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DISCUSSION ON

Determination of Steam Engine and Boiler Efficiency.

CHAIRMAN: THE HON. SECRETARY.

The CHAIRMAN: We have met this evening to consider the subject introduced by Mr. G. J. Wells in the paper published in our August issue, and those who were able to take advantage of the opportunity afforded by the courtesy of the East London College Authority to visit the College and witness the demonstration kindly given by Mr. Wells, will be in a better position to follow the course of the paper and discuss the details. The author will elucidate the more prominent points prior to the discussion, and illustrate these by views on the screen. Mr. W. McLaren will kindly undertake the manipulation of the lantern. Before calling on Mr. Wells, I have a contribution from Mr. Donald F. Call to read to the meeting so that it may be referred to when the question raised comes under review.

Mr. DONALD F. CALL: There is one point which Mr. Wells in his paper considers to be a serious source of loss in heat units, namely, the loss due to radiation. I think the cause of losses due to radiation might almost form the subject of a separate paper, in fact far too little attention is given to this important question. It would be exceedingly interesting if tests could be carried out to determine the losses in heat units say in the pipe lines between boilers and engines, one test made with the pipes naked and similarly with the pipes and all fittings including flanges fully clothed. Not only in connection with pipe lines, particularly the large flanges which possess an extensive area for radiation, do we find large surfaces unprotected against radiation, but even in the actual heat producer, the boiler itself. With some firms the practice seems to be to ignore the bottom drums of water-tube boilers entirely. In fact the temperature of the bottom drum is not a great deal below that of the top drum, which is usually carefully lagged.

A large colliery in Scotland which I had the opportunity of visiting some time ago possessed a main steam pipe line between boilers and engines of no less than 200 ft. long and in several places the lagging was entirely stripped, exposing the main steam pipe to rain and snow, forming a veritable condenser. What the losses in this pipe line alone were I am not prepared to estimate, but they must have been considerable. What a spectacle for an engineer! Actually throwing money into the atmosphere.

Mr. Wells remarks that Carnot showed that the only method of heating a substance without waste is to supply the heat required at the highest possible temperature. A little elucidation of this, to me, rather vague utterance would be much appreciated.

Mr. Wells: Taking the paper as having been read, the author took the opportunity of enlarging upon the statements made in par. 13, using the water wheel as an analogy and demonstrating by its means the exact significance of the terms "Adiabatic expansion and compression" and the effects of "turbulance." At the College the test witnessed was explained and attention called to the results obtained as not being entirely reliable, because the author was answering questions put to him, when he should have been attending to his share in the work of recording the observations. The author stated his indebtedness to the reports of the Institute of Mechanical Engineers Research Committee, and he had availed himself of their records to illustrate his subject freely, and he referred the members to their reports for a full discussion of the subjects involved.

Mr. Jas. Shanks: At the present time when the great majority of our members are so fully occupied, it is difficult to create concentration of mind on subjects of importance to our profession outside the daily duties we are called upon to perform, and in such circumstances Mr. Wells is to be congratulated on placing this paper before us. Those who visited the East London College on Tuesday last to witness a steam engine test will marvel at Mr. Wells' energy, and wonder how he finds time to devote to a paper of this description in the midst of his multitudinous duties.

The author draws attention to our late President's address regarding the desirability of obtaining reliable data from sea-going members for the guidance of builders towards improvement of ship and engine design, and an award is now offered to encourage this object. Mr. Wells' paper is the outcome of this suggestion, and he gives us valuable hints as to the lines on which data may be obtained.

It is unfortunate we have to admit that few Marine Engineers give the attention to engine and boiler efficiency that it deserves, and I am sure the author will be repaid for his efforts in arousing our interest on the subject.

In Para. 7 we are told that it is necessary to take samples of the funnel gases and to weigh the ashes; with this I agree, but it should also be necessary to take the temperature of the gases, otherwise we may know little of what is taking place in the furnaces. Those gases should contain about 10 to 13 per cent. of CO_2, but without the temperature the information is of little value. Suppose for instance when everything is in perfect order and the combustion good, that the normal temperature of the funnel is say 600°F. Again at another time we find by analysis that combustion is complete, but the temperature has risen to say 800°F. To get such a result we know there is something wrong, and it may be due to a variety of causes. The importance of knowing the percentage of CO_2 in the gases is clear when we know that too much air going into the furnaces may in many cases represent a loss of 20 per cent. in efficiency, and with an inadequate supply of air it may be even worse, and result in flaming in the uptakes with very detrimental results, the majority of sea-going members know this to their cost.

The author describes an apparatus (Fig. 1) for sampling the gases, and I would like to ask if this is a costly apparatus and can be practically applied by the Marine Engineer at sea. Such apparatus used on shore are generally elaborate and costly, and would be useless to the sea-going engineer. What we want is a simple and cheap article; does the author know of such. My attention has just been drawn to an article in the *Journal of Commerce,* dated August 26th last on "Steam Boiler Efficiency," where it is stated that an apparatus may be in the form of a simple tube, and can be purchased at 75 cents, what is this?

The results of the tests given in Appendix A are most instructive, and as the author says must be carefully studied. These results were obtained from a locomotive boiler, but I am sure that nothing comparable could be obtained from a marine cylindrical boiler. It would be interesting to know what air pressure or its equivalent was used when burning 140 lbs. of coal per sq. ft. of fire grate; it would appear that although the combustion was good much of the coal must have been swept up the funnel. In a locomotive boiler no doubt the thickness of the fire is much greater than it would be possible to have in a marine cylindrical boiler, and consequently a higher air pressure could be used. I hope that as the author suggests in Para. 8, that some tests may be arranged for the benefit of members who have not had experience in this class of investigation.

In Para. 9 the author says, "It is most remarkable that the losses in the steam mains are so generally ignored." I am pleased to see this remark in regard to the neglect in efficient lagging, we know it is only too true, and there is no earthly excuse for it.

In another part of the paper reference is made to the clothing of the boilers; here again we have glaring neglect and consequent loss of efficiency. In the majority of boilers we find the bottoms uncovered and also the ends of the large longitudinal stays passing through the steam space; really it is like a refrigerator engineer neglecting to insulate the beams in an insulated hold, and you all know what the result is if this is not efficiently done.

In regard to engine testing, I am pleased that the author has so ably enlightened us on the thermo-dynamics of the problem, and we who witnessed the engine test last Tuesday fully appreciate the value of this part of the paper.

In regard to losses due to deviation from adiabatic expansion the author states in Para. 18, "The losses are chiefly due to the exchange of heat between the cylinder walls and the steam." This is a point on which there are great divergences of opinion.

Consider the case of a reciprocating engine running at the low rate of 60 revs. per minute, the steam from the time it enters the cylinder until it leaves is only in contact with the cylinder walls for half a second; can we imagine any appreciable change in the temperature in the metal in such a time. I think from results of experiments carried out by the late Mr. P. W. Willans some years ago, it was shown that the changes were so small as to be not measurable. Before you can say that the steam is condensed by contact with the cylinder walls you must presume that there is a fall in temperature, and I would like the author to give us evidence of this.

My friend Mr. T. R. Thomas (whom many of you will know as the author of a valuable paper read before this Institute), I remember showed me some diagrams taken off two marine engines, the results of which he had carefully analysed. In one case the compression was abnormally high, and in the other very low. In the first case the steam consumption was extremely low, and the second very high, and he held the opinion that initial condensation in the cylinder was not due to the effect of the cylinder walls but dependent upon the state of the steam remaining in the cylinder at the time the new steam was admitted, and that consequently if you could compress your steam at the end of the stroke to boiler pressure, initial condensation would disappear.

A Swiss made engine showed remarkable economy where the steam exhausts through ports in the centre of the cylinder and compression is carried on for the greater part of the stroke. In talking over the paper with a friend a few days ago, who is a Marine Engineer of wide knowledge and experience, I have jotted down the news he has expressed to me in the hope that it may encouarge discussion.

Engine Testing Paper by Mr. G. J. Wells.

