NOTES.

Palm Oil for Diesel Engines.

A series of trials is in progress at the Admiralty Engineering Laboratory to ascertain the suitability of certain fuels of types not ordinarily used, but of which supplies may be available for use in emergency. Palm oil has recently been tried in the unit cylinder of the H. Class submarine type engine.

Palm oil is a product of the fruit of the West African palm, and is not to be confused with the oil obtained from the cocoanut palm. The tree is also grown in Sumatra. The oil is obtained from the pericarp surrounding the kernel, of which 85 per cent. consists of oil, the balance being impurities and fibre waste. Another product called palm kernel oil is obtained from the kernel of this fruit.

The properties of the oil tested were as follows :—

S.G. at 105° F. (liquid)	·897.
S.G. at 60° F. (semi-solid)	·923.
Melting point	64° F.
Flash point	352° F.
Viscosity at 110° F.	135 seconds.
Calorific value	16,700 B.T.U's.

This oil being semi-solid at atmospheric temperatures, it was necessary in the first place to provide heating apparatus to the ready use tank, which was placed immediately adjacent to and slightly higher than the fuel pump on the engine. A three-way cock was fitted at the pump inlet to enable the engine to be switched over to shale oil and a drain cock was fitted to allow the pipe to be emptied on shutting down and so to avoid the necessity of thawing out the palm oil in the pipe when changing over to palm oil. No modifications were made to the working parts of the engine.

Preliminary tests showed that the best temperature at the pump suction was about 95° F.; at lower temperatures there was a tendency for the exhaust to become shaded and the running of the engine was not so steady.

The results, in comparison with shale oil and Texas oil (calorific values 19,200 and 19,300 B.T.U.'s respectively) follow: —

Oil.	Revolutions.	B.H.P.*	Fuel in lbs. per B.H.P. Hour.	Blast pressure lbs per sq. in.
Shale	376	30·1	·407	950
	341	22·4	·406	800
	297	14·9	·421	700
	237	7·5	·466	600
Texas	375	30·0	·426	950
	341	22·5	·422	850
	299	15·1	·446	750
	236	7·5	·494	550
Palm	375	30·0	·489	950
	345	22·7	·482	775
	297	15·0	·507	690
	240	7·6	·577	600

* No allowance made for power required to drive compressor.

On a calorific basis, it will be noted that the results for the palm oil agree very closely with those obtained for Texas oil. In this respect the latter is somewhat inferior to the lighter shale oil.

The performance on palm oil should, of course, be debited with the energy required to keep the fuel liquid, but in practice this would probably be obtained from the surplus heat in the exhaust.

Alternative arrangements for priming the pump were fitted, one adjacent to the delivery and one on the suction in order to determine which was the better from the starting aspect.

When priming to the delivery :—

(*a*) Using shale oil for priming, no difficulty was experienced nor was any special action necessary for the starting up and changing over to palm, provided shale oil was used for the last five minutes of the trial on the previous day.

(*b*) If palm oil had been used up to the time of shutting down the engine, it could be started the following day using shale oil for priming the pump, but it was found necessary to heat the fuel pump with a blow lamp as near as possible to the suction side. No heating was required on the delivery side of the pump. With similar heating, the engine could also be readily started when priming the pump with hot palm oil.

In priming on the delivery side it is necessary only to pump such an amount of fluid as will ensure movement of the semi-solid column of oil in the delivery pipe. It is not necessary to clear this pipe by allowing the column to be discharged through the test cock near the spray valve.

When priming to the suction :—

(*a*) Using shale oil for priming, no difficulty was found in starting up, even when palm oil had been used up to the time of shutting down on the previous day. No heating was required at the delivery side.

(*b*) Using hot palm oil for priming, it was not difficult to start up under the conditions referred to under (*a*).

Generally it would appear that the use of shale oil was not absolutely necessary, but it was helpful.

The engine was examined after about 50 hours running on palm oil. It was found that the piston was clean, except for a thin hard carbon deposit on the crown. Fuel oil had apparently passed the piston and deposited in the solid state on the crank splash guards; this observation indicates the possibility of a limitation in the useful employment of this oil, seeing the danger of choking of oil ducts in the event of this semi-solid oil accumulating in the crank chamber. The deposit in the exhaust valve box and pipe was very slight. Solid palm oil was present in the spray valve up to the non-return ball in the blast air connection. It was noted that the oil had a brightening effect on copper fittings and that the brass sleeve of the fuel valve was discoloured. In view of these indications, the corrosive effects of palm oil on various metals will be investigated.

