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The Storage of Bituminous Coal, with reference to its liability to Spontaneous Combustion in storage heaps, bunkers or cargo

(ILLUSTRATED BY LANTERN VIEWS),

BY MR. JOHN H. ANDERSON (Member).

READ ON

Tuesday, April 2, at 6 p.m.

CHAIRMAN: MR. J. THOM (Member of Council).

OWING to various reasons, probably more coal is held in reserve at the various works throughout the country at the present time than there ever has been before.

One can notice the accumulation of this fuel, yet in how many cases are proper precautions taken to prevent loss either by deterioration or even by fire, due to the over-heating of the heap, and causing spontaneous ignition, in all probability losing a considerable amount of the material.

The writer has been called to examine heaps of coal that were on fire, and the results of these examinations have supported the practice embraced in the following lines. On carrying out the suggestions given, no further trouble was experienced.

There is not much information published on this subject, so perhaps it may be interesting, and at the same time be a service, to those who are responsible for the storage of this material—either ashore or afloat—to record the methods employed, which have given satisfaction, and so far have not given any trouble as regards firing of the stock.

Although these notes are based on a pile of just over 16,000 tons, this quantity is a very small portion of the tonnage deposited, from which the general experience was gained. Some of the other heaps have been deposited over three years.

This pile was selected as an example due to its being all small coal, consisting of several kinds—washed and otherwise—some of a supposed dangerous kind for storing, containing a lot of very fine smalls.

All the material was of a bituminous nature, fairly high in volatile matters, and the whole was stored in the open, therefore it had to undergo all effects due to atmospheric conditions.

As the method of depositing and the re-lifting of the material is not of great interest, we will skip over this very briefly by stating that the material was Seaborne coal, discharged from colliers into self-discharging wagons, running on standard gauge rails, as the tonnage of coal deposited increased, the rails were slewed over to the edge of the heap, thus a continuous "tip" for the material was obtained.

The picking up was done by steam grab filling end-door wagons, which were hauled away by locomotives to a tipping machine which elevated the wagon; then the door was opened, thus releasing the coal, which then went through a guiding hopper into lighters, thence by river to its destination.

As the storing of the coal was considered a temporary measure, very little preparation was done to the site, which was on marsh ground in its original state of alluvium deposit, excepting a ditch about 90 feet wide, which was full of water and mud. This we filled in with ashes to the level of the surrounding marsh.

About three years ago we deposited 10,000 tons on this site; a year later we picked this up.

A second heap was deposited on the same site, but of an increased tonnage (16,050 tons); here and there we increased the depth of the heap (for experimental purposes), and owing to the difficulty on securing the particular coal one would desire to store, we made this heap up with various kinds which one would scarcely store under ordinary circumstances.

Under these conditions extra carefulness was exercised. Temperature readings were taken at 14 different places nearly every day, at the same depth from the surface.

In addition to these we occasionally took readings at the vent-pipes, of which there were fifty off in this heap.

Further than that, to find hottest part of the heap, whenever there was anything doubtful, we took readings at every foot, from top to bottom, of certain places.

The maximum and minimum temperature of the atmosphere and the kind of weather was also recorded.

From previous experience we found the warmest place to be between 6 and 8 ft. deep from the surface, so from this we established a depth of 7 ft. as the standard depth to record temperature.

This we found necessary for comparison, as some of the piles were in different counties, and the readings were very often taken by different persons, who forwarded their records to a central place.

Occasional check readings and all warm places (taken at every foot) was done in addition, personally. Generally speaking, I found the readings taken were very trustworthy; the men took a great interest in the work.

These temperature tubes were $\frac{3}{4}$ in. or 1 in. gas tubing, and are driven from the top to the bottom of the coal. They should be long enough to project 2 or 3 ft. above the coal, and each tube had a numbered metallic label fixed on, so that it could easily be recognised by whichever person recorded the readings.

Regarding vent pipes, in most cases these were old scrap tubes about 8 ft. long and 3 to 4 ins. in diameter. Four holes were punched in the pipes about every 8 ins. or so, stabbed from the outside with a square-tapered punch to about $\frac{3}{4}$ in., thus leaving a burr, which prevented the coal going down inside the tubes.

To facilitate the driving into the coal, the ends of the tubes were flattened, chisel shape, just leaving an aperture of about $\frac{1}{2}$ in., thus preventing the accumulation of water, and at the same time allowing for further venting area.

These vent pipes were driven down to the 7 ft. mark (which I previously said was generally the hottest part found), thus leaving about a foot projecting above the coal. On this a distinctive number was painted, and to which temperature readings were credited similar to the temperature pipes.

The plan of heap shows the position of both temperature and vent pipes, and the numbers attached to same.

Generally speaking, this is a triangular-shaped figure with a surface area of about 46,000 sq. ft., with an average depth of $13\frac{1}{2}$ ft. and a maximum depth of 16 ft. The actual pile consists of North Country, Scotch and Yorkshire coals, the distribution of which is shown on the plan.

Although it would be best to deposit coal during cool, dry weather, no choice could be taken, as vessels had to be rapidly discharged and sent back to the loading port for a further cargo.

Some coal was deposited during very hot weather, while other was deposited in heavy rain; again, some of the material was quite dry when discharged from steamer, while other was as wet as it possibly could be, this latter due to the drainage to the bottom of hold during the transport of washed coal.

Bearing these conditions in mind, and also that the heap is in the open, one gets as near as possible to the maximum difficulties one could expect as regards the liability to create spontaneous ignition and general depreciation of the heating value of the fuel when finally consumed in the furnace, that is, if care is not observed in the treating of the pile during storage.

It is generally well known that coal is in a state of combustion at all temperatures, due to its absorption of oxygen from the atmosphere.

When the coal is at a low temperature this oxygen absorption is very little, therefore there is not much heat generated, and in many cases this little heat escapes to the atmosphere just as fast as it is generated. This is generally the case with the larger coals or coals free from small dust when there is usually a path here and there sufficient to allow the heat to get through to the surface by natural means.

On the other hand, heaps may be composed of small coal, which may be so dense that there will not be sufficient apertures or paths for the generated heat to escape; the consequence is that this heat gathers, thereby increasing the temperature of the coal, and incidentally, due to the increase of heat, it increases the rapidity and capacity for further oxygen absorption in a given time, thus giving off more heat in a given time than when the heap was cooler.

It will be seen from this that if a heap has a tendency to rise in temperature steps must immediately be taken to arrest this, otherwise the increase of heat will be so rapid after a time that it will not be possible to cope with it unless drastic measures are taken, such as to turn over the heap, or, as it has happened before, letting it burn itself out.

If any of you have had the experience of putting a fire out that has occurred in a heap of coal or in bunkers or cargo, you will readily understand the difficulty experienced, particularly when well alight. Even in the open, and with plenty of water, there is great difficulty to get to the mischief. The heat is great, and the fumes are overpowering. In bunkers, where the fumes to a certain extent are confined, there is also a further risk of generating gas and making an explosive mixture with all its serious risks. Believing that prevention is better than cure, I am sure that if the method we use for storing was carried out generally, and if the results of our system were applied to vessels carrying cargoes of dangerous coal for long voyages, there would be very little danger from the point of spontaneous ignition.

Again, if on reading this paper through and then appreciate the source of danger from the little things that set up the initial rise of temperature, I rather gather that you will think there are many places on board ship that may set one thinking. I am speaking more of bunkers and the holds next to boilers and engine-room, where there is sometimes just the bare bulkhead between the heat and the fuel. Very often one will see steam pipes close to these bulkheads, and, of course, you need no teaching from me how readily steel or iron plates conduct heat, thus setting up the initial heating, which gradually accumulates until one gets mischief.

By taking periodical readings of the heat of pile, and comparing them with previous readings, one gets ample warning to prevent a fire.

We made 90° Fah. a warning temperature. When this reading was obtained at any place four further temperature pipes were driven down north, south, east and west about 10 ft. from the warm pipe. The next day the readings of these four pipes were carefully noted. The highest one would then be made the centre, and further pipes would be put down in this direction. The idea is to locate the source of heating, which may be communicating only a portion of its heat to the standard temperature tube. When this warmest place was found an additional vent pipe would be put in there, which generally arrested the rise of heat. We would then pull out the smaller temperature tubes.

We made 100° F. a danger reading—that is, if the insertion of a vent pipe failed to arrest the rise of temperature—but let it reach 100° F. We gave orders for a trench to be dug, one foot deep, on every occasion. Thus if the daily readings were at 100° F., say, for three days, then this spot would be found trenched three feet deep.

Originally this danger temperature was 95° F., and on four occasions we trenched at one place. This was the only trenching done in the heap—about 10 tons of material removed in all.

At no time did the readings of this pile reach 100° F.; probably the trenching on this occasion may have been unnecessary if additional vent pipes had been inserted. However, this was the hottest part of the pile throughout the whole period.

This part was in the neighbourhood of No. 4 temperature pipe, and where the coal was deposited to a depth of 16 ft.

There are several factors which tend to create a rise in temperature in a pile of coal. I will endeavour to treat them in the following order:—

Handling of material previous to storage.

Size of coal.

Depth deposited.

Weather and moisture effects, rain, sun, disintegration.

Nature of coal, friability, pyrites and foreign material.

Looking at a seam of coal in the mine, it presents a surface of apparent solidity, which has to be broken up by the miner either by manual labour, blasting, or by cutting machinery, and in many cases a combination of these methods are used. Quite scientific methods are used by many of the men on working the coal, whereby very little smalls are made. On the other hand, some collieries do not possess this type of careful collier, or there may be a lack of supervision, and, therefore, quite a lot of smaller coal than there need be is often created and sent up. Of course, again a great deal depends on the nature of the seam, which may be intermingled with bands of foreign material. The roof may be bad, and occasional crushing and falling of the roof may take place, part of which may be sent to the surface with the coal. Again, the floor may be bad, and occasionally has a tendency to rise. Thus, with these actions taking place, there is bound to be a crushing effect on the coal, which if it is of a friable nature, then quite a lot of smalls are sure to be made.

One of the most dangerous and no doubt the most laborious task of the miner is that of undercutting the coal by means of a hand pick.

In some seams—due to the height—he lays on his side and plys the pick, gradually cutting out the supporting material, so as to facilitate the effect of explosives blasting out the coal.

It is interesting to watch some of the older miners working, their methods are such that they utilise the weight of the roof to burst out the coal, these men work as easy again as others, and yet obtain as much coal, use less powder, and what is of more consequence in relation to the value of coal, they will not break it up the same as some of the less experienced.