"Too much stress is sometimes laid on so-called efficiency, overlooking the fact that engine and boiler efficiency is sometimes limited by the commercial aspects of the case: the machinery may be theoretically efficient, but the ship as a money-making concern may be very inefficient, due to the large amount of space occupied by various auxiliaries, etc., to the exclusion of freight-earning capacity.

When pointing out to a shipowner some time ago that a particular ship was singularly inefficient from an engineer's point of view, and suggesting that it would pay to put another boiler into the ship, he remarked that the boiler would take up so much cubic space in one of the holds, which space was worth a certain amount per year to him; that the boiler repairs came to a considerably less amount, and therefore it paid him to leave the ship as it was.

The tests suggested in the paper appear to be elaborate when applied to marine machinery: particularly as steam is required in passenger ships at all hours for dynamos, refrigerators, fresh-water pumps, galley appliances, heaters, hot-water system, tube blowers, ash hoists, etc., perhaps the author would state over what period he would propose to run the tests, and how he would estimate the steam used for the above purposes.

Personally, I think that the present type of marine steam engine has about reached the maximum economy that may be expected on a commercial basis, and that it would be more interesting to apply tests to ascertain whether there is any economy in separately driven air and circulating pumps, feed and sanitary pumps, etc., instead of them being driven from the main engine.

Another fruitful source of research would be the actual comparison under service condition of ships of similar size but having different arrangements of machinery with regard to coal consumption, speed and freight-earning capacity.

With reference to the proposed boiler tests, would the author weigh all the coal used in raising steam for the test, then after the test draw all fires and weigh the residue; or is the suggestion to note as far as possible the state of the fires before the test, and subsequently on its completion to see that they are in substantially the same condition; if either method is adopted there appears to be a considerable chance of error.

Roughly about 12 lbs. of air are theoretically required for the combustion of 1 lb. of coal, but in practice almost double the quantity is used. It would appear that the more "excess" air supplied, the lower would be the efficiency of combustion, other things being equal, on account of the cooling effect of the fire. It is noted, however, from Appendix A that at a rate of fire of 30 lbs. the excess air supplied was 8·28 lbs., whereas at a rate of 140 lbs. the excess air was 3·78 lbs.; perhaps the author would explain how the amount of "excess" air is arrived at, particularly as it is observed that the loss by formation of CO is greater at the higher rate of firing, which would make it appear that there was insufficient air supplied to form CO_2."

I have already given my opinion as to what really happens here, but perhaps Mr. Wells will enlighten us more fully. To enable sea-going tests to be conducted with any degree of accuracy and value, it should not be left to the sea-going engineer alone, he must have the support of the shipowner and superintendent to enable him to carry through tests without interfering with the general working of the ship.

Mr. Wm. McLaren: I thank Mr. Wells for his paper and specially for the demonstration he has given this evening with the views on the screen as this has helped to emphasise and explain the leading points in the paper.

With regard to engine testing I was on the *Meteor* when the first test was made by Prof. Kennedy, and for the 18 hours after leaving the pier head it was a species of pandemonium in the engine-room. Certainly great pains were taken to obtain data sufficient to arrive at a test of efficiency, and the experimentalists did at that time try their hardest. Some of the leading superintendents, about 18 altogether, were at the trials, but on account of the unpropitious weather, I do not think the 18 hours for the complete trial promised were obtained for the purpose in view. It seems to me that you can more easily deal with a small steamer, but even then not for long periods, yet secure results which would be useful for comparison. From experience in the *Meteor* to carry out the tests aimed at, I should say that about "double" the number of the crew allowed under normal conditions would be required for the time occupied.

I adopt a very simple method for a check on the coal analysis and evaporation from boiler, also the daily ash taken, allowing 13 lbs. coal per No. 7 firing shovel, which in the worn condition will carry 7 lbs. coal, the number of shovelfuls consumed over say half-an-hour, the feed-water to boiler shut off, the amount of water lowered in water-gauge glass in that time, and the contents previously measured of that space that the boiler contains, gives one a fair test for comparison which can be done with any reasonable stoker. When furnace gases leaving the chimney are say 650°, then add an economiser which becomes part and parcel of the boiler, with 60 lbs. steam pressure, at 360° as a basis one will grasp the loss, hence the advantage of an economiser of such importance as a heat absorber providing you don't lower the escaping gases below 450°.

Every steamer has its own peculiarities, even sister ships differ, sometimes in a very marked degree; indeed, cases have occurred and might be cited to evidence this, where the engineers have been changed from one ship to the other without producing changed results.

Mr. H. E. Newton: I should like to ask Mr. Wells if he considers it possible to use with any success in a ship's engine-room any ordinary water meter such as a Siemen's or Kennedy's for measuring the boiler feed. In many large electricity generating stations such meters are employed and give a continuous and valuable record of the amount of "Condensat" (to use the electricians' term) for the condensed steam, also the amount of feed passing to the boilers.

Engineers at sea have little or no time for rigging up plant for engine and boiler tests, and unless an opportunity is given them by the owners in providing suitable instruments, such tests will seldom be made. In the large generating stations practically every known useful apparatus is provided for measuring quantities and temperatures, and results are recorded which indicate where improvements may be made.

With reference to the consumption of 140 lbs. per sq. ft. of fire grate, no locomotive boiler would stand such forcing unless it is running at a high speed on the road. Circulation being then much improved, due to vibration, causing the steam when formed to rise much more quickly.

Regarding superheating: a case in point might be mentioned where it was attempted to supply steam at 80 lbs. pressure through about 300 feet run of $1\frac{1}{2}$ in. pipe to a Worthington pump; as practically only water arrived at the pump it would not work. The steam has now been superheated at the boiler to 500°F. and the pump works well.

Mr. F. O. Beckett: Referring to the *Meteor* which Mr. McLaren has mentioned, I believe the trial was made with a view to getting a new basis for the diagrammatic curves. With regard to the tests made on boardship by engineers, usually the first consideration is economy of fuel, but so far the ultimate result of the present ideal has not been arrived at, that of getting 1 I.H.P. for 1 lb. of coal. The changes in the quality and in the necessary treatment of coal to get the best value out of it are so frequent during a long voyage that it is difficult to carry through a series of steam tests with any degree of accuracy for a serviceable comparison of results. When the quantity of fuel used is mentioned as a basis the best way of measuring is by the bucket, the weight of the containing quantity having been gauged.

I had the opportunity of being present at the demonstration at East London College given by Mr. Wells last Tuesday, and in noting the tests, I found differences in the time element of a minute and a half, and in the weight of the load, so that the horse power must have also varied, and the regular course of the test was therefore interfered with.

Any tests which I have carried out on boardship have been to find the coal consumption at certain speeds of the vessel with revolutions of engines, at certain draughts, and with certain conditions of weather.

Mr. O. B. Richardson: The thanks of the members are due to Mr. Wells for his valuable paper, the detailed problems are most interesting and worthy of study by all engineers, as guides to economy and efficiency, but I should like to say that I do not altogether hold that these tests could be put into practical use at sea; certainly we use the instruments on the up-to-date power stations on shore, but, let us say, in the Atlantic, I am afraid the difficulties in the wav of making use of all the gear enumerated would prevent its being of service, although the testing may be always done in fine weather, as it is of no use testing the engines and the coal when you have bad weather.

The Chairman: I am tempted to enter into the discussion of many of the points commented upon, as several of these could be profitably enlarged upon in the interests of economy, but the night is too far advanced to justify a further encroachment upon your patience. It is hoped that further papers will follow on the obvious improvements suggested in the course of the discussion. We are indebted to Mr. Wells for the paper, for the demonstration given at the East London College—a demonstration which he has verv kindly offered to repeat should members express the desire either by giving their names this evening or later, when suitable arrangements can be made—and we would tender our vote of thanks also for this evening, especially as his presence with us has only been possible at considerable personal inconvenience.

The vote of thanks was cordially passed.

The reply given by the Author to the discussion is reported on the following page.