Mercury Boiler and Turbine.

It is reported that the first commercial mercury boiler and turbine is ready for installing in a generating station at Hartford, U.S.A. This development has been under investigation by the General Electric

Company of Schenectady for a number of years, and its commercial application will be watched with the greatest interest by power plant users.

In principle the system consists of a special design of boiler fed with mercury and fired by oil fuel. The boiler contains about 30,000 lbs. of mercury, and the tubes are of steel. The mercury vapour is led to a turbine, in which it will carry out useful work, and then to a condenser, which takes the form of a modified water boiler, in which the heat in the mercury is utilised to raise steam which is in turn used to do useful work.

In effect, therefore, the development of a unit of power will be attended by the use of a lesser amount of steam than in a straight steam installation, and so to a lesser amount of heat rejected to the condenser. The mercury turbine will be suitable for driving a 2,000—K.V.A. generator and the steam from the mercury condenser will be taken to the steam line of the existing plant.

It is hoped by the designers to cut down the fuel consumption per kilowatt hour by approximately 50 per cent. through the use of the mercury turbine and utilisation in steam production of the heat given up in the mercury condensation process. The employment of mercury is, of course, attended by many practical difficulties, including that of coping with leakage, and it can be presumed that these have been solved in the earlier experiments to at least a sufficient degree to justify this commercial application.

Multiple Effect Evaporators.

In addition to the distillation of water, evaporators are very widely used for concentration and similar purposes in the sugar refining, food stuff, and chemical industries. The necessity for economical production leads in those cases to the multiple effect being employed. In general, where evaporators are used for concentrating trade solutions the general practice is to arrange for two or three effects so that the pressure in the first effect does not need to exceed 5 lbs. per sq. in. gauge, thus enabling the evaporation being done by exhaust steam from the various engines required for power production.

For distilling water, however, and here the application is largely for overseas purposes, multiple effects up to six in number are employed, and in general the water passes through the tubes. In such an installation the water to be distilled is taken from the circulating water which has been used in the distilling condenser and pumped first through heaters served by the drain of the last effect, and then successively through the small heaters arranged in the tube system of each effect. By the time the feed has passed through the first effect, its temperature will not be much below the temperature of the steam supplied to that effect. At this point the feed may in certain cases be taken to a lime catcher containing a steam coil which brings the water to a temperature at which certain of the constituents are precipitated. After filtering, it then passes to the coils of the first effect. The shell of the first effect receives steam from the boiler and the condensate from this effect is returned to the boiler. The steam formed in the tubes of the first effect together with the water pass to a separator where the steam separates from the water and is led to the shell of the second effect, whilst the water passes into the tubes of this effect. The pressure in the shell of this effect practically corresponds with the pressure of the tubes of the first effect, but the pressure of the tubes of the second effect is lower. Hence, as the water entering the tubes is at the higher temperature of the previous effect, there is an immediate and spontaneous evaporation of some of the water and this causes a lowering of the temperature of the remainder, which permits of heat being transmitted from the steam on the other side, causing further evaporation of a further quantity of water and the condensation of the steam outside the tubes. Again, the water and steam pass to a separator and the separated steam is led to the shell of the third effect and the water to its tubes, but as the water produced by the condensation of the steam supplied to the shell of the second effect is not wanted for boiler feed, it is drained into the shell of the third effect and there imparts some of its heat to the water in the tubes. Spontaneous evaporation also takes place here owing to the water entering a vessel in which the boiling temperature of water is lower than the temperature of the incoming water.

This cycle of operations is repeated in succeeding effects until the last one is reached. From here the water drained from the second, third, fourth and fifth effects, together with the water of condensation formed on its own tubes, is drained to the evaporator feed heaters and thence to the condenser. The steam from the last separator passes to the heaters where some is condensed and then to the condenser where the remaining steam is condensed and it, together with the drainage water, cooled as required.

The residual water or concentrated brine, if treating brackish or sea-water, from the sixth separator is pumped out by the brine pump. The amount of feed water flowing through the apparatus is regulated in such a way that the brine may be of such a density that it will not give rise to excessive deposits on the tubes and system.

