INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1914-15.

President : SIR ARCHIBALD DENNY, BART., LL.D.

VOLUME XXVI.

Paper of Transactions, No. CCV.

Wood Charcoal, Its Manufacture and Uses.

BY MR. W. D. ASHTON BOST (Companion).

READ

Monday, February 2, 1914.

CHAIRMAN : MR. ROBERT BALFOUR (Member of Council).

ONE of your members, Mr. Robert Balfour, last year read a paper on "An Investigation of the Inflammability of some Insulating Materials" to the Cold Storage and Ice Association. That paper largely dealt with a report prepared by Dr. Rosenhain, of the National Physical Laboratory on an extended series of experiments on certain materials—principally on Wood Charcoal. Many of your members were present at the reading of the paper, or are otherwise familiar with it, and as the remarks made at the discussion and afterwards led me to believe that the fundamental difference between the different classes and forms of charcoal were not sufficiently appreciated, I thought that your Institution might be interested to have a clear statement of these, even if some old ground had to be gone over again.

Let us first examine very shortly the construction of wood. Wood is usually divided into two classes, hard and soft, but there is a class midway which users class as hard or soft according to the purpose for which each intends it. Another classification is wood with round leaves and wood with needle shaped leaves. The latter always contains resin, and those of this class containing the most resin are distilled solely for the obtention of the resin and turpentine. Very little acetic acid or methyl alcohol is obtained, and the charcoal is very soft and brittle, and not well suited for furnace purposes.

Wood and coal have two things in common:—

(1) When burned with free access of air they disappear with the exception of a small quantity of ash left behind.

(2) When distilled with exclusion of air much of the carbon as well as the ash is left behind.

But here the similarity ceases, for whereas the carbon left by the coal bears little or no semblance to the coal used, that left by the wood retains the form and even the markings of the wood from which it was made, and any one conversant with wood can at once tell from what wood any charcoal was made at a glance.

Mr. E. Chevandier (Annales de physique de chimie, 3rd serie, vol. X) found that in general, wood recently cut has the following composition:—

Water	...		40·00 per cent.
Ash ...	...		·65 per cent.
Carbon	...	29·61	
Hydrogen	...	3·6	
Oxygen	...	25·59	
Nitrogen	...	·55	59·35
			100·00

In carbonising wood, part of the carbon distils over along with the hydrogen and oxygen, forming a long series of compounds of different groupings of these elements, such as water, H_2O—methyl alcohol, CH_4O—acetic acid, $C_2H_4O_2$. Tar is a compound substance in which no fewer than 13 different combinations have been found from benzol, C_6H_6 to paraffin, $C_{20}H_{42}$. The rest of the carbon remains as charcoal. There is no acid in wood. It is only a product of the destructive distillation of wood.

Wood is composed principally of vasculose, cellulose, and paracellulose. In paper making, cellulose is what is sought for, and if it were possible to eliminate the cellulose without destroying the vasculose, a very valuable material for production of acetic acid would be obtained, for cellulose not only produces very little methyl alcohol but produces much formic acid so intimately mixed up with acetic that it is a matter of extreme cost to separate the two. Vasculose, on the other hand, produces, in destructive distillation plenty of methyl alcohol, and the greater part of the acetic acid. According to Messrs. Fremy and Urbain, vasculose varies from 18 per cent., in poplar to 40 per cent. in lignum vitae, and cellulose from 64 per cent. to 27 per cent. in the same woods.

The above particulars have a bearing upon the choice of the wood to be carbonised for any particular purpose, and as indicating the probable financial yields in a wood distillation works.

Wood as grown forms the staple raw material for the manufacture of wood charcoal, and, to this, the first part of my remarks solely apply.

Flake charcoal is not made from wood as grown, but from shavings, and the amount made is so small comparatively speaking that it would merit only a small paragraph were it not that it now and for many years has bulked very largely in work which at some time or other interests you, as Marine Engineers, very much, and the country at large in helping to provide the means whereby we assure a supply of necessary perishable food stuffs from abroad.

Since Mr. Balfour read his paper new facts have come to light which have a bearing upon the results of Dr. Rosenhain's report, and I indicate these and my remarks thereon and hope that somewhere in this paper each will find something he did not know or realise before.

Nobody who has worked with wood fires can have failed to notice that under the ashes, if the fire goes out, will be found charcoal. The ashes form a coating sufficiently impervious to the air to allow the charred wood to cool without access of air. The advantages of charcoal for culinary purposes would be so obvious that the reduction of wood to charcoal in an analogous way, but with less loss of wood must have appealed to primeval man at an early point in his life, after the discovery of fire. As charcoal contains more heat producing material than wood its use became imperative when the extraction of metals from their ores was attempted, and when making the charcoal in big masses condensation of part of the gases was bound to take place on the portion furthest removed from the source of heat, and tar would run out from the bottom of the heap. The antiseptic properties of this tar, and especially that obtained from carbonising the cedar, were early recognised, and it was largely used in embalming processes. Tar produced in this way from coniferous woods known as archangel tar is still used in the preparation of ropes as a preservative.

We therefore have a natural sequence of events from an intelligently observed fact down to a certain point, but there is a lapse of many centuries to the point where the composition of the tar was examined into, and nearly two centuries elapsed before advantage was taken of the results of this examination. It was only in 1858 that Glauber demonstrated that the acid contained in the distillate from wood had the same composition as vinegar, and only in the beginning of the 19th century was it discovered that methyl alcohol and acetone were also constituents of the acid liquid.

Another discovery relating to the utilization of gases produced in the carbonisation of wood was made by Phillipe Lebon, in 1767, namely, that they, or rather a part of them, could be utilised as an illuminant. He started works under a contract from the French Government to supply the tar produced to the Navy as part of the process, but could not make a commercial success of the other part of the process owing to the immense amount of lime he had to use in order to free the gases of acid products, including the carbonic acid. Pettenkoffer was able to greatly improve the illuminating power of the wood gas by superheating it, but the introduction of coal gas with its much greater illuminating power at less cost killed any chance of going on with this industry. The industry, had, however, got a start, and investigation was pushing forward. According to Klar, a works for wood distillation was started in 1819, at Hausach (Baden), but it did not pay. Later on the discoveries in connection with the manufacture of Aniline colours called for products and derivatives of wood distillation such as pure methyl and acetone, and it was only then that the wood distillation business may be said to have been born, in so far as the manufacture and recovery of all its products is concerned.

Outside of the recovery and utilization of all the products it is evident that there has always been a demand for charcoal, originally for heating purposes, such as cooking and metal smelting, but with the invention or introduction of gunpowder a new demand sprang up. The charcoal for this purpose should be easily ignited, burn quickly, and leave little ash, and the more cellulose a wood contains the more suitable for gunpowder will be the charcoal. Dogwood and alder are the woods preferred for sporting powder while for blasting powder birch can be employed. For making certain powders it is preferable that the distillation be not carried to complete carbonisation, but that some of the gases be left in the wood which is then brown instead of black and called "Charbon Roux."

Very exacting regulations were at one time inserted into powder contracts so as to secure uniformity in the analysis and properties of the charcoal employed in its manufacture. The manufacture of gunpowder owing to the use of smokeless powder has of late fallen off very considerably, and the demand for charcoal for this purpose is consequently now insignificant compared to what it was at one time.

Another use to which charcoal has been put for many years, is in the foundry, where it is used in the form of a wash for painting the moulding sand so as to form a skin between the molten metal and the sand. In preparing charcoal blacking, for this purpose the nature of the wood again plays an important part, oak producing the best, but as for some castings blacking made from gas coke can be used, it is evident that for certain classes of work almost anything is suitable.

I am indebted to Messrs. Turnbull and Co., of Glasgow, the oldest manufacturers in Scotland of moulders' blacking for the following particulars:—

"Wood blacking is made from oak or beech wood charcoal, and is specially prepared before it is milled to the finest powder, suitable for the foundry. It is used principally on greensand castings for baths, columns, and all light ornamental work. The aim of the founder is to get the smoothest skin possible, and of a bluish nature, which rightly or wrongly many of the practical founders assert they can only get from oak or beech wood charcoal blacking. For loam and drysand castings a mixture is made with oak wood and a mineral carbon, which, after preparation, is milled also to the finest grade and is used as a blackwash on all marine and other heavy castings such as ingots, cylinders, sole plates, etc., etc.

The blackings used in this class of work have to show a very high percentage of carbon to resist the metal eating into the sand. These blackings are sold under the names of imperial or patent blackings and have a large sale at home and abroad. A further use in the foundry for wood blacking is a grade milled like meal, and is used as a burning blacking, and also along with bone charcoal is utilised as an annealing agent."

The greatest demand for charcoal used to be for the manufacture of charcoal iron, but in this country the demand has fallen off very greatly since the introduction of steel which is so much cheaper.

Mr. George Turner, 300, Langside Road, Glasgow, has written a most interesting pamphlet on "Ancient forestry and the extinct industries of Argyllshire and part of the adjacent counties," from which I cull the following most interesting information.

From the twelfth century onwards, Scotland, on account of its woods, produced charcoal iron. In many cases bog iron was used, but traces have been found where shallow pits were mined to get the hematite. It was found cheaper to carry ore to the charcoal than charcoal to the ores. Each furnace devoured the wood annually from 120 acres of land so that the furnaces were constantly being shifted to follow the wood. As a consequence there have been found in the West of Scotland no fewer than 2,000 slag heaps, but many of these bear evidence that once the timber had grown up again in the locality, the furnaces came back and the slag heap was again utilised. At first the furnaces were built in valleys open to the prevailing wind thus getting a natural blast, but when bellows were discovered many went to water courses where they could utilize the water power while also being near the wood. The small furnace originally used produced small blooms, which were slightly spongy but malleable. Later on, as furnaces got bigger, the iron became more of the nature of cast iron till now it is entirely in that form. The journal of the Royal Society of Arts contains an article by Mr. Henry B. Wheatly, D.C.L., F.S.A. (vol. LXI. Sept. 19th and 26th, 1913), which gives some very interesting information *re* charcoal iron works in England, but overlooks those of Messrs. Harrison Ainslie as being still in existence. In reviewing the course of iron works prior to the use of coal or coke, he alludes to the danger to the country by denudation of forests which threatened to become so acute that the Navy Commissioners about 1660 nominated John Evelyn to investigate the subject. Mr. Wheatly quotes a very interesting paragraph from Evelyn's report, as follows:—

"Nature has thought fit to produce this wasting ore more plentifully in woodlands than any other point, and to enrich our forests to their own destruction—a deep execration of iron mills and iron masters also."

It was in Scotland that Messrs. Harrison Ainslie started their Lorn Works at Bonawe in Lorn (Argyllshire) in 1753, removing them later to the Lindal Moor Mines near Ulverston, and I am indebted to them for the following information:—

"We are still manufacturing charcoal pig iron, our brand being known as 'Lorn,' and we consume upwards of 3,000/4,000 tons of lump charcoal per annum, which we require in the manufacture of this special iron. At one time charcoal iron was extensively made in this country, but owing to the increasing cost of charcoal and to the scarcity of it, different furnaces have gone out of blast, and have been dismantled, and now the furnace owned by this company and situated at Backbarrow, on the River Leven, is the only charcoal furnace working in Great Britain. This furnace was erected in the early part of the eighteenth century, and with the exception of heightening the original furnace to increase its capacity the process of manufacture is identical with that used at that time. The furnace produces about eight tons per day of cold blast 'Lorn' charcoal pig iron. This iron is expensive to manufacture, and is the dearest on the market, but in spite of the cost of manufacture it has a ready sale, and is despatched to all corners of the world. It goes to Australia, New Zealand, Japan, China, Europe, and is very largely used in the United States, where it is mixed with other irons to make malleable castings.

