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Boiler Heating Surface.

BY MR. G. J. WELLS (Member of Council).

READ

Tuesday, November 5, at 6 p.m.

CHAIRMAN: MR. JAS. SHANKS (Chairman of Council.)

The CHAIRMAN: We are met to-night to hear a paper by one of our members of Council on a subject which is of the greatest importance to all engineers, and which requires considerable study. You have not had time to digest it, but I ask you all to give the closest attention to Mr. Wells while he is reading it, so that you may be able to take a part in the discussion immediately afterwards.

A committee has recently agreed that the size of the safety valves of the ordinary type required on each boiler shall be determined as follows:—

$$\text{Area of safety valve in square inches} = \left\{\begin{array}{c}\text{total heating surface}\\ \text{of boilers in sq. ft.}\end{array}\right\} \times \left(\frac{1{\cdot}25}{p \times 15}\right);$$

where p is the working pressure in pounds per square inch.

Later it is laid down that all the steam generated when all the stop valves are closed and under full firing conditions must be passed by the valves without any undue increase of pressure. The author has always found that the amount of heating surface is but a poor guide to the steaming power of a boiler. A knowledge of its ability and capacity to burn coal is a much better index of the power of the boiler to meet the demand for steam. Holding this view, it appears to be an opportune moment to provoke an exchange of opinion upon the subject amongst the members of this Institution, and the following remarks may provide a peg for boiler users to ventilate their views upon the true value of heating surface.

Heating surface is the passage way for the flow of heat from the products of combustion to the water. It has been very generally assumed that the greater the extent of this heating surface the greater will be the efficiency of the boiler. It is analogous to argue that the number of blank cheques in one's possession is the true measure of wealth. Cheques are an expensive luxury if the balance at the bank is zero, and so is an acre of heating surface without a store of heat energy.

The heat energy of the fuel passes into the water partly as radiant heat and partly by conduction. Probably nearly one-half of the total energy reaches the water through the sides of the fire box. This proportion is modified by the thickness of the fuel bed and the character of the combustion. This will be evident when it is realised that the exposed surface and temperature are not much increased by thickness. Thus in the case of a thick fire there will be more heat carried into the flues than when the fire is worked thinner. The amount of radiant heat expressed in Br: Thermal units per square foot per hour is given by (Stefan's law)—$16 \times 10^{-10} (T^4 - t^4)$; where T is the temperature of the radiating surface, and *t* the temperature of the boundary expressed in degrees absolute Fahrenheit's scale. This formula illustrates the importance of a hot fire, and contains much of interest to the engineer in search of a low coal bill. The tube surface receives comparatively small quantities of radiant heat, as this surface is usually screened (or in a shadow) from the direct radiation of the incandescent fuel in the furnace.

The efficiency of the tube surface may be expressed thus—

$$E = 1 - e^{-\frac{cl}{m}};$$

where C is a constant, l is the length of the tube, and m is the hydraulic mean depth. It should be noted that the area of the heating surface is not so directly of importance as the way in which it is arranged. In order that E may be large, $e^{-\frac{c}{m}}$ must be large so that for any particular set of conditions m should be relatively small, and for tubes of circular section $m = (d \div 48)$ feet, where d is expressed in inches. Hence small diameter tubes will be the more efficient. For example, a 6 ft. tube 1 in. diameter is equally efficient as a 12 ft. tube 2 in. diameter; the tube surface for the 6 ft. tube = 1·57 square feet, and for the 12 ft. tube the surface is 6·28 square feet, *i.e.*, four times as much!

This is but another way of stating that for heating surface to be efficient it must be well scrubbed by the products of combustion on the one side, and by the water on the other side. Prof. Nicolson's experiments upon boilers, Jordan's experiments on tubes, Dr. Stanton's condenser experiments, and others all prove the validity of this conclusion. How often one hears the comment that "it is the wind that makes it so cold to-day." The scrubbing is so effective!