The pressures and other data for such a system in a typical installation using brackish water would be as follows :—

Tubes.	Shell.	Absolute pressure.	Temperature.	Temperature Difference.	Theoretical Evaporation for 1 lb. of boiler steam admitted to first effect.
		Per sq. in.	° F.	° F.	
—	1st	56	288	—	—
1	2nd	36	262	26	·766
2	3rd	23	236	26	·731
3	4th	14	210	26	·7
4	5th	8	182	28	·663
5	6th	4	152	30	·62
6	Condenser	1	102	50	·62

Total - 4·1 lbs.

5½ lbs. of water are pumped through the apparatus per pound of boiler steam, of which 4·1 lbs. of distilled water are produced and 1·4 lbs. of brine are discharged. For an evaporation of 12 lbs. of water in the boiler, which is possible when using good coal and high temperature feed, the production of distilled water per lb. of coal would be in theory 49·2. Actually the calculations do not allow for radiation and other losses, but allowing 10 per cent. for this, 44·3 lbs. would be obtained which is in agreement with the result obtained under similar pressure conditions in practice.

Rustless Steel Propeller.

The results of the trial of a rustless steel propeller in Steam Pinnace No. 474 are now available. Since fitting this propeller, the boat has been on service in the vicinity of Chatham Dockyard for a period of eleven months, of which it was in use during each working day for seven months, the remainder of the time having been spent at moorings in the Boat Basin in tidal waters. The boat is not sheathed but the usual gun metal under water fittings were in place. It is reported that each blade is badly corroded for about two-thirds of its length, the corrosion being more marked towards the boss and more pronounced on the astern driving faces than on the ahead faces. The corrosion is about ·015 ins. deep and is fairly general over the surfaces mentioned. In places there are pits, from which cracks are developing. In addition there are other cracks adjacent to the boss. The propeller was covered with a rust scale which was easily removed.

It is not possible to draw definite conclusions from the results of a single trial, and in view of the very satisfactory behaviour of this material in resisting corrosion when exposed to adverse conditions in other applications and the great advantages which it offers for propellers in respect to strength, &c., it is probable the experiments will be continued, making some variation in the composition and possibly the heat treatment.

Monel Metal

In 1884 during the construction of the Canadian Pacific Railway through the Province of Ontario, a deposit of copper ore was discovered at a point near Sudbury. This deposit was opened on a commercial scale, but as the mining progressed, it was found that what had been discovered was not a copper deposit, but one containing both copper and nickel. Methods of separation and refining were developed and from this chance discovery originated the great nickel industry of America. In about 1905 it was conceived that for certain purposes it was not necessary to separate the nickel and copper, but that an alloy could be produced direct from this ore without separation. This was soon proved to be technically and commercially possible and the experimental production of monel metal was begun. Its properties are such that a market was soon found and the scope of its application is extending at a great rate.

Monel metal is a natural alloy, inasmuch as it is made directly from the ore without separating the constituent metal and consists approximately of 67 per cent. nickel, 28 per cent. copper, and 5 per cent. other metals, including iron and managanese, but it contains no tin, zinc or antimony. In appearance it is very similar to pure nickel and it takes the same finish. It machines readily and can be rolled, drawn, cast, forged, soldered, brazed and welded, either by the acetylene or electrical process. The weight in the rolled conditions is 558 lbs. per cubic foot, and in this condition it is, like pure nickel. magnetic at room temperature, but this property ceases at a temperature of from 200 to 300° F., depending on the composition. The coefficient of expansion is ·0000076 (as compared with ·0000063 for steel) and the heat conductivity is 1/15th that of copper.

Processes of Manufacture.—When taken from the mines, the ores is subjected to a preliminary refining process which reduces it to the form of matte. It is sent in this form to the works of the International Nickel Co., at Huntington, West Virginia, U.S.A., where conveyers elevate the matte to a special type ball mill which grinds it to the consistency of coarse sand. Thence it is sent to the calcining furnaces which are heated by natural gas so that in this, as well as in the numerous subsequent heating processes, there is no possibility of impurities entering the metal from the fuel. From the calcining furnaces the metal goes to the reverberatory furnaces, and from them cast as pigs; thence to the electric furnaces, where it is re-melted and cast in the form of 2-ton ingots. So far as refining in the electric furnace and ingot casting are concerned, the handling of the Monel metal does not differ from the usual steel mill practice.