Mr. Wells in the first place remarked that the two usual criticisms had been made in this as in all discussions of this subject of testing: first, that there is no time to make the tests; and secondly, that the apparatus required is too elaborate and costly to within the range of the ordinary steamers' staff. With reference to the first objection it may be noted that to-day every chief must render an account of the fuel and stores used on each voyage, and the management deduces therefrom the cost of freight per knot so far as regards the motive power required. In this connection the author's object was to point out how these records should be tested from time to time so that the chief may be sure that he is doing the best that is possible with the type of engine fitted to his steamer. Mr. Shanks touched the necessity for dealing with this point when he said "the machinery may be theoretically perfect but the ship as a money making concern may be very inefficient. . . ." The success of the shipbuilder depends upon an accurate knowledge of the way engines, &c., are handled at sea, and the success of the devices fitted to prevent mishandling with consequent loss of efficiency. An example of the losses that the owners of steamers sustain is given in the current issue of *The Marine Engineer and Naval Architect*, where on pages 76 and 77 the results of some tests are recorded. Looking at the record for the test with a "long grate" it will be noticed that only 13·6 pounds of coal was burnt per sq. ft. of grate per hour, manifestly the grate was too large, for this figure should be not less than 20 pounds if the draught is anything like what it should be. The furnace arrangements were remodelled and a second test showed that the rate of coal consumption was increased to 19·2 pounds and the H.P. rose to 116. If the chief had been able to calculate he could have used a rule given by Seaton in 1884, which reads "If the sea full speed horse-power of a merchant ship be multiplied by 0·133 the result is the grate area required for that power." In this case $116 \times 0{\cdot}133 = 15{\cdot}43$ sq. ft., the area actually used was 17 sq. ft.

In the details given it is stated that the funnels were burnt out in four years, and that the boilers gave much trouble, &c., so that in this case the owners must have lost much money during the four years that elapsed, before their professional advisers succeeded in finding that something was wrong. Mr. Shanks also called attention to the figures in Appendix A, and asked for the degree of forcing usual in locomotives. The amount varies greatly with the load, and gradients, weather, &c., probably 5·5 to 6·5 inches of water is usual in the smokebox, rising at times to eight or even 10 inches. The reduction of the excess air used as the rate of firing rises is a well known result when forced combustion occurs. It is mainly due to the increased facility of mixing the air with the gases in consequence of the higher velocity of the air entering the furnace so that the margin of air supplied is reduced. The author has given the calculations for finding the excess air required for three given experiments on locomotive boilers which will give the answer to that query completely. In each of these tests the furnace and smokebox temperatures are given and it should be noted that as the furnace temperature rises so does the temperature observed in the smokebox, in fact the fall of temperature between the furnace and the smokebox is greater at the higher temperatures, showing that with efficient combustion the fall for any boiler is very nearly constant.

The second criticism *re* the costly character of the apparatus required may be judged from the following items (pre-war prices): the Orsatts' gas analysis apparatus complete from £3 to £5 5s. according to the degree of elaboration; Hemples' gas analysis apparatus in like manner ranges from 17/6 upwards: for weighing the fuel, one or two baskets or sacks and a spring balance with a hook to hang the same. One or more vessels to receive the air-pump discharge, and a spring balance to weigh the contents would be sufficient to go a very long way.

The subject of cylinder condensation is much too long to deal with in a reply, but Mr. Shanks should consult the paper by Callendar and Nicolson, Proc. Inst.C.I., Vol. CXXXI., p. 147, in which the method of measurement adopted for determining the change of temperatures in the steam cylinder during each stroke is detailed. Mr. Willans did not measure directly the cylinder temperatures in his classic experiments, but later workers using the Callendar methods have succeeded in doing so both for the steam and gas-engine and at much higher speeds than 60 revs. per minute, for details see the Proc. Institute Mechanical Engineers, where papers on the subject have been contributed by Mellanby, Nicolson, Jordan, Coker, and others.

As regards the making of the tests suggested I would refer to the paper and the preliminary remarks, in which the explanation of the basis of the tests made and witnessed at the East London College were amplified.

Mr. McLaren alluded to the tests of the *Meteor* and the confusion that reigned, but it should be remembered that there were visitors and others present in the engine room, that under the circumstances for the time being only the conditions usually obtaining at sea during a voyage would be absent, and then the position would be improved. Further, the trials of the *Meteor* were the first of the series making such a complete test under any circumstances at sea, and to find all the "niggers" that have to be dealt with in every investigation. At the conclusion of the series of tests three years later Prof. Beare said, "One of the chief objects of the Committee was to show that it is perfectly practicable to carry out a complete test of the propelling machinery of a steamer without seriously interfering in any way with the working; this the author (Prof. Beare) thinks has been decisively proved." A further result claimed was that the feed might be measured by means of a meter as simply as weighing the coal.

Test Number.	201	206	212
Coal burnt per sq. foot of grate. lb. per hour ..	32·85	80·83	139·04
Gas Analysis CO_2 % Volume	10·62	13·23	13·00
CO % ,, ...	0·07	0·23	0·30
O_2 % ,, ...	8·40	5·07	4·37
N_2 % ,, ...	80·91	81·47	82·33
Mean temp: in Firebox Deg. Fahr:	1,885	1,938	2,162
,, ,, ,, Smokebox ,, ,, ...	513	607	667
Difference or fall of temperature	1,372	1,331	1,495

To convert the volume analysis into the equivalent weight analysis, multiply each constituent by its molecular weight, and express each of these weights as a percentage of the total: thus for test 201.

CO_2 — $10{\cdot}62 \times 44 =$	467·3	or 15·55 %	by weight.
CO — $0{\cdot}07 \times 28 =$	1·96	,, 0·06	,, ,,
O — $8{\cdot}40 \times 32 =$	268·80	,, 8·94	,, ,,
N — $80{\cdot}91 \times 44 =$	2,266·00	,, 75·45	,, ,,
	3,004·06	100·00	,, ,,

Next find total weight of carbon present in each 100 pounds of dry flue gas—

$$15{\cdot}52 \times \frac{12}{44} + 0{\cdot}06 \times \frac{12}{28} = 4{\cdot}24 + 0{\cdot}025$$
$$= 4{\cdot}265 \text{ pounds};$$

From the analysis of the coal it was found that 0·842 pound was carbon in each pound of dry coal, hence the total of dry flue gas was—

$$\frac{100 \times 0{\cdot}842}{4{\cdot}265} = 19{\cdot}74 \text{ pounds};$$

Each pound of air contains 23 per cent. by weight oxygen; hence, since in each 100 pounds of dry flue gas there were 8·94 pounds of free oxygen present the air in excess will be—

$$\frac{8{\cdot}94 \times 100}{23} = 38{\cdot}87 \text{ pounds};$$

hence the excess shown by the flue gas analysis is 38·87 per cent. by weight or the excess air per pound of dry fuel was—

$$\frac{38{\cdot}87 \times 19{\cdot}74}{100} = 7{\cdot}67 \text{ pounds}.$$

In a similar way the other tests may be calculated, and the results collected in tabular form are:—

Test Number.		201	206	212
Analysis of Gas.	CO_2 per cent. of weight ..	15·51	19·20	18·82
	CO ,, ,, ..	0·06	0·21	0·28
	O_2 ,, ,, ..	8·94	5·35	4·60
	N_2 ,, ,, ..	75·45	75·24	76·30
Weight of carbon in each 100 pounds of dry flue gas in pounds		4·265	5·326	5·133
Weight of carbon in one pound of dry fuel, in pounds		0·842	0·842	0·842
Weight of dry flue gas per pound of dry fuel ..		19·74	16·19	16·03
Weight of excess air, per cent. by weight ..		38·87	23·26	20·00
Actual excess of air in pounds per pound of dry coal turned		7·67	3·678	3·206

The following is the article referred to in the course of the discussion; it is reprinted here by the courtesy of the editor of *The Journal of Commerce*:—

Analyzing a Marine Steam Plant.

The fundamental principle of furnace design and proper combustion is that the air must pass through the combustion zone; not around it, or over it, nor under it, but through it. The combustion zone consists of two parts; they are the fuel bed and the flame space. The flame space is sometimes known as the combustion chamber. Hard coal requires very little flame space, because it has very little flame, and such as there is exists mostly in the fuel bed. Soft coals require large flame space. There are two kinds of flame, that caused by the combustion of volatile products, which give a white flame, and that caused by the combustion of the gas, carbon monoxide, which gives a blue flame.