There are many types of boilers in actual use which differ greatly in the ratio of the heating surface and fire grate area, and yet, in spite of these variations, the recorded efficiencies do not differ much. In fact, it is often said that one type of boiler is as good as any other if judged solely by its efficiency as a steam generator, and an examination of many test records serves to make this statement appear quite reasonable. For example, compare the following:—

	HS/GA.	Coal per sq.ft G.A. per hr.	Water from and at 212° per lb. of coal	Water evap. per sq. ft. Heating surface per hr. from & at 212° F.	Efficiency.
Lancashire type ..	47·3	28 lb.	6·5 lb	·3·86 lb.	73·6 p.c.
,, ,, ..	,,	24½ ,,	9·5 ,,	4·91 ,,	76·5 ,,
,, ,, ..	,,	24½ ,,	10·0 ,,	5·42 ,,	80·3 ,,
Locomotive type ..	68·2	35½ ,,	12·2 ,,	6·20 ,,	80·7 ,,

Here, if heating surface is all important, the locomotive had the advantage of over 46 per cent. over the Lancashire, but the efficiencies do not differ by much.

From the same records an average of 40 tests on Lancashire boilers, the average efficiency attained was 64·2 per cent., with a best of 73 per cent. As the result of an examination of 377 tests on many types, Mr. Bryan Donkin plotted a curve of efficiency and water evaporated per square foot of heating surface per hour giving mean values and maximum values, and this curve is a very suggestive commentary.

In all such tests where the necessary data has been recorded it is quite clear that the efficiency of a boiler, considered as a transmitter of heat from the gases to the water, is a *constant* quantity, and the variable factor is the *furnace* efficiency. Each variety of coal requires its own special treatment in order to obtain the best results. Variations in the air spaces between the fire bars, slight as they frequently appear, will make an enormous change in the resulting efficiency of combustion. There is some rate of combustion that will give the best results which must be determined carefully if the maximum efficiency is desired. In a word, it is imperfect combustion that brings down the boiler efficiency.

The rate of combustion is usually given per square foot of grate, but for some years the author has felt that there must be some relation between the volume and form of the furnace and the weight of fuel that may be successfully burned, quite as important as the quantity burned per square foot of grate area. So far, however, there are too few experiments on this point recorded to enable any satisfactory deductions being made. Probably the most conclusive are the experiments made upon a locomotive at Altoona, which have been carefully analysed by Mr. L. H. Fry, from whose figures the following have been taken:—

Area of Fire Grate	sq. ft.	55·5	39·5	29·8	55·5	39·5	29·8
Total Coal burned	lb.	2000	2000	2000	3000	3000	3000
Coal per sq. ft. Grate per hour	lb.	36·54	50·6	67·2	54	75·9	100·8
Furnace Efficiency	per cent.	88·0	90·8	89·7	81·2	82·5	81·2
Transmission ,, ...	,,	79 2	79·1	79·7	78·8	79·4	79·6
Boiler ,, ...	,,	69·7	71·8	71 5	64 0	65·5	64·6
Evaporation ,, ...	,,	66·4	68 4	68·1	61 0	62·4	61·5
Evaporation from and at 212°.F. per lb. of Coal	lb.	10·20	10·20	10·35	9·33	9 30	9·13

Area of Fire Grate	sq. ft.	55·5	39·5	29·8	55·5	39.5	29·8
Total Coal burned	lb.	4000	4000	4000	5000	5000	5000
Coal per sq. ft. Grate per hour	lb.	72·1	101·2	134·5	90·1	126·6	168
Furnace Efficiency	per cent.	75·3	75·70	74·30	70 4	70·2	68·6
Transmission ,, ...	,,	78·6	79·4	79·1	78·3	79·2	7·88
Boiler ,, ...	,,	59·2	60·1	58·8	55·1	55·6	59·4
Evaporation ,, ...	,,	56·4	57·3	56 0	52·5	53·0	51·5
Evaporation from and at 212°.F. per lb. of Coal	lb.	8·62	8·55	8·50	8·04	7·90	7·84

From the results the transmission efficiency varies from 78·3 per cent. to 79·7 per cent., with an average value of 79·1 per cent., and this between the limits of 36·5 and 168 pounds of coal per square foot of grate per hour! Hence it is clear that the boiler transmission efficiency is constant. The efficiency of the combustion varies between 90·8 per cent. and 68·6 per cent., and the varying rates per square foot of grate do not seem to affect this efficiency so long as the total weight burned in the fire box remains the same; consequently, the evaporation per pound of coal does vary much.

