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VAN SUID-AFRIKA

FUEL RESEARCH INSTITUTE
OF SOUTH AFRICA

ONDERWERP:
SUBJECT: STORAGE OF COAL WITH SPECIAL REFERENCE TO QUALITY DETERIORATION AND SPONTANEOUS COMBUSTION.

AFDELING:
DIVISION: CHEMISTRY

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA

REPORT NO. 28 OF 1951

STORAGE OF COAL WITH SPECIAL REFERENCE TO QUALITY DETERIORATION AND SPONTANEOUS COMBUSTION.

1. INTRODUCTION:

Although the storage of coal is probably almost as old as its use, and is practiced on a smaller or larger scale by all coal consumers, there are certain aspects and problems associated with coal storage which require very careful consideration and attention, as not only deterioration in quality of the stored coal is involved, but also the risk of the coal firing spontaneously has to be faced.

1.1 Types of Storage.

Coal storage can usually be classified under one of the following two categories, viz. tactical and strategical storage.[8)]

1.1.1 Tactical Storage.

The tactical storage system consists of a stock of coal, possibly amounting to about a week's requirements, and with the object of meeting day-to-day fluctuations in deliveries. The method of stocking varies considerably with the size of the undertaking, but the reserve is invariably situated fairly close to the point of consumption, and in the case of larger consumers the amount and speed of throughput may justify full mechanization of the means of putting to stock, recovering and moving the coal to the point of consumption.

As quality deterioration and spontaneous combustion of the coal is not, as a rule, encountered with this type of storage it need not be discussed in any detail, except for stating that spontaneous combustion may sometimes unexpectedly occur in the tactical reserve. Usually the reason for this is that coal has been allowed to remain stagnant in a bunker (or portion(s) of it) for too long a period, allowing it to heat up unduly. The best way to avoid this is to have more than one bunker and (or) to ensure that a bunker is completely emptied, also of any stagnant coal, at regular intervals, the duration of which is best determined by experience, but which may be anything between two and eight weeks.

1.1.2 Strategical Storage.

The strategic reserve of coal is a large stock to draw from during seasonal or other obnormal periods of shortage.

As the movement of coal to and from this reserve may be only infrequent (normally not more than once a year, and possibly not for 4 or 5 years) the stack does not necessarily have to be in close proximity to the point of consumption, and the expense of installing elaborate mechanical handling equipment capable of moving coal at a fast rate is not normally justified. This is an important consideration from the point of view of spontaneous combustion, where speed in the removal and cooling of heated coal is sometimes called for. It is obvious, therefore, that deterioration and spontaneous combustion of coal are two factors intimately associated with, and not to be disregarded when undertaking strategical stock piling.

1.2 Coal Handling Systems.

1.2.1 Tactical Storage.

The following are methods of tactical stocking of coal suggested for different types of consumers:

(a) The coal is tipped from lorries into a number of bays having brick walls and a concrete floor. The coal is picked up by hand into wheelbarrows, or into cocopans running on rails.

(b) The coal is tipped from lorries into an underground hopper and taken out by means of

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a bucket elevator.

(c) The stocking area is traversed by a moving gantry which carries a movable crane and grab. The coal is unloaded from the railway trucks with the grab and deposited over the stocking area. The coal is also reclaimed by the grab which places it in a small hopper feeding a belt conveyor leading to the plant.

(d) The coal is emptied from hopper trucks into underground bunkers from where it is discharged by belt conveyors.

1.2.2 Strategical Storage.

The coal handling equipment used for strategical stock piling on an extensive or fairly extensive scale is usually one or more of the following:

(a) A bulldozer or large mobile shovel.
(b) A rope drag scraper.
(c) A mobile crane on railway tracks parallel to the railway siding.

1.2.3 General.

It is beyond the scope of this brochure to present detailed data on the various coal handling systems that may be employed by those undertaking stock piling. Very useful information on types and design of installations, different methods and rates of handling and moving coal, and costs of the various individual installations and systems, and combinations of them, covering both tactical and strategical storage of coal, is available in the literature[13), 3), 9), 10)]. The interested reader is strongly advised to condult these publications.

1.3 Data for Space Requirements.

Protective stock pilers of coal may find the following general data useful in the calculation of their space requirements:-

The natural angle of repose for coal is usually between 30 and 40°. South African coals likely to be stored have bulk densities of 50 to 55 lb./cu.ft.*, i.e. 1100 to 1200 short tons per foot-acre, or in a consolidated state, possibly as high as 1400 tons per foot-acre.

2. DETERIORATION ON STORAGE:

2.1 Under Non-Heating Conditions.

If spontaneous combustion occurs in a pile of coal the coal might deteriorate to any extent, depending on the amount of heating or combustion taking place. The following arguments are, however, valid provided that the coal has not suffered any appreciable heating during storage.