In the next step, its reduction to commercial form, a number of operations are involved that are entirely lacking in the steel processes. In the case of steel, the ingot goes directly to the soaking pit and being a metal very susceptible to oxidation, the surface defects on the ingots are automatically removed by the heating and rolling processes in which the oxide scales off, leaving clean metal. Monel metal, on the other hand, is highly resistant to oxidation so that it is necessary to remove the outer skin of the ingot completely with its accompanying surface defects before proceeding to the heating and rolling. The ingots are accordingly taken to milling machines where a heavy cut is taken off each side and the milled ingots are then closely examined and any surface defects discovered are chipped out with pneumatic tools. After this the ingots go back to another battery of furnaces in the hammer department where they are cogged down to bloom size and are then ready for delivery, if required in this form, or for the further manufacturing processes such as are carried out in the rod or sheet mills. In these latter processes there is no apparent difference between its production and that of steel. With a metal consisting chiefly of nickel and copper, however, the greatest problems are naturally involved in the heating of it and this is equally true in every stage of the process from the calcining furnace to the final annealing.

Properties.—While possessing the quality of strength in a marked degree its most valuable commercial attribute appears to be its great resistance to corrosion, considered in relation to the high ductility and the ease with which it can be worked. It is not immune from corrosion in the presence of certain fluids and gases, but its field of application in this respect is considerably wider than the other commercially used metals, and its use has led to very marked economies in many commercial processes which had hitherto relied upon metals or fabrics which necessarily had a short life under the corrosive and straining influences to which they were exposed.

In regard to strength it resembles steel and its leading properties may be summarised as follows :—

Cast Metal :

Tensile strength - - -	19 to 25 tons per sq. inch.
Elongation - - - -	10 to 20 per cent.

Hot Rolled Metal:

Tensile strength	38 to 41 tons per sq. inch.
Elongation in 2 inches	36 to 45 per cent.
Proportional limit	15 to 16 tons per sq. inch.
Yield Point	18 to 19 tons per sq. inch.
Brinell Hardness	180.
Izod Test	120 foot lbs.
Arnold Reversal Test	523 reversals.

The stress strain diagram exhibits a marked and definite yield point and proportional limit similar to steel and in contrast to the elastic behaviour of most non-ferrous materials.

In respect to toughness, the Izod and Reversal tests given above are superior to those obtained from steel, for which Hatfield gives a maximum for steel of all kinds, to be Izod 73, and Arnold 445. In the Izod test the Monel metal test pieces are not broken, as the test piece bends and allows the weight to pass.

The effect of cold drawing is to raise the tensile strength at the expense of the ductility. Typical results for (*a*) a $\frac{5}{16}$ inch rod subjected to very heavy cold drawing, and (*b*) a turbine blade of this material, are :—

	(*a*)	(*b*)
Tensile strength	59·2	41·9
Elongation per cent.	9	30·4
Proportional limit	16·5	13·9
Yield Point	47·7	37·7

The normal qualities of the material can be restored after cold drawing by suitable annealing.

The qualities of the material when heated are maintained in a much higher degree than for other non ferrous alloys. For temperatures up to about 650° F., its tensile strength falls at the rate of about 1·0 ton per 100° temperature rise, giving a diminution of 12 per cent. in strength at 660° F., as compared with a diminution of strength in phosphor bronze of 33 per cent. for the same temperature rise. As is generally known, the tensile strength of rolled mild steel at this temperature is in general rather greater than when the material is cold and in this respect Monel metal is inferior to steel.

Uses.—Its applications form a comprehensive list and it is only necessary to refer to them in so far as will give an idea of its special features. It has proved particularly reliable for the valves, valve seats, springs and similar fittings exposed to highly superheated steam, and has been found to resist erosive and corrosive influences to a high degree. Its high ductility enables it to be drawn to the smallest sizes; in the form of small gauge wire it has found a wide field of application for use as filter cloths in the chemical and food stuff manufacturing industry, where it is found to stand up to conditions in a markedly superior way to the fabrics or metals formerly used. For the internal parts it is extensively used in laundry, dyeing and bleaching machinery. In the handling and distributing of food stuffs and for hotel, restaurant and kitchen services, it has been found superior to the other materials previously employed, due to the fact that it is more sanitary, requires no cleaning or other protection and will stand more wear from hard service than the softer materials customarily used.

Valves, seats, rods and liners for pumps, exposed to corrosive water constitute another application. It is also used for turbine blading and turbine discs.