Charcoal iron is made very extensively in Sweden and in Russia, the Swedish particularly is sold in Great Britain, and competes to a certain extent with the 'Lorn' charcoal pig iron, but for special manufacture the 'Lorn' iron, though it is more expensive, holds its own, as it has peculiar properties which the Swedish and Russian charcoal irons do not possess. This is accounted for by the different class of iron ore used to make 'Lorn' iron as against Swedish and Russian iron. The ore used for the manufacture of 'Lorn' iron is specially selected from the Hematite Mines situated at Lindal Moor in the Furness district, and the secret of the specially peculiar properties of the 'Lorn' iron is the use of special ore which can only be had from these mines. For many years the manufacture of the 'Lorn' brand of charcoal pig iron was intermittent, and a great deal of the market was lost at the time owing to the irregular manufacture of same, the various users of our 'Lorn' iron being unable to depend on receiving their requirements. This was due to short supplies of charcoal. At that time the furnace was entirely dependent on charcoal produced in Great Britain, the chief source of supply being what was termed country charcoal, viz.: charcoal burnt in kilns in the coppices in the immediate neighbourhood of the furnace. For a radius of 30 and more miles from the furnace it has been the practice of landowners to grow coppice wood specially for the manufacture of charcoal, for which there was always a ready sale to the Backbarrow furnace, and coppice wood is still grown throughout the English lake district, in which the furnace is situated, for this purpose, but as time has gone on fewer coppices were grown, so that there came a time when the local supplies were insufficient for the requirements of the furnace, and to augment it chemical charcoal was bought, and all surplus chemical charcoal on the British market was sold to the Backbarrow furnace. Even this was not sufficient to keep the furnace going for more than four to six months per year. There being an increasing demand for the 'Lorn' brand of iron, other sources of charcoal had to be found, and we are now importing charcoal very largely from the Continent, it being found that the best chemical charcoal could be delivered at our furnace from abroad at prices equal to and even less than the chemical charcoal manufacturers in this country insisted that they required to make their business pay. To make our iron, wood charcoal is absolutely essential, just as much so as the special ore used, but the writer is strongly of opinion that there is no room for the increased manufacture of charcoal pig iron in this country. We have plenty of ore, but as already pointed out there is an insufficiency of charcoal, and further there is a limited demand for the iron owing to its high cost. Swedes make and export ordinary charcoal pig iron in very large quantities, and they can afford, owing to their being able to procure cheap charcoal, to undersell any iron which could be manufactured in this country, and if it were not that we manufacture a charcoal pig iron which they cannot copy, owing to their being unable to secure the ore, the Backbarrow Furnace would not pay to work."

In America the output of charcoal iron is enormous owing to the vast amount of cheap wood and the furnaces carbonising it for themselves and recovering the products. Many works also are situated in the natural gas belt which enables their fuel costs, always a serious item, to be cut down to the lowest point. A large outlet for charcoal iron, even after steel had been long introduced, was in the tinplate trade in Wales, but it has had to give way there also to steel under the stress of competition, though it has still its uses there.

I have tried in the foregoing to give some idea of the rise of the manufacture of wood charcoal from small beginnings to its present immense proportion consuming thousands of tons of trees per day, and its position in this country to-day. Charcoal in any shape or size may be used for gunpowder or blacking, but it requires to be in good sized lumps for burning purposes, and this requirement has led to the necessity for finding an outlet for the smalls and dust caused by the breaking down of the charcoal in the retorts and in transit. Such an outlet has been found in charcoal briquettes such as are now extensively used in Dalli irons and carbotron stoves. Owing to the method of manufacture the charcoal is generally re-carbonised and at a higher heat, and is therefore slower burning, and, if well made, quite inodorous. It is perhaps needless to say, that in burning, it gives off carbonic acid gas same as most other combustibles.

We now come to a class of wood charcoal, namely, flake charcoal, differing in the shape of the raw material used, and the totally different plant necessitated by its form, which plant in its turn materially affects the conditions under which it is produced. As a matter of fact, the weight of acid from any wood, whether in the log or in shavings (the raw material for flake charcoal) is the same for equal moisture, but shavings produced in the manufacture of spools for thread are made from very dry wood, distil quickly, and allow of very high temperatures being used in order to get a large daily output per unit plant. This high temperature, however, has an effect on the charcoal which is much lighter than that produced from logs but the yield in charcoal is much less, being about 33 per cent. of the weight of the logs (after deducting moisture) and under 20 per cent of the weight of the shavings. The charcoal produced from the shavings is thus more difficult to ignite than that made from the logs, and is also much lighter per cubic foot. It is this latter quality which makes it so valuable (along with its shape) for insulation.

A word or two now about the manufacture of charcoal. Originally, and following the experience of charcoal made as the result of a fire of wood, wood was piled in a heap in the open. It was then set on fire and covered up with earth, mud or clay, which cracked in all directions, under the influence of heat and the pressure of the gases. The gases oozed out through the cracks thus formed, in great quantities up to a certain point and then gradually fell off till when the wood was completely carbonised they stopped almost completely. The cracks were then carefully plastered over and the heap left to cool. A variation on this process was subsequently made by digging a trench in which the wood was placed, thus diminishing the surface which had to be plastered. Both these methods are still in use all over the world in spite of their great antiquity. I was lately in the English lake district, and was taken high up into the hills, where I saw men at work making the heaps, firing some and smothering others. As the entrance of air during the cooling process would mean a loss of charcoal through burning, and as the charcoal burners are only paid according to the charcoal they produce, it requires constant attention day and night, and in all weathers.

It is under totally different conditions that wood must be carbonised if the gaseous products have to be recovered, and for this purpose plant which will let no gas escape to the air is necessary. Originally, the plan was to replace the mud and clay by bricks and mortar, but this was soon found to be impracticable, both as regards saving the gas and preventing the access of air during the cooling process. There are still some of these in use, principally for the manufacture of archangel tar, the price of which is such that, coupled with cheap wood and cheap labour, the losses can be ignored. The bulk of the wood is now carbonised in cast or malleable iron cylinders, the size of which varies from 3 ft. dia. to 8 ft. Each size has its devotees and advantages and disadvantages, from the point of view of time for each operation, yield of products and cost of handling. There is a further difference dependent upon whether the retorts remain permanently on their seating or are lifted bodily out with their contents after each operation, and also whether the wood is run into it on a wagon which is withdrawn when charred to be replaced by another ready filled with a fresh charge of wood. Whatever the style or size of the retort, the after process as regards the charcoal is the same. If the retort and contents is lifted bodily, it is conveyed to the cooling shed, and all ingress of air prevented by careful luting with clay or other suitable material, and if this is properly done and the retort is otherwise quite airtight the charcoal will be quite cold within 24 hours. If the wood is run in in wagons then these wagons are run into duplicates of the retorts from which they were drawn and then are carefully closed. If the wood is simply thrown into the retort then it is drawn out as charcoal into barrows or conveyors and placed in suitable receptacles which are carefully closed. I would here draw special attention to a most important fact, namely, that this charcoal made from whole wood and therefore in large pieces, can be and is completely cooled, and the liability to refire all gone by excluding air.

In the book on "The alleged liability of Charcoal to Spontaneous Combustion," the phrase "Absorbing all its oxygen" frequently occurs, but as charcoal extinguished by exclusion of air is quite cold before being exposed to the air, it is evident that this phrase is erroneous. It was used owing to a wrong observation and a "post hoc ergo propter hoc" misconception. It is only if any part of the charcoal is at a sufficiently high heat when withdrawn from the coolers that firing takes place on exposure to the air.

I have drawn special attention above to the method of extinguishing lump wood charcoal by exclusion of air because the reverse method is adopted in extinguishing flake charcoal. In extinguishing flake charcoal it is freely exposed to the air and was supposed to absorb oxygen in the process and thereby be extinguished. Undoubtedly it does absorb as much oxygen as it wants, but this has nothing to do with the cooling which is effected by allowing it to give off all its heat while being tossed about. If you supply a blast of air to it as it leaves the retort it will burn freely and fiercely, but by exposing each particle to the air it cools in falling, till after a certain number of such exposures it is quite cool. This takes place about five minutes after the tossing begins, but is only true of the charcoal in flakes. The shavings being produced in the bobbin factory, some faulty bobbins are found among the shavings, and being bigger than the flakes, are not so easily extinguished. If any such are put in the bags along with the flakes and are not cooled to the heart the same thing takes place as with hot lump wood charcoal. The heat, being prevented from dissipating owing to the non-conducting properties of the flakes, concentrates in the hot piece which finally takes fire and sets the bag on fire. Within ten minutes after leaving the retort the flake charcoal is put in bags and stands for 48 hours before being finally stored. The reason for this preliminary storage is that if any hot bobbins have found their way into the bags they will fire long before this, and any such bag is carried away before it has done much damage.

I repeat lump wood charcoal takes 24 hours to cool with exclusion of air; flake charcoal takes 10 minutes when exposed to the air. The difference of time necessary to carbonise shavings is also less than that necessary for lump charcoal. The latter takes at least 12 hours whereas shavings take only 35 minutes. This is on account of their dryness, and the small quantity in the retort at one time. As a matter of fact, the ground space necessary for carbonising the same quantity of lump wood or of shavings is practically the same. The same remarks that apply to lump wood charcoal and to bobbins in the flake apply equally to ground charcoal.

Charcoal of any shape is thoroughly cooled before being ground for moulders' blacking and similar purposes, but in the grinding, heat is generated, and in many cases sparks, from friction, are formed, and unless all the ground charcoal is dead cold when put into barrels or bags the warm part will become a nucleus from which heat cannot escape, and it will concentrate there till fire actually occurs.

These latter paragraphs have naturally led me to a point where it is permissible to speak on the question of spontaneous combustion in charcoal and refer to Dr. Rosenhain's report, which was embodied in Mr. Balfour's paper already referred to. In five bushel bags piled one on another to a height of 20 ft. and with a base 100 ft. square, no signs of fire have ever shown themselves over 30 years' experience, whether the bags were in the open air or under cover.

Dr. Rosenhain's instructions practically amounted to this: "Set fire to the charcoal in any way you like and tell how you did it so that we may judge whether such conditions can be met with at sea." He did this and sent in his report. The conditions he found necessary for firing the charcoal were shown to be such as could not be found at sea except in the case of fire outside the charcoal setting it on fire, with one exception—I refer to sulphur dioxide. As there were other objections to the use of sulphur dioxide, and there are efficient substitutes, I gave no thought to this phrase and the discussion about it, till lately when I noticed some letters in a shipping journal which were very much to the point.

A brief summary will suffice. If it is acknowledged that Clayton's gas will extinguish a fire, then either Dr. Rosenhain's experiments with sulphur dioxide have no bearing on the use of Clayton gas or you are faced with a "reductio ad absurdum." For even taking a non-insulated ship you cannot have cargo stowed in it without large quantities of wood. In the event of a fire much of this wood cannot fail to become charcoal, and you would then have the Clayton gas extinguishing the fire and then re-igniting the charcoal thus formed, then re-extinguishing it, and so on ad infinitum. It would be well to bear in mind that Dr. Rosenhain's experiments were made with pure sulphur dioxide and pure air. In the Clayton system it is not pure air, but air drawn from the burning hold which is circulated along with sulphur dioxide. This was the only gas which Dr. Rosenhain found had any heating effect on the charcoal.

Another factor which might tend to cause the charcoal to fire is heat. Now there are two sources of heat to which the insulation could be subjected: First, from the back of the boilers; second, from the sun's rays heating the skin of the ship.

Dr. Rosenhain's first experiment was more severe than could occur in actual practice, for the charcoal was put loosely into a perforated box surrounded on all sides by 3in. of air free to move; whereas in practice the charcoal is in an air-tight casing. Even under these conditions the temperature was raised to 370° cent., or nearly four times the temperature of boiling water, without ignition taking place. Neither of the sources of heat mentioned above could give this temperature.

Dr. Rosenhain's further experiments of sending air into the space while interesting to scientists could not take place in tightly packed charcoal in air-tight casings, so do not affect charcoal insulation.

It might, however, be said that spite of the results of these tests, and admitting that charcoal in the insulation is not liable to spontaneous combustion, yet it might help to propagate a fire. The following figures from Board of Trade reports on fires in British steamers of 100 tons and upwards for twelve years speak for themselves, and show that:

(A) In proportion to the number of ships fitted with charcoal and silicate cotton respectively, there have been more fires in the latter than in the former (Table V.) or practically the same (Table VI).

(B) If, instead of making the comparison between charcoal and silicate cotton, it is made between combustible and incombustible insulating material, it is again found that in proportion to their numbers there have been more fires in the latter than in the former (Tables III. & IV.).

(C) And, further, the claim that if once a fire is started on an insulated ship, the one on the ship with the combustible insulating material is likely to be more serious in character than the one on a ship with incombustible material, is not borne out by the figures; in fact, exactly the opposite is proved to be the case (Tables IV. & VI.).

