that the average preventable loss in steam generating plants is about 20 per cent.; and as the total quantity of coal used for steam-raising purposes is, approximately, 187 million tons per annum, 20 per cent. thereof is 37 million tons, which it would be possible to save provided the boilers are designed, equipped, and worked in the most economical manner.

It is not a difficult matter to fit up the necessary gear for making accurate evaporative tests to determine the boiler efficiency of any steam generating plant, and I may venture to say that it is the duty of steam users and engineers to do this in order to endeavour to save some of the coal which is now wasted through lack of knowledge of the best conditions to be observed in the working of steam boilers.

Next to the economical generation of steam is, of course, the economical use of it in the steam engine and other steam motors. Great economy has been effected in this direction during the last 40 years. In 1863 the consumption in the best class of marine engine was about 4½lbs. per horse-power; and in a recent review of marine engineering during the last ten years the figure of 1.46lbs. of coal per horse-power is given as the average consumption in the marine engine. There are, however, many examples of engines on land that develop one horse-power for a consumption of from 1lb. to 1.2lbs. of coal.

Professor E. Josse, of the Royal Technical School, of Berlin, Charlottenberg, by means of a waste-heat engine that uses part of the heat (which usually goes to the condenser) to do useful work, has succeeded in reducing the consumption of coal per horse-power to .73lbs., and estimates that in large combined engines of a capacity of from 1200 to 2000 horse-power the coal consumption would be about .6lb. of coal per horse-power per hour. The description of this engine has appeared in several of the technical journals, to which I have to refer the members for further particulars thereof, and of the principle on which it is worked and the special features of its design. These figures show a great improvement on the general practice in steam engineering, and it is satisfactory to know that the investigations of many able thermodynamists indicate that we may look for further economy in the production of power by the combustion of coal.

Besides the production of power by the use of steam, there is a large quantity of steam used in connection with manufacturing industries. It is, however, difficult to obtain accurate statistics showing the total quantity of coal and other kinds of fuel consumed for manufacturing operations in which steam is extensively used for heating and evaporating purposes.

A few examples may, however, be mentioned with the object of showing that these form no inconsiderable items in the total coal consumption, and to indicate the direction in which economy in the use of steam, and consequently coal, may be obtained by the use of multiple evaporation.

In this connection reference will be made to the use of multiple evaporation in the sugar and other industries.

The estimated crop of both beet and cane sugar for the season 1901-1902 is, in round numbers, 10½ million tons, and, as many of the members are aware, a large quantity of water has to be evaporated in the process of producing one ton of sugar and in the subsequent refining of it. In round numbers, the quantity may be taken at from 190 to 210 gallons of water per ton. With the ordinary system of evaporation in a steam boiler or other kind of vessel in which an evaporation of about 8lbs. of water per 1lb. of coal may be obtained, the total quantity of coal required to evaporate the water in the production of 10½ million tons of sugar would be about 11,720,000 tons. The system of multiple evaporation may be applied to about 60 per cent. of the total evaporation necessary in the production of a ton of sugar, the remainder, 40 per cent., being evaporated by single effect in vacuum pans.

The following figures will show the economy of fuel to be derived by the use of multiple effect evaporation on the basis of 1lb. of coal evaporating 8lbs. of water, assuming a co-efficient in each effect of 95 per cent.—

Single effect will evaporate 7.6lbs. water per lb. coal.
Double effect will evaporate 14.43lbs. water per lb. coal.
Triple effect will evaporate 20.60lbs. water per lb. coal.
Quadruple effect will evaporate 26.10lbs. water per lb. coal.
Quintuple effect will evaporate 32.00lbs. water per lb. coal.
Sextuple effect will evaporate 35.30lbs. water per lb. coal.

In the manufacture of sugar the number of effects used is generally four, and sometimes five; there are, however, some sugar factories in Egypt where sextuple effects are used, where there is obtained an evaporation of 35.3lbs. of water per lb. of coal. In the manufacture of salt and in the evaporation of salt water to produce fresh water six effects are frequently used.

The effect of improved evaporation on this industry can be readily judged by the fact that the entire evaporation of the water to concentrate the juice is performed in many countries by the use of megass, or refuse of the cane, as fuel. In beet sugar factories the amount of fuel required depends greatly on the number of effects used for evaporation. The following figures will show the saving to be effected, assuming coal to be used to evaporate the required quantity of juice in the manufacture of 10½ million tons of sugar:—11,720,000 tons of coal would be required to do the evaporation by single effect; then 60 per cent. of 11,720,000 tons equals 6,032,000 tons, which is the amount which would be required to do 60 per cent. of the evaporation by single effect. But as 60 per cent. of the evaporation may be done by quadruple effect, by which there is obtained 26.1lbs. of water evaporated by 1lb. of coal (instead of 7.6 by single effect), only 1,753,000 tons of coal would be required instead of 6,032,000 tons, or a saving of 4,276,600 tons. For further information on the principle of multiple effect evaporation I would refer the members to a paper on this subject in the third volume of our proceedings.