In the Naval Service it has been used in a few isolated cases for air compressor pump rods, auxiliary turbine blading and discs and in the impellers of water extracting pumps. In the last-named application it has failed to stand up to the conditions any better than the materials previously used; the cause of the failure in this case appears to be a water hammer effect similar to that giving rise to erosion in propellers in fast running ships, and not to corrosion. A propeller of this material has also been fitted in a steam boat with satisfactory results, and an order has been placed for condenser tubes of this material with a view to trial in a turbo-generator condenser.

Working and Machining.—The correct forging temperature for Monel metal is 1048° to 1100° C., over which range the colour changes from salmon to orange. Oil fired furnaces using creosote or oils low in sulphur or gas fired furnaces are recommended. The metal is liable to absorb oxygen and other gases, carbon and sulphur when hot and, if coal and coke furnaces are used, it is necessary to take special precautions to protect the metal from the flame or blast; a smoky flame carbonises and hardens the metal and causes difficulty in forging. It must be handled with speed when hot as the heat is not maintained during forging to the same extent as in steels. Monel metal can be soldered as easily as copper; the same flux, solders, tools and methods are used. Any oxide on hot worked material must be removed by pickling. It can also be brazed in the same manner as copper, using ordinary spelter with borax as a flux.

Monel metal machines with a long, tough chip, in this respect resembling copper, but requiring more power to cut. Owing to the great toughness, tools with a keen edge are necessary in all machine work, and the tools should be ground with a very decided rake in all directions. For ordinary machine work it may be cut dry very satisfactorily. Cutting speeds very greatly from a slow speed of 8 feet per minute, with heavy cut and feed, to a high speed of 250 feet per minute with light cut and feed. A good average speed for general work would be from 50 to 60 feet per minute with $\frac{1}{8}$ in. cut and $\frac{1}{32}$ in. feed.

* Factors in the Spontaneous Combustion of Coal.

Size of Coal—Fineness of Pieces.—The heating of coal is believed to be a surface phenomenon. If a ton of bituminous coal could be delivered in a single cube, each dimension of the cube would be about 2·8 feet. When coal heats, it is due to something that goes on with respect to the surface and not something that happens inside of the piece. So far as we know, this is true no matter how finely the piece is divided. We are, therefore, interested in the area of the total exposed surface in a ton of coal. If the cube, having originally an area of about 47 square feet, be continuously sub-divided, the rate of increase in the exposed surface is rapidly increased until, if the size of the pieces is reduced so that they are fine enough just to pass through a 16-mesh screen, the area of exposed surface becomes an acre. It is perfectly obvious from this why it is that trouble from spontaneous combustion originates in fine coal, because the great increase in extent

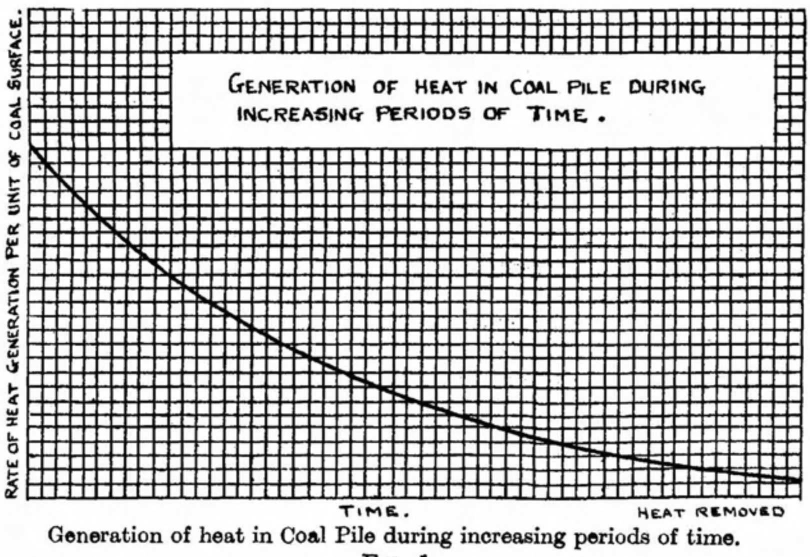
* Published by the U.S. Bureau of Mines.

of surface does not begin until we get below $1\frac{1}{4}$ inch, or nut size. If fine coal is kept out of the pile, the heating surface is relatively so small as to remove the cause of spontaneous combustion. This remark applies not to the fact that one may buy lump coal, but to the size of what actually gets into the storage pile. Coal bought as lump at the mine and handled with modern disregard for breakage may be far from lump coal when in the pile.