2.1.1 Appearance.

The "rusty" and dullish appearance that a coal may develop on exposure is, per se, no criterion of the amount of deterioration suffered by it, and although giving the coal an unattractive, dirty appearance is of no importance.

2.1.2 Calorific Value.

Contrary to widespread belief the loss in calorific value of coal during storage, is very small, the following table cited by Taylor[14)] reflecting the deterioration with time for British coals:-

Years of Storage	Percentage Deterioration
1	0.8
3	2.0
5	3.0
10	4.0
25	5.0

* A short ton of the coal occupies 36 to 40 cu.ft.

For South African coals a decrease in the dry, ash-free calorific value of 2 - 3 per cent, has been found after exposure of the coal to the wheather in thin layers for one year[1]. This deterioration will probably be much less if all the coal in a comparatively large heap, where only a small proportion of the coal at the surface suffers direct exposure, is considered.

Certain factors may, however, by their indirect action create the impression that considerable loss in heating power has resulted during storage. They are: Degradation in size and increase in friability, and consequent higher proportion of unburnt fines which may be lost, e.g. through the fire-bars. (See also: 2.1.6). This may be more noticeable if the fresh coal had caking power providing coherence in the fire-bed, as the caking power decreases, and may soon disappear on exposure to the atmosphere, resulting in a non-coherent fire-bed.

2.1.3 Moisture.

With sized coals surface moisture resulting from rain is usually not very objectionable as drainage is good and fast.

An increase of 10 per cent in surface moisture will result in a decrease in effective heat generation of about 1 per cent.

The air-dry moisture content of coal increases on storage, but for normal storage periods this increase will hardly be noticeable for most South African coals.

2.1.4 Volatile Matter Content and Thermal Gas Yield.

The volatile matter content of British coals is only slightly decreased by storage (of the order of ½ per cent. over 1 year)[6], and the same was largely confirmed in the tests on South African coals.[1]

The thermal yields of gas for stored British gas coals decrease by about 2 therms per long ton over 6 months, but after this period the decrease is very small.

2.1.5 Coking Power.

The coking power of coal is very susceptible to deterioration, and if this property is an essential one for a particular use, storage might ruin the coal completely for that purpose (e.g. if the coal was to be carbonized). (See also: 2.3).

2.1.6 Size and Friability.

If coking coals are disregarded, degradation in size and increase in friability of coal on exposure to wheather are perhaps the two most serious forms of deterioration encountered. For South African coals it has been found that the greatest increase in friability occurs during the first month of exposure, the increase becoming very small after about 3 to 6 months[1]*. In this case, too, it must be pointed out that these two forms of deterioration are usually limited to the outer surfaces of a heap of coal, the coal in the interior being largely protected from weathering[14].

2.2 Choice of Coal to Ensure Minimum Deterioration.

2.2.1 Size.

The available surface of lumps of coal determines to what extent, and at what rate, oxygen of the atmosphere can react with the coal to cause deterioration (and also heating). For a given weight of solid material the external surface varies inversely with the diameter of the particles,

*The tests were carried out on coal sized 1 to 1½ inches, square mesh.

whence it is clear why large coal stores better than small sizes.

2.2.2 Rank.

The rank of a coal is intimately associated with its properties. Thus high rank coals usually exhibit high calorific values, low inherent moisture contents, low affinity for oxygen, and low deterioration on exposure to the atmosphere. The opposite is the case for low rank coals.

The friability of a coal, i.e. its tendency to form fines on being handled, is also a function of its rank, high rank coals being usually more friable than those of low rank.

In spite of their more friable nature higher rank coals are invariably preferred for storage purposes on account of their better storing properties and smaller liability to spontaneous heating.

Generally speaking, the more important South African coals can be classified according to rank in the following order:-

(a) Natal Coals (highest rank),
(b) Witbank-Middelburg coals,
(c) Breyten-Ermelo coals and
(d) Northern Free State-Southern Transvaal coals.

Of these coals those from group (d) should preferably be avoided for storage purposes as deterioration (and possibly also spontaneous heating) is likely to assume serious proportions within a short time.

2.2.3 Cleanliness of Coal.

It is well-established South African experience that a lump of shaly coal will deteriorate to a greater extent, especially in respect of friability, than a lump of clean coal from the same seam and locality. For this reason coal should be well cleaned, preferably in a washer, before being put to storage.

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2.3 Economic Time Limit of Storage.

Unless coal can be stored with total exclusion of air, (e.g. under water), deterioration, especially in respect of size and friability, may assume such large proportions after a time as to seriously impair the value of the coal. The economic time limit of storing coal is therefore usually put at about five years.[9] This, however, does not apply to coal intended for carbonization, and, generally, where appreciable deterioration of coking properties cannot be faced.