There are many other industries which require a large amount of coal for evaporation purposes, and to which the principle of multiple effect evaporation may be applied. Take, for instance, the manufacture of salt, the production of which in the year 1900 may be taken at nine million tons, a large proportion of this being produced by the evaporation of salt water in kettles. The consumption of coal for this purpose averages about one ton for each ton of salt produced, whereas by the system of multiple evaporation it would require less than one quarter of a ton to produce one ton of salt. It is difficult to obtain the figures representing the quantities of the various substances in which evaporation is the chief element in their production. The following may, however, be mentioned:—Soda,, soda-ash, glue, glycerine, tannin, glucose, wood-pulp, concentrated milk, and a number of others. I think it may be safely said that the number of industries the existence of which depends greatly upon the possibility of cheap evaporation places the question of multiple evaporation next in importance to that of the production of steam for power.

In these brief remarks I have endeavoured to indicate a few directions in which the engineer may, by scientific design and control, help to conserve the great store of fuel which has been buried by our Creator in the bowels of the earth, to be carefully and reasonably used. As our charter states, our Association primarily exists for the general advancement of engineering and mechanical science, and more particularly those branches of civil and mechanical engineering which tend to develop the resources of Australia; and as coal is the principal one of the great "sources of power" in Nature which (so far as can be seen at present) will be the main factor in the development of the resources of Australia, it should be our constant care and thought to see that everything possible is done to conserve it. There are so many ways in which portion of the heat produced by the combustion of coal is dissipated, and it may be said lost, so far as its utilisation is concerned, that it would occupy too much time to refer to them all. Reference may, however, be made to a few, with a view to indicating how some of the many losses may be greatly reduced. First, then, the loss of heat by radiation in connection with what may be considered good systems of steam boiler setting, may be taken at from 8 to 10 per cent. of the total available heat in the coal. Secondly, the loss of heat by radiation of steam pipes and vessels in which steam is used. Thirdly, the steam which passes from the low pressure cylinder of a condensing engine to the condenser is seldom below a temperature of 180deg. Fahrenheit, and it carries with it about 80 per cent. of the heat required for its production. There is no apparent reason why a large percentage of the heat contained in the steam cannot be recovered and made to do useful work in raising the temperature of the feed required for the boiler or for some other useful purpose. I feel I owe you an apology for taking up so much time in referring at such length to what must be clear to the mind of every engineer. However, I console myself with the belief that it is my duty on the present occasion, when I am addressing a body who of all others are those who can do most in the direction of conserving our fuel supply by being constantly on the watch to effect economy in the obtaining of coal and its ultimate use. Men of science and others have for many years been anxiously concerning themselves with the question of when, and how, shall we reach and pass the critical period when the coal and other fuel supplies shall have become exhausted. The question is one of ever increasing importance, and will doubtless cause scientists and engineers much thought in the future. It may, however, be safely predicted that long before the coalfields and other sources of fuel supply of the world have become exhausted, the worker on the borderland of engineering will have discovered some plan of tapping the immensely great store of energy around us, so that when the coal supply shows signs of becoming exhausted other sources of energy other than that of combustion of coal will be utilised to do a share of the work of the civilised world. The available sources of power which will doubtless be utilised in this direction in the future are, the energy contained in the direct rays of the sun, water power, and wind power. At the present time water power is the most available, and when fully taken advantage of will go a long way towards supplying the power required for carrying on the work of the civilised world. A great demand will no doubt be eventually made on the power afforded by the motion of the wind for purposes of pumping water to higher levels, and for irrigation, or in cases where steadiness or continuity of action are not important.

The availability of sun, light, and heat for the purposes of producing power and supplying heat varies greatly on different parts of the earth's surface, and it may be said that Australasia is not unfavourably situated for the utilisation of solar energy when the time for doing so arrives.

The following remarks by Professor Langley, of America, indicate his estimate of the value of solar energy:—

"If all the coal deposits of Pennsylvania were burned in a single second, it would not liberate a thousandth part as much heat as does the surface of the sun in that unit of time."

Professor De Volson Wood, the distinguished American thermodynamist, has arrived at the conclusion that about .24 horse-power can be obtained per square foot of receiving area; and Ericcson, who has invented a successful solar engine, contends that it can supply one horse-power from 100 square feet of receiving area on a bright, clear day.

There is little doubt that the results obtained by Ericsson and others in their efforts to construct an efficient solar engine will be greatly improved when the time arrives which will render it necessary for solar energy to be utilised to a considerable extent in the production of power.