Temperature at Time of Storage.—A unit of area of this coal surface generates a certain amount of heat, provided the coal can find the combining material, that is, oxygen. The amount of heat generated depends upon the temperature of a piece of coal. That is to say, coal put into storage at a temperature of 80° F. will generate very much more heat per unit of surface than if put into storage at the temperature of 60° F. How much more the generation of heat increases cannot be predicted, but chemists tell us that in general the rate of chemical reactions doubles for every 10° rise in temperature, and if that applies in this case, beginning at a temperature 20° higher means a fourfold increase in the amount of heat generated. It has already been a matter of observation that coal stored during the hot months of summer and in heated regions is much more liable to spontaneous combustion than coal stored in colder climes and in cooler seasons of the year.

Freshness of Coal Surfaces.—Another most important factor is the freshness of the broken surface. A freshly broken surface of coal has a rate of heat generation that is a function of the kind of coal. It is practically zero with anthracite and is largest with the younger coals. The quantity of oxygen contained in the coal seems to be the fairest measure of this rate although it is by no means reliable. High-oxygen coals and sub-bituminous coals and lignites show increasingly active rates of heating.

In time, the coal surface apparently becomes satisfied, that is, nearly ceases to take up oxygen, and the heat produced falls practically



Generation of heat in Coal Pile during increasing periods of time.

FIG. 1.

to zero. The rate of heating then follows a curve somewhat like that given in Figure 1. This means that for the first few days or weeks, a freshly broken surface is very much more active than after a few weeks or months—fact that must be borne in mind when considering the wisdom of crushing coal immediately before storing it. Spontaneous fires rarely occur after the coal surfaces have been exposed for three months.

Rise of Temperature to Danger Point.—As the rate of heating increases with the temperature, it is evident that if the heat generated is not removed, the process becomes a self-aggravating one, and the rate of heat generation instead of falling as in Figure 1 may rise with time. If the temperature of the pile reaches 140° or 150° F. and continues to rise, there is a high probability that within a few days or a few weeks a destructive temperature will be reached. If the temperature reaches 160° or 180° F., there is almost a certainty that a destructive temperature will be reached and that the coal must be moved. Immediately the question of getting rid of the heat is presented.

Dissipation of Heat Generated.—A coal pile is cooled by radiation and by the movement of air through it. Air moves rather freely through a pile of coal. To illustrate this point, one may cite a partial cargo of coal that was loaded into a bottom at New York and carried under sail to Norfolk. The general temperature of the pile at loading was known; on arrival at Norfolk the temperature of the coal had so increased as to make the adding of further cargo dangerous. From the known rise in temperature of the coal, it was possible to estimate, roughly, the exchange of air that must have been made within the partial cargo in order to supply the amount of oxygen represented by the heating effect. The general order of magnitude was that all of the air in the interstices between the pieces of coal must have been changed 20 to 30 times during the time of heating. This coal was, of course, protected from winds, and the illustration shows how great may be the natural ventilation produced within a coal pile by differences in temperature and by the daily variations of barometric pressure. In many piles of coal this natural change, or breathing, of air is enough to carry away the heat generated.

Segregation of Coal by Sizes in a Pile.—Suppose that coal is delivered in four uniform sizes and put in a conical pile by dropping at a single point. The granular arrangement of parts will be such as to furnish a foundation, under nearly the whole pile, of larger sized pieces and the lower flanks of the pile will also be of the larger sizes. Nearly all of the smallest pieces will be in the central core of the pile.

Access of Oxygen—Ventilation.—In the region of large pieces in such a pile the air would move freely and the area of coal surface exposed would be a minimum; hence there would be little likelihood of heating. In the centre of the pile the movement of air would be small and the total of heating surface would be great. If the fine coal is so densely packed as to prevent an exchange of air, there will be no heating because there will be no supply of oxygen to combine with the active surfaces. Somewhere between the two extremes of the central core of fine coal and the large-piece region there may be areas where the ventilating current is just sufficient to supply oxygen for a maximum rise in temperature and insufficient to remove the heat as generated. In Figure 2, lines have been drawn showing in general the progressively difficult paths for the movement of cooling air.