The process of combustion taken out of the text books and put into a Scotch boiler is about as follows with average coal. Suppose that we are dealing with an incandescent bed of fuel six inches deep, working at full load. Such a bed consists of pure carbon and ash, since all volatile hydrocarbons have been driven off, or the mass would not be incandescent. The air comes up through the grate bars and passes through the fuel, oxidizing the carbon, and thus creating heat. If plenty of air is going through, the products of combustion are carbon dioxide and other gases which we will consider later. If there is not enough air going through, as when the fuel bed is too heavy or the draft is poor or the boiler is being crowded, carbon monoxide is formed, which means that the fuel is only half burned, and the monoxide gas will take fire and burn further if it finds air while it is hot. If a blue flame appears on the surface of the fire bed when the furnace doors or the shutters in the door are opened, it means that the fuel is not getting air enough. This can be remedied by increasing the draft or by admitting air above the bed through the fire door shutters.

When fresh coal is thrown in on the hot fire bed, the first action of the heat is to warm up the new coal. This distils off the volatile hydrocarbons or tars in the form of green smoke. These will burn if supplied with air above the fire bed, ignited by some of the fire bed left uncovered, or by white hot brick work. If, on the other hand, this vapour is kept cool by the iron sides of the furnace and does not meet an incandescence to ignite it, the calorific value of the volatile constituents will all be wasted in the form of dense volume of smoke up the stack. With a hard coal running 20 per cent. volatile matter, this loss would be immense, and with a soft coal running 35 per cent. volatile matter the losses would be so large that they would attract attention.

If too much air is admitted, another loss occurs which can be very large. No more air should be admitted than is necessary for combustion, because it costs just as much to heat air as to heat water. To illustrate: Each pound of pure carbon requires about 12 pounds of air for its combustion. The calorific value of fuels is usually calculated by taking into consideration the amount of carbon and hydrogen contained, but this formula is disputed by some, and a much simpler one is as follows:—The calorific value of pure oxygen is 7,760 British thermal units, no matter what it is burned with. Air consists of 23 per cent. of pure oxygen by weight. We know that it takes eight pounds of oxygen or 36 pounds of air for each pound of hydrogen in the hydrocarbons of coal. We know that it takes $2\frac{2}{3}$ pounds of oxygen or 12 pounds of air for each pound of carbon in the fuel; therefore, after a glance at the chemical analysis of a fuel, arithmetic will give the theoretical amount of air required. Practically, from 12 to $12\frac{1}{2}$ pounds of air are required for the combustion of average coal. One pound of air is about 12·4 cubic feet, or a total of about 150 cubic feet of air required for each pound of fuel. Air requires about one-quarter of the heat that water does to raise its temperature one degree. Suppose that there is twice as much air going through a furnace as should (there is often five or six times as much as should) be. This air is discharged from the stack of a Scotch boiler at an average temperature of 1,000 degrees F. It may be taken from the fireroom at 100 degrees. This is a total rise of 900 degrees. For twelve pounds of air, this gives twelve times 900 times one-quarter, or 2,700 British thermal units lost per pound of coal by admitting too much air. As the coal has a calorific value of, say, 11,000 British thermal units, the loss amounts to about 26 per cent. for every 100 per cent. of excess air, a prolific and common source of loss.

If it is desired to burn low-priced coals, which carry large percentages of ash and are of small sizes and full of dust, it is necessary that the boilers are not crowded, otherwise cleaning fires becomes such a burden and the condition of the firerooms so intolerable that the men rebel, and their efficiency is lowered. It has been demonstrated time and again in all branches of industry that high-grade help well treated pays the best dividends. Ample boiler power lowers the rate of combustion and prevents the formation of unmanageable amounts of clinker on the grates.

If a great deal of soft coal is burned, an arch of fire brick over the bridge wall will assist in keeping the green gases ignited and prevent smoke. It is also a good plan to line parts of the combustion chamber with brick for the same reason, but the brick should not be more than one thickness so that a portion of the heat may be transmitted through to the heating surface beneath and thus make use of the heating surface, as all marine boilers have a deficiency of heating surface compared to the load they carry. This system can hardly be applied to ferry steamers, because the brick work retains so much heat that the boiler makes steam long after the fires are out.

The object of " working " a fire, breaking it up with slice bars, etc., is to prevent a solid bed forming which would prevent the air from passing through. This melting together is caused by two elements—first, the molten ash or slag which accumulates and tends to seal the air passages, and second, the tarry constituents which tend to melt and flow before being evaporated, leaving the coke behind; therefore, a coal high in volatile matter and also high in ash will be hard to fire and tend to run together.

There are several ways of working fires. The most wasteful way and the hardest on firemen is simply to throw in coal regardless of other considerations. A better way is to shovel into the front of a furnace and shove the coal back after a few minutes while working the fires. The reason is that the volatile constituents are kept hot and ignited by the fire bed in the back half of the furnace instead of escaping as smoke and vapors. By the time the coal is shoved back it is mostly coke, and the vapors are so reduced in volume that they will be burned in the ordinary course of combustion. Between the time of firing and the working the fire the door shutters should open so as to supply air for the combustion of the vapours above the fire bed, but they should be closed after the charge is coked to prevent an excess supply of air. Another way of firing is to fire only a little at a time, say two scoops full, and fire oftener. The charge is spread all over the furnace and the door shutters kept a little open all the time so as to make sure that the vapors burn.

Another way is to fill up one side of the furnace at a time and open the shutters in the door on the opposite side, if a two-door furnace, or to open them half-way in a one-door furnace. This method is not so economical because some of the vapors in the rear of the furnace will escape without being burned.

The object of cleaning fires is to remove the clinker without removing any more fuel than is necessary. With a poor coal, practically the entire fire is removed, as all the fires in one afternoon must be cleaned together for practical reasons. This is the most trying part of a marine fireman's work and the cause of most of the administrative trouble in firerooms. Criticism should not be made of the character of firemen in general, because they are just what conditions have made them. In an oil-burning fireroom, one does not find the character of the fireroom men inferior to anyone else aboard the ship, because it is comfortable work; so anything which ameliorates the horrible conditions of the average fireroom raises the character and efficiency of the men aboard. There is no scientific method of cleaning a fire, patience and a good vocabulary being the necessary requirements in separating clinker from the grates. Ash ejectors, hoists, etc., all help, but the best returns are gotten from providing plenty of boilers, so that fair headway can be made when one-quarter or more of the fires are on the floor plates instead of the grates. The greatest help of all is to buy coal that is low in ash. Cleaning fires, then, while no picnic, does not interfere seriously with the schedule. Many a 12-knot steamer of good boiler capacity can pass a 14-knot boat whose boilers are over worked on a long run because of the difference in cleaning fires each watch or a difference in coal.

When an ashpan door is one-quarter open it admits the same quantity of air as when it is wide open, and to cut down the supply the door should be open only an inch or one-half inch. Air may be admitted anywhere where there is incandescence and something to burn, but not where things are black hot, no matter whether there is smoke or gas there or not. The proper amount of air admission is ascertained from the appearance of the stack and from the analysis of stack gases. Air should be admitted whenever there is smoke, especially above the grate bars, but the smoke will not burn unless it passes through a zone of incandescence. After the smoke disappears the air may be cut down until a little smoke appears, but some caution must be used, because if the fuel bed be all coked and hot there will be no smoke under any conditions, and a deficiency of air causes the fuel to half burn and give off monoxide, which is half burned gas instead of dioxide, which is whole burned gas. Both gases are invisible, hence there is no knowledge of the loss, except from a chemical analysis by an apparatus which can be attached to the stack. This apparatus must be in the form of a simple tube, which can be purchased for 75 cents (3s. $1\frac{1}{2}$d.), and any engineer can use it; or it may be an automatic recording device making an automatic test every fifteen minutes and recording the results on a dial. In any case the test depends upon the principle that when perfect combustion is taking place from 13 per cent. to 15 per cent. of carbon dioxide is formed. If the combustion is imperfect, this percentage is reduced air admitted, the products of combustion show less than in proportion to the imperfection. If there is too much, the proper amount of carbon dioxide, but no carbon monoxide. If too little air is used the products show less than the proper amount of carbon dioxide but also a proportion of carbon monoxide, or half burned gas. The apparatus, whether of the elaborate or simple type, depends upon the principle that certain chemicals easily obtainable will absorb each of these gases without the others. Many kinds of apparatus are available for the analysis of the products of combustion. None of them costs as much as even a cheap indicator, and far more can be learned from the stack in the way of economy than from indicator cards. The analysis will show just exactly what the furnaces are doing. Analysis may be made also for hydrogen, oxygen, sulphur, moisture, and sulphuric acid. Any practical man can make the tests by using the chemicals and following directions, and simple books can be procured which explain the meaning of the analysis.

