mention that the quantity of coal produced in this State to the end of 1902 is put down at 103,387,070 tons, valued at £41,701,443.

In his excellent work on "The Mineral Resources of New South Wales," which was published in 1901, Mr. E. F. Pittman, (then Government Geologist of New South Wales, now also Under Secretary for Mines), estimates the area of the coal deposits in the State at 16,550 square miles, with a reasonably safe thickness of 10ft. of workable coal underlying that area, and representing a total quantity of 115,346,880,000 tons. He also states that previously (in 1890) Professor David estimated the available quantity at between 130,000,000,000 and 150,000,000,000 tons, assuming 4,000ft. to be the limit down to which coal can be profitably worked, and not taking into consideration seams of less than 3ft. in thickness.

The Royal Commission (1866-71), in dealing with the question of the probable duration of the coalfields in Great Britain, reported that it might be fairly assumed that a depth of 4,000ft. might be reached, bearing in view expedients that may be brought forward for further reducing the temperature. In their estimate the Commission took into consideration seams of rather less than 2ft. thick.

The whole matter is now the subject of another inquiry, and the result, with the depth considered attainable, will be looked forward to with special interest.

The question of mining at such a depth is attended by many difficult and interesting problems. Let us briefly consider some of them.

Without doubt, the chief obstacles to deep mining are those imposed by natural laws, viz , increased temperature and increased pressure, and it is generally conceded that the former is the greater of the two.

From observations made by myself, and others, of the temperatures of our rocks to a depth of 3,000ft., I think it is probable that the temperature of our coal-bearing strata would be about 114 degrees Fahr. at a depth of 4,000ft. Of course, I am only speaking of the temperature of the rock, and by the aid of powerful modern ventilating machinery, a current of say 500,000 cubic feet per minute could be produced, which would probably reduce the temperature of the air in the mine to between 70 and 80 degrees Fahr.

Nevertheless, as the development of the mine carried the working faces farther and farther from the shafts, the ventilating current, picking up heat from the strata as it swept along the roadways, would eventually reach a temperature maximum to human endurance.

No doubt, when mining at such a depth becomes general, mechanical means will be adopted for cooling the air current, and this, and the use of auxiliary fans underground, will afford relief. When the properties of liquid air were brought before the world a few years ago, it was thought by some that its use would greatly extend the limit of deep mining, but from later experience it appears that the cost of such a system will keep it beyond the range of commercial possibility.

Of course—except, perhaps, under some extremely favorable conditions acting as a set-off to the depth—mining at 4000ft. from the surface is not likely to be engaged in until the more easily accessible seams are worked out, and it may reasonably be assumed that the scarcity of fuel would then mean enhanced prices, as a set-off to the increased cost of production.

No doubt, if the air in the mine is very dry, workmen would be able to endure a higher temperature ; but, on account of dust dangers, it might be very undesirable to allow it to be so.

The case of two American mines may be cited as showing an enormous difference in temperatures. The Comstock Mine, in Nevada, at a depth of 2230ft., showed that the temperature of the strata increased 1deg. Fahr. for every 33ft. in depth, and in the galleries on this lode men are stated to have worked in a temperature of 116deg. Fahr. The abnormal heat in this case is supposed to be owing to the fact that the surrounding rock is heated from the lode, probably by volcanic action. Immense volumes of hot water were met with, which no doubt carried the heat.

In the Calumet and Hecla Mine, Lake Superior, the increase in temperature of the strata is only 1deg. Fahr. for every 223ft. depth, and at a depth of 4,530ft. the temperature of the air at the bottom of the shaft was only 72deg. Fahr. In this case, the coolness of the rock is considered to be entirely due to the proximity of the immense body of cold water in Lake Superior.

The effect of pressure will be found in the difficulty of maintaining roadways. This trouble will, however, depend to a very large extent on the nature of the strata overlying and underlying the seam, as experience shows that it is by no means proportional to the depth. Much of the initial difficulty in the opening up of deep mines is caused by the pressure of gas which is drained off as the roads are driven out.