There are indications that the better coking coals from Natal could possibly, if necessary, be stored up to a year, but that some of the blend coking coals from the Witbank-Middelburg area (e.g. No. 5 seam coal) are much more susceptible to deterioration of coking properties on storage, and should probably not be stored for longer than about a month or two in open air if the best results on carbonisation are aimed at.

2.4 Covered Storage and Concrete Floor.

The cost of providing extensive covered storage for coal is not justified by the limited benefits accruing from such storage.[11]

A sound concrete floor on which the coal can be laid down is a desireable refinement, especially from the point of view of avoiding contamination when the coal is to be picked up again. It is, however, not essential, and the cost of providing an extensive concrete floor for strategical storage is usually not justified.

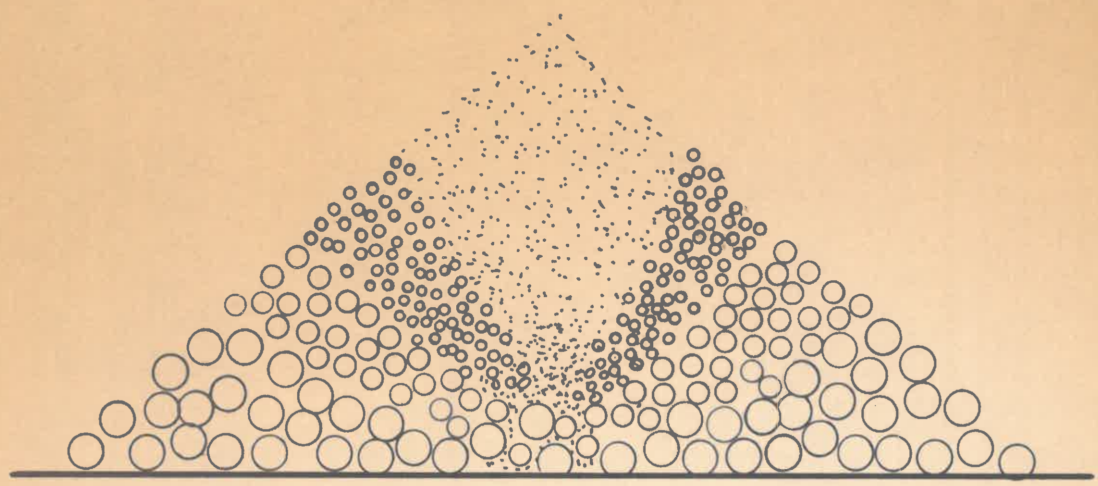
3. SPONTANEOUS COMBUSTION OF COAL:

3.1 Some General Considerations.

3.1.1 Literature.

The literature on the subject of spontaneous combustion of coal is voluminous*

*A report[7] consisting of a survey of recent literature was prepared at the Fuel Research Institute in 1950, and anybody interested in the subject may apply to the Institute for a copy of it.



SKEIDING VAN GROOTTES. DEURSNIT VAN KEËLVORMIGE HOOP.

SEGREGATION OF SIZES. SECTION OF CONICAL HEAP.

FIG. 1

and the phenomenon is so well known that it is not necessary to enter into any detailed discussion of it here. In order to be able to know why, when storing coal, certain precautions have to be taken, and in order to emphasize their necessity, a few aspects will, however, briefly be dealt with.

3.1.2 Quantity and Height of Coal.

Spontaneous heating of coal is essentially a phenomenon assuming practical importance only when dealing with relatively large quantities of coal, and when such quantities of coal are piled up to such heights as to preclude effective dissipation, through radiation, conduction and convection, of the heat formed by the coal in combining with any oxygen that may be available. Thus spontaneous combustion in open heaps of coal not exceeding about 200 tons, or in larger quantities of coal stacked to a height not exceeding about 5 feet is very rare indeed.[16)]*

If air has access to the interior of a pile of coal it is generally regarded that the tendency for spontaneous heating to occur within the pile is proportional to the square of the height of the pile.[2)]

3.1.3 Size of Coal.

The importance of size of coal in relation to its deterioration and heating on storage has been mentioned above. (See: 2.2.1).

While a minimum size limit for coal to be stored cannot be stipulated, it has been observed that sizes from nuts upwards are usually fairly well

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*The 200 ton limit may be considerably reduced if the coal consists of slack or improperly screened peas, or duff, or mixtures of these, or if the coal is stored in a bunker providing air leakage from the sides and (or) bottom. Also, comparatively small accumulations of the dust from certain coals have been known to fire spontaneously.

screened, while, due possibly to mechnical complications, and often also to dampness of the coal, the elimination of fines from peas is less perfect. In many instances duff is deliberately left in, or added to peas at the request of, or by agreement with the consumer. It follows, therefore, that well-screened sizes consisting of nuts, or preferably larger, are better for storage purposes than peas or duff, or mixtures of these.