A great deal of this dangerous work is now done by machinery, which under-cuts much more rapid than by hand, and at the same time a deeper cut is made, consequently less blasting is needed, and more larger coal is obtained.

The rapidity of this cutting, particularly on long-wall working, means that more coal can be extracted in a given time, therefore there is not the same risks of roofs caving in through the weakening due to exposure.

The slide shews a large "Pick Quick" cutting at pavement level. No doubt these will be interesting to you as they show the machines actually at work in a Lanarkshire mine. The next slide shows a small "Pick Quick" undercutting a 16-inch seam, also in Lanarkshire. From the view shown you will appreciate some of the difficulties of obtaining coal when most of our easily wrought seams are worked out, and to put this off as long as possible, it behoves us to use this national asset of ours in as economical a manner as can be done.

This coal at the face is loaded into small hutches, or tubs as they are called in some parts of the country, either by hand or, as in many modern pits, by conveyor belt. These hutches are taken to the shaft bottom on rails, run into a cage and elevated to the surface of the mine.

The coal may be then either tipped as it is, direct into railway wagons, or, as in most collieries, it may be tipped over a screening arrangement whereby the smalls are separated from the larger pieces.

These larger pieces are usually diverted to an endless belt conveyor, travelling at a slow speed, and from off this belt various impurities are picked off by hand. Sometimes special pieces of coal are picked off this belt as a selected coal.

Regarding the smalls, this may be sent to market in its condition after first screening, but in most cases it is further screened through several graded screens, and classed according to the size of the coal.

The final residue may be quite small, like dust.

Some collieries wash all their coal, excepting the very large pieces. Other collieries only wash the final residue, or slack, and as some do not wash any you will see that quite a number of descriptions or names can be given to coal that may all have come from the one seam.

Again, sometimes the washed smalls are mixed with the larger coals extracted on the original screening, and, further, different seams may be blended.

Generally speaking, the process of screening leaves the major part of the impurities with the final residue, and if the process of washing is also carried out the separation of impurities is greater, and most are entirely washed out as sludge from the smallest screenings.

The coal is usually taken by railway trucks and tipped into vessels' hold. There are various appliances for this purpose, a great many of which are credited with properties that they do not possess in actual practice.

These are to, and probably would, prevent a lot of breakage of the coal, providing the human element was taken into consideration. But the principle idea to-day is rapidity of dispatch; therefore, a lot of ideas are put to one side, so far as looking to the size of the fuel is concerned, particularly when those handling it are not responsible for it other than getting so much per ton for doing so.

During the voyage of steamer heavy weather may be encountered, which may, and often does, pound the cargo into a considerably reduced space.

On discharging the vessel the coal is all again handled by either machine or manual labour. Sometimes this coal has to be thrown out two or three times, depending on the type of vessel being discharged. Then, again, there are the operations of handling the coal to the point of storage. The handling of the coal so many times makes a great difference in the appearance of same when it arrives at its destination, and with some of the more friable coal quite a large percentage of smalls are made from the coal, which was all screened pieces at the colliery heapstead. The liability of this small coal to create spontaneous combustion is very pronounced, both from its size and also from it closing up the paths, whereby the heat generated would otherwise escape freely to the atmosphere. This will better be understood by considering the greatly increased area of coal that is exposed when a lump is broken up; therefore, more surface to absorb oxygen. I rather suggest from this that most of this oxidation is superficial; therefore, if the smalls absorb more oxygen in a given time, then they must generate more heat in a given time than the larger coal, and, as we have said before that the obstruction is greater with the smalls, therefore the summary of this is that small coal is more liable to fire than the large coal, particularly if steps are not taken to let this heat out. This means that there is one safe height that must not be exceeded, but as there are other factors that must also be taken into consideration at the same time, it will almost be impossible to fix this safe height for every heap. The height of pile can be increased above this safe height mentioned, providing means are taken to vent it, the more it is vented the higher the heap can be piled.

Generally speaking, 12 to 14 ft. is about as much as one should deposit small graded coals. Nine to 12 ft. for unwashed mixed coals.

For slacks it depends a great deal on the composition of same. Two heaps of this material we allowed to rise up to 120° F. before moving it. These heaps gave considerable trouble at the height it was—10 ft. Eventually we reduced this height to 6 ft., when even then its tendency was to increase in temperature.

I was rather glad to get rid of this material, as it was communicating heat to another pile of coal which was close by. My opinion of the cause of trouble was bad washing of the material; thus after a shower of rain the shaly-like material formed a sort of plastic mass, with the coal practically preventing any escape of the heat. A diagram of the temperatures of this heap is shown; also a photograph of the picking up of same. Heavy clouds of vapour rose from this when it was grabbed. As a rule little trouble is experienced with the storage of large coal, but one must be careful even with this, as in the event of a fire great difficulty will be experienced on putting it out owing to the ready access of oxygen for supporting combustion. Care should be taken not to make any smalls when depositing this coal, and if possible the coal should be selected that will weather best, otherwise that on the top will crumble up and fill up the interstices underneath. If this so happened, and this part overheated, whereby a fire was to start, you will readily see that there would be greater loss than in a pile of all small coal, particularly if a system of temperature recording was carried out. One would get sufficient warning and be able to excavate down to and remove the source of trouble owing to there being an insufficient supply of oxygen for rapid combustion in the smaller coal. This naturally may raise a question as regards the treatment of a fire that may occur. I will come to that later.

If you look at a large piece of fresh wrought coal, in most cases you will notice that it is free from cracks. Probably it will possess a lot of whitish or reddish material like porcelain on it. Sometimes you will see yellow streaks like brass; and in some seams of coal this is inches thick. Now put this piece of coal in the open, exposed to all weathers, and carefully examine it, say, once a week for a year.

After a time a discolouration of the porcelain-like material will take place, and this will eventually drop off, exposing the coal. Examine the coal closely with a glass, and you will discover minute cracks, which in course of time will develop, and ultimately the piece splits up, thus offering a great many more surfaces for the atmosphere and moisture to take effect on.

The sun, rain and frost play a very important part in this disintegration. I have split many a piece of coal that was exposed to the sun for some time by simply pouring a glass of water on the lump. Again, the brassy streaks or pyrites, commonly called brasses, decompose, resulting in their swelling and causing a certain amount of breakage of the piece. These pyrites are generally effected by moisture, and although the total amount of heat that is possible to generate by them is small in comparison to that generated by the oxidation of the coal, yet personally I am inclined to believe that they play a very important part in the storage of coal, particularly in conjunction with rainy weather, thus being an incentive to set the pile in active oxidation.

I had rather an anxious time for some weeks with several heaps, due to the rain during last summer. Probably some of you will remember that we had some very heavy rainstorms. At any rate, the following extract from our local paper refers to the case:—

> "The incessant rains throughout this week has proved unprecedented; in fact, all records appear to have been broken locally, the total fall from Sunday to Wednesday being 5·05 inches. On Sunday evening 1·5 inches fell in an hour. On Monday the rainfall was ·96 inches, while the incessant downpour on Tuesday and Wednesday resulted in falls of ·92 and 1·63 inches respectively."

Up to this time all our heaps were in a perfect state of balance regarding the escape of heat as it was being generated, but soon after many of the readings began to rise. Vapour arose quite freely out of the vent pipes, and continued to do so for several weeks afterwards. Several additional vents were inserted, and we trenched at one place where the highest readings were obtained.

On close examination during trenching we found that active oxidation of the pyrites had taken place, and that quite a layer of fine pyritic shale had formed, thus practically sealing the coal underneath. This material, I suggest, is from the weathered, disintegrated coal from the top, which probably had been washed down with the rain; of course, as it further oxidised it would swell and close up still more. The moisture would cause the oxidation of the pyrites, and the difficulty of penetration for the heat to escape would thus insulate and communicate the heat to the coal underneath instead of escaping to the atmosphere, thus setting up oxidation of the coal itself, which would then have a cumulative effect till we got sufficient vent pipes inserted or excavated the trenches so as to release this imprisoned heat.

Regarding the nature of coal and its liability to heat, generally speaking, I find that the geological age is a fair guide, the anthracites being the safest to store and the lignites the most dangerous. A good guide is the weathering effect on a sample rather prominently exposed and occasionally moistened with water by hand, that which readily crumbles up being the most dangerous. But, of course, a great deal depends on the composition of the coal, considering the impurities and foreign material that may be mixed with it.

Anything that ignites at a lower temperature than the fuel should be kept out of the heap, such as pieces of wood, pit props, rags, waste, shavings and straw; very often straw is put in wagons to prevent leakage of small coal. There are also other reasons for the use of this material.

In case of a fire in a heap of coal, although plenty of water should be available to quench out a fire if flames were seen issuing, still common sense must be used before we do even this, it being better to dig all round the fire; then, if possible, remove the hot coals away from the heap, then quench the material there.

As I have previously said, plenty of warning will be given and the spot localised before there is any actual danger if a systematic method of temperature readings are carried out. Then in case of overheating, the seat of heating would be dug out; at any rate, great difficulty would be experienced to get water to a fire in the middle of a heap, and no doubt the fire would cause a certain amount of the coal to melt and form a coking mass if it were a bituminous coal in the heap.

If it were possible to get the water to the fire, then quite a lot of this water would then get heated. Naturally, it would gravitate to the bottom of the heap, and there spread out. This heated water may then just be sufficient to set the whole heap into active oxidation, whereby all the coal may have to be removed. Again, some of the steam formed may be decomposed and assist the formation of a flaming gas.

Of course, if the fire was in a receptacle that could be flooded out, such as a storage bin or a vessel's hold, it may be the best plan to flood; but I certainly should not do this except when there was an actual fire that could not be treated otherwise.

I hope I have shown how these fires start from small beginnings; that can be controlled with a little forethought. The whole thing can be summed up by keeping the material as cool as possible, the safety depends on the care exercised and action taken at these low temperatures.

As a rule, the greatest danger is up to about three months from the time of taking the coal from the pit.

Although the experiences mentioned are mostly the result of land practice, I do not hesitate in saying that the ideas can be embraced in marine work, particularly in so far as long distance cargoes are concerned, and also with regard to the coal used as bunkers.

In many cases you will notice a recess built into the main hatch of vessels for the donkey boiler, thus increasing the area of bulkheads. Then, again, steam pipes, hot water pipes, etc., may be placed in such a position that heat may be conveyed to the bulkheads, further than that modern tendency is towards higher steam pressures, sometimes with superheating, all of which offer higher temperatures in and around where the bunkers are. Thus you will see that everything is favourable for the initial heating of the stock of coal both in bunkers, and also cargo next to engine-room bulkheads.