On this point some experiments by Mr. Isherwood are worth study. These experiments contain a series in which the grate area was reduced, and the total coal burned proportionately reduced; two series are recorded which differed only in the amount of coal burned. The following results have been extracted:—

Grate Area.	Combustible burned.		Evaporation from and at 212° F.		Evaporation per hour per sq. ft. o	
	Total.	Per sq. ft. G. A. per hour.	Total.	Per lb. of Combustible	Grate.	Heating Surface.
36 sq. ft.	711 lb.	19·75 lb.	6740 lb.	9·48 lb.	187 lb.	7·1 lb.
30 ,,	535 ,,	17·82 ,,	5773 ,,	10·79 ,,	192 ,,	6·08 ,,
24 ,,	424 ,,	17·68 ,,	4884 ,,	11·52 ,,	203½ ,,	5·14 ,,
18 ,,	344 ,,	19·10 ,,	3963 ,,	11·52 ,,	220 ,,	4·17 ,,
13½ ,,	257 ,,	19·02 ,,	2896 ,,	11·27 ,,	215 ,,	3·05 ,,
36 ,,	282 ,,	7·84 ,,	3510 ,,	12·45 ,,	97·6 ,,	3·69 ,,
36 ,,	473 ,,	13·13 ,,	5440 ,,	11·50 ,,	151 ,,	5·73 ,,
30 ,,	259 ,,	8·65 ,,	3210 ,,	12·20 ,,	107 ,,	3·38 ,,
24 ,,	269 ,,	8·71 ,,	2436 ,,	11·65 ,,	101·5 ,,	2·56 ,,
18 ,,	152 ,,	8·43 ,,	1895 ,,	12·29 ,,	105·3 ,,	1·99 ,,
13½ ,,	109 ,,	8·08 ,,	1366 ,,	12·53 ,,	101·2 ,,	1·44 ,,

There were some experiments made upon water tube boilers which gave very similar results, and need not therefore be quoted. An examination of the results show that with each reduction of grate area the evaporation per pound of coal steadily improved until the last two experiments were reached in the first series, and here probably the volume of the fire box was too small to give the best results with the total weight of fuel burned, as in the second series the same grate areas when *less* fuel was burned a greater evaporation was secured. Unfortunately the records available do not give any information about the efficiency of combustion or the excess air admitted, etc., so that these experiments are of less value than the Altoona experiments quoted.

Some experiments made upon a locomotive boiler, divided into compartments in which coal and water are recorded, thus enabling the relative values of the fire box and tubes to be measured:—

Draught.	Coal burned per hour. Total. lb.	Coal burned per hour. Per grate area. sq. ft. of grate area. lb.	Water evaporated per hour. Total.	Per sq. ft. Grate.	Per sq. foot Heat Surf.	From and at 212° F. per pound of coal.
0·79 in.	476·2	53 9	3602 lb.	400 lb.	4·55 lb.	9·00 lb.
1·57 ,,	743 0	82 6	5110 ,,	568 ,,	6·45 ,,	8·19 ,,
2·36 ,,	923·7	102·6	6997 ,,	777 ,,	8·83 ,,	9·02 ,,
3·15 ,,	1025·0	113·9	6990 ,,	773 ,,	8·82 ,,	8·12 ,,
3·34 ,,	978·8	108 8	7984 ,,	887 ,,	10·08 ,,	9.71 ,,

Draught. ins.	Coal burned per hour. Total. lb.	Coal burned per hour. Per sq. ft. of grate area. lb.	Water evaporated per hour. Total. lb.	Per sq. ft. of grate. lb.	Per sq. ft. heat. surf. lb.	From and at 212° per lb. of coal.
0·79	388·0	43 1	3278	364	7·73	10·06
1·57	610·7	67·9	4240	471	10·00	8·27
2·36	707·7	78·6	5619	624	13·25	9·45
3·15	793·6	88·2	6252	594	14·75	9 38
3·94	848·8	94·3	6886	765	16·25	9 66