Excess air causes high stack temperatures, because the excess of air takes heat from the furnace and carries it out of the stack instead of giving it up to the boiler. The reason that the heat is not given up to the boiler is that the hot air is lower in temperature than the products would be alone, and the heat does not flow into the boiler so fast. The temperature of a stack should be about 600 degrees F. on a good watertube boiler to 1,000 degrees F. on a crowded Scotch boiler. If the temperature in the stack is more than these figures and there is not excess air in the furnaces, either the boiler is being crowded or else it is deficient in heating surface.

There are several means of possible improvement in fireroom conditions but progress seems to be slow along this particular line of endeavour. It would probably pay some large steam-ship line to spend some money experimenting with possible devices. Chain grates look promising, if adapted to marine boilers or even if the boiler is adapted to the grate, if necessary; a watertube boiler and chain grate is by no means an unknown combination, and it would eliminate the dreadful task and loss of cleaning fires. Down draft Dutch ovens, made after the general design of a gas producer discharging ash from the bottom, have been used on shore with great success and burn soft coals without smoke. Actual gas producers are in operation in Mexico (or were), which feed hot unscrubbed gas to steam boilers.

The use of oil fuel is one of the most rational solutions for conditions in a marine fireroom. Standards of fuel oil are now obtainable all over the world which are as safe as coal, everything considered. It requires less than half of the storage space for the same calorific value and burns with higher efficiency. It dispenses with the bulk of the firemen and their quarters. It is handled, loaded and unloaded without soiling the ship and has numerous lesser advantages. There are many kinds of fuel oil and considerable technique to its use, all of which is discussed at length in easily obtainable books on the subject. The general principles of combustion or oil are the same as already described, and the principles of its use follow in a general way the principles for the combustion of the volatile hydrocarbons in coal.

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REPORT OF PRELIMINARY INQUIRY (No. 2416.)

By MR. W. T. PHILLIPS.

Explosion from a Main Feed Check Valve Chest.

The explosion occurred at about 6 a.m. on Sunday, the 12th December, 1915, when the vessel was removing, under her own steam, from her discharging berth in Boucau Harbour, Bayonne. Ali Salee, the fireman, who was on watch in the stokehold at the time of the accident, was killed.

The chest, which contains two valves, the main check and the master or stop valve, was made of brass, the thickness varying from $\frac{5}{16}$ to $\frac{3}{8}$ of an inch. The valves and covers were also made of brass. Both valves are practically of the same size and have a diameter of $2\frac{11}{16}$ inches across the guiding webs. The covers were attached to the chest by means of six steel studs having a diameter of $\frac{1}{2}$ inch over the threads. The portion of the casting containing the check valve measures $7\frac{1}{4}$ inches from under the valve cover to the bottom of the flange where attached to the feed pipe, while the portion containing the master or stop valve measures $8\frac{5}{8}$ inches from the front of the boiler to the valve cover.

No particulars as to the makers or age of the valve chest are available, but it is most probable that it was made and supplied by the makers of the engines, the Actien-Gesellschaft, Neptun, Schiffswerk und Maschinen-fabrik, Rostock, in 1898, when the engines were made. As far as is known no repairs have been made to the valve chest beyond grinding in the valves when the covers were removed for inspection. The last examination was made in January, 1915, when the machinery and boilers were opened out for the purpose of being inspected by the Company's superintending engineer, and the Surveyors of the Society with which the vessel was classed before being taken over by the present owners.

Five studs out of the six securing the check valve cover to the chest were fractured and the remaining stud, on which the cover was hanging, was considerably bent. The cover itself was forced on one side and sufficiently displaced to allow of the check valve being projected out of the chest, thus leaving a free passage for the escape of the hot water and steam from the boiler. The pressure of steam on the boiler at the time is said to have been 150 lbs. per square inch.

The explosion was due to the failure of five out of the six studs which secured the check valve cover to the chest, the failure of the studs, in my opinion, being due to excessive pressure produced through an insufficiency of escape valve area.

The vessel, which was originally a German vessel and built in Rostock in 1898, was bought by the present owners, in January, 1915, after condemnation in the Prize Court. She is fitted with a set of triple expansion engines which are supplied with steam from a single-ended boiler having three furnaces and carrying a working pressure of 180 lbs. per square inch. At the time of the accident the pressure is stated to have been 150 lbs. The boiler lays fore and aft, and the stokehold, which is athwartships, is only separated from the engine room by a screen bulkhead having a door on the starboard side. The two main feed pumps, one at the forward and the other at the after end of the pump crosshead, each have a diameter of $2\frac{9}{16}$ inches and are worked by levers from the piston rod crosshead of the after engine. Each pump has an escape valve of $1\frac{15}{32}$ inches diameter fitted directly on the pump barrel which was stated to be adjusted to lift at slightly over the working pressure, but I was unable to ascertain the amount to which they were loaded when the accident occurred as the chief engineer had released and readjusted both valves. Each of these valves is provided with four guiding wings which reduce the effective area of the escape passage by 35 per cent. The main feed check valve case also contains a stop valve between the check valve and the boiler; both valves have a diameter of $2\frac{11}{16}$ inches and are provided with screwed spindles so that the check valve can be closed if necessary, while in the case of the stop valve it is attached loosely to the spindle by a horse-shoe collar on the back of the valve and a collar on the inner end of the spindle, and this valve should remain open to an extent depending upon the number of turns given to the spindle, as the boiler pressure is on the face of the valve. When fully open the check valve had a lift of ·4 of an inch, while the stop valve when fully open had a lift of 1·2 inches, but owing to the collar on the back of the stop valve as well as the collar on the end of its spindle being badly worn, the valve had a play of half an inch on the spindle and thus the spindle would require to be turned to give this amount of opening before the valve was actually held off the face of its seat. The two covers on the valve chest were each secured by six steel studs having a diameter of practically half an inch over the threads and the accident was due to five out of the six studs holding the cover fracturing. The remaining stud was bent and the cover was found hanging on this stud but sufficiently displaced to allow of the valve being projected out of the chest. When the steam and hot water had cleared sufficiently to allow the engineers to examine the chest and search for the check valve it was found on the stokehold plates. The furnace door of the port fire was found open and it would therefore appear that Ali Salee was working this fire at the time of the accident, and as the main check valve is situated on the end of the boiler, just by this door, he most probably received the full force of the escaping hot water and vapour. When found he was, however, lying on the stokehold plates, by the donkey boiler, in the starboard wing. As the ship had been waiting, under steam, to remove from her discharging berth it is probable that sufficient water had accumulated in the condenser to fill the hotwell and fully charge the feed pumps as soon as the engines had made a few revolutions.

The engineer who was in charge of and working the engines declares he fully opened the valves on the boiler and I believe he thought he had, at least, sufficientlv opened them, but he was unaware of the play in the feed stop valve and this reduced the effective lift to such an extent that the feed passage was almost closed. The failure of the studs was apparently due to excessive pressure produced by the feed pumps, owing to their being fully charged while the feed passage was almost closed and the area of the relief valves provided being insufficient to relieve this pressure effectively. The owners have now had a relief valve fitted to the main feed pipe line which has an area equal to the main check valve and is loaded to about 10 lbs. above the working pressure.

Observations of the Engineer Surveyor-in-Chief.