I suggest that there should be a certain amount of non-conducting material between this heat and the coal. The hot surfaces in many engine-rooms could be better protected, thus making it more safe and comfortable, and a certain amount of economy would be effected.

As regards vessels carrying cargoes of coal, I am surprised that more fires at sea have not occurred, but I put this down more than anything else to the way the large coal naturally separated from the smalls when it is tipped into the hatchways.

In the older type of vessel the hatches were small in proportion to the size of hold. The consequence was that, the coal being tipped at or about one place, the larger pieces would run to the bottom of the cone formed. Then as more coal was tipped these large pieces would run to the bulkhead before the small could get there. Later, when trimming was necessary, still the larger pieces would offer less throw for the men, and no doubt they would take advantage of it. Thus you will see, although done unintentionally, a natural vent was formed. The smalls gathering under the hatch space no doubt would be the danger point, particularly if any moisture was present and the coal contained any pyrites.

Of course, if the fire was in the smaller coal it would be more of a smouldering nature owing to the lack of oxygen, but this fire may travel to the larger coal, where there would be no difficulty in the supply of oxygen. Then this would be a serious matter.

I see no reason why a few vent pipes could not be driven into these places where the smalls are, and instead of the usual ventilators causing the fresh, moist air, probably laden with ozone going into the hold, we used a sort of ejector to extract the heated air from the hold. I believe this would give better results. It must be clearly understood that the term "vent pipes" used in this paper does not mean ventilating pipes; but that they are used purely and simply as escape pipes for the hotter gases in the heap.

Although it is not usual to store coal in this country to the extent carried out during the past three years, yet I anticipate that this storage will in future be continued more so than in the past.

It is an asset to know that you have sufficient fuel to carry you over a certain period; probably it may be bought at a more favourable price during certain months of the year. It will be an incentive to a steady production at the collieries; certainly it would have a tendency to steady railway traffic.

The losses in calorific value as a fuel are exceedingly small, particularly if stored in a method reducing the exposed area to the atmosphere, such as shown on plan rather than in heaps of a triangular vertical section, or coned heaps.

The losses are the surface weathering, plus that given off as heat from oxidation.

If the heaps are kept cool, this latter item can be neglected; as regards the former, this could be overcome by covering. But this would be rather costly for large heaps; it can be minimised by choice of coal.

These losses are more apparent than real, certainly weight for weight between the new wrought coal and the same coal after being stored for a considerable time, would show in favour of the new coal, but I suggest comparing the tests from a common base such as on, say 10 tons of coal as ordinarly received, then deposit 10 tons of the same coal for a period seeing that none is pilfered, then using this heap as a test.

There is a further loss, but this is mostly lost shortly after the coal is mined, that is in a gaseous form, but as this would effect most coal, it can be neglected so far as storage is concerned.

Generally speaking, the elements lost in storing are those which in most cases are thrown away by imperfect combustion in the furnace, and I believe if the stoking of stored coal was given more consideration, practically the same results would be obtained from an evaporative point of view, as that from ordinary coals.

A certain amount of reduction in size is sure to occur due to additional handling.

An allowance must also be made for interest on capital cost of stock, rent of space occupied, together with expenses of handling, and, of course, insurance of the whole.

This latter item is quite nominal providing systematic methods of storing are employed, as suggested in this paper.

Considerable interest is being taken just now in connection with the utilization of ferro-concrete for ship-building, for this I am not an enthusiast, but I strongly advocate the more extended use of this material for construction work, and in relation to the more permanent storage of coal, which I think is bound to come. The following slides, all in connection with the handling of coal will show you what has already been done with this material.

There is sure to be a difficulty of obtaining steel sections for some time to come, therefore I think there will be an extended use of ferro-concrete.

The result of 14 years maintenance experience of ferro-concrete structures has taught us many a lesson, and if anyone present is interested in ferro-concrete ships, I strongly emphazise that the whole future in the life of this material lies in the care that is exercised in a few of the details of apparent minor importance which are usually left to that class of labour who take the slightest interest in the matter, and although it appears to be a simple matter to throw concrete inside a prepared mould, yet there are many things we have learned by experience which soon tell up when the work is done in an inferior manner.

Following the ferro-concrete slides some examples of steel storage erections will be shown, together with views of modern machinery handling the coal at different operations.

Slide 60.—Since this view was taken this pier—which is one of the pioneer piers of its kind and also one of the longest—has been extended by the addition of a further 400 feet.

Slide 61.—It has had to put up with several heavy collisions from vessels fully laden with a tonnage up to 9,000 tons, at full or nearly full speed.

The scientific experience gained from these accidents has proved very valuable to the concrete world and has a great deal to do with the confidence placed in ferro-concrete.

I am firmly convinced that if this pier had been built from timber, at least on two occasions a vessel would have clean swept a great portion of it, together with the loss of valuable plant.

Slides 138, 139, 140.—In this country we have been very conservative with our methods of using plant.

It is extraordinary how one gets a wet blanket thrown over them if one happens to be a little previous with some suggestions.

I remember a few years ago, quite a sensation was created, when a suggestion was made that we should cope with vessels of 6,000 tons or so running on the coast in the coal trade.

It is no secret to say that much larger vessels have been used than this, and have given good results, therefore justifying the idea and the increase of size of plant to deal with it. London as a port, would have been in a serious position to-day if this had not been done.

We shall need to go further than this with mostly everything.

Our units are far too small, and comparatively speaking are only toys to that which we will need to adapt ourselves to eventually.

There are no obstacles from the designer's point of view, providing there is no cringing about a few pounds on little things, get your plant substantially built, the increase of capital cost is nothing compared to the saving effected on quick dispatch, freedom from breakdowns, and confidence that can be placed on doing work you have plotted out to do.

The photographs shewn illustrate some of the methods of handling coal in the United States.

The first four photographs show the largest coal docks in the world, and they are operated by the Pittsburgh Coal Co.

You will see that there are 3 two-span bridges on the fore of the dock with 2 one-span bridges in the rear. The coal is piled to a height of 40 feet on this dock, which gives the dock a total capacity of approximately 825,000 tons of bituminous coal (2,000 lbs. to ton).

There is also shewn the docks at Superior, just across the bay from Duluth; this dock has a capacity of 1,000,000 tons, 800,000 tons of which is bituminous coal, which is stored in the open and 200,000 tons of anthracite which is stored in the covered shed as shown. This bridge has a span of 342 feet and a cantilever extension of 125 feet.

As can be seen it is fitted with man riding trolleys, which carries a six ton grab, which travels with full load at 1,000 feet per minute. Hoisting speed 250 feet per minute. The coal can be piled 48 feet high. These plants are fitted with screening arrangement which screens and delivers the coal in three different sizes.

The next photograph shows a Brown hoist at the Astoria Light and Power Co., New York. It is equipped with a 9-ton grab, and is worked at the same speed as previous machines.

They can pile the coal to a height of 40 feet, but in practice it is generally 30 feet.

The next photo is a much smaller plant used by The General Electric Co., Schenectady, with a grab of $2\frac{1}{2}$ ton capacity.

Here they pile the coal to a height of 30 feet.

The next two photos are those of a plant at Pittsburgh belonging to a Mining Co., Messrs. W. H. Brown and Co., and fitted with six ton buckets. The coal can be piled to a height of 55 feet.

The next photo is very interesting in relation to this paper as it shows a method of storing coal greatly favoured by some people, although very expensive in first cost. Here you will see a 30-cwt. grab operated by a Brown hoist loco-crane on the works of the Indianopolis Light and Heat Co.

The concrete pit you see with the water showing is 300 feet long and 100 feet wide and 28 feet deep, which is used to store the more friable and dangerous coals in. The pit can store 30,000 tons, 13,000 tons of which can be covered by water if necessary. This crane can handle 80 to 100 tons per hour.

The next two photos show the coal storage system of the Detroit Edison Co. This is much on the lines of some of our methods used in this country, although it offers a large area for the weathering of the coal.

You will notice the great difference in the size of the units employed in the States to that which we use over here, and in so far as storing is concerned, they do have fires, but take little notice of them. They do not prove disastrous simply because the fire can be excavated in a few minutes owing to the plant being able to cope with the rapid handling of the material, consequently nearly all the practice there, is to utilize a high capacity storage in comparison to the area occupied.

My endeavours have been to put this paper before you in as simple a manner as possible, giving you our practical experience of temporary storage, and illustrating this by tracing the coal from mine to consumer.

DISCUSSION.

Mr. S. G. MARTLEW: Spontaneous combustion is due to heat, which is in turn caused by the absorption of oxygen by the fuel, the resulting chemical combination being accompanied by rise of temperature which, if unchecked, reaches the ignition point and originates a fire. We should, therefore, aim to keep the coal in a cool condition, and, undeniably, the safest way is to place it under water. This method is in actual use; one instance which I can call to mind being that of Iowa coal for the Railway and Light Company of that State. The easily-ignitable nature of their fuel when stacked caused this corporation first to try having a 5,000 to 6,000 ton reserve in freight cars, but only one-tenth of the number of cars is now necessary in conjunction with the underwater storage, resulting in corresponding reduction in detention charges and the further advantage of releasing rolling stock for war purposes. On the other hand, grab cranes have to be employed for raising the combustible, and this means expense. Experiments prove practically no losses in calorific value from coal which has lain beneath the water. One of the most notable of these proofs is the test made on contents of the bunkers of the U.S.S. *Maine* when she was lifted, after being about eight years at the bottom of a Cuban harbour.

Ferro-concrete hoppers of large size have been, within the last decade, increasingly made use of for solid fuels, which generally are transported by means of hoists or conveyors to, and along the top of, the reinforced structure, and tipped. The lower part of the hopper is shaped so as to feed readily into trucks or on to conveyer bands. The initial cost of such a method is high, but is repaid where they are constantly in use, since ease of handling is assured once they are complete; and, moreover, the likelihood of spontaneous combustion is very sensibly diminished by the fact of the entire mass of coal being disturbed every time a little is discharged from a bottom outlet. Where stacks are resorted to, it is unquestionable that vent pipes and periodically-visited thermometer tubes are desirable, as also is the case in ships' bunkers. The greater the length of time the fuel lies dormant, the more heating-up is probable. My rule is to dig out the coal should the temperature rise above 150 deg. Fahr., if in stacks, or to turn on the hose if at sea. When piled, some combustibles deteriorate more than others, and, in reserving some from Welsh collieries in 1915, I covered the heaps with Yorkshire "hards," with the result that, as according to recent Government regulations, I must use all stored coal in this winter before getting more, it is pleasing to find that the three-years'-stacked fuel is unaltered as regards steam raising. Coal for storage should preferably be "screened lump," and should be entirely protected from the weather where possible.