In the first set of experiments the whole of the heating surface was in use, the ratio total heating surface ÷ grate area = 88; and in the second set half the tubes were stopped up, where the ratio was reduced to 47. Notwithstanding this great change in the proportions, the evaporation per pound is greater uniformly with the reduced heating surface. There are some sets of experiments by Isherwood which show this increased efficiency with a reduction in the tube surface, and it is pertinent to ask how the safety valve rule referred to at the beginning of the paper would answer in this case. Take the boiler as it was in the first series, then its heating surface was 792 square feet, so that the area of safety valves $= 792 \times \left(\frac{1\ 25}{80 + 15}\right)$ $= 10{\cdot}42$ sq. ins. or 3·64 ins. diameter. In the second case with half the tube surface then this formula would give the safety valve area $= 424 \times \left(\frac{1{\cdot}25}{80 + 15}\right) = 5{\cdot}580$; or 2·66 ins. diameter.

Heating surface.	Safety valve area.	Max. evaporation.	Weight of evaporation per sq. in. of S.V. per hr.
792 sq. ft.	10·42 sq. in.	7984 lb.	766·1 lb.
424 ,,	5·58 ,,	6886 ,,	123·4 ,,

A rule which gives results of this character is one that can hardly be deemed entirely satisfactory, and points to the desirability of returning to the notion that the maximum rate of evaporation depends upon the maximum capacity of the furnace to liberate heat energy. The area of the fire grate is surely the measure of the safety valve area.

A study of boiler performances includes an examination of the effect of change of velocity of the gases in the flues. A pound of coal requires roughly about 11 pounds theoretically for its complete combustion, but the practical impossibility of securing 100 per cent. efficiency of mixing of the products of combustion and the air it is necessary to supply an excess of 60 per cent. and upwards, depending upon the draught conditions. There is, therefore, usually some 20 pounds of flue gases per pound of coal burned which must pass through the flues. It is, therefore, clear that the flue area per square foot of grate will be some index of the velocity of the gases in the flues. The experiments on the locomotive boiler just referred to supply some information upon this point. An examination of the table shows that the rate of evaporation was very much increased from the tube surface as well as from the fire box plates. The second set of experiments, with half the tubes stopped, the velocity of the gases must have been nearly doubled.

Total Coal burned per hour.	Evaporation in pounds per hour.												
	From Fire Box.		Total from Tubes.		1st Section.		2nd Section.		3rd Section		4th Section.	
	Total lb.	per sq. ft. lb.			Total lb.	Per sq. ft. lb.	Total. lb.	Per sq. ft. lb.	Total lb.	Per sq. ft. lb.	Total lb.	Per sq. ft. lb.
476·2	1806	23 5	1796	49 8%	964	5·4	445	2·5	240	1·33	147	0·83
743 0	2356	30·7	2754	53·9%	1368	7·6	735	4·1	387	2·15	264	1·48
923·7	2933	38 2	4064	58·0%	1969	11 0	1025	4·5	645	3·61	425	2·38
1025·0	3291	42·9	3699	52·9%	1778	9 8	920	5·1	579	3·24	422	2·36
978·8	2981	38 9	5003	62·6%	2499	14·0	1228	6·8	774	4·32	502	2·81
With half tubes stopped.												
388·0	1811	26·5	1467	44·7%	803	9·0	356	4·0	191	2·09	117	1·31
610·7	2057	30·1	2183	51·5%	1138	12·8	550	6·2	308	3·37	187	2·09
707·7	2710	39·6	2909	51·7%	1448	16·2	722	8 1	449	4·90	290	3·24
793 6	2979	43·6	3273	52·3%	1624	18·1	845	9·5	475	5·18	334	3·75
848·8	3058	44·7	3328	55 6%	1874	21·0	948	10·6	580	6·34	425	4·76

The general results are most clearly shown by means of curves. A method sometimes adopted to increase the scrubbing action of the flues by the hot gases is the use of retarders and ferrules; the former is arranged so as to cause the gases to flow in a spiral path, whilst the latter throttle the entrance to the tubes, causing eddies and thus tending towards a more efficient contact between the tube surface and the hot gases. Isherwood's experiments give the following results:—

	Area of Flue-way.	Coal per sq. ft. of Grate.	Water from and at 212° F. per pound of combustible.
	sq. ft.	lb.	
No Ferrules.	0·99	16·57	8·33 lb.
Ferrules $\frac{3}{16}''$ thick	0·738	16·53	8·58 ,,
,, $\frac{7}{16}''$,,	0·460	16·61	8·56 ,,
,, $\frac{3}{4}''$,,	0·204	5 79	11·07 ,,

Isherwood's Experiments on varying the Tube Surface. Grate Area = 10·8 sq. ft.