The failure of this fitting was probably due to the feed check master valve having been shut or almost shut owing to the large amount of play between the valve and the lifting spindle. Notwithstanding that the valve was possibly shut when the cover was forced off, it is surprising that the relief valves fitted did not afford the necessary relief, if properly adjusted. The adjustment at the time was not ascertainable, however, as it was altered after the explosion occurred. Unfortunately one man was killed by the outrush of scalding water when the cover was blown off. A new feed stop valve, and a relief valve, equal in area to the check valve, have now been fitted.

A. Boyle.

Report of Preliminary Inquiry (No. 2420.)

By Mr. D. W. STEPHEN.

Explosion of a Works Boiler.

The explosion occurred about 11 a.m. on the 22nd June. No person was injured.

The boiler was of the plain, cylindrical, egg-ended type, 3 feet 9 inches in diameter, and 23 feet in length. It was made of iron throughout, with the exception of the bottom plate of the front belt, which was of steel. The shell was formed of six belts, the front one having four plates in the circumference, the remaining five being each composed of three plates; the hemispherical ends were formed of six radial plates, with circular crown plates, 1 foot 11 inches diameter. The shell was $\frac{3}{8}$ inch, and the ends $\frac{7}{16}$ inch thick respectively. All the seams were single riveted and lap-jointed; the rivet-holes were punched and were $\frac{13}{16}$ inch in diameter, pitched 2 inches apart. A manhole, 16 inches by 12 inches, was cut in the fourth belt of plating from the front end.

The mountings consisted of:—

Two safety valves, each $2\frac{1}{2}$ inches diameter, loaded by levers and weights to 35 lbs. per square inch.

Two wheel floats.

One steam stop valve, attached to safety valve chest.

One feed check valve.

One Bourdon steam guage, graduated to 100 lbs.

The boiler was supported by eight brackets, four on each side, riveted to the boiler, and resting on the brickwork of the flue.

The present owner of the boiler purchased it second-hand about 20 years ago. The maker's name and the exact age of the boiler cannot be stated, but the opinion was expressed that it had been in use for 12 years prior to the sale.

Several patches have been fitted to the shell plating, and about six years ago the bottom plate of the first belt was renewed. This repair was carried out by a local boiler repairer. No records whatever have been kept of the dates of any of these repairs, and no hydraulic test appears to have been applied afterwards. An annual examination of the boiler was made by the local inspector for the insurance company, the last occasion being on the 25th August, 1915. It was also cleaned out monthly, the last time being on Whit-Monday, the 12th June.

The lower plate of the first belt ruptured longitudinally for its full length, through the rivet holes of the right-hand seam, looking on the front end. From the back end of this rupture, the fracture extended through the second circumferential seam for a distance of 4 feet 6 inches. At the front end it followed one of the seams of a radial plate, then circumferentially round the crown plate, and, finally, into the solid metal of the adjoining radial plate. The boiler was lifted from its seating, and projected on top of the adjoining one, while the brickwork of the flue was completely demolished. The steam pressure at the time is stated to have been about 20 lbs. The explosion was due to the overheating and consequent weakening of the shell plating, through shortness of water.

The Works is a small establishment, comprising two coking ovens and a blacking mill, giving employment to five men. The steam plant consisted of a small Cornish boiler and a larger one of the egg-ended type, the latter being known as "No. 1," and most generally used. A blacking mill was driven by a single cylinder horizontal engine, coupled direct to the main shaft, and situated between the wall of the mill and the boiler which exploded. Work being carried on in the day time only, it was the practice to draw the boiler fire each night, and relight it next morning. At 7 a.m. on the 22nd of June last the fire was started under the egg-ended boiler by the attendant, who stated that it generally took from one to one and a half hours to raise 15 or 20 lbs. of steam, that being the pressure usually maintained. The engine was started at 8.30 a.m., and about 9 a.m. he tried the front float, which he found to be acting satisfactorily. Between 9 a.m. and the time of the explosion he was engaged at the blacking mill, excepting for a few minutes at intervals of about a quarter of an hour, when he had to fire the boiler, which was a part of his duties. He stated in evidence that he had no recollection of noticing the position of the float after he tested it at 9 a.m.

On examining the boiler after the explosion all the evidences of overheating were clearly defined, the bottom plates being plum coloured and distorted, particularly where the primary rupture occurred, a distinct water line was also marked round the inside of the shell at a height of about 6 inches above the lowest part. The plating was not unduly wasted, and the condition internally was satisfactory. Of the two wheel floats, the one nearest the front end was arranged to indicate the working water level, the junction of the brass wire of the float with the chain round the wheel forming a conspicuous point to gauge by, and it was understood by the fireman that, when this point was about three inches above the gland on the shell, the water level was correct. The back float appears to have been arranged as a high-level one, and only came into use when the amount of water in the boiler was excessive. Both floats were dislodged from their position, and partly broken by the force of the explosion, but their condition appeared satisfactory, and the wires were quite free in the glands. The feed water was obtained from the reservoir of an adjoining coal pit, situated on a higher level than the Works, and was conveyed by pipes to an open underground tank, placed beside the engine; a cock was fitted on this pipe about 30 yards from the tank, to regulate the supply. A trap door which could be lifted was fitted immediately over the tank for observation purposes.

The only means provided for feeding the boiler was a single acting plunger pump, placed vertically in the fly wheel pit, and worked by an eccentric on the main shaft; the pump valves were non-adjustable, but, on being opened out, were found to be in good condition. The feed check valve on the boiler was of the non-return type, and was fitted with an internal pipe carried down to within 12 inches of the bottom. This is a somewhat objectionable arrangement, providing as it does a means for allowing the water to be blown out of the boiler in the event of anything going wrong with the feed pipes and valves. Both the owner and fireman expressed the opinion that this was what had happened, but there is no evidence to support their theory. The feed pipes were not broken before the explosion, and the water would have had to pass two non-return valves before it reached the feed pump chamber, where the only escape would be through the gland of the plunger. The fly wheel pit would have then filled with steam, and thus attention would have been drawn to the fact that something was wrong, but, on their own statements, this did not happen.

In the boiler Insurance Company's report of inspection for the year 1908, it was "recommended that the position of the feed delivery be altered to deliver 3 inches below the water line"; this wise suggestion, however, was not acted upon.

The explosion was apparently caused by an insufficient supply of feed water. It was admitted by the fireman that trouble had been experienced the previous week with pieces of coke getting under the valves of the feed pump, rendering it inoperative, and it is possible that the same thing may have occurred again on the day of the explosion. The fireman appears to have been satisfied with looking occasionally at the feed water in the tank, but unfortunately he did not observe the position of the water floats between 9 a.m. and 11 a.m. His neglect to do so is difficult to explain, as he appeared to be a man of intelligence, and gave his evidence honestly. He had, of course, his other duties to perform, and these evidently did not leave him much time to attend to the boiler.

Observations of the Engineer Surveyor-in-Chief.

At the works where the explosion occurred, only five men are employed, one of whom attended to the boiler and did other work. Through inattention to the boiler, however, it was allowed to become short of water, and the part over the fire became overheated and ruptured.

It is not, as a rule, desirable to give a boiler attendant other work to do than that connected with the boiler, but, if such work is given, the owner should see that it is of a subordinate character, and not such as need interfere with the proper attention to the boiler.

Fortunately, in this instance, although the boiler was lifted from its seating, no person was injured.

A. BOYLE.

REPORT OF PRELIMINARY INQUIRY (No. 2427.)

BY MR. G. MACFARLANE GRAY.

Explosion from a Water-tube Boiler.

The explosion occurred at about 11 a.m. on Saturday, the 8th July. The boiler attendant and another man were scalded. The latter has not yet recovered from his injuries.

The boiler was a patent vertical water-tube boiler made of steel, 4 feet 6 inches in internal diameter and 10 feet 6 inches in height. The shell was made of two plates, each $\frac{13}{32}$ inch thick, the vertical seams being lapped and double riveted. The fire-box was 3 feet 11 inches in mean diameter and 5 feet in height, made of $\frac{1}{2}$ inch plate with a lap-welded vertical seam. The sides of the fire-box were shaped into flat tube-plates, at opposite sides. These tube-plates carried 46 water-tubes, $2\frac{1}{4}$ inches in external diameter swelled to $2\frac{1}{2}$ inches diameter for a length of 3 inches at one end; six of these tubes were stay-tubes, $\frac{1}{4}$ inch thick. Above this bank of tubes, and crossing them diagonally, there were originally two rows of tubes, four in each row, which passed through the circular portion of the fire-box.