Mr. Anderson: It is rather a big thing to reply verbally to so many suggestions put forward in Mr. Martlew's remarks, but, first of all, I should like to say that storage of coal in London to-day is a temporary measure pure and simple. In ordinary times it would not pay, as the coal can be brought right down from the mine in thirty hours, and it is in the bunkers the same day. It would not pay to store it under water in Great Britain unless to make provision for some emergency that might arise, for instance, through labour disputes, and as regards using it from the water ordinarily I would not do it; but should save this as a reserve stock; thus we should not be evaporating a great deal of free moisture all the time. One of the photographs shows 30,000 tons storage, the lower 13,000 tons flooded over with water, and many of the slides I have shown to-night show ferro-concrete storage bins, some up to 4,000 tons, together with steel bins and also the machinery used to handle the fuel to and from these bins, so that I will leave this part of Mr. Martlew's remarks at that. I should like to see much more mechanical handling done than we now do, not only ashore, but also afloat. Mr. Martlew said the greater the length of time the coal was stored, the more danger there was of spontaneous combustion. I find in practice that the case is diametrically opposite. Coal, from the time it is worked till a fortnight after, gives off a large quantity of gas called by miners, when mixed with air, "fire-damp." The technical name is methane—a quantity practically equal to its own bulk. And a quantity equal to about $1\frac{3}{4}$ times its bulk is given off in five months. I do not know the effect of this in relation to heating or if anyone has gone into the matter so closely as to find out this effect; however, I find that all the heat is generated at or about three months from the time the coal is brought from the pit. That is, I should say, the tendency to accelerate oxidation and give off more heat than can escape to the air; perhaps this is due to the air in the interstices of the coal when tipped, being gradually charged with inert gas from the products of combustion of the pile during this first storage period, as the oxygen is absorbed by the mass. In the paper I said:—"I hope I have shown how these fires start from small beginnings that can be controlled with a little forethought. The whole thing can be summed up by keeping the material as cool as possible," and then added: "As a rule the greatest danger is up to about three months from the time of taking the coal from the pit." I have pointed out that the safety of the coal begins with its treatment at the low temperatures. In storing coal, one must begin by thinking of the inevitable rise in temperature, therefore vent pipes should be put in to allow the heat to escape immediately the coal is deposited. The danger of spontaneous combustion is not from the low temperature; but if you do not look after the low temperature, the temperature gradually increases, and so also increases its (the fuel) properties for absorbing more oxygen. I might compare it to a safety valve. If the safety valve were too small and you fired under it, eventually the boiler would burst. It would be quite safe to have the heat at 70 deg. Fahr., or even 150 deg. Fahr., but it might suddenly rise up and get beyond control. Above 70 deg. its properties for absorbing oxygen are greater, and that is the cause of the rise of heat; in the piles of coal, of course, the heat cannot escape as fast as it is generated; therefore, like the boiler valve, a point would be reached offering greater resistance, or, I may say, too small an aperture for the quantity of heated gas to escape. The storing of coal under water is the best way as a permanent storage measure. This is different from the method of alternately wetting and drying. One method certainly prevents disintegration, and the other encourages it; but the whole question is one of overcoming a temporary difficulty by making the best use of existing areas under existing circumstances. The quantities we store would need a lot of consideration to justify this expense it would entail—roughly a quarter of a million tons.

Mr. Wm. McLaren: The author has given us the results of a great deal of experience he has had in storing coal under favourable conditions; that is to say, favourable conditions in having such quantities to deal with; and his experience goes to prove what Mr. Milton, junr., showed in his paper, that the

Temperature readings of pile of mixed small Coals, 16,050 Tons (2,240 lbs. = 1 Ton).

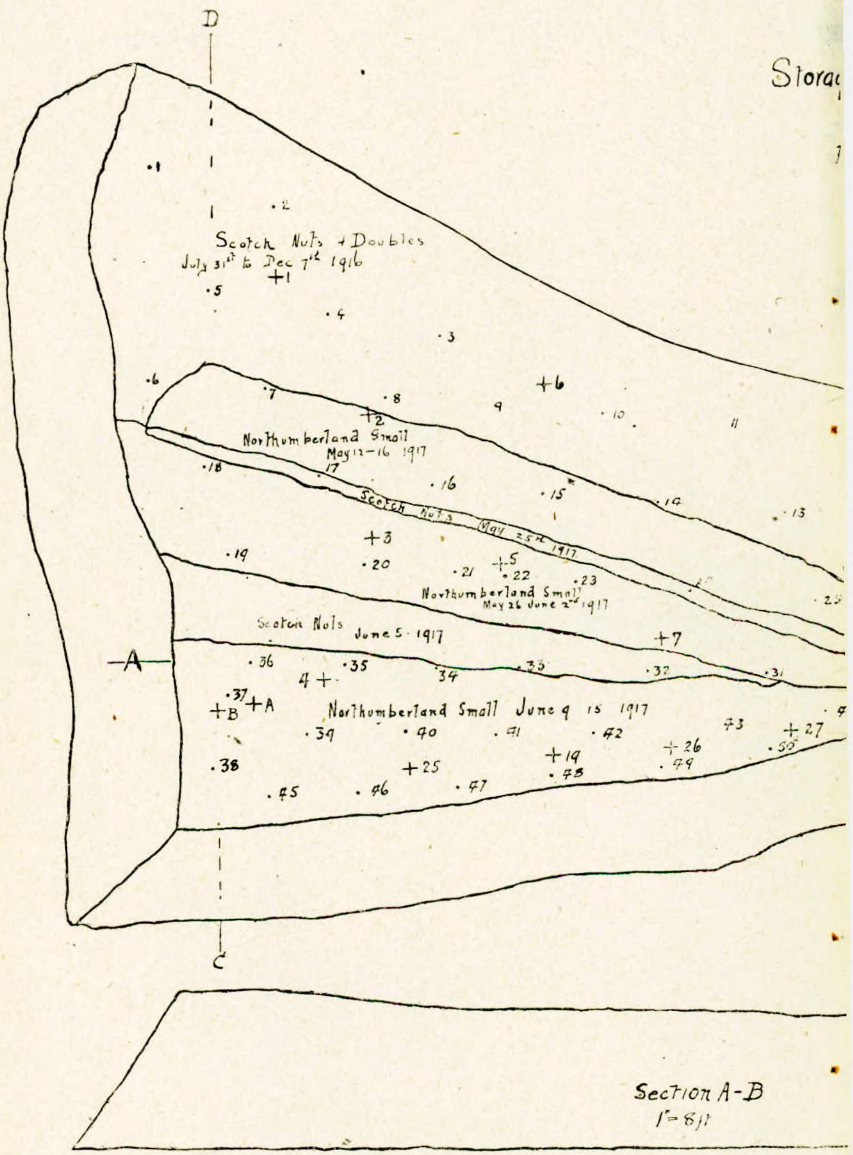
Abstract of 3 months from records of 11 months, showing readings from a vented heap.

Inserted 5 tubes around No. 4 July 29th. Then moved them as below:

```
C ·          · D
B ·
A ·          · E
      (4)
```

φ Trenched.
ϒ Added more vents.

1917												A	B	C	D	E	Pipe No. 25	Pipe No. 26	Pipe No. 27	Atmos. temp.	Weather
JULY. 20	76	68	70	84	88	76	78	70	76	76										88	
21	76	70	72	82	80	78	76	72	78	78										82	
23	78	70	76	84	82	76	80	78	78	80										78	Slight rain.
24	74	68	78	82	72	70	70	66	68	78										76	
25	68	68	66	80	74	76	72	70	72	70										80	
26	66	68	70	80	72	70	66	70	68	72										74	
27	78	74	80	86	82	74	76	80	78	80										76	Fine.
28	78	78	80	90	84	80	78	82	80	74										82	Fine.
30	68	72	70	86	78	70	74	76	78	72	8.0 a.m. 88, Noon 90	90	96	88	74	76 φ					Heavy rain.
31	68	70	72	84	74	66	72	76	74	68		94	98	88	76	78 ϒ				68	Heavy rain.
AUGUST. 1	68	72	76	86	76	68	78	68	78	76		86	96	88	74	74				66	Heavy rain.
2	62	62	70	80	78	78	74	64	76	70		88	96	92	78	78				68	Heavy rain.
3	62	60	66	80	76	74	70	68	70	66		88	96	94	80	80				64	Rain.
4	66	68	72	84	78	76	80	68	72	66		88	94	92	80	80				62	Slight rain, evening.
				86	82								92							62	Dull, 11 a.m.
6	70	68	68	86	72	80	76	68	78	72		86	92	86	78	78					
7	78	78	80	86	84	76	80	80	78	76		90	96	90	82	72				80	Fine.
8	74	76	78	84	80	72	76	76	74	76		86	92	88	78					72	Dull.
9	72	74	78	82	80	70	74	74	70	74		88	92	84	78					76	Rain.
10	66	68	70	86	82	66	78	70	78	72		90	92	86	80					76	Fine.
11	68	68	70	80	78	70	78	70	76	70		86	90	84	78					80	Fine.
13	70	72	72	80	78	70	78	70	80	72	Pipe No. 19	90	92	86	82					72	Fine.
14	72	74	72	82	76	72	78	72	78	70		88	90	84	82						Heavy rain 1 hour.
15	68	66	68	76	80	70	74	76	76	74		82	88	84	76					66	Fine.
16	68	68	68	86	80	70	76	70	78	76		86	90	88	78					62	Slight rain.
17	68	68	70	80	78	70	80	72	80	74	84	88	90		82					64	Slight rain.
18	64	64	68	80	80	66	78	68	76	74	88	88	90		80						
20	68	66	70	86	82	70	76	70	74	76	90	86	92		82					68	Fine.
21	68	72	76	80	80	84	80	76	76	74		88	90		82					68	Fine.
22	70	74	78	82	82	80	78	78	76	74		86	88		80					70	Fine.
23	70	70	76	80	80	74	80	72	78	76	80									66	Fine.
24	70	72	76	80	82	78	80	74	78	76	82									64	Fine, heavy wind.
25	68	70	76	82	78	74	78	70	78	74	80									62	Dull.
27	64	70	76	86	76	62	74	62	74	70	76									66	Slight rain.
28	64	70	72	82	74	62	72	60	.72	68	74									66	Slight rain, heavy wind.
29	64	64	68	78	74	64	70	60	70	68	72									66	Slight rain.
30	62	70	78	78	82	64	72	62	78	64	70									68	Fine.
31	64	70	78	78	82	66	70	62	70	62	80									68	Fine.
SEPTEMBER. 1	68	72	76	74	78	66	72	68	76	68	78									68	Dull.
3	78	78	82	88	84	74	80	76	84	78	88									70	Fine.
4	68	70	80	86	84	70	74	76	82	74	84									82	Fine.
5	66	68	76	82	82	66	72	74	78	72	82									88	Fine.
6	66	68	80	86	82	68	72	74	78	72	84									82	Heavy rain during night.
7	66	68	78	86	82	68	72	72	80	74	86									78	Fine.
8	66	68	80	84	84	66	72	74	78	70	86									76	Fine.
10	68	70	78	82	80	66	74	70	82	72	80									78	Fine.
11	74	78	84	84	80	70	78	74	82	78	82									82	Fine.
12	74	74	78	82	80	68	76	74	80	76	82									78	Fine.
13	66	68	74	82	78	64	74	70	78	76	78									70	Fine.
14	70	70	78	82	80	68	76	70	82	78	82									72	Fine.
15	72	68	76	84	84	66	74	70	78	74	84									66	Fine.
17	68	68	76	84	80	64	74	68	78	72	80									64	Fine.
18	68	70	78	84	82	64	74	70	78	74	84									70	Fine.
19	70	70	76	84	80	66	74	70	76	74	84						76	82	80	70	Fine.
20	68	68	76	84	82	64	74	70	76	72	86						80	82	78	68	Fine
21	68	68	78	84	82	64	74	70	78	72	86						78	82	76	66	Fine.
22	66	70	76	84	80	64	74	70	76	72	84						78	80	74	64	Fine.
24	72	72	78	86	84	70	76	72	80	76	86						80	84	78	60	Fine.
25	72	74	80	86	84	70	78	76	80	76	86						82	84	80	60	Fine.
26	68	70	76	86	82	64	76	72	76	70	84						80	80	78	66	Fine.
27	68	68	76	86	82	64	74	70	76	70	84						78	80	76	66	Fine.
28	66	70	76	86	80	64	74	70	74	70	84						80	78	74	66	Fine.
29	66	72	76	84	82	66	76	70	78	72	84						80	80	74	66	Fine.
OCTOBER. 3	66	68	74	86	80	64	72	70	74	70	104						78	76	72	62	Dull.
4	66	66	72	82	78	62	72	68	74	68	80						80	78	74	60	Fine.
5	66	78	72	80	72	64	72	68	74	68	82						80	80	74	60	Dull.
6	68	76	74	82	76	66	72	70	72	68	80						76	78	76	62	Fine.
8	66	68	74	80	78	64	72	68	74	66	80						76	76	74	56	Dull.
9	64	68	74	78	76	64	70	66	72	66	78						74	74	72	60	Fine
10	64	68	74	78	72	62	70	66	70	68	72						68	74	70	60	Fine.
11	64	68	74	78	74	64	70	68	68	64	74						74	76	72	58	Fine.
12	64	66	76	80	80	60	72	66	70	66	76						76	78	74	56	Wet.
13	64	66	74	78	78	62	70	68	68	66	80						74	76	72	58	Wet.
15	62	62	72	82	80	64	70	68	74	66	80						76	82	76	58	Wet.