Possibly this might be accounted for in the case of silicate cotton by the material having sunk, thus leaving a passage for the flames through the insulation. There may be other reasons, but the fact remains. Whatever other deductions may be made from the facts *re* fires in boats insulated with incombustible material, one point is made abundantly clear, namely, that the above figures show that the combustibility of the insulator plays no part in starting or propagating of fire on board ship. The woodwork is the dangerous part of the insulation.

At the same time it seems to me that, with the exception of cases where candles or other naked lights, placed against this woodwork have started a fire, it is more difficult to ignite and propagate a fire against a wooden wall than amongst, say, packing cases, between which the flames could play.

The late Mr. C. M. B. Dyer read a most excellent paper before you in 1908 upon timber used in insulating work, and I think that a careful perusal of this will convince anyone that shipowners are fully alive to the necessity for either doing away altogether with timber, or fitting up their vessels with timber rendered fire, damp and rot proof. All the figures in the tables relating to fires have been compiled from information supplied by the Board of Trade, and the figures relating to insulation, numbers of ships, &c., from Lloyd's register books for the years under review. As the list supplied by the Board of Trade extends to 270 large folio sheets, and gives details of 2,430 fires, much time and labour had to be expended in order to tabulate the results with accuracy, especially as each case had to be compared with Lloyd's Register books for the year in question to see if the vessels appeared as refrigerated vessels. This care was the more necessary, as frequently there are several ships of the same name, and the identity had to be established by comparing the official number instead of relying merely on the name. Only the totals and averages for the twelve years are given, with the corresponding percentages, but the complete tabulated information on which these averages and percentages are based are available for any impartial authority for comparison.

TABLE I.

Average number (for 12 years) of steamers in Lloyd's Register Books :—

Of **100** tons net register and upwards :—

Without refrigeration	8,653
With refrigeration	**406**
	9,059

Of the refrigerated steamers in Lloyd's Books the material used as insulation has been tabulated for the twelve years and the results come out as follows :—

Charcoal alone	212·60	= 52·40°/o	72·9°/o
Charcoal and Silicate Cotton ...	11·15	= 2·74°/o	
Charcoal with other materials	13·80	= 3·44°/o	
Silicate with other (combustible) materials	3·10	= 0·76°/o	
Other (combustible) materials	54·86	= 13·50°/o	
Silicate Cotton alone	46·40	= 11·43°/o	12·1°/o
Pumice	2·80	= 0·70°/o	
Material not stated	61·20	= 15·07°/o	
	405·91	100·04°/o	

These may be divided into three classes, viz. :—

(*a*) Steamers insulated with combustible material	72·9°/o
(*b*) ,, ,, ,, incombustible ,,	12·1°/o
(*c*) ,, ,, ,, unnamed ,,	15·0°/o

TABLE II.

Total fires on steamers of and over 100 tons register in 12 years	2430
Average per annum	202·5
Percentage of average number of fires to average number of steamers in register books ..	2·23°/o
Total number of fires in the 12 years in which insulation was reported to be damaged ...	49
Average per annum	4·1
Percentage of average number of steamers in which insulation was damaged by fire to average number refrigerated	1°/o
Total fires on uninsulated steamers in 12 years ...	2181
Average per annum	182
Percentage of average number of fires on uninsulated steamers to the average number of such steamers in the register books	2·1°/o

TABLE III.

Including all fires on insulated ships, whether the insulation was involved or not.

Nature of Insulating Material.	Average number of Ships Insulated.	Percentage of 406·	Average number of Fires per annum.
(*a*). Combustible Material	295·5	72·9%	15· = 5·07% of 295·5
(*b*). Incombustible ,,	49·2	12·1%	3·4 = 6·9 % of 49·2
(*c*). Material not stated ..	61·2	15·0%	2·3 = 3·75% of 61·2
	405·9	100·0%	20·7 = 5·1 % of 405·9

Even if Class (*c*) were found on further investigation to belong wholly to Class (*a*) it will be seen that the result would not be to the disadvantage of the Class (*a*). This applies equally to the following Table :—

TABLE IV.

Including only fires in which the insulation was involved.

Nature of Insulating Material.	Average number of Ships Insulated.	Average number of fires per annum.	Average number of Fires per annum involving serious damage.
Combustible ..	295·5	3· = 1·016% of 295·5	1· = 33% of 3·
Incombustible ..	49·2	$\frac{7}{12}$ = 1·185% of 49·2	$\frac{4}{12}$ = 57·1% of $\frac{7}{12}$
Not Stated ..	61·2	$\frac{6}{12}$ = 0·817% of 61·2	$\frac{2}{12}$ = 33% of $\frac{6}{12}$
	405·9	4·1 = 1% of 405 9	

In case it should be held that Charcoal benefits by being associated with other materials, combustible or incombustible, we have extracted the figures for Charcoal alone and Silicate alone as under :—

TABLE V.

Including all fires, whether insulation involved or not.

Insulating Material.	Average number of Ships Insulated.	Percentage of Total Insulated Ships : 406.	Average number of Fires per Annum.
Charcoal alone ..	212·6	52·4°/o	10·6 = 4·9% of 212·6
Silicate alone ..	46·4	11·43°/o	3·1 = 6·6% of 46·4

TABLE VI.

Including only fires in which insulation was involved.

Insulating Material.	Average number of Ships Insulated.	Average number of Fires per annum.	Average number of Fires per annum involving serious damage.
Charcoal alone ..	212·6	2·41 = 1·13% of 212·6	·916 = 38% of 2·41
Silicate alone.. ..	46·4	·50 = 1·08% of 46·4	·250 = 50% of ·50

———o———

DISCUSSION.

CHAIRMAN: Before asking you to discuss this interesting paper, I should like to supplement it with a few remarks. Mr. Bost, in his opening paragraph, refers to a paper I read last year before the Cold Storage and Ice Association. That paper gave publicity to a report prepared by Dr. Rosenhain, of the National Physical Laboratory on an investigation of the inflammability of flake charcoal, undertaken at the instance of Lloyd's Register of Shipping, with the co-operation of the Cartvale Chemical Company. The general object of the investigation was to ascertain the conditions under which flake charcoal, as used in the insulation of chambers on board ship, could undergo ignition. The reasons for an exhaustive inquiry being made are given in my paper, which doubtless, some of you have read. The result of the experiments made showed that flake charcoal is a material which can be used for insulating purposes with the utmost confidence so far as risk of fire is concerned. In spite of this, however, only last month the old "hue and cry" of the danger in using it for such purposes was again raised, probably due to a fire which was reported to have occurred in a vessel trading in the Far East, which has its holds insulated with charcoal and wood. I understand that this fire originated in the bunker contiguous to the hold. Reverting to my paper I think Mr. Bost is justified in referring to the discussion and in taking this opportunity of showing the differences between the various classes and forms of wood charcoal. To my mind, for example, it is unfortunate that charcoal is so well known in connection with the manufacture of gunpowder. The author deals briefly with the construction of wood. In connection with this, I am reminded of a very interesting article on "Wood, Chemical and Physical Characteristics and Diversity of its uses," given in the Fuel number of *The Times* in December last. Under the heading of "Wood Ash," the article goes on to say: "Deducting the weight of the ash (which is about 1 per cent.) the elementary composition of solid wood *dried* at 140°C (284°Fahr.) as determined by Chevandier is given as follows:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Beech	49·89	6·07	43·11	0·93
Oak	50·64	6·03	42·05	1·28
Birch	50·61	6·23	42·04	1·12
Aspen	50·31	6·32	42·39	0·98
Willow (Ash 2 p.c.)	51·75	6·19	41·08	0·98

It will be seen from the above table that in its chemical composition wood varies but slightly, and that the carbon supplies about half the weight. If heated in a kiln to expel the hygroscopic water, the wood will be found to consist of 50 per cent. of oxygen and hydrogen and an equal weight of carbon; if the temperature is carried higher a chemical change ensues."

In dealing with the constituents of wood, the author mentions some of the useful by-products resulting from the carbonization of wood, a knowledge of which must have an important bearing upon the choice of wood. At this stage in his paper Mr. Bost uses the word "flake." I can imagine his feelings and how reluctantly he wrote, as through the whole of the paper there seems to me desire to avoid anything savouring of self-advertisement.

Mr. T. HANSOM: May I ask if the ship referred to by the Chairman was fitted with the cold air system of refrigeration?

CHAIRMAN: I am not in a position to say, the matter is *sub judice* at present.

Mr. HANSOM: My reason for asking is that if the cold air system was fitted, that is the cooler with a fan driving the air through the various rooms after being cooled by a battery of pipes, there is more liability to fire. You spoke of the fire occurring in the bunkers, and I have known one or two instances where men have gone about the bunker with lamps. There has been a shrinkage of the insulation and, perhaps through knots falling out, an opening in the timber, and fires have taken place through the man applying the flame of the lamp to the opening to show that the air can be drawn in. The flame in some instances has been drawn through about 5ft. In one case the whole of the woodwork was gone before the fire finished. With the grid system there would be no air drawn through and a fire would be difficult to ignite under those conditions. I have seen attempts made and no fire has taken place, and with it also there is no moisture taking effect in the charcoal. In another case the origin of a fire was explained to me by the carpenter who did it. In this case it was a lead sounding pipe which went through the insulation, and on one occasion he found the pipe frozen up. He made a rod red hot and inserted it in the pipe, but it went through the pipe before it got through the ice, and the result was there was an extensive fire. Of course, incidents such as this do not come out in the inquiry. I, as a repairing engineer on ship work have had a good many experiences of fires, and in talking over the matter with the engineers have found that almost invariably they were caused by a light being drawn in or through the shrinkage of the wood. In the tabulated reports the fire is generally said to be due to spontaneous combustion; but I have in mind many cases where I have been told exactly how the fire originated, and they are generally due to the causes I have mentioned.

Mr. J. Thom: We have had an excellent paper from Mr. Bost, and he has brought out a great many points in connection with the manufacture of charcoal and its by-products. Seeing that these by-products are so valuable and that we are only beginning to know the value of them and how to use them, I should think the manufacturers will soon be able to sell the charcoal at a very low figure. The speed at which flake charcoal can be manufactured is quite a revelation to me. I was astonished when I heard that it could be cooled in five minutes, but one must agree that it will cool very rapidly if exposed to a current of air which circulates freely around it. At the same time, of course, there is a possibility of it being done too quickly if there are particles of larger size than others. The author mentions about the manufacture of Archangel tar from the distillation of wood, and he comments upon the anti-septic properties of the tar. When serving my apprenticeship it used to be common practice in the workshops to use a piece of tarred tow to bind up a damaged finger, but I did not know it was recognised by the medical profession as an anti-septic. With reference to fires in holds or other places. most of the insulators in use have combustible materials around them, and it is extraordinary how quickly these materials change in condition from the time they are put in place. Different pieces of timber are fastened together so as to be practically air-tight, but if the wood has not been well seasoned, there is soon a gap between the two pieces. These gaps increase for a time and then remain stationary, but during the time that contraction is taking place, the wood has changed to a great extent in its combustible tendency. Fresh wood will burn much more readily than wood which has been seasoned in a dry refrigerated atmosphere. You cannot ordinarily have a humid atmosphere in a low temperature. It is evident, therefore, that the condition of the wood and the materials round it is such that there is no very great liability to catch fire even when carelessness with lighted materials is experienced. It is often mentioned that electric wires passing through the holds have been the cause of fires, through some of the insulation wires getting damaged causing sparking across in consequence. That is not so likely in a hold after being filled with goods. As a rule the lights are cut off entirely when work ceases, so there is no current passing through. It is not a good arrangement to have live wires passing through a compartment which is shut off for a number of weeks or days as the case may be. I do not know that there are any insulating materials which can be used without having some combustible materials about them which are liable to catch fire with carelessness. Mr. Hansom mentioned about the circulation of air. There are, of course, many different ways of carrying out the principles of refrigeration in a store or hold, some by circulation and some by convection. In the latter case the air is cooled at the top which displaces the warmer air, which in turn comes up to be cooled and this goes on indefinitely. Of course, there is very little circulation of the air in the latter case; if there is a hold or refrigerated space which is perfectly air-tight, and the ship begins pitching in the ordinary way, a pumping action is set up. When the ship rises by the stern the air moves towards the bow, and *vice versa*, and this pumping action is always going on. That liveliness in the air is sufficient to cause a circulation beyond what is naturally going on, even if there are no fans, and it will be noticed that wherever there is a *fault* (an opening) in the insulation leading to another compartment, the air will be travelling either in or out. This motion, however, is different from that caused by the fan, but it causes draughts or travelling of the air into places one does not always know of, and are a great loss, which has to be made up.