The ordinary tubes were No. 11 S.W.G. thick, and all the tubes were lap-welded iron tubes. The boiler was constructed for a working pressure of 100 lbs. per square inch. A man-hole, 11 inches by 14 inches, was provided in the upper part of the boiler shell. The following mountings were fitted:—Two spring-loaded safety-valves, 2 inches in diameter; one main stop-valve; one steam pressure-gauge graduated to 200 lbs. per square inch; one water-gauge and usual cocks, and one blow-down cock.

The boiler was thirteen years old at the time of the explosion. In the summer of the year 1914 a tube burst in the top row, and was blanked off. In May of the following year, 1915, the tubes in the two top rows, eight tubes in all, were blanked off. The boiler has been periodically examined by an inspector in the employment of an Insurance Company. The last thorough examination was made by him on the 4th June, 1915, and, on the 5th July, 1916, it was inspected by him under steam.

The bottom tube in the row nearest the fire-box door, and close to the left-hand tube-plate, ruptured for a length of about $1\frac{1}{2}$ inches. Through this opening the contents of the boiler escaped into the furnace, and thence into the boiler room. The explosion was due to the thinning of the tube, by external wasting, to such an extent that it was unable to stand the working pressure. It is termed the Hopwood patent boiler. It was installed at the works in 1903, for generating steam for separators and other dairy plant. During the summer months the boiler is in use every weekday, but in the winter it is not used so much. The manager of the place has had several years' experience of boilers and plant, but is not a trained mechanic, neither is the boiler attendant. All appears to have gone on satisfactorily with the boiler until the summer of 1914, at which time one of the tubes in the top row burst, and the boiler emptied itself, but fortunately no one was injured. The tube was blanked off and the boiler again used. On the 18th December, 1914, the insurance inspector made a thorough examination of the boiler, and sent the following notice to the owners:— "Fire-box plates a little wasted in places, several of the old "tubes much reduced, and one has been plugged. The boiler "requires re-tubing, after which it should be tested by water "pressure, say to 150 lbs., to see that all is tight. Please in-"form us when done." As a result of this communication, as many tubes as were accessible in the main bank were renewed, while those in the two small banks were cut out and the holes plated, but no water-test was applied. On the 4th June, 1915, the inspector made an internal examination and made the following note in his book:—"All O.K. except the old tubes a "little wasted, but apparently good enough under the "hammer." This was the last thorough examination by the insurance inspector. In November, 1915, and on the 5th July, 1916, working inspections were carried out by him. On the 8th July last, at about 11 o'clock in the morning, work having been going on for about three hours, a tube in the main bank of tubes ruptured for about $1\frac{1}{2}$ inches, close to the left-hand tube-plate. The boiler emptied itself through this opening, scalding the boiler attendant slightly, and severely scalding a milk seller who was standing near the boiler. The tube that ruptured was found to be wasted away externally for some distance at each end, the thickness of the tube at the wasted part being quite unfit to bear any useful pressure. The middle portion of the tube was fairly good. The owners apparently relied on the insurance company to keep them advised as to the condition of the boiler, but, unfortunately, their recommendations were not carried out. A water-test was asked for after the repairs, but was not applied. No water-test has been applied since the boiler left the makers; the safety valves and other mountings have never been opened up, nor has the steam pressure gauge been tested against a standard gauge. The insurance inspector, according to his evidence, trusts more to the hammer and sight tests than to a water-test, but it is impossible in boilers of this type to test by these means alone, and, the hydraulic test should be applied in addition to the other tests. As there are a number of similar boilers of about the same age installed in the neighbourhood, it will be well if notice is taken by them of the advisability of applying the hydraulic test. Fortunately both the men scalded by the explosion are recovering.

Observations of the Engineer Surveyor-in-Chief.

The rupture of the tube appears to have been due to thinning in the ordinary course of working. The defective condition of the tubes was pointed out to the owners and some of them were renewed, but it would have been more prudent on their part to have subjected the boiler to a suitable hydraulic test as recommended by the insurance inspector, for such a test might have revealed the extent of the corrosion which other tests failed to detect.

A. Boyle.

August Issue.—The blocks for the illustrations of the burst steam pipe were kindly lent by the Editor of the *Shipbuilding and Shipping Record.* J.A.

The Metric System.

At the meeting of the British Association held on September 9th this subject was under review, and in the absence of Sir Richard Burbridge, Dr. Hunter, of Messrs. Swan, Hunter & Co., gave the address to initiate a discussion, intimating at the same time that the foundation of the address was laid by Sir Richard. The following report is from *The Glasgow Herald*:—

Dr. Hunter urged that the time had now come when the subject of decimal coinage and weights and measures must be very seriously taken up if Great Britain was to hold her own in competition after the war. He spoke of the advantage of the decimal system of coinage over the present system, and urged the extreme necessity of preparing for the change now, so that at the end of the war we may be in a better position to compete with trade advances. The Government, he declared, should effect the necessary reforms without delay. For a period of some years after the war not much trade would be done between Germany and the Allied countries, but so far as neutral countries were concerned they would naturally place most of their orders with those who used the weights and measures to which such countries were accustomed. The United States were aware that if they wished to share—and they wished to have the lion's share—of the trade of which Germany had so large a proportion they would have to adopt the metric system in their dealings with foreign countries. The French had adopted our meridian; why should we not change our weights and measures system for that endorsed by every other civilised country? There should be one language of weights and measures throughout the whole world. There was no possibility of any nation adopting our weights and measures system, for no country which has taken over the metric system as its own had ever considered the question of relinquishing it. The reform would have benefits at home, saving the time now occupied in school education. (Cheers.) Further than that, we might improve our antiquated system of spelling, which would also save time. (Cheers.) There would also be a great saving in bookkeeping and in clerical work. If we adopted the reform in respect to coinage, the line of least resistance in his view would be to retain the pound and the florin. The change in respect to weights and measures presented considerable difficulties, and could only be carried through by degrees; and therefore it should be begun now by reforming such weights and measures as were in common use in our commercial dealings with foreign countries.

Mr. Gerald Stoney, of Newcastle, president of the engineering section, mentioned an instance in which the metric system had been used in the manufacture of turbines, but added that in the stress of war conditions and when Admiralty work was on it had been necessary to adhere to the English system. But there was no difficulty in having both running side by side.

Sir Henry Cunningham remarked that it was important to recognise that one could not move in this manner without advice and the Colonies coming in. It should be an Anglo-Saxon movement.

Mr. Loriol, a Colonial delegate, said that the Colonies were ready, and only awaited a move of the Mother Country in this matter; and Dr. J. F. Focher, speaking for medicine and pharmacy, said it would be a very simple matter to adopt the metric system.

The president of the section (Professor Kirkcaldy, of Birmingham) wished it to go forth that, while so many changes were being made, the section took the view that the Anglo-Saxon world should come together and try to bring this reform about.

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Tools for Steamships.

Mr. I. Vesey Lang, referring to Mr. J. Hamilton Thomson's paper on "Power Driven Tools" and the subsequent discussion, writes as follows:—

Personally, I have always been an advocate of efficient working gear, both in the shops ashore and on board ship afloat; but the difficulties may be briefly summarised as follows and in the order named:—

(A) No suitable tools on the market.

(B) In many cases—certainly the majority of cases—no room in existing ships.

(C) More or less willingness on the part of superintendents to recommend power tools.

(D) Because of the unlikelihood of engineers taking an interest in or using such tools.

(E) Cost. This is probably the least of the objections, if only suitable tools were made and standardised.

On the foregoing heads I would further comment as follows:—

(A) Some years ago I gave the subject some considerable thought and wrote to several tool makers on the subject of a lathe for the engine room. I made inquiry through factors but received no enlightenment. I attended an Engineering Exhibition, at that time, being held at Olympia, and interviewed several principals who promised to write me and submit offers. I do not remember to have received any replies. It must not be overlooked that the last thing an English manufacturer desires you to put before him is something at all different from what he makes and what he thinks ought to suit you. If he is at all busy he simply does not want to be bothered with you. Such tools as are illustrated in Transactions No. CCXX. are quite useless for the engine room of a cargo steamer, and such elaborate and costly machines will never find a ready place aboard ship.