3.1.4 Segregation of Sizes.

If coal is deposited as a conical heap the larger lumps will roll down the sides and concentrate at the base of the cone. If the coal originally consisted of a mixture of sizes, or if much breakage occured through handling, this effect will be even more noticeable.

If the size of the cone is increased by repeatedly of continuously adding coal at its apex, segregation will continue approximating ultimately the condition indicated schematically in figure 1. The fine coal, concentrated in the core, will be surrounded, especially towards the base, by larger coal which can act both as a heat insulator and as a duct for conveying air (oxygen) for reacting and producing heat with the finer coal in the core. If heating starts in the latter, stack effects will develop, and air circulation and undersirable heating may assume larger and larger proportions with time.

There is usually great danger of heating under a stationary discharging chute where fines were produced and segregation allowed to take place.

Segregation of sizes results in an increase in the volume of voids, which is however reduced again if the different sizes are thoroughly remixed.

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3.1.5 Prevention of Segregation.

An important reason why coal should contain a minimum of fines, and should preferably consist of a fairly narrow size range before being put to storage, is to counteract the tendency for segregation to take place.

In building up large stacks of coal for storage purposes no effort should be spared to avoid the coal being deposited in such a way as to enable size segregation to take place. For example, if coal is deposited by means of a grab, each lot should be dropped in a new position relative to that preceeding it so as to avoid the formation of a single large conical heap.

If the formation of a cone cannot be avoided, repeated or continuous flattening of its apex will largely counteract segregation, remixing small and large lumps to their original natural size composition.

Use of a bulldozer in moving the coal has been found in practice to cause a minimum of size segregation, while having an excellent counteracting effect on any that might have taken place previously.

Whenever fresh coal is added to old coal in an existing stock, great care should be taken to integrate the fresh coal with the existing surface so as to avoid a possible state of size segregation at the interface.

3.1.6 Rank of Coal.

The relation between rank and properties of a coal has been dealt with above (see: 2.2.2), and it has been pointed out that, generally, higher rank coals are less liable to spontaneous heating.

Coals differing appreciably in properties as a result of differences in rank should not be stored together in the same pile.

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When considering coal storage in relation to spontaneous combustion it is difficult, when other properties are approximately equal, to choose between a softer high rank coal, low in affinity for oxygen, and a harder coal, slightly lower in rank, but with higher affinity, as there are so many other variables involved. It can, however, be said that, provided the precautions described below are meticulously carried out, it should be possible to store both Natal and Witbank-Middelburg coals (and possibly also Breyten-Ermelo coals) with a reasonable degree of safety.

3.1.7 Moisture - a Heating or Cooling Agent.

The condensation of moisture on coal can result in an appreciable rise in the temperature of the coal. The moisture obsorption capacities of low rank coals are higher than those of high rank coals, and the effect can therefore assume greater importance with the former. A hot spot would easily be initiated in relatively cool coal within a pile by moisture condensing thereon, or in trying to combat heating in a localized spot in a pile by applying water, the trouble may inadvertently be extended to other parts of the pile (see: 3.4.3).

Although it would probably be impossible in practice to attain a uniform moisture content in all the coal being laid down in a storage pile, this condition should be aimed at. Washed coal may offer an advantage in this connection, an additional benefit resulting from the cooling effect of the evaporation of excess moisture from the mass of coal during its transport and putting to stock, thus ensuring a lower starting temperature in the pile.

3.2 Precautions Against Spontaneous Combustion.

3.2.1 General.

Whenever coal is to be stored the above general considerations must be borne in mind and applied as far as possible. In addition the following must be observed:

(a) Waste or other combustible material liable to easy ignition or self heating must not be included in the coal.

(b) Coal must not be laid down in places where there are external sources of heat, e.g. heated surfaces, steam and hot water pipes (even if insulated), insufficiently covered sewers carrying hot effluents, etc.

3.2.2 Providing Ventilation (sized Coals).

Where sized coal can be stored in small quantities (200 tons or less) and (or) to depths not exceeding 4 to 5 feet* the dissipation of heat through the natural ventilation is good practice and can be recommended. If space permits, and in order to limit any spontaneous heating that might be experienced, it is best to arrange stacks as long trails, about 20 feet wide, with roadways between them.[5)]

It is also common practice overseas to build up a stack in stages. A 4 to 5 feet layer of coal is deposited and "aged" for 8 to 9 months, during which period the reactivity of the coal towards oxygen will largely have subsided and may generated heat dissipated. From then on, at intervals of 3 to 6 months, further layers of coal, about 1½ to 2 feet thick, may be added on top, but not until temperature measurements (see: 3.3.2) have indicated that it is safe to do so.*

*Well-screende size grades of coal containing a minimum of fines can usually be stored safely when stacked to a height of about 8 feet, but this height should not be regarded as "safe". It merely constitutes a compromise between economic use of the stocking site and reduced likelihood of spontaneous combustion.