Heating Surface.		H S ÷ G A	Area of Flue-way.	Coal per sq. ft. Grate.	Water from and at 212° F. per pound of combustibles.
			Sq. ft.	lb.	
Normal	150·30 sq. ft.	14	0.99	16·5	8·33 lb.
	125·10 ,,	11·58	0·64	16·5	8·13 ,,
	99 91 ,,	9 25	0 495	16·5	8·75 ,,
	74·72 ,,	6·92	0·25	16·5	8 94 ,,
	125·10 ,,	11·58	0·64	13·75	8·41 ,,
	99·91 ,,	9·25	0·495	11·03	8·95 ,,
	74·72 ,,	6·92	0·25	7·48	11·00 ,,
All Tubes stopped	45·5 ,,		0·721	16·57	6·325,,
	45·5 ,,		0·510	16·58	6·34 ,,
	45·5 ,,		0·248	11·77	7·79 ,,
Grate area = 8·64	149	17 24	0·99	15	9·11 ,,
,, = 8·64	149	17·24	0 99	20·73	8·34 ,,
,, = 6·48	148	22·84	0·99	15	9·16 ,,
,, = 6·48	148	22 84	0·99	27·42	8·08 ,,
,, = 4·32	147	34·03	0·99	15	9·68 ,,
,, = 4·32	147	34·03	0·99	27·58	8·17 ,,

These results are in accord with those previously cited, and the safety valve rule quoted appears to be quite inadequate to deal with the relief of boilers in its present form. There are many other boiler trials reported by Bryan Donkin, D. K.

Clarke and others which confirm those given, but have not been quoted, as they do not add any fresh points. Water tubes would appear to be more efficient than smoke tubes, as arranged in the boilers, but in the absence of fuller particulars concerning the details of the combustion efficiencies in the several cases the superiority noted may be more apparent than real.

As bearing upon the question of the disposition of heating surface, two boilers described by Mr. Vaughan Pendred may be cited. In one of these heating water by means of gas burners, the flues were 7 inches long, $\frac{1}{4}$ inch wide by 5 inches deep, and the temperature of the gases after passing through was about 160 deg. to 180 deg. F. The second boiler was fitted with short tubes of about 1 inch outside diameter and 1 foot long, and some excellent results were obtained from it.

The author trusts that enough has been said to enable the value of heating surfaces generally to be discussed, and a clearer view of its practical limitations to be realised by boiler designers and users.

The CHAIRMAN: I am sure we have all listened with attention to the excellent paper we have had from Mr. Wells. The whole subject bristles with information to all engineers, and I hope that some of the members present will lose no time in making some remarks.

Mr. R. BALFOUR: I endorse the Chairman's remarks. Although it is a short paper, there is ample matter for discussion, particularly as it touches upon fuel combustion, and in this connection I would commend to the members a most interesting lecture by Mr. David Wilson, Technical Adviser to the Coal Controller, delivered at St. Bride's Institute, and published in *Engineering*, October 18th, 1918. At no time in our history has there been greater need for studying the economy of fuel than now. I would rather defer further remarks and communicate them by correspondence, meantime thanking the author for his interesting contribution.

In further commenting on Mr. Wells' paper, Mr. R. Balfour added, by correspondence: Many important points arise from thinking over this interesting paper, but I must confine myself in my observations mainly to the efficiency of the fuel consumption.

The author has thought fit to make his comparison between boilers of the Lancashire and locomotive type respectively, and whilst the marine type would probably have been more to the taste of the members present, no doubt he had his own reasons for offering the figures, which we find no less interesting as a basis for discussion.

An important point at once manifest is that in spite of the wide difference in the ratio of heating surface to grate area wherein the locomotive type has the apparent advantage of 46 per cent., the efficiencies are nearly equal. Is this not due to the fact that the Lancashire is fully clothed in insulations? *i.e.*, by the brickwork setting and the upper surface with the usual covering, whereas the locomotive type is necessarily deficient in this protection.