NOTE.—Block used for repro

small coal or dust is dangerous to store. There are difficulties in connection with flooding with water; one cannot do that at sea, although it may be done on shore, but, as the author has pointed out, it is only in case of emergency that the coal is stored at all. At present I have 1,000 tone under storage, and I would never have had that quantity in pre-war days. The space available for storage is not what one would desire. On the south side of the river one is offered arches under the railway for this purpose for double screened coal of a very small kind, and one naturally hesitates to take the responsibility for storing under these conditions. I should add we have inserted, with the Insurance Company's approval, several $\frac{3}{4}$ inch gas or steam tubing or barrel, say, 10 ft. in depth. This applies to large and small coal. We drop a piece of copper wire down within a few inches, and at various depths in the tubes for short periods, just as a precaution against heating.

Mr. Anderson: I may say that the pile of coal described in the paper is of the smallest class; some is absolutely "slacks," the maximum is about $\frac{3}{4}$ inch, with the exception of one corner piece of a few 1,000 tons, which is nut coal. The smalls are more dangerous because they offer a bigger superficial area for absorbing the oxygen. When you break up coal the superficial area is increased, and the absorption of oxygen depends upon the area exposed. A lot of the slides shown illustrated the various handling of the coal from the time it is in the solid working face; each operation means a certain amount of reduction of size, therefore more area to take effect on. We should reduce this handling as much as possible after the coal has left the screens at the pit.

Mr. G. Lloyd Jones: I should like to ask Mr. Anderson if he could give us some idea of the characteristics of the coal which makes it liable to spontaneous combustion. What is the quality which gives rise to the liability for firing? My personal opinion is, simply, that of two kinds of bituminous coal, one of which is non-caking and the other caking, one can look for trouble in the one which cakes, and the non-caking coal never gives rise to trouble at all, and I think this is due to the packing of the coal preventing circulation or dissipation of the heat in the atmosphere. The vent pipes Mr. Anderson advocates would have to be looked after or they might form chimneys to encourage combustion, and, therefore, those vent pipes should be removable. I do not know whether Mr. Anderson can trace origin of fires to pyrites; any material susceptible to rapid oxidation, thereby generating heat, is really the source of trouble. With regard to the question of storing coal under water, virtue has been claimed for salt in saving coal. It is said that by applying salt in different forms three tons can be produced out of one ton of coal, and it would therefore seem that if the coal is stored under salt water one might expect more calories. People tell us that there is no loss when under storage; pound for pound, there may not be much loss in tonnage, but what is the aggregate loss in calorific value?

Mr. ANDERSON: Mr. Lloyd Jones has spoken from the chemical side, but this is a practical paper, and I have purposely kept away from the chemical aspect. I quite agree that pyrites have a great deal to do with it, but at the same time I stick to the old-fashioned idea that the initial effects depend upon the weather and method employed on handling and storing the coal; the secondary is a pyritic effect. It is said by some people that a shower of rain has nothing to do with it, but I am firmly convinced by practical experience that rain has everything to do with the secondary condition of the heating of the coal. This pyrites is generally accompanied by a considerable amount of shale. This shale forms a plastic mass, which seals the coal underneath, and the pyrites on oxidation swells and further chokes up the apertures, which, consequently, cause the cumulative effect of increasing the temperature and giving off more heat through further oxidation. This, then, will be a further, or third step. With regard to the vent pipes, I do not mean ventilation pipes. I call them vent pipes pure and simple for the purpose of allowing the escape of the hot gases. The heap of coal I spoke of is 400 or 500 ft. across, and has a perfectly flat surface. Where is the displacement to come from for the supply of free air which would necessitate the pulling out of these pipes? In the paper I said the losses by storage were more apparent than real. If you take the coal to be tested to the West Ham Laboratory you get a faithful representation of the sample as it is at the time, perhaps to the detriment of the stored coals original analysis, but if the coal absorbs oxygen, then there is a chemical operation. A very small amount of the carbon is used, but a greater portion of oxygen has combined with the hydrogen and forms water. This is, a ton of coal to-day may be more than that in a year's time; it will be found that it has increased in weight to a small extent. It would be impossible for the laboratory to tell you this, because it depends on the temperature you allowed the pile to go to.

Mr. Lloyd Jones: Does that make up the loss in the chemical value?

Mr. Anderson: Yes, with certain reservation from a practical view, it compensates the loss shown by chemical analysis. It is rather a big subject, but we have not yet reached the best practice in the scientific burning of coal. For every shovelful of coal put on a furnace there is a certain amount of loss, and that loss is represented by a portion of those lighter gases which form a part of the volatile matters in coal. Those gases that are lost by the average stoker on firing are the gases which are lost in storing the coal, so that there is practically little difference unless they take a more scientific view as regards the method of supplying air for supporting combustion. From some closely conducted experiments by some of our friends on the other side of the water, it was conclusively proved that after coal had been stored for several years it gave practically as good results as new wrought coal in a boiler furnace. We know what to expect from a chemical analysis, but there are other conditions which make a difference in practice. That is why I say in practice the loss is nothing.

Mr. Lloyd Jones: There is an alteration in the hydroscopic moisture in coal which ought to make a difference.

Mr. Anderson: That is true; but in practice there is an increase of weight of the total bulk which compensates this.

Mr. Lloyd Jones: The structure is altered and the hydroscopic contents are altered.

Mr. Anderson: Yes, there are those differences, but the stoker does not consider that there are certain vital qualities in coal and its effective gases. He simply throws the coal on the fire and fires so many tons per shift. So far as chemistry is concerned there are so many units of heat lost, but if those gases have already escaped it would not make any difference in the heating value, as some of those gases are the ones which are lost in storage. A coking bituminous coal, I agree, is more subject to overheating than the non-coking. I have noticed that coking coals generally show the weathering of bituminous pyritic shales very pronounced feathery ferrous-sulphate sticking all over the place. I have often thought that this weathering of the shale has a lot to do with the alteration of coking value of stored coal; if so, perhaps the addition of shale to a non-coking coal might solve the problem of coking the anthracites.

Mr. Martlew: Having tested a coal steam-raising plant for a number of years and noting the effects of using newly delivered coal and coal which has been for a number of months or years under storage, I find that as regards steam raising—that is to say, if we get x lbs. of steam with a pound of newly-won coal—we shall also find that we get very nearly, if not quite x lbs. within 1 lb. of the stored coal. That is my practical experience of the effects of storage, providing great care is used in storing, as suggested in my previous remarks.

Mr. Anderson: That is one of my points—method of storage to prevent deterioration. I rather think that Mr. Lloyd Jones will agree there are some things in coal of which we do not know everything yet.

Mr. Lloyd Jones: I want to know why you go to the boiler house to determine the calorific value; why not rely on the calorimeter?

Mr. Anderson: I quite agree there is nothing to compare with the scientific analysis of coal. You then know what to expect, but the stoker does not know what to expect; he does not care. Personally, I think we ought to go to the stoker much more than we do to explain the analysis of his fuel as determined in laboratory. At the beginning of 1916 I wrote a paper, which was intended purely for stokers and owners of plant, now published by E. and F. Spon, and distributed it all over the country. I believe in going to the stokers; we do not educate them enough. They ought to possess a certificate of some sort as regards their knowledge, then the scientific analysis of coal would possess a greater value than it now does, apart from the buying of different kinds of fuel. No one knows better than Mr. Lloyd Jones that I encourage the greater use of scientific analysis of fuel. But at present this result is purely used from a commercial point. I should like to teach the stoker what to do with the coal from the results of analysis, and then to get all from coal that is in it, thus incidentally reducing his own work, his master's costs, and, the greatest point of all, extending the time of prohibitive use of our country's most valuable asset—Coal.