*In view of the rather rapid deterioration in the friability characteristics that has been domonstrated in the case of South African coals[1)] there may be serious objection against this type of procedure causing a fresh layer of coal to be subjected to rather intense weathering every time. On the other hand, if the coal is to be crushed or pulverised before use the procedure may offer a distict advantage.

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By erecting a rough wall, possibly consisting of the larger blocks of coal, and capable of allowing free access of ventilating air to the interior coal, storage space can sometimes be saved.

Attemps at ventilating and cooling relatively large stacks of coal by means of ventilation ducts, as has been described in the literature[4)] cannot be recommended, as the provision and maintenance of such ducts for adequate ventilation may be so difficult under actual working conditions that the whole method becomes impracticable.

3.2.3 Restricting Ventilation. (Sized or Unsized Coals).

In cases where the provision of adequate natural ventilation and cooling is impossible or uneconomical, the other extreme, viz. restriction of ventilation, is the precaution that has to be adopted. The aim is then to prevent the generation of heat, or at least reduce it to a low level. In this case the coal does not necessarily have to be a sized product.

3.2.3.1 Storage under Water and in Closed Bins.

Storage under water (e.g. in concrete bins) is more or less the ideal method of storing coal safely, but the method is expensive and not likely to find any extensive application in South Africa under present conditions.

If storage is in a closed bin or bunker, this must be free from air leaks, especially at the discharge chute. It must also be borne in mind that if coal is kept in a confined, unventilated space, combustible gases given off by the coal may form an explosive gas mixture consituting a hazard if open flames are brought nearby.

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This condition can, however, be tested for by means of a miner's safety test lamp.

3.2.3.2 Storage on Open Ground.

(a) General.

The site for the proposed stack of coal should be firm and preferably level or gently sloping. However, a valley or hollow can also be satisfactore; e.g. a hollow could possibly be filled with coal to the level of its surroundings. There should be no fences, trees, poles, upstanding foundations or heaps of scrap or waste on the site.

It is desirable to decide before hand on the area to be covered by the stack, as it is better to deposit coal over the whole area than to add on laterally to an existing pile that has been built up to some height.

(b) Combating Wind Effects.

It is well established experience that prevailing winds can cause air to penetrate the side of a pile of coal causing spontaneous heating within it, and it is recommended that if space and circumstances permit, the pile of coal be of an elongated shape, with it's longest side in the direction of the prevailing winds. Even so, prevailing winds may differ in direction in different seasons, so that further precautions are necessary.

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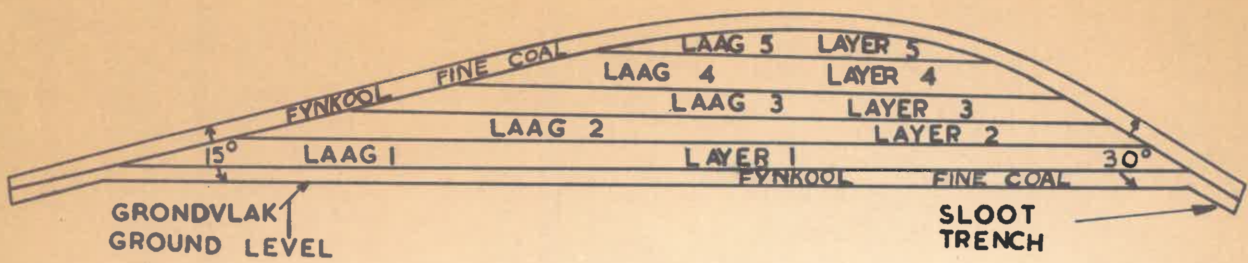

DEURSNIT VAN GEKONSOLIDEERDE HOOP STEENKOOL.

SECTION OF CONSOLIDATED STACK OF COAL.

FIG. 2

Avoiding segregation of sizes may be difficult along the edge of a pile, where, however, concentration of large sizes is particularly undersirable, as wind penetration has to be combated.

A good method is, therefore, to have a stout, airtight retaining wall around the coal, preferably not lower than the height of the coal itself, which will prevent air from entering at the bottom and sides, and in particular counteract wind effects. Alternatively, and excavated earthern pit, having air-tight side walls, could fulfil the same function.

(c) Consolidation.