Mr. E. W. Ross: I had hoped to get some knowledge or insight into the manufacture of charcoal; but in Mr. Bost's paper we have the mere fact stated that the wood is put into cylinders. Beyond that I cannot gain much information as to the manufacture, and I am sure others besides myself would be obliged to Mr. Bost if he would give us a few more particulars as to the *modus operandi*. We have heard how long it takes to cool the flake charcoal, but I do not think it is stated how long it takes to manufacture.

Mr. Bost: I have mentioned in the paper that it takes 35 minutes.

Mr. Ross: I was always under the impression that when wood is distilled a certain acid came off. In one part of the paper the author says that is the case, but in another he gives a different view.

Mr. Bost: I said there is no acid in the wood. Hydrogen, carbon, and oxygen are distilled off to form an acid, but the wood itself is not acid. There may be botanic acid in some woods, but not acetic acid.

Mr. Ross: We hear a lot about fires with charcoal and wood; but I do not think, as a rule, it is put down to spontaneous combustion. As Mr. Balfour has indicated, it is usually due to the vicinity to the stokehold bulkheads or some similar cause.

Mr. Bost: I am quite at one with Mr. Ross. I touched very lightly upon the question of manufacture because I did not want to make the paper too long. However, I shall be most happy to give a full description and send it in to be included in the printed copy.

Mr. G. A. Nelson: I am very pleased to have had the opportunity of coming to hear this very interesting paper, and am indebted to your chairman, Mr. Balfour, for the invitation. I have enjoyed greatly the description given of the methods of manufacture of the different kinds of charcoal, as I knew very little about it before; but I feel in somewhat an invidious position, because one of the materials which I manufacture is competitive to charcoal, and Mr. Bost has mentioned it in his paper—silicate cotton. Before going further, I may say that, generally, I do not agree with the conclusions Mr. Bost has drawn, and I trust that will not be put down to bias, because I accept his arguments in good faith, and he will also give me the credit of not having bias in the matter. It is simply a different point of view, and it is only in that way that we are able to get at the whole truth. A reference has been made to Dr. Rosenhain's paper. That was fully discussed at the meeting to which Mr. Balfour referred; but there is one point that might be dwelt upon in regard to Mr. Bost's comments. He says: "Dr. Rosenhain's further experiments of sending air into the space, while interesting to scientists, could not take place in tightly packed charcoal in air-tight casings, so do not affect charcoal insulation." If I remember rightly, Dr. Rosenhain stated that where there was air circulation flake charcoal will go on fire at a temperature of less than that of boiling water, and that seems to me to be worthy of note. This meeting is for the expression of opinion of practical men. There is one other remark I would like to make and that is in regard to the figures given. Referring to the fires on steamers, it must be illuminating to all here to know that where an incombustible is used fires are more numerous than where a combustible is used! It seems necessary to put in charcoal or coal or some other kind of fuel as an excellent means of preventing an outbreak of fire! The remark in the paper "Silicate with other (combustible) materials" is not intended to be misleading, I am sure, but to those who do not know that silicate is incombustible, it may lead them to think otherwise. Of course silicate cotton is a pure *mineral* fibre, and Mr. Bost will doubtless make that correction. As to the figures, unfortunately, different results are obtained according to the way they are worked out. I should like Mr. Bost to say whether the statistics given, the *results* of the compilation of figures he gives, have been prepared by the Board of Trade or Lloyd's Register. I will tell you frankly why I ask. At some trouble I took out a number of figures with regard to fires on ships from information supplied by the Board of Trade, as Mr. Bost knows, and the results I got were strikingly different from those which he has given, which shows that figures, when treated by different people, may give different results. Perhaps Mr. Bost will be good enough to state by whom the figures were prepared. Of course, when one gets such a percentage of fires as ·5 per year (or half a fire per year), one fire in the course of the year would throw up the percentage by 2 per cent. One point Mr. Bost has not mentioned in regard to these fires. He has not said what was the cause of the fires on the ships where silicate cotton was used. Where silicate cotton is used—a perfectly incombustible material—he will certainly admit that the fires did not start in the silicate cotton, nor did the silicate cotton help to spread the fires.

Mr. Matthew Taylor Brown: I should like to refer for a moment to Mr. Nelson's remarks. Quite naturally, he has been astonished at the results brought out by Mr. Bost's investigation of the Board of Trade figures, and it seems extraordinary at first sight, when you class two groups of materials, combustible and incombustible, to find that more fires occur where incombustible materials are used than with combustible. But it so happens that that is what the figures do show. It does not mean necessarily that Mr. Bost wants to prove that silicate cotton is more dangerous from a fire risk point of view; he merely uses the figures to disprove the allegations sometimes used that fires have been more numerous proportionally when charcoal has been used than with other materials. Mr. Bost's figures show that, whatever the cause of the fire, it cannot have been due to the use of charcoal as the filling material. The classification of the insulation into "combustible" and "incombustible" is in itself, to some extent, misleading, because even where the material used is incombustible, it is enclosed in a combustible lining, viz., wood. Here we come to what we believe is the origin of the danger in insulation, if danger may be said to exist, and I think Mr. Nelson will see that it would be to the interest of the manufacturers of silicate cotton and the manufacturers of charcoal to take joint action and unite in trying to devise means whereby the danger from the woodwork would be eliminated, either by treating the woodwork in some way to render it less inflammable or by devising plans whereby the use of naked lights in insulated chambers and other dangerous practices might be prevented. I think that one of the most interesting figures Mr. Bost has brought out is the fact that while we hear a great deal about these fires in insulated chambers, they do not bulk so largely as some people are inclined to think. The actual fires in insulated chambers only reach 1 per cent. of the insulated ships—a surprisingly low result, when one bears in mind that taking all the ships on Lloyd's Register of 100 tons and upwards the fires average 2 per cent., and this in spite of the fact that refrigerated steamers have a larger average tonnage and are, therefore, on that account alone, more liable to fire risks.

Mr. J. P. Smith: May I say at once that I am interested in the manufacture of silicate cotton; but I trust it will not be assumed that what I have to say is for the sake of advertisement. I speak because Mr. Brown made a statement about doing away with woodwork and substituting some fireproof material in its place. That is an excellent suggestion, and I hope that in time it will be taken up; but there is one point to be borne in mind, that even with that you have not done away with the whole danger of fires in the holds, because, whatever material is used, it would have to be of some compressed, hard substance, which will not burn, but which will become red-hot, and if the material behind that is combustible it will incandescence and cause fire to other parts of the ship. It seems to me that the whole of the tables given in the paper are not of very much service, because it ought not to be a question in ship work of putting in combustible materials if you can get an incombustible. If you come to the conclusion that you would prefer to run the risk of using a combustible material, there ought to some reason for this, and the only reason would be that the material was a better insulator—a better non-conductor. I do not know why, I suppose it is an omission on the part of Mr. Bost, but we have had no data given as to the non-conducting properties of charcoal, and I can only take it that if charcoal is used so freely in insulation it must be the best non-conductor, and it would be interesting to have the figures. I speak now from the marine engineer's point of view. I should like to have those details given, because that, after all, is the whole reason for insulation, for non-conducting properties. The ship's architect has to provide the very best non-conductor, and if you advocate flake charcoal give a reason why.

Chairman: I hoped that someone would present the Institute with appliances which would enable us to make comparative tests of the various non-conducting materials used. It would be a most valuable asset to the Institute.

Mr. Nelson: I am quite sure my firm and other firms would be only too pleased to contribute for such a purpose.

Mr. E. Shackleton: I cannot add much to the discussion with regard to the question of insulation. It has occurred to me, however, that it is not altogether impossible to produce a gas where you have charcoal, and if air is allowed to circulate through it there would be some risk if there was any heat near. I do not know if any experiments have been made in that direction. Charcoal is very largely employed in the East and in Africa for the production of power gas. A reference was made earlier in the evening to the anti-septic properties of some of the by-products of charcoal manufacture. In a certain case of a gas plant using wood as fuel, the water from the scrubbers is discharged into the main sewers, and that water is quite sufficient to stop the local sewage farm; in fact a writ was served to prevent the discharge of the water into the sewers as it so affected the bacteria microbes that they were rendered useless. Undoubtedly, therefore, the anti-septic properties of wood tar are very powerful. Mr. Bost refers to the manufacture of gas by Lebon. Many years ago I had some considerable experience with the use of wood gas for driving a gas engine. It is a thing about which more may be heard in the near future. It seems to me that wood is a most suitable material for producing fuel alcohol for motor-car purposes. Mr. Bost refers to the production of acetone. It is rather amusing to think that the casks of vinegar we see may have been produced from wood and is, in reality, wood vinegar made from waste wood and containing no malt.

The HON. SECRETARY: I think we may agree that where fires have occurred they have been largely due to want of proper attention, and not to the insulating material. Mr. Brown's explanation of the point which Mr. Bost made, appears to me to be correct, that, tracing from the effect to the initial cause, it was not due to the combustible material in the insulation. Those who have investigated the causes of fires which have occurred in holds and sometimes in bunkers, have generally found that in the first cause it has been due to a lamp or candle hung upon or near the woodwork and left alight. As has been indicated, this may happen near to where there is loosely packed charcoal, the flame has been drawn in, ultimately leading to the fire. Cases have occurred where a fire has broken out next to a warm bulkhead adjoining the stokehold, due to the heaping of ashes upon it, or, an adjacent boiler, and the heat has penetrated into the insulating material. Referring to the question of loosely packed insulation or to a chamber which has been inadequately packed, we may find that the insulating material has subsided a foot or so from the top of the chamber, thus leaving an air space. Such a case came under my notice, and on commenting upon it I was told that the chamber must have been properly packed, as the charcoal was hammered down! So that instead of encouraging it to fill naturally and coaxing it by means of a sharp instrument; the hammering tended to form a shelf for the new materials to lie upon for the time being, and when ultimately the whole was shaken by the ship's movements, it resulted in the top being empty. One point in connection with insulating material which we ought to consider is whether it is better to have charcoal or silicate cotton where there is a tendency to moisture, as where pipes are carried through deck spaces or bunkers, and the insulation is not so perfect as it should be to keep out the heat surrounding it—there is a great deal of moisture, and it is a question which is the best material to use under such circumstances, and what material is least detrimental to the pipes. I have been very much interested in hearing Mr. Bost's paper and we are much indebted to him for coming here to-night.

CHAIRMAN: With regard to Mr. Adamson's experiences in connection with the state of the insulation at the top. In all non-conducting materials which do not lend themselves to lateral packing therein lies the difficulty, and the greatest care has to be taken in finishing off the top. In most ships nowadays, in place of fitting boxes, Lloyd's Register recommendations are adopted, viz.: that the overheading should be carried to the ship's sides and the bulkheads, bearing in mind the inaccessibility of these places to replenish any settling that might take place on the sides or bulkheads, in such cases silicate cotton is chiefly used for filling as it lends itself to lateral as well as vertical packing at top of sides and bulkheads also. In finishing overheadings, Mr. Adamson desires to know which material keeps the best under moist conditions. I understand he is referring to what we meet from time to time, unfortunately too often, where a cluster of brine pipes are passing through bunkers or from one hold to another. I have found that silicate cotton does not assist in the exclusion of air around this cluster of brine pipes, and we have frequently to remove the silicate and put in flake charcoal, which lends itself to filling in all the inequalities or the surroundings of these pipes, thereby excluding the air and preventing any accumulation of snow or frost around the pipes.

In connection with the question of Clayton gas, the controversy referred to emanated from myself, and the result of a report which I submitted to my principals, on a fire which took place in an insulated chamber which had been previously disinfected by Clayton gas. Dr. Rosenhain was requested to include the question of air contaminated with SO_2 in his investigation. He found that wood charcoal became heated when submitted to a current containing 5 per cent. of sulphur dioxide, when passing at the rate of five cubic ft. per hour. Mr. Bost in his paper somewhat defends the use of Clayton gas, and as the result of a perusal of the correspondence in a well-known shipping paper by chemical and other experts, I am quite in agreement with his summing up. He says: "One is faced with the *reductio ad absurdum* of using a gas to put a fire out and yet using the same gas for re-ignition." If 10 per cent. of Clayton gas were used for fire extinguishing in a chamber it would smother the fire. But as the wood linings of the insulation are supposed to be practically air-tight, it is assumed that possibly the charcoal may have absorbed only 3 to 5 per cent. There is, however, another aspect of the situation, and I believe now, after considering it for some time, that perhaps Mr. Hunt, of the Clayton Co. is correct. He declares that his Company do not use the same kind of gas as Dr. Rosenhain used in his experiment, which was pure sulphur dioxide.