Mr. Arbuthnot: I find that there is a reduction in calorific value.

Mr. Anderson: That depends on the way one looks at the matter, such as from an analysis of a sample or the results of the whole mass. Both will depend on the care taken on storage.

The meeting concluded with a vote of thanks to the author, proposed by Mr. W. E. Farenden, seconded by the Chairman.

Mr. JOHN KIRSOPP (Gateshead-on-Tyne): Mr. Anderson's paper is an exceedingly interesting and valuable one, as he has graphically dealt with the question of the maximum limit of height (or depth) stacks of various classes of coal could be safely teemed to without actual risk of their heating or firing through spontaneous combustion, one on which apparently up to the present there seems to be (whether erroneously or not) considerable elasticity of opinion.

According to the depth, in the paper (also the maximum temperatures it would be safe to allow a heap of each respective class of coal to rise to before taking any steps), for each various class of coal, we have, viz.,

	Aver. depth in feet.	Maximum depth in feet.	Temperature allowed to rise to degrees Fahr.
1. Mixture of North Country, Scotch and Yorkshire coal	13½	16	
2. Small graded coal	—	12 to 14	See p. 114 the
3. Unwashed mixed coals	—	9 to 12	Author's reply.
4. Slack	—	not above 6	
5. Best large	—	20ft	

are they heights that can be arrived at before the adoption of vent pipes and daily readings of temperature are advisable, or are they the maximum limits of height it is safe to teem the heaps up to altogether, without risk of excessive heating or firing?

If the former, it would seem that any heating in a coal stack invariably commenced after the pile had reached a certain height, hence the advisability of the adoption of vent pipes. Consequently, does their adoption entail their remaining standing down to their original driven depth of (as quoted) 7 ft. below level of top of stack (or, as it then was), and there remaining till the stack is filled out and an additional number of vent pipes gradually brought into use, and as the heap gradually advanced in height each in its turn driven down to a depth of 7 ft; or are the whole of the vent pipes uniformly kept with the bottom ends above level, and all periodically raised to the same uniform level as the heap of coal is gradually piled up in height; or, if so, how often? If such is the case, it would appear that the nature of the different classes of coal and a time element in the rate of teeming operations or the rate the stack grew in height would be a consideration.

Referring to the previous enumerated five distinct stacks of different classes of coal, would the author kindly supplement his remarks by stating, in the case of (1) whether the different coals as teemed were mixed through and through on the heap—or was each distinct class teemed at, and built up different parts of one big heap—and could the whole of this coal be classed as unscreened? Also, whether (2) was washed, small graded coal, as also the case of (4) and (5) in hereinbefore mentioned table?

It may be interesting to many members to compare the views expressed in Mr. Anderson's paper with those arrived at by previous authorities and Commissions on this subject. Some few years ago the writer went very fully into the question of "Coal Shipment and the laying out of Staith-heads, with special reference to Anti-Breakage Arrangements," throughout the British Isles and abroad, the whole (with photographs and diagrams) being exhaustively embodied in a paper read before and published in the Trans. of the Institute of Mining Engineers.* With this paper he also wrote one on "The Various Types of Cargo Steamers, with special reference to Doxford's Self-Discharging Boat."

In the first mentioned paper the writer briefly referred to the subject of spontaneous combustion, and what conclusion had been arrived at to lessen such possibility in the case of stacked coal, as he considered it one very closely related to the use of anti-breakage appliances, especially so with regard to the first portion of cargo deposited in the holds.

After researching into this subject he would wish to mention that one of the most complete and valuable papers on this subject is one on "The Spontaneous Heating of Coal, particularly during Shipment," by Sir Richard Threlfall, F.R.S., (*Journal of Soc. of Chemical Industry*, 1909, vol. xxviii., page 759), from Sir Richard's researches and those of other authorities quoted in his paper, it is difficult to conceive that iron pyrites can play any serious part in spontaneous heating, although this is a theory which appears to die hard.

On the other hand, it has been conclusively proved that dry coal will absorb oxygen much more readily than moist coal, even when both are freshly won, and after a short period dust and slack do show most decided signs of heating to some very appreciable extent. Sir Richard, however, admits that moisture in coal may cause pyrites to decompose by air and

* Trans. Inst. Mining Engineers, 1908, vol. xxxvi., page 610: 1909, vol. xxxviii., page 596; 1910, vol. xxxix., page 650; and 1911, vol. xl.

moisture combined, under circumstances when it could not do so by either agent separately, and so he thinks that probably the weathering of pyrites may have some important indirect influence favouring spontaneous combustion.

Mr. Henri Fayot found, as the result of experiments with various coals from the north of France and Belgian coalfields that the inflammability of coal is highest with lignite, passing downward through gas and coking coal to anthracite in the order named; but the difference between gas and coking coals was not great, which is an important fact, as there has always been a tendency to make too much of supposed great differences in the natural tendencies of coals to inflame spontaneously.

Various Commissions have proved that the risk of a spontaneous fire is much greater when the cargo is loaded in summer than when in winter, and that the size and depth of the ship (or hold) has also an important bearing. In 1874, with cargoes shipped under 500 tons, the number of spontaneous fires that broke out was less than a quarter per cent., whereas with shipments of over 2,000 tons the number rose to nine per cent. All the Commissions have also failed to find a single undoubted case of a spontaneous fire having occurred originally in any other place than in the heap of dust formed immediately under the hatchways.

The second New South Wales Commission recommended that where large ships are being loaded during warm weather (say, when the temperature is 90 deg. Fahr. or over), a hose should be played down the hatchway so as to wet, at all events, the coal which collects at that point. Some authorities still consider that a considerable collection of iron pyrites, combined with moisture and coal dust, in the cone which is built up in the vessel's hold immediately underneath the hatch, really does play an important part in causing spontaneous heating.

Some collieries, for the preservation of their coal in wet weather, take the precaution of covering their loaded wagons with tarpaulin during transit between the colliery and the place of shipment. This practice is adverse to the views of both Fayot and the New South Wales Commission.

Fayot also claimed that the height of the stack played an important part in heating, more especially when composed of unscreened coal or slack. From his own observation no cases had occurred in heaps of less height than 6½ ft. (2 metres), whereas when the heaps were more than double this height spontaneous combustion invariably occurred. It is recognised that outbreaks seldom or never occur with vessels of two decks.

It seems to the writer, whether pyrites plays an important part in spontaneous heating or not, the remedy most assuredly lies in diminishing the amount of small coal, and more especially of dust contained in the cone built up immediately underneath the hatchways.

Allowing the human element to enter into this question or not, this can only be affected or modified by some form or other of anti-breaking appliance, preferably one which reduces the crushing or grinding action (and thus the quantity of dust created) to a minimum, and distributes the mixture of small over as large an area in the hold as possible.

All authorities unanimously consider that one of the means of, if not preventing, spontaneous heating altogether, at any rate counteracting it, is by having a sufficiency of ventilation either by means of vertical shafts or pipes, and, where possible, by horizontal open air courses as well as from shaft to shaft. These shafts could be used for pouring water down into the hold in case the coal began to heat.

On the face of these preceding remarks by Threlfall, Fayot, various Commissions and others, who all endorse more or less the practice of sufficiently ventilating coal stacks, if from his environment and experience Mr. Anderson is able to supplement his valuable paper by furnishing data that would establish a reliable working standard basis of safety as regards the radius of area of surface of heap, it is advisable not to exceed, for each vent pipe of, say, a uniform given size and for heaps of each distinct class of coal, it would be of great value, not only as furnishing a thoroughly reliable principle, the establishing of which would reduce the risk of all possibility of heating and firing to the minimum, and would also probably form a basis for insurance companies to work off, in basing their sales, which at present seem somewhat vague.

As the author's views on the question of the use of water in case of fire is rather adverse to the views hereinbefore expressed (and especially in the case of the firing of a stack of large coal), is it possible for him to supplement his original remarks in any way in this respect?

A recent paper has been published on a method of teeming up a series of conical shaped heaps not exceeding a height of 15 ft., North Country coal, but as every colliery or works has not sufficient waste or available ground for this purpose, it seems to the writer that if one large heap can be built up with safety, it possesses advantages.

I am obliged for the advance copy of Mr. J. H. Anderson's paper, and have pleasure in contributing the following remarks to the discussion thereon:—

I have been much interested in Mr. Anderson's paper, with the valuable record of his experience. It is important to note that his results corroborate those of the large number of others whose attention has been directed to this subject, and that the precautions suggested by him are the same as have been repeatedly put forward by others. Thus there is a general concensus of opinion that heaps of coal should not exceed 12 to 14 ft. in height, that tubes or rods should be put down at intervals in the heaps to determine the first signs of heating, that a heap should be properly ventilated, and that trenching should be resorted to when there are indications of heating. Indeed, I am only in disagreement with one statement, namely, that "there is not much information published on this subject"; I hold that there are a few questions concerning coal upon which more has been published in recent years than upon the spontaneous combustion of coal. In the first place, the theory of the subject has been admirably elucidated by that important series of papers emanating from the Doncaster Coalowners' laboratory, which have appeared in the Transactions of the Institution of Mining Engineers, the first having appeared in 1913, vol. xlvi. The two reports of the New South Wales Commissions on the Spontaneous Combustion of Coal are fairly well known, but a more recent volume on the Weathering of Coal, by Dr. J. B. Porter, published in 1915 by the Canadian Department of Mines, is not as well known in this country as it deserves to be; in it Mr. Anderson would find a tolerably complete bibliography of the subject—commencing with the reports of De la Beche and Playfair in 1846—which occupies several pages, and is by itself sufficient to show that there had been a very great deal published on this subject of the spontaneous firing of coal. Dr. Porter's recommendations agree closely with those of Mr. Anderson. A valuable paper that should be mentioned is one by Sir Richard Threlfall, published in the *Journal of the Society of Chemical Industry* for 1909. More recently a report on the subject has been issued by the South Wales and Monmouthshire School of Mines, and as recently as

February 9th a very useful paper on the same subject was read before the North of England Institute of Mining Engineers by Mr. John Morison.