In concluding these brief remarks on the importance of conserving our coal supply, I may be permitted to refer to the question of smoke abatement in the city, as this matter is now occupying the attention of engine and steam users.

In the daily papers recently there appeared an announcement to the effect that the Mayor had decided that a limit of six minutes per hour should be placed upon the time allowed for a chimney to issue black smoke. The time limit quoted by some of the sanitary authorities which I have looked up is as follows:—

In Birmingham ..	15 minutes per hour.
Bury	10 minutes per hour.
Croydon	10 minutes per hour.
Norwich	10 minutes per hour.

And in other cities the time varies from 4 to 10 minutes per hour. The question suggested to my mind by the varying periods of time allowed for the issue of black smoke in the different cities is this:—

Does not the class of coal used in different districts control, to some extent, the time limited for the issue of black smoke?

If this be so, then it appears to me that the municipal authorities should take some steps to determine what would be a fair time limit to apply to all in the city for the issue of black smoke, giving due consideration to the varying character of the coal used. The importance of minimising the smoke nuisance is admitted, but in trying to do so we should take care that it is not done at too great a sacrifice of coal economy.

With a view to indicating some of the difficulties surrounding the question of smoke abatement, I will briefly refer to some remarks made last session when Mr. Meldrum's paper was under discussion.

The precise nature of smoke is still rather obscure, and no reliable or recognised standard method of testing it to determine the degree of intensity has yet been introduced. The Smoke Abatement Commission, which concluded its investigations in Paris in 1897, tested 110 apparatus which were submitted to them as effectual smoke preventers, and that number comprised—

16 Mechanical stokers.
20 Supplementary injection of hot or cold air.
5 With injection of steam, with or without the addition of air.
7 For thoroughly mixing the products of combustion tion and smoke.
7 For burning gaseous fuel.
2 Fired with powdered coal.
16 Smoke washer or soot catchers.
37 Miscellaneous.

This number was reduced to 30, and then finally to eight. The trials extended over three years. There were three prizes offered, viz., £400, £200, and £80 respectively. No first prize was given, as none of the apparatus exhibited were considered worthy of it. The furnaces that produced the least smoke were burning 5.2 and 7.9 lbs. of fuel per square foot of fire-grate respectivly, and there was difficulty in keeping steam.

The official conclusions show that smokelessness and economy do not always go hand in hand, and the trials disprove the opinion which has always been held, viz., that thick or dark smoke carries off a large proportion of the fuel; and it is now known soot contains much black matter, and that the blackest smoke only carries off an insignificant proportion of carbon.

The actual loss of carbon in the shape of soot does not, according to Mr. Scheiner-Kestiner, exceed 1 per cent. or 2 per cent. of the total carbon in the fuel; and from investigations made by Lewicke the ratio of the volume of soot to the volume of gases at the temperature of the flue is about 1 to 70,000.

During the Paris trials it was shown that the apparatus which gave the least smoke was not more economical in evaporation than the ordinary grate when carefully stoked, and it appears probable that to reduce the amount of smoke entails certain expense, either by complications in the grate or a loss of evaporative efficiency of the fuel, and as a rule fails to supply the same weight of steam from a given size of boiler.

There is a very significant remark contained in the summing-up of the Commissioners who conducted these trials, for they say it is very doubtful whether the different apparatus experimented on would last if subjected to hard, practical work, and it is well known to all engineers that most boilers have to be worked to their fuel capacity.

The difficulties which beset the question of smoke prevention may be gathered from the fact that up to the present time there is no apparatus in use which can prevent the production of smoke entirely, although the question of smoke prevention has been under discussion since 1785, in which year the distinguished engineer, James Watt, took out the first patent for smoke abatement. In 1819 the attention of Parliament was directed to the question, and a Select Committee was appointed to enquire into the question.

In 1889 a committee was formed to test smoke-preventing appliances in England, and, notwithstanding these efforts to prevent the production of smoke, the Health Committee of Sheffield accepted a recommendation from the committee that the permissible limit of smoke omission should vary with the number of boilers.

I am quite sure it is a source of much annoyance to all steam users and engineers to see large volumes of black smoke issuing from steam boiler chimneys, and how to reduce it is a question which, no doubt, causes them much anxious thought. It seems to me a fair inference to say that if smoke could be entirely prevented, and—as some of the patentees of smoke-preventing devices contend—fuel saved, the question would have been settled long ago; and there can be no better proof of the great difficulty surrounding the question of smoke prevention than that it has been under consideration by a number of special commissions, and that there has been over one thousand patents taken out with the object of preventing smoke, while the question at the present time seems as far off settlement as ever.