The particulars of the experiments on the locomotive boiler where the restricted heating surface is compared with the full surface to the advantage of the former, is of the utmost interest, and to my mind therein lies the key to the cause of the inefficiencies of fuel combustion.

Whilst agreeing with the author in all he says as to the "scrubbing" of the gases on the surface of the tubes, is not the real reason of the equal and ever increased efficiency shown by this test to the boiler with half its surface throttled, due more to the reduction of the actual volume of the gases passing through the boiler, or, in other words, the reduction of the *excess air* that finds its way into a furnace where no restriction is offered to the volume of air supply for combustion, and this raises an important point which should be taken up by some of the members of the Institute—namely, a close investigation into the regulation of the proper air supply to suit the given amount and quality of fuel it is desired to consume on any given furnace.

In connection with this I hope due consideration will be given to the employment of pyrometers, CO_2 Recorders or analysers, draught gauges and ashes, without which no useful data can be obtained. It should be the prime duty of all engineers in charge of steam boilers of any kind to eliminate all air other than that actually required for the practical combustion of the fuel—excess air may be termed the "Kaiser" of the boiler, and if 10/11 lbs. air is only consumed in the chemical combustion of 1 lb. coal, why should we allow sometime 2/3 times this quantity free access to the furnace?

Much prominence has recently been given to the value of the analysis of flue gases. The existence of 20 per cent. of CO_2

gives ideal conditions or complete combustion, but for practical purposes we must leave this out of the question. However, an attempt to obtain the next best should be made.

The following figures may be taken as the approximate position of affairs:—

20 per cent. CO_2	Complete Combustion
16 per cent. CO_2	10 per cent. of fuel lost
12 per cent. CO_2	15 per cent. of fuel lost
9 per cent. CO_2	20 per cent. of fuel lost
6 per cent. CO_2	30 per cent. of fuel lost
4 per cent. CO_2	45 per cent. of fuel lost

If a test or series of tests could be made we would doubtless realise the great waste of fuel.

In connection with this, I append an extract from *Power Plant and Engineering*, of October, 1918, which may be of interest to the members.

In conclusion, if the present paper is the first of a series which the author intends to give us, I am sure that I voice the majority when I say that the second edition cannot come too soon. Mr. Wells is ably fitted to deal with the subject.

CO_2 Per Cent. Doubled in an Hour.—I am not much of a hand for writing testimonial letters, but I made a test yesterday that just goes to show how easy it is to save coal if you put your mind on it and have the aid of Vulcan appliances. I stepped in at the Y.M.C.A. College, as I had promised the engineer that I would help instal the gas analyser I sold him two weeks ago, along with a draught gauge. They have two Scotch marine boilers with McMillan furnaces, and they had always considered their plant pretty efficient. He had the draught gauge already connected when I came, and it showed about three-tenths of an inch draught. He had fixed the pipe, to which he could attach the gas machine, and so we were all ready to start taking the first sample of gas. This showed that he was getting 4 per cent. CO_2 instead of the 14 per cent. that he confidently expected. The figure appeared to be too low, so we took another sample, but it showed the same. I then traced the pipe back to where it was getting the gas, and found that it was too close to the damper. I put it in a little further and took another sample. This showed a trifle over 6 per cent., and although we took a number of samples at intervals of two or three minutes, the figure stood at the same mark.

A peep into the furnace showed bad holes in the fire. I smoothed these over with a poker, making the fire bed as even as possible, and then took another sample of gas. This showed that he was now getting 8 per cent. CO_2, so we began to look around for something that would increase the percentage still more. His draught still stood at three-tenths of an inch, and we began experimenting with the damper. We reduced the draught a trifle and took another sample. This showed a little better than 9 per cent., so we knew that we were in the right track. We reduced the draught to 0·015, and the next sample jumped the CO_2 to above 11 per cent. Not getting it above this point, we looked for other causes, and found that there were air leaks around the plate in the rear of the boiler. The furnace setting was far from being air-tight, and these leaks probably accounted for a considerable per cent. of waste. The steam gauge before we started to take a sample of gas said 60. When he got through it showed 85 lbs.; this increase of 25 lbs. was without adding a single lump of coal. On the basis of 11 per cent. CO_2 the engineer sat down and figured out how much coal he could save in a month. When he got through he announced the result as 56 tons. As the instrument cost him $35 and the draught gauge $16, you see that he saved the price of the instruments in about a week. This is what it does in a small plant; and it is easy to figure what it will do in a plant where the coal consumption runs much higher.