Mr. Bost: Mr. Hansom has given some very interesting information, and I have nothing to say in reference to his remarks. Mr. Thom, in the course of his remarks, referred to the size of the flake. If Mr. Thom makes an experiment of heating up a flake on a red hot plate and putting it on a cold plate, he will find it to cool very quickly.

Mr. Thom: I presume it is like a piece of paper.

Mr. Bost: Yes, exactly. With regard to electric wires; in ordinary practice, in houses, theatres and other places, fires have frequently occurred from the fusing of electrical wires in the walls or ceilings where there is no insulation, charcoal or otherwise, and it is quite evident that it is a source of fire where there is woodwork. Consequently, if they are passing through woodwork, where there is silicate cotton, or charcoal or cargo of any description, they should be properly insulated. Mr. Clark referred to other uses of wood charcoal. When it is considered that there are many hundreds, if not thousands, of tons of wood charcoal being produced per day, I do not think that the chemical uses in making sulphurous acid or for filters would amount to much. Bone charcoal is better for decolourising than wood charcoal, but the total quantity produced is comparatively small. I do not agree with Mr. Shackleton if he thinks it possible to use the alcohol from wood for commercial purposes. The price of alcohol made from wood runs at 2s. 6d. per gallon. This can be used in methylating, to the extent of about 5 per cent., and methylated spirit is always cheaper than pure wood spirit. The utilisation of shavings for driving purposes is practically killed for the same reason as in Le Bon's time, viz., the immense amount of acid in it, and it requires large quantities of an alkali to neutralise this, which is costly, otherwise plant is destroyed. This is not a paper on insulation, but I may say there is not a testing machine for insulation that is anything like right. I have spoken on this subject at Vienna and Paris and at other places. The basis of the methods adopted is essentially erroneous. Basing on Fourrier's Law that the passage of heat is in inverse ratio to the thickness, heat is caused to traverse a comparatively thin slice of the material to be tested. Knowing the thickness of the slice the heat that would pass through a metre is then calculated, and a coefficient found which can be applied to any thickness. I do not dispute Fourrier's Law, but the application of it to this particular deduction. When I give you one simple illustration you will grasp my position. If you take a flat piece of cast iron and cut it into four pieces equal in all dimensions, and leave one as it is, polish another, lampblack the third, and polish one side of the fourth and lampblack the other side, it is, I think, rudimentary knowledge that you will find a different amount of heat passing through each, though they are all of the same thickness. The effect of character of surface is left severely out of account in all experiments up till now. I leave to other designers of testing apparatus the working out of a method by which this can be ascertained or eliminated. The correct way in my opinion is to test many separate thicknesses in plant in which the thickness can be increased without increasing the surface, and applying Fourrier's Law, deduce from these multiple data the effect of surface for any material. I designed a suitable apparatus, and described it both at Paris and before the Ice and Cold Storage Association in London in 1909. However, the comparative values are well known for practical purposes, and one is safe in leaving shipowners to judge as to the respective merits of the different materials. With regard to Mr. Nelson's remarks, I read out a paragraph which is not on the printed proofs of the paper before you, in which I said that whatever deductions may be made from the fires on board ship, one point is made abundantly clear, viz., that from the figures given it is evident that the combustibility of the insulator plays no part either in starting or propagating a fire on board ship. The woodwork is the dangerous part. When you have a fireproof coating to the insulation, then will be the time to talk of changing the insulator.

Mr. Nelson: I trust the author will permit me to hold a different opinion.

Mr. Bost: There are two things requisite in any statistics put forward. The first is, are you sure of your data? Mr. Nelson's figures may show different results or they may not; the question is, do you accept the figures I have given in the paper as being probably correct, or do you consider the basis of the figures unsound?

Mr. Nelson: May I ask if Mr. Bost is seeking to cross-examine me?

Mr. Bost: I am simply asking the question.

Mr. Nelson: The question I raised was whether those figures are compiled by the Board of Trade or Lloyd's Register, or by yourself.

Mr. Bost: The data as regards fires on board ships have all been compiled by the Board of Trade and extracted by me. The figures with regard to the insulator are not given by the Board of Trade except in isolated cases. These I have taken entirely out of Lloyd's Register and checked and cross-checked. Here is the Board of Trade report. In this report will be seen underlinings on each page. Lloyd's Register was turned up for that year to see if the ship was an insulated one or if there was insulation on board, and the 2,400 vessels were treated in that way. Having done that, I underlined those that were so insulated, and copied out the particulars of all those underlined. So that I have a record of every insulated vessel on which a fire occurred. The Board of Trade guarantee nothing; they merely accept the information given to them. Mr. Nelson is quite correct as to the ambiguity he refers to. The phrase should read "silicate (with combustible insulators other than charcoal)," and I shall have this corrected. I certainly never intended to insinuate that silicate was combustible. Everyone knows the contrary.

Mr. J. Thom: Does that include passenger boats with small chambers?

Mr. Bost: Yes, every boat with a refrigerator. In cases where an item occurred such as "Fire in steward's room. Cause unknown. Trifling," it has been first entered as an insulated boat, but as to all intents and purposes it was not an insulated boat for the purpose of this investigation, I subsequently deleted such, and have given the figures, both including and excluding them.

The same remarks apply to cases in which it is stated that serious damage was done to the ship, but no mention whatever is made about the insulation, and I have left those out of account as insulated boats simply because I did not know and could get no information as to whether the holds or chambers were insulated or not.

Mr. Brown: I presume this applies to boats fitted with silicate cotton insulation also.

Mr. Bost: Yes, every boat. I only accept it when the fire reached the insulation, no matter what the insulation was.

A vote of thanks was accorded to Mr. Bost on the proposal of the Hon. Secretary, seconded by Mr. Nelson.

———o———

Communication from Mr. Bost: As promised, I give herewith a short account of what is done in a wood distillation works.

Wood is cut in the forest in winter after the sap has gone down and before it rises again in the spring, and should be stacked there well thatched on dry ground for one or two years in order to dry. This is not always done, but whether done or not it is finally brought to the works. Any part of the tree is good for distilling, but as measurable wood commands a high price, and smaller wood and branches are waste material to the wood merchant, the latter is what is generally used. The wood, whether dry or green, is cut into suitable sizes and put into cast or malleable retorts as described in my paper, and a lid or door luted down. In order to economise fuel, which forms such a large item in the expenses of a distillation works, the drier the wood is the better. The retort, like a gas retort, has a hole in it to let out the gases, and is connected to condensers immersed in water. Everything being now ready, the fire, which had been damped down, is stirred up and distillation begins. At first only water comes over, then the distillate becomes darker and acid until a certain point, when it becomes gradually less acid till no further liquid runs from the condenser. The wood is then thoroughly charred, the fire damped down, and the retort opened to take out the charcoal and refill it with wood. In addition to liquid products incondensable gas is also evolved almost from the beginning, and this is burned under the retorts or under the boilers, thus saving some coal. The liquid which runs out is, as I have said, dark, caused by some of the tar being dissolved by the acetic acid. It contains from 4 per cent. to 14 per cent. of acetic acid, according to the dryness of the wood used, as well as some methyl alcohol, and about 10 per cent. of undissolved tar. It is allowed to settle, and the clear liquid is run into stills for a partial purification. The tar which has settled out is used for Brattice cloth making. The acid after distillation is slightly yellow, but is too weak and impure to sell as such. It is impossible to concentrate acetic acid by fractional distillation, as the boiling points of water and acetic acid are so close to one another. It is, therefore, necessary to fix the acid by means of a base, and it is then possible to boil off all the water. The most common bases are soda, lead, and lime. If soda is used, then the solution is boiled up to crystalising point and set aside to cool and crystalise. The mother liquor is run off, the crystals dissolved in water, and again boiled up and allowed to crystalise. Several crystalisations are necessary before the required purity is reached, and the salt contains about 40 per cent. of acetic acid. It is used in dyeing and for the manufacture of very pure acetic acid. Acetate of lead, or brown sugar of lead, is made by dissolving litharge in distilled acid, and in crystalising gives no mother liquor. It is used in dyeing for green and yellow colours, and is very poisonous. The most usual product is acetate of lime, as owing to its high acetic acid contents (60 per cent.) it is the least costly to carry (per unit acid). Acetate of lime is used for making acetic acid by decomposing it with (a) hydrochloric acid; this gives an acetic acid of about 40 per cent., which is suitable for dyers, printers, and white lead makers; but it is too impure for many purposes; or (b) with sulphuric acid; this gives a very brown acid of about 60 per cent., from which a large proportion of 80 per cent. can be obtained very pure by fractional distillation; it is used for making white sugar of lead, and also for pickling purposes, as well as for the same purposes for which that made from hydrochloric acid is used. Whichever base is chosen the acid, after neutralisation, is allowed to settle, and is then run into a still to take off the methyl alcohol. This latter is unaffected by the base and distils over along with a lot of oils and other compounds of low boiling points. It is separated from these, and the water by repeated distillations, also treatment with chemicals, and is sold at 60 to 62 O.P., water white and miscible with water in all proportions without becoming milky. It is used for rendering ordinary, or ethyl alcohol, unfit for drinking. It contains, besides methyl alcohol, ammonia, aldehydes, ketones, and other impurities from which it can be separated by special treatment, but the Government do not allow of this being done except under Excise supervision. Pure methyl alcohol is used for making a series of most beautiful dyes, such as methyl green, orange pink, etc. Another use to which acetate of lime can be put is for the manufacture of acetone (di-methyl ketone), one of the best and cheapest solvents for gun-cotton which, when dissolved in it, is used in the manufacture of cordite and other explosives of that character.

The above is only a faint outline of product and processes incidental to the carrying on of a wood distillation works, so for those who desire a deeper knowledge, I append a list of books which may be consulted. I would, however, warn any of you who think that by reading them they may hope to become expert wood distillers as I may say that I have not found any of them giving away anything, and that most of them are just a hash up of other books and patent office specifications which the authors have never tested, and which probably never got beyond the complete specification stage.

LIST OF BOOKS OF REFERENCE ON WOOD DISTILLATION.

CARBONISATION DES BOIS EN VASES CLOS, Vincent, French only.

DES EMPLOIS CHIMIQUES DES POIS, Petit, French only.

TRAITE PRATIQUE DES EMPLOIS CHIMIQUES DES BOIS, Klar, French and German.

WOOD PRODUCTS : DISTILLATES & EXTRACTS, Dumesny & Noyer.

INDUSTRIAL ALCOHOL, J. G. Mackintosh.

MANUFACTURE OF EXPLOSIVES, Guttman.

UTILISATION OF WOOD WASTE, Hubbard.

THE UTILISATION OF WOOD WASTE BY DISTILLATION, Harper.

Copyright, "Marine Engineer."

UNVEILING OF "TITANIC" ENGINEERS' MEMORIAL, ANDREWS PARK, SOUTHAMPTON, APRIL 22ND, 1914, BY SIR ARCHIBALD DENNY, BART., LL.D. (PRESIDENT, INSTITUTE OF MARINE ENGINEERS).

"Titanic" Engineers' Southampton Memorial.

UNVEILING CEREMONY

PERFORMED BY

SIR ARCHIBALD DENNY, BART., LL.D.

(President of the Institute of Marine Engineers),

Wednesday, April 22, 1914.

ON Wednesday, April 22nd, 1914, at Andrew's Park, Southampton, a handsome Memorial to the engineers of the ill-fated *Titanic* was unveiled in the presence of nearly ten thousand spectators by Sir Archibald Denny, Bart., LL.D. (President of the Institute).