There is, in fact, a vast amount of literature dealing with the spontaneous ignition of coal, even excluding all that has been published on the Continent of Europe, and though opinions as to the causes of such ignition were somewhat conflicting before the researches of the Doncaster Coalowners' Laboratory were undertaken, there is surprising unanimity as to the preventive and remedial measures that ought to be adopted, and it is gratifying to find that Mr. Anderson's experience has led him to the same conclusions.

Yours faithfully,

HENRY LOUIS,

Professor of Mining, Armstrong College,
University of Durham.

I am much obliged to you for sending me the proof of Mr. Anderson's paper on the "Storage of Bituminous Coal," and enclose herewith a few remarks which I have to make upon the paper.

I regret that I will be unable to attend the meeting to which you have invited me.

I read last month, before the North of England Institution of Mining Engineers, a paper upon a similar subject, and if you have not got a copy of this paper I shall be glad to supply you with one previous to the meeting, or, as I am going from home, if you would apply to Mr. P. Strzelecki, Albany Buildings, 39, Victoria Street, S.W.1, he will be able to give you a copy.

The conclusions come to by Mr. Anderson, as given in his report, are very much the same as those to which I came.

You will find, however, that in my paper I advocate, instead of temperature tubes, plain rods of iron, which were drawn through the hand, which is sufficient and more convenient than taking the exact temperatures, which are not necessary.

Whenever heating is observed at all the precautions which are advocated in my paper, and which are also advocated by Mr. Anderson, of trenching and wrecking the surface should be commenced.

I have also used vent tubes similar to those referred to by Mr. Anderson, and find them beneficial.

I consider any tendency at all to heating is an indication of danger, which should be at once attended to.

In Mr. Anderson's paper, when he refers to the method of storing the coal by running the tramway on the top of the heap, then shifting it over the edge, if it can be avoided this is an undesirable method, as it consolidates the top of the heap and prevents dissipation of the heat when it arises. If some other method can be found, such as that illustrated in my paper, I consider it is better.

I observe in the paper a reference by Mr. Anderson to the effect of shale or dirt in the coal forming layers which retard the dissipation of heat. This same is also referred to in my paper.

The conclusions as to the height of the heap by Mr. Anderson agree also very closely with the conclusions I came to.

The conditions of coal in cargoes in ships are different, and it is very difficult to use the same precautions as those which can be effectively used on the surface. It is absolutely necessary, if proper precautions have to be taken, to lay coal against the bulkheads where there is any heat such as from the engine-room steam pipes, etc., and all cargo ships carrying coal for long voyages should have some means of preventing this, and the most effective precaution here would be a double bulkhead open to the very bottom of the hold and separating it from the hot bulkhead, an air space being left which would be free for ventilation.

I am not sure that the vent pipes suggested would be effective, and am of opinion that a system of compressed air pipes connected right through the cargo, along the bottom, with ventilating pipes up through the cargo, would prove more effective. This system could be easily introduced by placing a small air compressor in any convenient part of the ship, and it would not require a very large compressor for a ship of considerable size.

Yours faithfully,

J. MORISON, C.N.

MR. J. H. ANDERSON: In reply to Professor Henry Louis, it gives me great pleasure to hear that the experience we have had coincides with the general opinion of others, particularly those who touch the subject from a scientific point.

Regarding the only point that Professor Louis disagrees with me, namely, "There is not much information published on this subject," I thank him for drawing my attention to some of the already published works. I have had the pleasure of reading a few of them, but I have not come across a paper or article written on the practical results of the storage of a large heap of coal, giving the daily results of same, with the temperatures plotted out and set forward as on the charts exhibited.

Unfortunately it will be impossible to reproduce those charts owing to the amount of detail on them, together with the various colours employed to distinguish each pipe record, but I will endeavour to supplement this by preparing a tabulated statement of about a year's result of these temperatures.

Mr. John Morison's remarks and results also give me gratification.

It is a coincidence that his paper and mine were written about the same time and that most of our results agree so far as treatment of a heated pile is concerned. Probably we start a little sooner than Mr. Morison by inserting vent pipes immediately the coal is tipped. By doing this I firmly believe that it delays the tendency of initial heating and thus ensures a greater prevention of danger.

Mr. Morison's remarks on the use of plain rods of iron "which are drawn through the hand is sufficient and more convenient than taking the exact temperatures which is not necessary." This of course is a matter of opinion and my idea is the opposite of Mr. Morison's in this respect.

The matter of sensitiveness of touch is different with most people, and also with the same person judging the heat. I might illustrate this by suggesting a simple experiment which you can try any time at your convenience, that is, get three bowls of water, each of a different temperature of even only a few degrees—for instance, 70°, 80°, 90° Fahr.—put your hand into the 90° basin and from there into the 80° basin, the 80° water will feel quite cold; now reverse the order, put your hand into the 70° basin and from thence into the 80°, the 80° will feel quite hot, but apart from this it is depending too much on the party taking the results, to remember all these places he has tested, it will be impossible to keep a record of the performance of the heap, whereas in years to come if you wanted any reference regards any particular coal, if you used thermometer readings you could always refer to them any time. I question if insurance companies would agree to rods in preference to thermometer readings.

As regards the handling of the coal by tipping from the top, I employed this method because from an engineer's point of economy of working we utilize gravity in as many instances as possible; therefore it is much simpler, more economical and what meets present day requirements, reduces the number of men necessary, by simply opening a door allowing all the coal to run out itself rather than employ steam cranes to build up a heap. I might here say that in the south we cannot secure special plant to-day, and most everything used in the handling was adapted to meet the circumstances of temporary storage.

The running of the wagons on the top of the heap would appear to be detrimental to the coal, but in practice we found that this was more apparent than real. Further than that, from the point of precaution in the event of a fire, these rails were left on the top of the heap so that if any coal had to be removed at all then we could start doing so without making a lot of work when time is a great consideration on salvage of a heap, owing to these rails being already there.

Mr. Morison's idea as regards ventilating pipes with a positive pressure appears to me to be a danger to adopt this for shipping inasmuch that it would be impossible to get this air throughout the cargo to cool same, but in the event of any moisture setting the pyrites off oxidizing then this great supply of air would aggravate the matter by supplying oxygen in an unlimited quantity. If a fire was to occur then, it would act similar to a blacksmith's fire. The pipes I suggest are not ventilating pipes, but pure and simply a vent for the escape of heat gradually as it is made, and thus to prevent the further rise of temperature of the mass with its property of acceleration of oxygen absorption and consequent heat generation beyond that which could escape to the atmosphere.

Mr. John Kirsopp's remarks are very interesting, and I will try to answer some of his questions as they are queried.

A general answer to the first few questions is that the heights mentioned are those which we tip at one operation and the time we commence to take precautions for the prevention of fire is as soon as possible after the coal is tipped.

The great disadvantage with written communications is that one cannot get the advantage of the illustrations shown by lantern. In the paper read there are 140 slides shown dealing with the handling of coal from the mine to the consumer. Most of these show something or other effecting something in relation to spontaneous ignition of a pile of coal when deposited, in so much as each operation adds a little to the reduction of size of the coal, or there are weather effects to contend with, heavy weather at sea, etc.

My experience a few years ago with some other experimental heaps that were not vented until a certain temperature was reached taught me that most of the danger is within the first few weeks after deposit, the temperature chart gradually rose and got to a height that warranted some action being taken. I am sorry in a sense that we could not allow a destructive test to be carried out, as it would have involved a risk that could not be tolerated at the time. After carrying out some crude methods of disturbing the coal here and there, putting some few pipes in, the heat gradually reduced, and ever since has remained quite normal and steady. This has been deposited over three years and is composed of small coal all under 5-16ths. in. I have so much confidence in this result that after a time I would not hesitate to build up another pile on the top of coal that has been deposited for some time, providing mechanical difficulties or cost of piling warranted it.

I cannot say from practice whether it would be the right thing to extract the pipes in the lower heap and thus treat the top of the old coal as the bottom of the pile, and then put pipes down in the new coal similar to other heaps.

If we were called upon to increase the height, I should prefer leaving the old pipes where they are and extending them to the surface of the new coal. The new coal deposited I should vent right down to the surface of the old coal; but of course this is only a suggestion which I have no practice of. As at present situated the cost of piling an additional pile on the top would be prohibitive while there is other areas that could be covered to a safe height at one deposit by gravity.

Regarding the tabulated statement that Mr. Kirsopp wishes me to fill up, this can be done in a few words without mentioning temperatures. Fix a certain temperature as given in my paper, for example, and also certain rules. Do not go beyond these rules, let them be hard and fast, then you will see that if your heaps get to these fixed temperatures, and stay there, you ought (as per rule) to excavate a foot per day at the hot place, thus if it continued to keep high (to exaggerate matters) all your coal would be excaved at the hot place. This would hardly occur in practice unless there was an actual fire which did not communicate a part of its heat to some of the surrounding temperature pipes.

The temperatures mentioned in my paper are by no means a danger temperature from the point of ignition of the coal, but the higher you make this reading for taking action the more risk you run of a sudden increase to the ignition point. On the other hand the lower you make this warning and action, or as I call it in my paper, danger temperature, the more work you can expect in trenching, etc.

The fixing of these two temperature points in my paper is what may be called a line of demarcation between the point of labour for prevention and the danger and labour necessary for greater measures in the event of a fire.

I think my temperatures are about right, but of course further experience from other sources would no doubt be beneficial to corroborate mine. However, in the particular heap that paper is based on, as I said only about 10 tons of material was removed, and this was when the danger reading was at 95° F., which later I altered to 100° F., when probably this 10 tons would not have been shifted. I think you will agree that we are not far out so far as taking action is concerned.

Regarding questions in brackets: Diagram and slide No. 8 answer this very well by showing the location of the various coals in the pile. They were not mechanically mixed other than teeming the material as it came; and all of the coal was mechanical stoker coal. Some were nuts and others were mixed washed nuts and smalls, while the major part were Northumberland and smalls, including all smalls up to about $\frac{3}{4}$ in.

Regarding No. 4, this was as the name says, slacks, and when you walked over it when wet it was necessary to clean your boots after. This will give you a rough impression of the material, as it stuck to you.

Regarding No. 5, we have this stored up to 20 feet, probably in as many if not more kinds of coal from various places; some all mixed together, and has never given trouble. This large coal could be stored much higher if cost would warrant so doing.

One of my slides shows the latest bunkering machine of Messrs. Doxford, a machine I have had experience of; not only that, but views were shown of most of the coal handling appliances of any consequence, bunkering up to a rate of 1,000 tons per hour, and also hand work, so that it is hardly necessary to reply to most of the other part, some of which I have answered in the other parts of the discussion, principally regards pipes not to be treated as admission pipes for fresh air, but rather as heat escape pipes.