LOUIS SIMONS.

Later, when the air leaks had been thoroughly stopped and further attention had been given to the draught and fire, the average reading of CO_2 ran near the 14 per cent. mark; and there it has continued to stand, simply because boiler room efficiency has been brought up to a high degree, and engineer and firemen have learned what is possible.—Editor, *Power Plant and Engineering*.

MR. B. P. FIELDEN: I share Mr. Balfour's views. I should have felt more at home if Mr. Wells had dealt with marine boilers rather than locomotive.

I do not know whether the author assumes that the Committee that are settling the size of safety valves are settling the size for locomotive or Lancashire boilers. I happen to be one of the members representing the Institute of Marine Engineers on the committee to which Mr. Wells referred, "The British

Marine Engineering Design and Construction Committee," and they have recommended the formula, which Mr. Wells gives in his paper, for the size of safety valves, but so far they have only dealt with marine boilers of the tank type. Up to the time this committee met the size of safety valves was settled by the area of fire grate. The fire grate is a very variable quantity, and there is nothing definite about it; it can be increased or decreased, and it is a variable quantity which in my opinion we ought not to have in an engineering formula if we can have something better.

The committee took the view that the most satisfactory way of settling the size of safety valves would be to base it on something which could not be altered, and that was heating surface.

The Board of Trade have had very many years experience of safety valves, and so have Lloyds and the other Registration Societies, and their experience was placed before the committee.

The safety valve, as the name implies, has to be fitted for safety purposes, and we do not want to cut down this size to the lowest limit.

If one has to settle the size of the safety valve on the efficiency of a boiler, what does that amount to? The shipbuilder has to order his safety valves when building the ship, and cannot wait until the efficiency of the boiler is discovered. Then, again, as regards fixing the size by the amount of fuel burnt, we have now arrived at a stage where we burn oil as well as coal; some ships start off on a voyage and burn coal part of the way and then change to oil. What is the fire grate area in that case?

The figures given in the paper are very interesting, but are more than I can tackle now, and I do not propose to offer many criticisms. I will just make this general statement, that the coal burnt per square foot of fire grate according to the figures given is a constant quality coal; we have not a constant quality coal—we are given all kinds of coal, good and bad, and this also applies to oil.

Both coal and oil vary in different parts of the world in calorific value, and the sizes of safety valves have to be arranged to suit all conditions. They are very similar to other things fitted into a ship, viz., approximations to suit different circumstances.

The Board of Trade fixed their sizes of safety valves from the results of accumulation tests; the stop valves of the boilers were shut down and the fires were continued to be forced and the safety valves had to be a sufficient size to prevent an accumulation of pressure beyond 10 per cent. The accumulation test is rather a hard test on safety valves, as it is not likely that a boiler in the ordinary way would be worked under such conditions, but on the other hand it is a safe test, and provides against extraordinary things happening.

With regard to retarders, I think most of us have been using these for years, and I think Mr. Wells will agree with me when I say the area through the tubes in most boilers is much larger than it need be. Some boiler designers, when high power is wanted on light weight of boiler, put in a fairly large proportion of the heating surface as tubes. By plugging up some of the area of the tubes and fitting retarders in them an advantage is gained in two directions, firstly by shutting off part of the unnecessary area, and secondly, by having the heat travel round a spiral so that the heat is deflected against the metal of the tubes.

I have tried different types of retarders, but found the best to be those which were made of twisted steel about two-thirds the length of the tube. If the retarders are kept too close to the combustion chamber they are apt to choke the tube if the latter leaks at all.