Elimination of size segragation will minimise void volume and air peneration, but considerable further reduction of these can be achieved by consolidating the coal, preferably with a bulldozer, moving, mixing, levelling and consolidating simultaneously, if the scale of operations permits this. An ordinary heavy roller could also be used, or lorries depositing the coal can be made to travel all over the deposited coal, thus consolidating it.* Consolidation must not be left until the stack has reached its final height but should be applied after each layer of coal, which should not exceed 2 feet in thickness, has been deposited,

*When designing and constructing the retaining wall (or pit) not only the method of depositing and recovering the coal should be borne in mind but also the method of effecting consolidation, allowance being possibly made in the wall for vehicular traffic.

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mixed and levelled, and should extend right up to the retaining wall, where there should not be a concentration of segregated large pieces allowing air to enter towards the bottom and interior.**

(d) Surface Finish of Stack.

When the stack of coal has reached its required height, its surface should be firm, free from undulations, and approximately level. It should than be provided with a top layer of fine coal, not less than 6 inches thick, and thoroughly consolidated in order to minimize air penetration into the coal below. If found necessary, this layer of fine coal can be protected against erosion by covering it with a thin layer of lump coal (say, nuts).

(e) Alternative Procedure for Excluding Wind and Air.

Where a retaining wall cannot be, or has not been provided, entry of air from the top and sides, and in particular wind effects, can be combated by an alternative method, which has the additional advantage of being more practicable and less expensive under certain conditions.

The method is based on that recommended for the storage of opencast coal in Britain[12)], and in principle consists of building a stack of coal, consolidated layer by layer as described

**It may be argued that the production of fines through thorough mixing and consolidation of the coal will favour spontaneous heating in the pile, but the nett result is, actually, that the benefits derived from reduced air penetration resulting from these operations by far outweigh the undesirable effects of the fines created in the process.

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above, in such a way that the slope of the sides, which are also consolidated, nowhere exceeds 30°. A smooth crust of compacted fine coal, not less than 6 inches thick, is finally provided all over the finished surface of the stack, using preferably a road roller for achieving this state. Reducing the angle of rise to, say, 15° to 20° results in greater safety still, but space requirements may be a limiting factor. In one direction, at least, the slope should be less than 30° so as to enable lorries to gain access to the top of the stack. The slope should gradually become gentler as the side of the stack is ascended, and the completed stack should be approximately flat and level at the summit, its general shape being domed or whale-backed. An excavated trench along the periphery of the stack ensures that a good seal of the fine coal covering the stack can be effected at ground level. The trench should be dug in advance, and before starting to deposit the coal the area to be covered should be provided with a ground layer of fine coal, 6 to 12 inches thick and well consolidated, extending into the trench mentioned above. This ensures a good seal between coal and the ground and between ground layer and crust. (see figure 2 for a schematic representation of a section through a completed stack.)

(f) Height of Correctly Build Stack not Limited.

Provided air is not allowed to circulate into the interior of a stack of coal, (which should be the case if the precautions described above were observed) there is no limit to the height to which the stack may be built, but economic and other considerations will usually determine a limit for each individual case.

(g) Providing an Impervious Capping.

A further precaution that may be taken against the entry of air into a completed stack of coal is to provide an impervious asphalt or tar coating over the entire exposed surface.* Any cracks developing in this capping should be immediately repaired so as to maintain a perfect air-tight seal. Usually, however, this additional precaution can be dispensed with, or at least postphoned until undue and uncontrollable heating is actually taking place. The latter is unlikely to occur if the precautions described previosly were thoroughly carried out.

(h) Resealing a Stack Disturbed after Completion.

If at any time a completed stack is temporarily disturbed, allowing air to enter it, e.g. by recovering coal from it, or through erosion by rainwater, the rupture should be repaired as soon

*Bituminous emulsion suitable for capping a pile of coal costs about 1/9d. per gallon, and about 2 square yards of surface can be treated with a gallon.

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as possible, in any case within a few days, and consolidation effected, so as to reestablish the former sealed condition of the stack, or that portion of it not immediately required for consumption. (See also: 3.5)

3.3 Supervision of Coal Piles.

3.3.1 Regular Inspection.

During the building of a pile of coal in accordance with the principles and recommendations described above, and after its completion, it has to be regularly and thoroughly inspected in order to establish any development of spontaneous heating inside the pile. In certain instances the steps recommended below may have to be taken before the pile is complete.

Metal rods inserted into the coal so that the ends project above the coal, can, on feeling them, give a warning of heat development below the surface, but this method is not informative enough to be recommended.