Among the distinguished company, which included officers representing all the shipping lines running from the port, the ex-Mayor, Sheriff and Aldermen of Southampton, representatives of the local Consulates and of regiments stationed in Southampton, were the following office-bearers and members of the Institute:—Mr. F. J. Blake, R.D., R.N.R. (Vice-President. Chairman of the Memorial Committee), Mr. Alex. Boyle (Vice-President), Mr. J. T. Milton (Vice-President), Mr. J. H. Rosenthal (Vice-President), Mr. J. E. Wimshurst (Vice-President. Member of the Memorial Committee), Mr. Joseph Hallett (Chairman of Council), Mr. Alex. H. Mather (Hon. Treasurer), Mr. John Clark (Member of Council), Mr. E. H. Dashper (Member), Mr. Robt. Elliott, B.Sc. (Member), Mr. J. Thom (Member), and Mr. F. P. Wallau (Member).

A procession was formed at the Library, and proceeded to the site of the Memorial, headed by a processional cross and the white-surpliced choir of St. Mary's Church.

The introductory address was given by Colonel A. W. Swalm, the American Consul at Southampton and the Chairman of the Ceremony, in the course of which he said that the courage of all the men on that sinking ship reminded one of those sturdy sayings of Cromwellian days: "It is a great instruction that the best courages are but the beams of the Almighty," and so out of the wreckage of ship and humanity had come the Memorial shortly to be unveiled by their distinguished speaker, Sir Archibald Denny. Why a memorial to one professional class? might be asked. Simply because the appreciation of the world demanded it; simply because of the fact that of this class of men many died at the post of duty, and in every engine-room of every class of steam-driven craft, on every sea—tramp, liner, man-o'-war, all—the act of these men received the highest honour and craftsman's honest esteem.

A short but impressive religious ceremony was followed by the rendering of the "Dead March in Saul," by the Southampton Police Band.

In formally unveiling the Memorial, Sir Archibald Denny said: "We are met to-day to unveil a Memorial to men who, by the manner of their death, carried out one of the finest traditions of our race. In the beautiful service we have had to-day you heard a text quoted, 'Greater love hath no man than this that a man lay down his life for his friends.' These men sacrificed their lives in the interests of their fellow officers, the crew and passengers, many of whom they cannot possibly have known, even by sight. This day two years ago we had just realised the full extent of the terrible disaster connected with the sinking of the *Titanic*. She was the last word in Naval Architecture, had been built without reference to expense by world-renowned builders, for owners whose experience in shipping, and whose care and consideration for their passengers and crew is a household word; and was under the command of an officer of tried experience; yet with all these advantages, and on a perfectly calm clear night, she received a blow from an iceberg which opened up to the sea more compartments than it was possible for her to survive. The accident occurred at 11.40 p.m. on the 14th April, and while the blow was fatal, it was almost inappreciable to the passengers. But those in charge, the Captain and the Chief Engineer, knew within a very few minutes that the ship had received a mortal wound; still the call to duty was immediately responded to.

Mr. Roche, in his speech in Lord Mersey's Court of Enquiry said: 'It is one of the noblest traditions of the engineering profession on board ship, that in case of accident the rule is, 'all hands below,' and Mr. Sanderson said, 'I think the engineers on the *Titanic* were fully alive to the danger in which they stood, and that if they did not come on deck it was due to a magnificent conception of their duty.'

We know that the forward boiler room (No. 6) was immediately flooded, that boiler room No. 5 was slightly pierced in the forward bunker, and that the watertight doors which had been shut from the bridge were, at the request of the engineers, unlocked and opened up to No. 6. All the pumping power available was applied, and in addition to the fixed suctions, portable hose was dragged along to No. 5, and thus the suction power increased to the maximum. But the engineers must have known that no pumping power could do more than delay the final catastrophe, yet they stuck pluckily to their duty, driven back from boiler room to boiler room, fighting for every inch of draft to give time for launching the boats.

The electric lights were burning until the last fatal plunge, and not one of these 35 brave officers was saved to tell the tale of their desperate fight. Even if they managed to struggle on deck at the last moment, they came up from the engine-room over-heated, and were immediately plunged into icey cold water. Thus they stood practically no chance of surviving to be picked up by the small boats as some of the crew and passengers undoubtedly were.

Where all those lost faced practically certain death with calmness and fortitude, it seems invidious to single out one group, but I think that the friends of the others who were lost, will not feel I do wrong when I select the Engineer Officers for special mention, and when I commend the subscribers to this beautiful Memorial for their kindly action.

The action of the engineers may be compared with that of the men on board of the *Birkenhead*, but there the soldiers stood together at attention in the open-air and in daylight, whereas our comrades worked below to the last, and perished in the dark. The noble action of these men on board of the *Birkenhead* has inspired many in all countries to similar actions; these brave engineers also, 'while dead yet speak,' and this Memorial is a worthy reminder of their bravery.

Many of us lost friends on board of the *Titanic*, and therefore we can the more sincerely offer our sympathy to the widows, the children, and friends of those engineers who lost their lives. It may be small comfort to them, but we know that the effect of their sacrifice has been an International agreement whereby passenger vessels will be rendered safer in the future, that there will be at least boats for all, and that wireless telegraphy will be installed and worked under such conditions that there should be no chance (as happened in this case) of one vessel being within a few miles of another in distress, and yet failing to hear the call for assistance.

Finally, this dreadful catastrophe will be constantly in the minds of those who are responsible for the design and navigation of vessels, and this will certainly lead to such disasters being still rarer in the future than they have been in the past.

The vessel sank at 2.20 a.m. on the 15th April, two hours and forty minutes after being damaged in such a way that thousands of tons of water entered within the first twenty minutes. We feel sure that it was due to the unremitting efforts of the engineers that the vessel survived so long, thus enabling nearly all the small boats to be launched.

I should like to quote a few lines by a poet using the *nom de plume* of "Touchstone," which I think focus my remarks.

Beneath the stars that shone so cruel cold,
In sight of that relentless hungry sea,
Were done such splendid deeds as shall be told
By generations that are yet to be!
On crowded decks men laboured patiently
The frail and weak to save,
Bidding defiance to the encroaching wave,
Deaf to the last to nature's coward plea!

But what of those brave souls who toiled below,
Uncheered, unheeded, fighting their last fight?
Their agony of mind we may not know,
Who toiled unceasingly in death's despite,
Giving their lives to feed the blessed light
That lit the sinking wreck
And poured a flood of radiance on the deck,
Where else had reigned confusion and black night.

O light whose glorious beams shall never fade!
O beacon that the memory yet shall keep
Of that great sacrifice so freely made!
Victors o'er death that walks upon the deep.
Not theirs the harvest of our praise to reap
But, dirge most meet for them,
The mighty engines thundered requiem
Till all was hushed in everlasting sleep!

In respectful memory to those brave Engineer Officers who, when the *Titanic* sank in deep water, remained at their posts and sacrificed their lives, I unveil this Monument that it may be for all time a witness of our gratitude and an inspiration to succeeding generations to tread fearlessly the path of duty."

After the dedication the choir sang the "Sevenfold Amen," and a company of buglers sounded "The Last Post."

The Chairman of Committee then formally handed over the Memorial to the Southampton Corporation, and it was formally accepted by Alderman C. J. Sharp, J.P., on behalf of the Corporation.

The memorable occasion came to an end with the singing of the hymn, "O God, our help in ages past."

The Memorial is a beautiful erection in Aberdeen granite. It is circular in plan, the centre forming an architectural treatment of a Roman altar. On the frontal piece are two bronze panels in relief, suggesting engineers sacrificing themselves in their devotion to duty. In front of the reliefs and resting upon the prow of a boat, is the central figure representing Glory, with outstretched arms, crowning the martyrs with laurel wreaths. The inscriptions below the statue read as follows:—

> "Greater love hath no man than this, that a man lay down his life for his friends."
>
> —*S. John, XV.* 13.

To the Memory of the Engineer
Officers of the R.M.S. *Titanic*,
who showed their high conception of
duty and their heroism by remaining
at their posts, April 15th, 1912.

[*Left-hand Tablet.*]

JOSEPH BELL
WM. E. FARQUHARSON
JAS. H. HESKETH
NORMAN E. HARRISON
GEORGE F. HOSKING
EDWARD C. DODD
LEONARD HODGKINSON
JAMES M. SMITH
BERT WILSON
HERBERT G. HARVEY

JONATHAN SHEPHERD
CHARLES HODGE
FRANCIS E. G. COY
JAMES FRASER
HENRY R. DYER
RENNY W. DODDS
ARTHUR WARD
THOMAS H. KEMP
FRANK A. PARSONS
WILLIAM D. MACKIE

[*Right-hand Tablet.*]

ROBERT MILLAR
WILLIAM Y. MOYES
WILLIAM McREYNOLDS
HENRY P. CREESE
THOMAS MILLAR
PETER SLOAN
ALFRED S. ALLSOP
HERBERT JUPE

ALFRED P. MIDDLETON
ALBERT G. ERVINE
WILLIAM KELLY
GEORGE A. CHISNALL
HUGH FITZPATRICK
ARTHUR A. ROUS
WILLIAM L. DUFFY

also

THOMAS ANDREWS
ARCHD. FROST
ROBERT KNIGHT

Erected by their fellow engineers and friends throughout the world.

The Committee responsible for raising the fund and for carrying out all the arrangements were:—F. J. Blake, R.D., R.N.R. (Chairman), W. Brodie, E. H. Dashper, J. F. Douglas, R. Elliott, G. B. Henderson, G. H. Heard, D. Lindsay, A. T. Patrick, F. P. Wallau, J. E. Wimshurst, E. Bullions Moody (Hon. Treasurer), Geo. Catlin (Hon. Secretary). They are to be congratulated on the successful accomplishment of their object in providing a striking and beautiful Memorial of an heroic deed, and in arranging a dedication ceremony which will live long in the memory of all who witnessed it.

———o———

BOILER EXPLOSIONS ACTS, 1882 & 1890.

REPORT OF PRELIMINARY INQUIRY. (NO. 2283).

Explosion from a Boiler Stop Valve Chest at Pinkston, Glasgow.

THE explosion occurred at about 1.50 p.m. on the 10th November, 1913, at Pinkston Power Station, Corporation Tramways, Glasgow.

The stop valve chest was the property of the Glasgow Corporation Tramways, 46, Bath Street, Glasgow.

No person was injured by the explosion.

Description and principal dimensions of the stop valve chest.—The stop valve chest, which was fitted to No. 12 boiler, was of the type shown on Plate I, and was made of cast iron, the gland and spindle being of gun metal. The chest measured $16\frac{1}{8}$ inches vertically between the faces of the upper and lower flanges, and the internal diameter at the body of the chest was 13 inches. The cover was of cast iron $13\frac{5}{8}$ inches in diameter and $1\frac{3}{8}$ inches in thickness, and was attached to the chest by ten $\frac{3}{4}$-inch bolts. The top flange was $1\frac{5}{16}$ inches, and the bottom flange $1\frac{1}{2}$ inches in thickness, the latter being 14 inches in diameter. The flange on the outlet branch was the same diameter, and $1\frac{7}{16}$ inches in thickness, and was attached to the steam pipe by twelve $\frac{3}{4}$-inch bolts. The neck of the chest, forming the seating, was $6\frac{15}{16}$ inches, and the

(Report No. 2283).

EXPLOSION FROM A BOILER STOP VALVE CHEST AT PINKSTON, GLASGOW.

VIEW OF VALVE CHEST

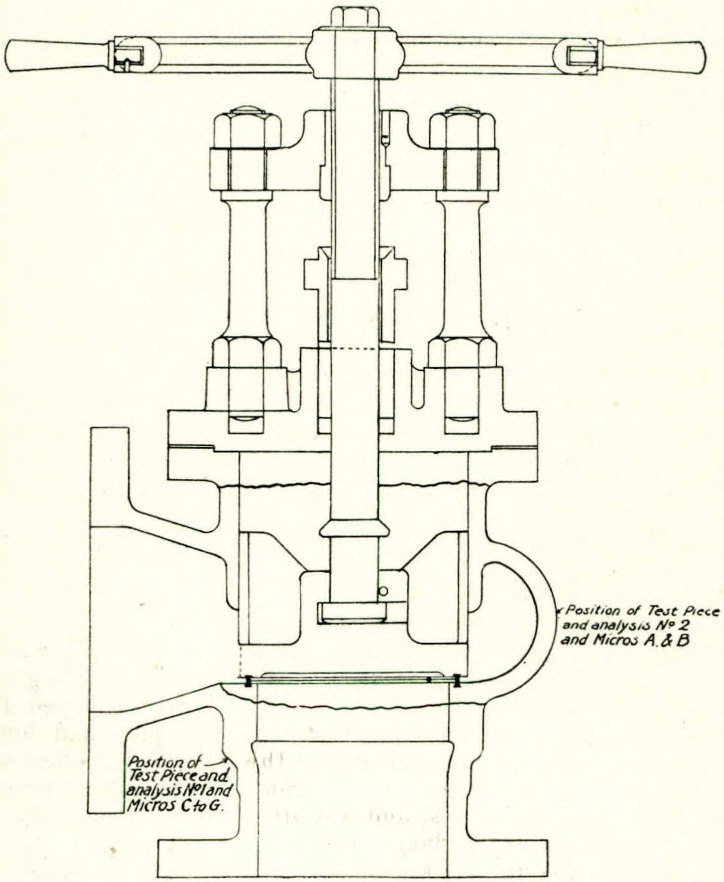

Plate No. 1.