I am thankful to say I cannot give my own experience of the use of water to put a fire out, but the conclusion I arrived at is the summary of other experience in relation to the use of water whereby this is transferred to steam and then its elements dis-associated. However, I have seen actual fires where the hose (a standard fire hose) was being played on and where there was difficulty on putting the fire out. Luckily, a portion could be sufficiently cooled to be gradually picked up in a hot condition and then utilized close by to obtain the remaining calorific value extracted from it. I also exhibited slides of fires that would have been impossible to put out with water.

In my paper I have rather emphazied the care necessary for the prevention of fire, and I have tried to explain that the care exercised at the low temperature is that which is of more importance than waiting until a temperature is reached when more drastic measures are necessary.

As regards forming a base of area for each pipe I have suggested to the British Fire Prevention Committee, and who have evidently agreed together with other suggestions I put forward that at least one pipe of 3ins. to 4ins. dia. per 600 sq. ft. surface is sufficient for a start; then other pipes could be added at any locality in the event of heating, that is if a daily record was kept of the temperatures. Of course a deal depends on the kind of coal that the heap is composed of. For instance, I find a difference even between Northumberland and Durham coals, and a much greater difference between either of those two mentioned and Yorkshire and Scotch, but even with either of these there is a difference with each of the seams so that it is practically impossible to predetermine any hard and fast rule regards number of pipes required for a heap. The number I suggest is well within a number that will not be a financial burden to place and look after. By the way, it may be as well to mention that these vent pipes should not be used to take temperature readings from. We have found them very far from being trustworthy, depending on the weather.

Regarding the last question and the suggestion of conical heaps, no doubt this would be a safer method of storing coal, but as Mr. Kirsopp remarks the superficial area of ground occupied is great in proportion to the tonnage, this partly answers the question, but as my paper concerns not only the prevention of fire, but also the prevention of loss of calorific value of the coal, and as the method we employ is that of offering as small an area for exposure of weathering by making large piles of a certain depth, levelling off the top, you will readily see the great difference in area exposed to the atmosphere between the two different methods.

Notes.

The following appeared in *Page's Engineering Weekly*, January 4, 1918:—

Deterioration of the Heating Value of Coal Through Long Storage.—The United States Bureau of Mines have issued a report on the deterioration in the heating value of coal during storage. These tests go to prove that the loss in heating power had been greatly over-estimated.

The tests with New River and Pittsburgh coal were made to determine the advantage to be gained by storing coal under water, particularly under salt water. The results show that the storage of New River coal under water effectively prevents deterioration of calorific value, and that storage in the air under severe conditions causes only small deterioration, about 1 per cent. in one year's exposure and about 2 per cent. in two years. After two years, the loss is continuous but slow, reaching 2·5 to 3 per cent. in five years.

The deterioration of Pittsburgh coal during one year's open-air storage was practically negligible. During the subsequent four years the deterioration proceeded very slowly, and did not reach an amount greater than 1·1 per cent. in the five years. The submerged portions suffered no loss measurable by the degree of accuracy of the methods used.

The tests of Pocahontas coal, a semi-bituminous type, were undertaken chiefly to determine the effect of tropical conditions.

They were made on an out-door pile of 100 tons of run-of-mine coal. During two years' outdoor exposure this coal deteriorated less than 1 per cent. in heating value.

The Sheridan, Wyoming, sub-bituminous coal, known also as "black lignite" is commonly supposed to deteriorate rapidly in storage, especially by "slacking" or crumbling of the lumps. Under the conditions of the test this coal lost 3 to 5·5 per cent. of its heat value in two and three-fourth years' storage, the greater part of this loss being in the first nine months. In general the lumps became badly cracked, but retained their form sufficiently to permit ready access of air. However, they were weakened, so that they broke up badly on handling. By the use of bins with air-tight bottoms and sides and a protecting layer of fine slack on the surface, the deterioration of Sheridan coal in heat value can probably be kept below 3 per cent. in one year, and the physical deterioration can also be largely prevented in the under portions of the pile.

With coal such as New River and Pittsburgh the expense of underwater storage equipment is not justified except as a preventive of fires from spontaneous combustion.

The following appeared in *The Practical Engineer* of June 6th:—

By way of supplement to Mr. John H. Anderson's paper on the "Storage of Bituminous Coal and Spontaneous Combustion" (read before the Institute of Marine Engineers), and published in our issues of April 18th and 25th, it is interesting to give the findings of the Bureau of Mines, U.S. Department of the Interior, on this subject.

The report, as summarised in the *National Engineer*, Chicago, recommends that coal should be stored in small quantities as near to the point of consumption as possible. Small coal piles rarely ignite from spontaneous combustion. Coal should be stored near the point of use to avoid re-handling, extra transportation, and the degradation of size which follows each re-handling. For these reasons the bureau would advocate storage, as far as possible, in the bins and yards of the ultimate consumer, thus dividing the risk of loss from spontaneous combustion. If large storage piles are necessary, certain general principles must be borne in mind. The generation of heat is the result of slow oxidation of the coal surface. The oxidation is much more rapid from freshly mined coal or from freshly broken surfaces. The oxidation rate increases rapidly with increased temperature. Different coals have different oxidising rates. These facts lead to the following recommendations:—Where there is choice of coal to be stored, that having the lowest oxidising rate should be chosen, if known. Between two coals, that which is least friable, and, therefore, which presents the least total coal surface in the pile, should be selected.

The method of handling should be such as to produce the least freshly broken coal surface. The coal should be as cool as possible when piled. Piling warm coal on a hot day is more likely to produce spontaneous combustion. The coal must be kept from any extraneous source of heat. Alternate wetting and drying of coal during piling is to be avoided if possible. The fine coal, or slack, which furnishes the larger coal surface in the pile is the part from which spontaneous combustion is to be expected. Piling of lump coal where possible is therefore desirable.

In the process of handling, if the lump coal can be stored and the fine coal removed and used immediately, the practice prevents spontaneous combustion in coals which would have otherwise given trouble. The sulphur content of coal is believed by many to play an important *rôle* in spontaneous combustion. The evidence on this point is still conflicting, but to play safe, it is desirable to choose coal having a lower sulphur content, when choice is possible.

There is a current belief that dissimilar coals stored in one pile are more liable to spontaneous combustion. The evidence on this point is also conflicting, but to play safe it is advisable to store only one kind of coal in a pile. The ground on which a coal pile is built should be dry. The foregoing recommendations are all derived from the factors affecting the heating of coal. There should be no spontaneous combustion, whatever the heating rate, provided the heat is carried away as rapidly as produced. This fact brings about the following recommendations:—

Coal piles should be so made that there is ready movement of air for ventilation throughout all parts of the coal pile. This is the condition when the entire pile is made of coarse lump coal. With ordinary coal piling this is difficult. The surfaces of coal piles should be so exposed as to allow the pile to cool; or else the coal should be so stored that air circulation within the pile is very small. When the air circulation is reduced to a minimum, as in an air-tight bin, with no opening in the bottom, the oxygen of the air is soon removed and the mass of the coal lies in an inert atmosphere, except for small local circulation near the surface. Air-tight bins are usually impracticable, but the following practice is recommended to approximate these conditions:—

In making a coal pile of mixed sizes, the coal should be so handled as to make a homogeneous pile and prevent the segregation of coarse and fine coal. This frequently determines the most desirable machinery for unloading coal. It is common practice to limit the height of a coal pile, this for two reasons:— A pile too high crushes the lower layers of coal, producing more fines; the larger the pile the less heat-dissipating surface there is exposed in proportion to the heat generating capacity of the pile. Twelve feet in height is a common limit.

Whatever precautions are taken in choice and handling of coal, provision should be made for keeping track of the temperature rise in a coal pile and for rapid re-handling of portions of a pile in case of excessive heating. In a coal pile covering a considerable area, it should be so sub-divided that in case of spontaneous combustion of a portion, the heat will not be transmitted to the whole pile, thus accelerating the heating of portions of the pile which normally would have remained cool.

To keep track of the temperature of coal piles, it is recommended that $\frac{1}{2}$ in. iron pipe be driven vertically into the pile at distances of 15 ft. or 20 ft. apart. A maximum thermometer lowered into the pipe to varying depths will indicate the temperature of the pile opposite the thermometer.

A survey of the pile and a survey of the temperature of all parts of the pile. Actual removal need not begin during the first three months after the pile is made, but once a week thereafter until the pile has evidently ceased to heat. As soon as any portion of the pile reaches a temperature of 150 deg., provision should be made for removing that portion of the pile. Actual removal need not begin until the temperature has reached 180 deg., but at these temperatures the rate of oxidation is dangerously rapid. The object of re-handling the coal is to allow it to cool below a dangerous temperature. Any method of re-handling which does not allow of cooling will only transfer the difficulty from the old pile to the new one. It is usually useless to employ water in an attempt to cool a coal pile.

Lack of provision for rapid re-loading, cooling and re-piling of coal is the cause of serious loss from spontaneous combustion.

Election of Members.

Members elected at a meeting of the Council, held on Tuesday, 14th May, 1918:—

As Members.

William Boag Aitken (Engr.-Lieut., R.N.R.), "Orcadia," Kilbarchan, Renfrewshire.
George Harry Connell, 45, Sholebrook Place, Chapeltown, Leeds.
James Paul Devlin, 53, Exeter Drive, Partick, Glasgow.
Wm. Arthur Ceredig Evans, Ty Nant, Whitechurch, Glamorgan.
James Gordon, Sejua Colliery, Sejua P.O., Maubhem Dist., Behar and Orissa, India.
Colquhoun Fraser Grant, "Fairholme," Grange Park, London, N.21.
Alfred Sam Hunter (Engr.-Lieut., R.N.), 18, Horringford Road, Aigburth, Liverpool.
Alfred Morrison Singer, 34, Abergeldie Terrace, Aberdeen.
Archibald Thomas White, 63, Eversley Road, Charlton, S.E.7.
Leonard Young, Union Street, Largs Bay, South Australia.

As Companion.

Joseph Henry Jacobs, 10, Mark Lane, London, E.C.3.

As Associate-Members.

Victor Lockney (Engr.-Sub-Lieut., R.N.), 53, Manuel Street, Goole, Yorks.
Gilbert Ashton Plummer, 2, Kenwood Road, Stretford, Manchester.

As Graduate.

Arthur Fredk. Wm. Wells, 30, Norfolk Road, East Ham, E.

Transferred from Associate to Associate-Member.

Herbert T. Smith (Lieut., R.E., E.E.F.), 109, Brudenell Road, Tooting, S.W.17.