Especially is this felt in new roadways driven in the solid coal; "bumps" frequently occur, heavy timbering is broken, the floor heaves, and the sides burst off. Some mines are also liable to sudden outbursts of gas, and, that, notwithstanding the fact that boreholes are kept in advance of the face of the drives. Pressures of over 250 lbs. per square inch have, in some cases, been recorded in such bores.

Another great difficulty, due to the effects of pressure and high temperature in deep mining, is the liability to spontaneous combustion.

In deep mines where two or three decked cages are in use, there is often a good deal of machinery fixed in the pit bottom for the purpose of loading and unloading all the decks of the main cage simultaneously. Consequently the inset or opening at the shaft-bottom requires to be lofty and of fair width, and this may extend some 30 or 40ft. on each side of the shaft. The effects of pressure have, in the case of many pit-bottoms, caused considerable trouble, and brick arching as thick as 5ft. has been crushed. In some cases, after the first failure of brickwork, wood blocks and bricks have been used alternately with apparently satisfactory results. It is a question whether hard wood blocks, cut to the proper shape to suit the radius of the arch, would not withstand the pressure better, and prove cheaper in the long run than bricks. In other cases, steel girders supported on side walls have been adopted; but where pressure such as has been described comes on, something has to go. Few of our mines here have their pit-bottoms supported in any other way than by timbering.

In the operations of coal mining, there is nothing of more vital importance than the continual supply of a sufficient volume of fresh air for diluting the noxious gases prevalent in mines, and for enabling the underground workers to breathe a comparatively pure atmosphere.

With the very powerful ventilating machinery now being made, there will be no great difficulty in circulating a sufficient volume of air, even at a depth of 4000ft., or more. Recourse may be necessary to some system of cooling air, but as far as volume goes, it is only a question of power. Of course, very deep shafts will require to be large in area, and the same remark applies, as far as is practicable, to the airways in the mine, in order that friction may be reduced as much as possible.

Fans are now being made to exhaust 500,000 cubic ft. per minute, and even higher results will yet be obtained. At a new colliery in Wales, there has just been erected a fan of the following dimensions and type:—Diar. 30ft.; width 9ft.; capacity 500,000 cubic ft. per minute, with a six-inch water gauge. It is of the Walker's Indestructible type, and is driven by $1\frac{1}{2}$in. cotton ropes from a pair of compound engines, having cylinders 24in. and 45in. diar. by 4ft. stroke. The valve gear is of the Corliss type.

Let us look for a moment at what the work of this fan means. The air current and water-gauge named mean a horse-power in that air-current of a little over 472 horse-power, and if we allow an efficiency of 70%, the engines would be developing

675 I.H.P. Further, 500,000 cubic feet of air per minute about represents a weight of about 18 tons, equal to 1080 tons per hour, and 25,920 tons per day of 24 hours. Assuming that the output from this mine will amount to 150 tons of coal per hour, it will be seen that the fan is capable of circulating more than seven times that weight of air in the same time.

We have fans of the same type, at the present moment, in this State, capable of exhausting 400,000 cubic feet per minute with a $4\frac{1}{2}$in. water-gauge.

When it is considered that good ventilation means that the current is practically continuous—day and night, Sunday and week-day—it will be seen how important it is that the fan and its driving engines should be of the very best type.

It will be impracticable in deep mines to convey the power required for the underground haulage of coal, from the working faces to the pit bottom, by means of wire ropes driven from hauling engines erected on the surface, as is commonly the case in shallower mines. Electricity is now being largely used for this purpose, and it is pretty certain that in the near future it will be still more so.

At one of the new deep collieries in England a complete alternating current equipment has been put in. Current is generated by a direct-coupled, three-phase alternater. Induction motors, aggregating about 1000 h.p., are used for driving "main-and-tail" and "endless" rope-hauling engines, for pumping and for several other auxiliary purposes. The mine is a gaseous one. Several other large collieries are installing similar and even larger plants.

The question of winding from deep shafts presents no great mechanical difficulty. Of course, it can easily be seen that at a certain depth a parallel rope would be unable to bear even its own weight from the head-gear pulley downwards, but that would certainly not apply to a depth of 4000 feet. Beyond the safe limit for parallel ropes tapered ropes could be used, or winding accomplished in stages.