The two irregular lines indicate positions of fracture.

branch was 7 inches in bore. The valve was of cast iron, and had six wings on the upper side for guiding it in the chest. The valve-face was formed of a nickel steel ring $7\frac{3}{8}$ inches inside and $7\frac{3}{4}$ inches outside diameter, dovetailed into the valve, and a similar ring forming the valve-seat was secured in the same manner to the chest. The spindle was $1\frac{5}{8}$ inches in diameter, with a square threaded screw having four threads per inch, and working above the cover in a bridge $1\frac{5}{8}$ inches deep, with a boss $2\frac{13}{16}$ inches deep, forming the nut. A cast iron wheel $17\frac{1}{2}$ inches in diameter, with five arms and six projecting spokes, was fitted to the top of the spindle.

At the fractures the metal varied from $\frac{11}{16}$ to $\frac{7}{8}$ inch in thickness.

Name of the maker and age of the stop valve chest.—The stop valve chest was made by Messrs. Schäffer and Budenberg, Ltd., Buckau Magdeburg, Germany, in March, 1901, and was therefore about $12\frac{1}{2}$ years old at the time of the explosion. Previous to leaving their works it was tested by water pressure to 450lbs. per square inch. No repairs, other than grinding the valve on its seat, and packing the gland, have been required.

Persons or Societies who have inspected the stop valve chest.—The foreman fitter employed at the Power Station examined the chest whenever the valve required grinding. The last date of examination, previous to the explosion, was the 22nd September, 1912. The stop valve chest was not insured.

Nature of the explosion.—The chest gave way circumferentially in two places, viz., just below the top flange and at the bottom of the body, the body itself, between these two fractures, breaking into thirteen pieces.

Cause of the explosion.—The explosion was due, in my opinion, to the long continued action of superheated steam on the cast iron, causing disintegration and deterioration of the material of the valve chest.

General remarks.—In the year 1894, the Glasgow tramways system was taken over by the Corporation. It was changed from horse to electric traction in 1901, and the system was at the same time considerably extended, the Pinkston Power Station having been laid down the previous year for the purpose of generating the current required.

The plant at that time consisted of four sets of three cylinder compound vertical reciprocating main engines, 2,500 kilowatts each, and a number of auxiliaries.

To generate the steam for driving this machinery, Messrs. Babcock and Wilcox, Renfrew, supplied 16 watertube boilers, working at a pressure of 160lbs. per square inch, and each provided with 452 square feet of superheating surface, intended to give a superheat of 120 degrees above the temperature of saturated steam due to that pressure. They also fitted the whole of the steam pipe ranges and the boiler mountings. The tee-pieces in the ranges were made by themselves, and were of "header metal," consisting of a mixture of cold blast iron and steel scrap, giving a bar of 2 inches by 1 inch section on supports 3 feet apart, a transverse strength of 28 to 34 cwts.

The crownhead valves were obtained from Messrs. Schäffer and Budenburg. There are two such valves on each boiler, one for saturated, and the other for superheated steam, though it was intended that the Power Station should be run by superheated steam only. From previous experiments Messrs. Babcock and Wilcox had found that Messrs. Schäffer and Budenberg's nickel seated valves gave the best results with superheated steam, as they kept tighter, and were not so much cut as valve-seats of other kinds. The specification sent to the makers simply stated that they were for 165lbs. pressure, with nickel seats, but it was thought to be understood that they were intended for use with superheated steam.

These boilers had been ordered in September, 1899, and were completed in May, 1901. On completion of each boiler at the Power Station, it was tested by water pressure to 250lbs. per square inch, with all the mountings in place, and with the valves shut, the test on No. 12 boiler being applied in June, 1901.

In January, 1908, six additional larger boilers were ordered from Messrs. Babcock and Wilcox, and these were supplied complete in May, 1909. They were also of 160lbs. working pressure, but were each fitted with 1,540 square feet of superheating surface, intended to give a superheat of 200 degrees above the temperature of saturated steam due to that pressure. The crownhead valves were of steel, similar to everything else in connection with these new boilers, as during the previous eight years Messrs. Babcock and Wilcox had gradually given up the use of cast iron in their boilers for all pressures over 120lbs. per square inch. Each of these boilers was also tested on completion to 250lbs. per square inch by water pressure.

During the above period the Glasgow Tramways Department installed a turbine engine of 3,000 kilowatts, and it was for use with this engine that the higher superheat was required. Twelve months ago another turbine engine of 5,000 kilowatts was installed, and to prepare for this, in July, 1912, it was arranged to fit the original 16 boilers with increased superheating surface, giving a total of 879 square feet per boiler, and yielding 200 degrees of superheat, similar to the newer boilers. The boilers were altered in pairs, and at the time of the explosion, eight of the original boilers had been so altered, but No. 12 was not one of them.

It is, of course, manifest that the boilers fitted for the higher superheat have been the most used, and those boilers not yet altered have only been put on when they could not be dispensed with, owing to an increased demand for current or to repairs or inspections being required at the other boilers, and it may be mentioned that from the 12th September, 1912, till the 22nd February, 1913, No. 12 boiler was under steam on 22 days only, and since the latter date had not been under steam at all until the day of the explosion. On that day another boiler had been put off duty for slight repairs, and it was decided to bring No. 12 boiler into use in consequence. This was prevented by the explosion, and another boiler was put under steam for 11 days, until the original boiler was again ready for work.

Plates II and III show the arrangement of the steam pipes, from which it will be noticed that each two boilers can be worked as a battery; the branch pipe from each battery being connected by a "gate" or "header" valve to a tee-piece on the main steam pipe range, these valves being fitted with byepasses. Although such valves are quite tight when new, it has been found at Pinkston that they are never tight after continual exposure to a high temperature, and all the branch ranges of steam pipes get very hot, owing to the leakage of steam, and the drain valves on these ranges, which are attached to the lowest part of the pipes near the crownhead valves, are always left more or less open. Also, if any internal work is required to be done in either of the boilers, it is necessary to break a joint on the branch range and insert a blank flange, as a matter of precaution, for although the crownhead valves are tight, they are never screwed hard down in order to make them so, nor are they fitted with any locking arrangement.

On the 7th July last a cast iron tee-piece on the main steam range, below one of the "header" valves, gave way around the root of the flange. The pipe was 16 inches in internal diameter, $1\frac{1}{4}$ inches thick, and 36 inches in length over the flanges, which were $23\frac{3}{4}$ inches diameter and $1\frac{7}{8}$ inches thick. The branch was at the centre of the length of the pipe, and was 9 inches in internal diameter, 1 inch thick, and 18 inches in length from centre line of pipe to outside of flange, which was 15 inches in diameter and $1\frac{3}{8}$ inches thick. This tee-piece fractured for a length of about 22 inches circumferentially on the lower side, *i.e.*, the side opposite to the branch.

As all the straight lengths of steam pipes were originally of steel, and all the new work in connection with the six later boilers was also of that material, it was decided to replace not only the fractured tee-piece, but the whole of the cast iron parts fitted to the original boilers and steam pipes by others of cast steel, and new castings were ordered accordingly, but no special haste was observed.

The boilers at Pinkston Power Station are under the inspection and insurance of The Scottish Boiler Insurance and Engine Inspection Company, and a thorough examination of No. 12 boiler was made on the 1st October, 1913, by one of their inspectors, being subsequently followed on the 9th October by a water test to 240lbs. per square inch. A water test to the same pressure had been carried out on the 23rd September, 1908, these two and the initial one when the boiler was new, being apparently the only water tests that have been applied to the boiler.

In order to apply the water test last October, a blank flange was as usual fitted between two steam pipe flanges on the branch range, thus cutting off Nos. 11 and 12 boilers, both of which were under survey, and the water test was applied to each of them, that on No. 12 being quite satisfactory, and that on No. 11 not being so. No. 11 boiler was therefore afterwards blanked off by itself at its own branch steam pipe joint. The crownhead valve spindle glands on No. 12 boiler were then repacked, and the safety valves ground in and rejointed, after which the blank flange which had been fitted in the joint on the branch steam pipe range was taken out. The fitter who did this states that when he slacked back the bolts and opened the joint, a large quantity of water came out of the pipe, on the "header" valve side, showing that that valve, although shut, had leaked considerably, and the steam had condensed in the branch range. After all the water had cleared away, it was followed by steam, and by the time he had re-made the joint, with the blank flange out, the pipes were all very hot. After doing this, he eased both the stop valves on No. 12 boiler, so that they should not get jammed with the heat, and they moved quite easily. During the water test, the drain valves fitted to the steam pipes above Nos. 11 and 12 boilers were shut, but were opened immediately afterwards.

On the 10th November last, orders were given for steam to be raised on No. 12 boiler, in place of No. 1 boiler, to which repairs were required. At 9 a.m. the shift engineer in charge looked at the boiler to make sure that the superheater was flooded, and the steam pipe drain open; he also eased back the crownhead valves between two and three turns to make sure they were in working order, and five minutes later shut them down. At that time the steam pipe connected to the boiler was very hot. The two fires were lighted about 12 noon, and at 12.45 p.m. steam was just showing on the pressure gauge. At 1 p.m. there was 50lbs. pressure on the boiler, and the bye-pass on the "header" valve was eased, and was gradually opened more and more till at 1.30 p.m. it was fully open. There was then 100lbs. pressure on No. 12 boiler. After the bye-pass was fully open, the "header" valve was opened easily, and it was fully open in about two minutes. The bye-pass was then closed. Twenty minutes later, when there was about 110lbs. pressure on No. 12 boiler, the explosion occurred. The shift engineer was in the engine room at the time, but ran into the boiler room, and noticing where the steam was coming from, immediately shut the "header" valve. During the whole time these various operations in connection with No. 12 boiler were in progress, the pressure of steam in the main range of steam pipes was about 155lbs.

To account for the explosion various theories have been advanced, viz:—

(1) Want of allowance for expansion in the range of steam pipes.

(2) The stop valve chest might have been strained by the valve being screwed down too hard during the water test.

(3) Previous partial fracture of the valve chest at some time.

(4) Straining due to the water test of the boiler a month previously.

(5) Sudden expansion due to the heat of the steam admitted through the header valve.

(6) Water hammer action.

(7) The effects of superheated steam.

Dealing with these in detail, satisfactory answers may be given as follows:—

(1) This was carefully studied when the power station was planned, and the arrangement of the pipes is such that it would be difficult to suggest anything likely to be more effective.

(2) This was unnecessary, as the blank-flanging of a joint in the branch steam pipe did away with any trouble likely to ensue if the valve had leaked. It is also in evidence that the valve was opened quite easily after the test.

(3) No escape of steam or water had been observed previous to the explosion, and none of the present fractures gave the appearance of age immediately after the explosion.

(4) This is a preposterous idea, unless taken in conjunction with the supposition that the material of the chest had deteriorated due to some other cause.

(5) The evidence points to the fact that the steam pipes in connection with the valve chest were always very hot, owing to the "header" valves leaking, and as half an hour was allowed for opening the bye-pass, the heat applied to the chest could not have been done suddenly.

(6) Since the branch steam pipes were always hot, and the drain valve more or less open, this is also an untenable theory. The staff at the power station had a good gauge to ascertain whether any drain valve was open sufficiently. It appears that water and steam leaked through the gland of the drain valve spindle, if there was the slightest choking of the outlet, and any shift engineer, foreman, or fitter noticing this, whilst on the periodical rounds, would immediately open the valve to a greater extent.

It must also be borne in mind that the superintendent engineer, the shift engineers, and the foreman all hold first-class Board of Trade certificates, and most of the fitters have also had sea experience, some likewise holding first-class certificates. The conditions under which the power station is carried on are therefore almost ideal as regards qualifications and ability of the staff.