3.3.2 Measuring Temperatures Inside the Pile.

The best way to detect and follow the tendency of sub-surface heating is to insert steel pipes of, say, 1 inch inside diameter, closed and pointed at the lower ends, into the pile at approximately 20 feet centres, and to read off temperatures with thermometers* at pre-determined distances from the surface. In stacks not provided with a retaining wall, coal near the side surfaces, and especially near the bottom, should be particularly observed

* If desired, thermocouples could be substituted for thermometers.

for heating, and distances between observation points reduced to, say, 10 feet. Recommended depths at which temperatures should be taken are at 2½, 5 and 7½ feet from the surface of the coal. If circumstances demand it, temperatures could be taken at a greater depth, but normally this should not be necessary. Maximum reading thermometers could be used, but if they are not available an ordinary thermometer can be made suitable by insulating the bulb with a piece of rubber pressure tubing extending about ½ and inch beyond both ends of the bulb. The protruding end of the rubber tube should be closed with a core of cork or rubber. Such a thermometer should be left undisturbed in position long enough to ensure that the mercury has attained the ambient temperature before reading it (one hour at least, and preferably longer.) On withdrawing a thermometer from its pipe to determine a temperature, no time should be lost in taking the reading, as the mercury may start receding in the capillary within a few seconds of withdrawal. After the temperature has been read the thermometer may be put back into the pipe - at different depth this time if desired, and left there for any lenght of time (not less than the minimum required as described above.)

A convenient method of ensuring that readings are taken consistently at the predetermined depth is to make knots in the string to which the thermometer is suspended at such positions that the bulb of the thermometer will be at the correct depth if the knots are at the rim of the pipe. A washing peg can then conveniently be used to hold the string from slipping into the pipe. Alternatively, two or more thermometers may be accommodated in the same pipe at the desired depths, but preferably

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on separate strings. A safeguard against strings slipping down pipes is to tie a ring, which is large enough to prevent it from entering the pipe, to the end of the string. An inverted empty tin, placed over the end of the pipe protruding above the coal, will keep out rain and other extraneous material while readings are not actually being taken.

3.3.3 Systematic Recording of Temperatures.

All temperatures should be systematically recorded so that tendencies in temperatures may be judged at a glance. A plan of the surface of the pile should be made and on it the positions of the thermometer pipes, numbered 1, 2, 3 etc. indicated. Temperature readings should then be tabulated, for example, as shown below:-

Position No.	Depth(ft.) below Surface	Date and Temperature (°C)							
		January, 1952				February			
		25	27	29	31	2	9	16	23 etc
1	2½	30	30	31	31	32	31.5	31.5	31
	5	31	31	31.5	32	32	32	33	33 etc
	7½	30.5	31	31	31.5	32	32	32.5	33
2	2½	28	27.5	28	etc.				
	5	27	27	28					
	7½	26.5	27	27					
3	2½	etc.							
	5								
	7½								
etc.									

3.3.4 Frequency of Temperature Measurments.

When the heating tendencies of a stack of coal are unknown, temperatures should be taken, say, every 2nd or 3rd day, but when it has been established that no undue heating is developing, readings may be reduced to once a week or fortnight, as may be appropriate.

The frequency of temperature observations may be further reduced, if, after a few months, there is no indication of appreciable temperature rise, or after temperatures in all parts of the stack begin to show a tendency to drop.

3.3.5 Discontinuing Temperature Measurements.

If it is obvious after several months that temperatures in all parts of the stack are dropping (due to heat generation dying away and not to atmospheric influences) it may be assumed that the stack, if left undisturbed, is safe, and temperature readings may be discontinued.*

If pipes are withdrawn from consolidated stacks the ruptures should, however, be compacted so as to maintain a uniform sealed condition of the surface.

3.4 Dangerous Heating and Fires.

3.4.1 "Dangerous" Temperature Range.

A "dangerous" temperature in a pile of coal is a relative conception and difficult to define. According to Taylor[15)] it may vary considerably, depending on circumstances, from, say, 35° to 70°C (95°F to 158°F).

*If undue heating withing a stack of coal is liable to occur at all this usually become evident within 4 to 16 weeks. It should normally not be necessary to continue temperature observations longer than about 9 months provided the stack remains undisturbed.

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When conditions are favourable for spontaneous combustion (e.g. rank of coal on the low side, presence of fines, stack abnormally high etc.) the "dangerous" temperature limit will be towards the lower end of the above range, and vice versa for conditons less favourable for spontaneous heating. In practice the range is usually narrowed down to between 45°C and 60°C (113°F and 140°F), and there is reason to believe that these limits will also apply under South African conditions. If the temperatures within the pile, recorded as indicated above, have increased to within this range, and show little or no tendency to attain constancy, trouble is developing, and the rate of temperature rise may at any time start to increase. Also, there may be points in the pile where the temperature is even higher than those recorded, and the position should immediately be ascertained by determining temperatures at additional places, intermediate between the original points, concentrating at those places where trouble seems to be most imminent. Even if temperatures taken at the new places are not higher than those previously recorded, there must be no hesitation in dealing effectively with the affected portion of the pile, as otherwise temperatures will only rise with increasing rapidity, culminating ultimately in the outbreak of a fire. It is quite wrong to delay action in the hope that conditions will take a turn for the better.