I need hardly say that the conductors and other fittings in the shaft, together with the winding engines and ropes, would require to be of the best description, so as to allow for fast winding.

In shafts of moderate depth the type of winding engine usually adopted is a pair of coupled direct-acting H.P. engines, and there is no attempt made (nor is it necessary) to balance the weight of the rope in the shaft. On account of the short duration of the run, the frequent reversing of the engines, and the necessity for ease in handling when raising and lowering the cage from the catches at the pit-top, the valves of these engines are arranged to steam practically throughout the stroke. This is wasteful, but it is convenient and saves complication—a very desirable matter, as anyone who has watched the work of a winding engine at a shallow shaft must know. However, deeper shafts afford an opportunity for working the steam expansively, the necessary gear being operated by a governor which not only brings the cut-off gear into play, but throws it out again automatically, at a certain speed of the engine, a little after the beginning and before the ending of each run. This saves a considerable quantity of steam, but there is still a great waste.

With still deeper shafts the policy of adopting compound engines has commended itself, the comparatively long run allowing an economical cycle to be established. The pressure of steam has been raised, and in a few cases condensers have been applied. Further, in most cases, the weight of the rope in the shaft has been partly or wholly balanced, either by adopting a drum of the spiral-conical type or using balance ropes. To the latter system there are many objections, and in the case of the former a deep shaft means a very heavy drum. Drums of this kind have been made ascending from 19ft. to 35ft. diar. and weighing as much as 80 tons.

To show how the question of winding engines has been treated in the case of one or two deep mines, I will quote the following figures:—At the Tamarack mine, Lake Superior, a winding engine has been erected having four cylinders, each 34 inches by 60 inches. Drum 25 feet diar. by 24 feet, 6 inches wide, weight of drum and shaft 134 tons, total weight of engines 535 tons. The drum-shaft is arranged in the centre, two of the engines (inclined to one another at an angle of 45 deg.) being fixed at each side with one crank common to each pair. The angle between the two cranks is 135 degrees. By this arrangement it is claimed that a very near approximation to constant turning effect is obtained, which makes the engine very easily handled. The valve gear is of the Corliss type. The speed of winding is said to be 4,000ft. per minute, and it is intended to work to a depth of 6,000ft.

At a new colliery in Wales a somewhat similar arrangement was adopted as to turning effect. In that case, the two H.P. cylinders (32in. diar.) are horizontal, and the two L.P. cylinders (50in. diar.) are vertical. The stroke is 6ft. and the drum rises from 15ft. to 24ft. in three revolutions. The engines are fitted with Corliss valve gear, and have automatic cut-off gear on both H.P. and L.P. cylinders. The shaft is 1,890ft. deep.

At a tin-mine in Cornwall, 2,582ft. deep, a drum of small diameter has been adopted, and it is therefore of considerable length. To avoid the side friction on the rope which this would entail, the engines are bolted to a travelling steel girder frame so as to be self-contained and independent of masonry foundations. This frame is mounted on 20 railway carriage wheels, and runs on two tracks of 4ft. 8½in. gauge. The cylinders are each 24in. diar. by 60in. stroke, the drum is 10ft. diar. by 21ft. long, and the side travel is 17ft.

Several compound engines of the four cylinder tandem type have been made for winding from shafts between 2000 and 3000ft. deep, but I need not weary you by quoting further dimensions. The diversity of the three cases I have named struck me as being interesting, and I thought it might be the same to you.

I was somewhat at a loss to know on what subject to address you to-night, but thought some remarks bearing on the question of deep mining in connection with our coalfields would be of interest.

We cannot compare our resources with those of other countries without a due regard to the difficulties and responsibilities which may be attached to their realisation.

I have touched upon a few of those connected with deep mining, and they are matters which will all have to be considered, sooner or later, in this State; indeed, they are now being considered.

In many other branches of industry there are matters of equal importance which have a direct bearing on the successful development of our natural resources, and which, therefore, call for the earnest attention of all who have the welfare of our country at heart.

There are great possibilities in the future of Australia, and we, as Engineers, have our part to play towards their achievement. Let us see that we play it properly, and that our efforts are ever so directed as to be to the credit and advancement of our profession.