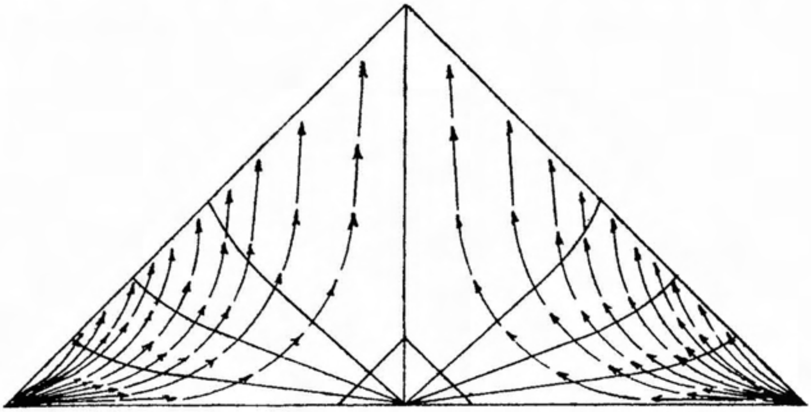
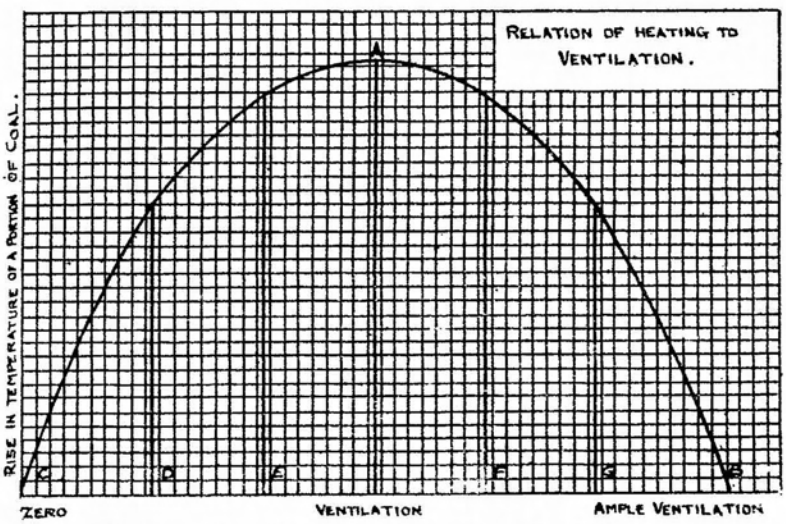


Diagram showing increasingly difficult paths for air circulation in a pile of coal.

Fig. 2.

Some observers have stated that, in general, fires in large coal piles are found in the region from 5 to 8 feet below the surface on the flanks of the pile. The rise in temperature of a coal pile is thus intimately connected with a very complicated ventilating problem, and we have no means of observing or measuring these small and wayward ventilating currents.

We know that if coal can be sealed tight, as in a glass jar, the oxygen soon disappears and the coal cannot continue to heat because of lack of oxygen. In Figure 3 the horizontal distances represent the



Relation of heating to ventilation in a pile of coal.

Fig. 3.

amount of ventilation of any portion of a coal pile and the vertical distances represent the rise in temperature. With no ventilation there will be no rise in temperature, and the zero point will represent the condition of coal sealed from the air or so densely packed that air cannot circulate. If, on the other hand, there is enough ventilation, the heat is all carried away as fast as generated, and some point, as at B on the zero line, must represent this condition, as in the case of coarse coal. At some point, as at A, between these two extremes there may be a condition of ventilation, which will supply just oxygen enough to provide for a maximum rise in temperature. What sort of a curve represents all of the intermediate conditions between C, A and B we do not know, but that the curve must first ascend and then descend is perfectly evident. This curve teaches that if we have a condition of ventilation as at D, an increase in the ventilation to E will produce a more favourable condition for a temperature rise. On the other hand, if the original condition is as at F, and we increase the ventilation to G, we can expect a reduction of temperature. Since we have no means of knowing just what the ventilation is in any given portion of a pile, there is great hesitancy in advocating ventilating schemes for coal piles, as we are as likely to make trouble as to prevent it, unless extreme and uniform ventilation is assured.

These curves illustrate the tendencies of what are believed to be the principal factors in the problem of spontaneous combustion.

There are many more factors of minor importance. One of the troubles has been that undue attention has often been given to the minor factors, such as the sulphur or the volatile-matter content of the coal, height of pile &c., while the main factors, such as initial temperature, breakage in handling, freshness of the coal, and the screening before storage have been overlooked or minimized.