This leaves superheat as the only probable cause of the explosion.

The metal of the chest when new is stated by the makers to have been of a quality considerably above the average best cast iron. No mechanical test or chemical analysis was made of the actual metal of the valve chests themselves, as none were asked for in the specification.

It should be mentioned that Messrs. Schäffer and Budenberg, so long ago as 1899, advocated the use of steel in connection with superheat, and also recommended the same material for saturated steam from 160lbs. pressure upwards. The question was, however, settled by their customers, and as in this instance they say that no mention was made of superheat, they simply carried out the order placed with them, and made the valves and chests as specified.

Since the explosion, careful mechanical tests, chemical analyses, and micro-photographs have been made of the material of the burst chest.

The mechanical tests resulted as follows, and for comparison, similar tests were made with the material of the tee-piece which burst last July. The test pieces were most carefully prepared, with ball ends and long curves, under the personal supervision of Mr. Seedhouse, of Lloyd's Proving House, Kinning Park, Glasgow, where they were tested. This shape was adopted in order to avoid cross breaking stresses in the grips, and gave the material a better chance than the ordinary shaped test piece does:—

Test Number.	Mark.	Diameter of Test Piece.	Area square inches.	Breaking stress in tons.	
				Actual.	Per square inch.
8420	G.W.B. 1	·500	·196	1·16	5·91
8421	,, 2	·564	·250	1·76	7·04
8422	,, 3	·564	·250	1·44	5·76
8423	,, 4	·564	·250	1·48	5·92

Test piece No. 1 was from the bottom of the body of the chest next the branch, No. 2 from the side of the chest opposite the branch, No. 3 from the flange of the tee-piece, and No. 4 from the body of the tee-piece, both Nos. 3 and 4 being close to the fracture.

Chemical analyses were made from the portions of the chest represented by test pieces Nos. 1 and 2; No. 1 by Messrs. Tatlock and Thomson, Analytical Chemists, Bath Street, Glasgow; and No. 2 by Professor Campion, Royal Technical College, Glasgow; with the following results:—

	No. 1. per cent.	No. 2. per cent.
Manganese	·50	·389
Silicon	2·12	2·16
Graphite	2·72	2·95
Combined Carbon	·20	·438
Sulphur	·144	·058
Phosphorus	·875	·896

The chief point to notice in these analyses is the great difference in the quality of combined carbon.

Micro-photographs were made from different portions of the chest, A and B by Professor Campion, and C, D, E, F, and G by my colleague Mr. S. A. Houghton.

Their reports are attached as Appendices I and II, and it will be observed that Mr. Houghton's surface micros of the inside of the valve chest bear out the conclusions stated later, that the effect of superheated steam is to break up the uncombined carbon areas of the material.

A water test to destruction was made in my presence at the Pinkston Power Station of an identically similar valve chest, which had been exposed to the same conditions for the same period as the chest that burst, and it gave way at a pressure of 880lbs. per square inch—at the same portion of the chest that is represented by test piece No. 1 of the burst chest. This gives a factor of safety of only 5½ when cold.

Before dealing with the conclusion that the above facts lead to, it might be well to describe briefly the causes and effects of the growth of cast iron by prolonged heating.

The matter has been the subject of extensive research and investigation in America, Germany and Great Britain, and the following facts have been established.

It has been found that if the heating is sufficiently prolonged, a growth takes place at comparatively low temperatures, the ultimate growth being proportional to the quantity of silicon present. Graphite is also an essential factor in the growth of cast irons under heat treatment, the presence of silicon causing deposition of carbon in the form of graphite. The presence of manganese modifies the action of silicon for the reason that graphite formation is hindered. The expansion is considered to be due to oxidation of the silicon, and slight oxidation of the iron, the increase of volume due to this preventing the material from contracting to its original size on cooling, and this goes on again when it is again expanded by heating, the growth being the ultimate result.

When cast iron cools from the liquid condition, the first portion to solidify is some of the carbon, which separates out as graphite, and which has a different coefficient of expansion to the other constituents. Owing to the slight breaking away of the graphite on heating due to the above cause, the superheated steam penetrates the cast iron along the graphite planes, resulting in the oxidation described.

Returning to the valve chest that burst, it will be observed that both of the chemical analyses show that the material was too high in silicon and phosphorus, and too low in manganese, and was, therefore, at the time of the explosion, not suitable for use with steam at a high temperature. The fact, however, that this and other similar chests have been in use for over 12 years without giving trouble seems to prove that when first installed they must have been of sufficient strength and durability for their intended purpose, and it consequently follows that their gradual decay has been due to some vitiating influence.

It has also been found that one of the effects of prolonged heating on cast iron is to lower the amount of combined carbon. This might be thought to be borne out in the two analyses, for the combined carbon in No. 1, where the superheated steam would have the most intense action, is less than one half of that in No. 2, where the action would not be nearly so intense. These effects are also supported by the results of the tensile tests, No. 2 yielding a tonnage 19 per cent. greater than No. 1, though all the tests give very low results, but Nos. 1, 3 and 4, which have been subjected to the greatest action of superheat, are exceptional. The cause of the increased combined carbon in No. 2 is probably, however, due to the fact that the analysis of No. 2 has been taken from the centre of the material, whereas that of No. 1 has been taken from the surface, where the combined carbon is less in quantity.

It may be objected by some critics that there would be greater contraction stresses at the part of the chest represented by No. 1, and it is therefore not likely that it would give as high a tensile result as No. 2, but I cannot admit that there would be such a great difference between them as 19 per cent., and I attribute the difference to the disintegrating effect of the more intense superheat on No. 1.

In conclusion, I may state that a number of manufacturers, with whom I have conferred whilst dealing with this case, inform me that they have entirely ceased to use cast iron, when superheat is specified, not only in land installations, but also in connection with marine work, as they do not consider it reliable.

As a result of this explosion, the three electric lighting stations under the control of the Glasgow Corporation are, in addition to the Pinkston Tramway Power Station, being entirely equipped with steel mountings on boilers and steam pipes, and it would seem, if superheating becomes common, or much higher boiler pressures are to be used in the future, then cast iron must be barred for boiler stop valves and in ranges of steam pipes, either as junction pieces or expansion glands.

I have the honour to be, Sir,
Your obedient servant,
GEO. W. BUCKWELL.

Observations of the Engineer Surveyor-in-Chief.—The rupture of the chest is attributed to the deterioration of the metal due to prolonged exposure to superheated steam, but although such action may have had an important bearing on the matter, there were, no doubt, other factors which contributed to the failure. For one thing, the material seems to have been originally unsuited for the purpose, apart from the consideration of its subsequent treatment. Many failures of cast iron chests might be traced to the indiscriminate use of material of which the constituents were not known, but selected cast iron, carefully remelted under conditions favourable for keeping the contents of phosphorus, sulphur and other impurities at a minimum value, is successfully adopted for many vessels subject to high and varying temperatures and pressures; cast steel is, however, undoubtedly preferable where ductility is of importance.

A. BOYLE.

The Assistant Secretary,
Marine Department,
Board of Trade.

APPENDIX I.

Remarks by Professor Campion on his chemical and microscopical examinations, 19th December, 1913.

I have examined the piece of metal which was received from you on the 10th December, and find the following results:—

Chemical Examination.—I am of opinion that the composition is quite unsuitable for a valve chest of any kind to withstand high pressures, but particularly for use with superheated steam, or in positions where it would be submitted to repeated heating and cooling, or stressed whilst at a high temperature. The iron has originally been too grey and too phosphoric. I consider that the silicon should not have exceeded 1·5 to 1·7 per cent., and the phosphorous should have been ·5 per cent., in order to secure the maximum soundness and strength. The manganese should have been considerably greater than it is.

Microscopical Examination.—The structure of the metal, as seen in a prepared and etched specimen, is of a type indicative of weak and brittle cast iron. The graphite plates are large and run in to the other in such a manner as to cause continuous planes of weakness. The appearance and arrangement of the graphite confirms the opinion formed from a consideration of the analytical results, viz.:—The iron has been very much too grey and open, and also that it has been cast at too high a temperature. Microscopical examination also shows that not only is the phosphorous present in too large an amount, but also that segregation of the phosphide has occurred, and it is irregularly distributed throughout the mass, thus intensifying the weakening and embrittling effects of the free phosphide. There is a slight indication at one or two places of intumescence of the graphite having taken place due to the heating and cooling action of the steam, but so slight that it cannot be considered to have caused failure of the valve chest.

I am of opinion that the failure of the valve chest has been caused by the use of a metal too grey and siliceous, and too phosphoric, which was poured at too high a temperature.

Micrograph A shows the general structure in the vicinity of the fracture, magnified 60 diameters.

Micrograph B, part of the same area as A at a magnification of 150 diameters, shows very distinctly the large patches of phosphide eutectic, and also a slight swelling in one or two of the graphite plates.

APPENDIX II.

Remarks by Mr. S. A. Houghton, on his microphotograrhs, 27th January, 1914.

The general structure consists of graphite, annealing carbon, pearlite, ferrite, and phosphorus eutectic, with sulphide of manganese in small globules; the latter does not seem to be at all near the quantity given in analyses. The metal is also rather porous. At the outside and inside of the metal there is a thin layer of pearlite, after which there is a band about $\frac{1}{8}$ inch to $\frac{3}{16}$ inch with practically none; it then commences again and increases towards the centre; the other constituents are fairly uniform. From this, it is evident that an analysis from the surface would differ in combined carbon from one taken right through, or from the centre part. This general structure applies to all parts of the valve chest, including the flange, where, however, there seems a greater amount of pearlite. The graphite plates are as a rule thin, and there is, therefore, a very large number for the quantity of graphite given in the analysis.

Towards the inside of the valve chest there exist lines of deterioration, some of which penetrate to about $\frac{3}{8}$ inch, and are the immediate cause of the failure. This deterioration generally starts from points where the surface pearlite is heavier than usual, and is of a dark pink colour, being plainly visible when the metal is unetched. The graphite and annealing carbon areas are heavier in these parts. It is suggested that the superheat causes an evolution of gas, and growth of the parts where the graphite existed at the inside of the casting, and that this action caused expansion of the inside metal, with consequent opening and porosity, leading to further decay.

INSTITUTE OF MARINE ENGINEERS.

The following were elected at a meeting of Council held on Thursday, April 23rd, 1914:—

As Members.

Robt. A. B. Ayliffe, Calle Victoria, 366, Buenos Ayres.
Cecil W. Butson, China Navigation Co., Shanghai.
Walter S. Crosbie, Marine Engineers' Institute, Shanghai.
Hugh. H. MacTaggart, Station Ironworks, Loanhead, Midlothian.
Denis J. Murray, Dominion Government Steamboat Inspector, Halifax, N.S.
John Nicol, 306, Barking Road, East Ham, London, E.
Leonard Parkin, 486, Woolwich Road, Charlton, London, S.E.
Herbert S. Reece, 5, Chowringhee Road, Calcutta, India.
John W. Sleight, "Homefield," Legsby Avenue, Grimsby.
Arthur C. Smith, 31, Ockendon Road, Islington, N.
William P. Stafford, Hedjuff, Aden.

As Graduates.

Richard Friedenthal, 6, Powis Road, Ashton-on-Ribble, Lancashire.
J. Lesslie Rutherford, 55, Warren Road, Leyton, Essex.
Charles P. Tanner, 30, St. Vincent Crescent, Glasgow.

* * *

The following were elected at a meeting of Council held on Wednesday, May 13th, 1914:—

As Members.

Neil M. Beck, Association of Engineers, Singapore.
Reuben Burbage Clark, 20, Palmerston Avenue, Whalley Range, Manchester.
Sterry B. Freeman, Messrs. Alfred Holt & Co., India Buildings, Liverpool.
Geo. W. Hollings, Burnside, Wallsend-on-Tyne.

Peter H. Hunter, The Anchorage, Millport.
Roy M. Laird, Birkenhead.
Henry M. Ormston, 7, Selborne Road, Ilford, E.
Henry P. Owen, 41, Arundel Avenue, Sefton Park, Liverpool.
Joseph F. Taylor, 4, Preston Avenue, Newport, Mon.

As Companion.

George H. Folkard, 21, Great St. Helens, E.C.

As Graduate.

Cecil I. Cordon, 6, Margaret Street, Greenock.