3.4.2 Steam, Smoke and Odour.

A dangerous condition is usually associated with the appearance of steam on the surface of the pile of coal, but this phenomenon is too dependent on wheather conditions to be a reliable indication.

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Actually on cold humid days steam may be visible on a pile long before temperatures have assumed dangerous limits. Nevertheless, if steam is noticed it should not be ignored as being of little or no importance.

A light grey smoke, accompanied by a distinctive odour, indicates that a fire is already developing, possibly only in a particular zone to start with, but liable to spread in any direction, although possibly appearing only sporadically at the surface as flames or a glowing patch.

3.4.3 Dealing with Dangerous Heating and Fires.

If temperatures in a pile of coal have reached the "dangerous" level in, say, a particluar zone only, more intensive consolidation in and around this zone may be tried.* For example, if a crane and grab are available, a closed and loaded grab could be repeatedly dropped on the affected area. If this is ineffective in checking rising temperatures water may be applied, but only if a copious source is available, as the supply from an ordinary garden hose may do more harm than good. The water should be applied, firstly in a ring around the affected area, and then all over the area, flooding it completely if possible. The idea is first to surround the hot spot with a wall of water-saturated coal so as to reduce the chances of heat being transffered by steam to adjacent cooler coal before applying the water to the hot spot itself.*

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*In the case of ventilated piles of sized coals (see: 3.2.2) this measure is hardly likely to be effective and it may be omitted from the series of measures recommended.

*Heavy spraying of a pile of coal is often practiced, but primarily as a means of retarding heating and keeping the temperature below a critical limit until the stack has been piloted through its peak heating period. Use of insufficient water may, however, do more harm than good (see: 3.1.7)

If water-flooding cannot be carried out thoroughly, or has failed, and it is not convenient to remove, scatter and cool the heated coal, sealing the pile, e.g. with tar emulsion, may be restorted to. If this is decided and it is desirable not only to seal off the effected area and its immediate surroundings but also to consider treatment of the entire surface of the pile.

Once a fire has started it is unlikely that it will be quenched by applying water. Sealing of the surface of the pile as mentioned above is recommended, but if this is not feasible the only alternative is to dig out the heated coal, and, either to use it immediately, or to scatter and cool it.**

3.5 Life of a Stack of Coal.

Once a strategic stock of coal has been laid down and has proved to be safe over a period of, say 9 months this stock should, for obvious reasons, preferably not be drawn from again within about 5 years (see: 3.2.3.2(h) and 2.3) unless circumstances (e.g. acute shortage of coal) demand it. For this reason, and also with a view to limiting the extent of any spontaneous heating troubles that might be experience, it may be better to build up two or more smaller stacks of coal rather than a single large one.

4. CONCLUSION.

It is virtually impossible to store coal without its suffering some deterioration at least, but it is possible to store the coal in such a way that it does not fire spontaneously, the

**A mobile crane with a grab is a most useful tool for dealing with heated coal and if it is available liberties may even under certain circumstances be taken with some of the precautions recommended, e.g. height of stack, etc.

Coal once heated and subsequently thoroughly cooled will be safer to store than the same coal freshly wrought.

only limitation being cost of storage. In practice the storage of coal usually comprises a compromise between amount spent on safety measures taken and risk run of experiencing spontaneous heating, and this probably accounts for the comparatively frequent instances of spontaneous heating encountered. However, it is put to those interested in the strategic storage of coal that it might pay them to carry out the recommended precautions with the greatest thoroughness, and aim at a large margin of safety, rather than to run the risk of a fire in the coal stack.

In the preparation of this brochure the literature describing conditions and procedures in overseas countries has had to be freely used, and a serious drawback has been the lack of first hand knowledge and experience pertaining to the storage of coal under South African conditions. However, the acute seasonal coal shortages experienced in the country lately have undoubtedly convinced consumers of coal that they shall have to think more seriously in terms of strategic storage in future, and, where it has been the aim of the Fuel Research Institute here to provide them with some quidance and assistance in this connection, it is hoped that they will, in time, reciprocate by making available to the Institute the benefit of their knowledge of, and experiences with the strategic storage of South African coals, so that this could possibly be incorporated in this brochure in the future.

(SIGNED) C.C. LA GRANGE
SENIOR RESEARCH OFFICER.

PRETORIA
13/11/1951

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