I am, of course, only alluding to the typical "tramp" steamer that forms the back-bone of the British Mercantile Marine, viz., the usual East Coaster built for $8\frac{1}{2}$ to 9 knots sea speed. Briefly, for the purpose of a "standard" type of ship lathe, I would divide this class up with four ranges or size of lathe. The average size of engine parts of a half-dozen of the best known cargo type engine builder will very nearly approximate to the following groups for deep-sea steamers:—

(1) Up to 3,500 D.W.
(2) 3,500 to 5,000 ,,
(3) 5,000 to 7,500 ,,
(4) 7,500 to 8,500 ,,

This will give you, approximately a range of H.P. cyl. 21″, 23″, 25″ and 27″ diameter, which would dominate the greatest diameter (in the gap) that could be economically used abroad. This would give us, approximately, a $7\frac{1}{2}$″, 8″, $8\frac{1}{2}$″ and 9″ centre lathe respectively. Anything under $7\frac{1}{2}$″ is a toy and over 9″ (or thereabouts) too large for a tool aboard ship. For length between centres I would make the feed and bilge pump rams the maximum, which would give about four lengths of 3′ 6″, 4′ 0″, 4′ 6″ and 5′ 0″. For main valve spindles the working part comes well within these lengths of centres, and the poppitt can be substituted by a bearing block. In the above are my ideas of maximum requirements in a lathe for ship work.

Briefly, the lathe should have (1) three-speed cone with back gear; (2) a leading screw; (3) change wheels—for screw-cutting —machine-cut gears; (4) compound slide rest mounted on saddle with angle adjustment; (5) gap opening, sufficiently wide to pass a valve spindle crosshead; (6) a faceplate, a dog-chuck, a full set of tools, and a spare set of centres; (7) a countershaft and brackets with "Balata" belting and fasteners. Leather is no good in a hot temperature. *N.B.*—I do not consider that either a back-shaft for separate self-acting feed is necessary, nor traversing feed screw to the saddle, as neither duplication nor time form the main considerations, and the inclusion of these would add to the prices named.

Now for the motive power:—

(*a*) If a dynamo aboard a motor would be the best.

(*b*) Otherwise a small steam engine bolted to the bulkhead similar to the little engines usually used on board ship (by repairers) for boring cylinders, etc.; say a 3″, $3\frac{1}{2}$″, 4″ and $4\frac{1}{2}$″ cyl. engine for the above lathe.

N.B.—Any drive off a rotary ballast pump or a turning engine would be generally unsatisfactory.

(*c*) No lathe aboard ship would be serviceable under all or any breakdown conditions without land power, as the motive power itself might be the subject of repair, or no steam be available. Therefore some form of man-power is required. Foot-power is almost at its limit on a $7\frac{1}{2}''$ centre lathe. By far the best arrangement would be (and I have never seen it in any lathe list) a hand-wheel drive on a bracket bolted to a bulkhead, and with a belt or rope drive to the counter-shaft. One or two men are always available for such emergency under sea conditions or in foreign ports.

(B) Some of the members are quite wrong in describing engine rooms in general as "roomy." I am acquainted with many steamers where one would be hard put to find room for a lathe at all. Briefly, steamers with two main boilers have side and reserve bunkers on both sides in the machinery space, and the engine platform space is very limited. In steamers having three main boilers abreast there is no room at the sides for bunker space, and consequently no reserve bunkers in the engine space. In these jobs there is ample floor space. Sometimes the steering engine recess might accommodate a lathe across its front, and sometimes the valve recess (if decked) is roomy.

Wherever a lathe is put, it should have provision allowed for the length of a main valve spindle to extend beyond the bed-plate; either a doorway or a hole through a bulkhead.

N.B.—In the latter case if put into a bunker or cargo space a boxing or tubed recess would be necessary.

The lathe would require to be firmly seated, and if on the existing engine platform, some extra support would be required under the ordinary platform bearers to carry the extra weight and vibration.

(C) I have conversed with superintendents who were in favour of some power tools aboard ship. Others say they would never be used. Personally, I have supplied a double-geared, $1\frac{1}{4}''$ spindle, hand drilling machine—to drill up to $1\frac{1}{2}''$—to all the ships under my superintendence.

(D) The use of power tools all depends upon the engineers. Some chiefs would take a keen interest in being able to do such repairs aboard; others would be more or less indifferent, and prefer to let things run until the ship came home. Probably one well used and one hardly used at all would not be far out in general practice.

(E) Cost—the crux of most things. I would certainly not call the average shipowner the stumbling block to efficient equipment. I have shown that no special ship lathe is on the market such as I describe as needed. Judging from lathe values I have had to do with in pre-war times such lathes should be procurable (on a pre-war basis) at about £40, £50, £60 and £70 respectively, complete with countershaft and hand-power.

A suitable engine (new or second-hand) would run to about £12 10s., £15, £17 10s. and £20, according to make and design. A "Pickering" or other quick-acting governor should be fitted to the engine. An electric motor, and its gearing would probably run to similar figures.

To the cost of lathe and motive power must be added steam connections, piping, valves, etc.; or switches, cut-outs, and wiring, together with any strengthening brackets, seating, etc., that various positions might make necessary, and carriages, putting aboard, etc., which might run anything from or between £10 to £25—assuming that the actual fitting up was done by the engineers themselves. On the basis therefore of the above figures the value (when aboard) would run to about £62 10s., £75, £95 and £115 for such lathes as I have mentioned. *N.B.*—It is necessary to the proper consideration of such a subject that cost should be entered into, but my figures are entirely estimated and may be taken as "minimum." As to what price lathes are now or will be later on it is impossible to say without going closer into figures.

One other item arises on the subject of a lathe on ship board, and that is material for its use. With an efficient lathe in an engine room there would require to be bar iron and steel for studs, etc., brass castings for neck and gland bushes, muntz metal bars for pump studs, spindles and pins. Some ingots of white metal and lead for liners and flanges. Breakages and repairs of the plant would be a question of the future. But I have stated sufficient to show that the pros and cons require due consideration.

I trust these remarks may assist the discussion and be of some interest.

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ELECTION OF MEMBERS.

Members elected at a meeting of the Council held on Tuesday, October 17th, 1916:—

As Members.

George Lloyd Allen, 141, Fenchurch Street, London, E.C.

Richard William Allen, *c/o* Messrs. Thos. W. H. Allen, Son & Co., Ltd., Queen's Engineering Works, Bedford.

David Cockburn, "Ardmore," Kilmacolm, Renfrewshire.

John Crawford, Erskine Villa, Alloa, Scotland.

Thomas Drake, Royal Mail Steam Packet Co., London.

Charles Wannell Fox, 36, Hanover Street, Swansea.

Edward Humble Law, 152, Jerningham Road, New Cross, S.E.

Alfred Herbert Larkman, 31, The Parade, Merthyr, Wales.

Charles Crichton Morton 18, Victoria Avenue, Great Crosby, near Liverpool.

Cornelius O'Neill, 70, South Mall, Cork, Ireland.

David Pottie, 24, Bernard Street, Leith, Scotland.

Norman Henry Reed, 270, Newport Road, Cardiff, Wales.

Norman Ventress Robson, 13, Delaval Road, Whitley Bay, Northumberland.

John Augustus Thompson, 28, Victoria Street, London, S.W.

James Watson, 19, South Park Parade, Ilford, E.

Frank Alfred Thomas Wheeler, 11, Cavendish Road, Harringay, N.

Frank Henry Woollons, 6, Champion Grove, Denmark Hill, S.E.

Transfer from Associate-Member to Member.

J. R. Baker, St. Catherine's Vicarage, Canton, Cardiff.

Transfer from Associate to Associate-Member.

(19th September, 1916.)

Donald F. Call, 124, Jesmond Avenue, Toller Lane, Bradford, Yorks.