Mr. W. McLaren: I certainly have to thank the author for his Paper. With regard to the safety valve question, no matter what class of boiler it is, in my opinion that boiler should be tested with the best quality of coal and not allowed to pass the examination until put under a test at the hardest firing, and when it gets up to the estimated pressure, that of safety, it should then blow off; and when dampers are shut and everything closed up, it may still blow off steam and be quite safe. The extra amount of steam should be gone in the very shortest time, I think in somewhere about 10 to 20 seconds. But when we get into port under certain conditions a hullabaloo goes up from the valves, we cannot hear one another, neither can the skipper hear the calls from the shore on the ship for the steam blowing off. That may repeat itself from time to time for, say, fifteen minutes. Then we have been presented with the locomotive and the Lancashire types. No matter what the kind of boiler, if you put four tubes into the heating surface, no amount of comparison will determine what the boiler might return in evaporating the water into steam, as it is the amount of heating surface you can get into it, and the freedom that the gases may have to circulate, with the scouring action that the author of the Paper speaks of—that is the secret of tube efficiency. I understand that the retarders in the spiral condition give the best efficiency, no doubt they found that out and put these retarders in the tubes, because they got the best condition. In the locomotive boiler we have all the tubes in it, and the size of the furnaces with a good depth from the furnace tube crowns of fire box to the fire bar level, which I think we neglect to consider. You can have a certain amount of grate area, but that might be at the crown of the fire box, or half way down, or wherever it may be placed. There is some sufficient distance from the heating surface to a fire grate that gives the best effect. We see that if we take any marine boiler and put the furnace bars across at a certain circumference of the tube, and we generally give them a certain amount of slope to the back of the grate—the coal is burnt better at the end of the fire bar which is close to the bridge. Why? Because it is the hottest end. Therefore that heating you get helps to burn some of the gases; it leaves the grate and it goes over the bridge. In some experiments I made, instead of shortening the grate I narrowed it and dropped it down, and thus got better results. That was reducing the grate area in one way. But instead of 15 or 20 inches or so from the fire bar, it gives somewhere about 25 to 30 inches. Therefore, we had that depth and had the benefit of more clearance, even with a 6 inch or 9 inch coal fire on top of the grate. Then we also had that grate wall of firebrick, which varies greatly, I may say, in furnaces, either to its betterment or detriment; and we start, with a brick bridge, say, 8 inches from the crown and go down somewhere about 12 inches; it depends whether your fires at that surface will either induce a false draught or a natural one. That is my experience, and some day at a very early date I will make more experiments and keep a record of what I am able to do. Whatever boiler you have, whether locomotive or marine and wherever the combustion chambers and tubes are situated, there are tubes which you can block up, as no doubt some are very excessive; that is where trial and error come in. With the variations in coal that one gets from time to time, I have no doubt all these difficulties occur whether it is anthracite or Welsh or bituminous coal, difficulties which you cannot get over in a few moments. There is one other point I might bring before your notice. The Coal Controller at the present time is making a great point of coal economy in boiler plants, and there are 400 gentlemen going about the country at the present time and getting into communication with engineers, I must give them that credit, in the initial stage. There is no doubt that they are all expert men and have, I believe, given their services free, so that it costs the country nothing. They will give you any advice you ask for and assist you in any way possible. No one needs to be frightened to put a question to them, or to coincide with their views. The point I wanted to bring forward was with regard to reduction of the grate bar. We have a boiler that does some very hard steaming for about three hours in one part of the day and the other part of the day it runs a 25 h.p. engine. To meet this we take a bit of sheet iron, cut it to half length, and put it up against the back part of the grate, leaving the clinker and ash on it and only fire on the front of the grate. Putting in this damper under the conditions the boiler would be running in, we made about 8 per cent. CO_2 by that simple method. You could take the other half piece of sheet iron and put it into the other furnace. You might adopt that means of economising coal if you were running under good conditions. It will act as a damper plate as long as you get that CO_2. You have two lengths of bars, because the bearer bar makes a nice projection for the plate to lie up against. I might add it is like an ash pit damper under the fire bars on the same principle one adopts on the front end of the furnace tube to check the air supply.

Mr. H. Owen: I would like to say a few words in reference to the author's statement as regards increasing the fire grate in order to enlarge the efficiency of the boiler. Mr. McLaren referred to some of the inspectors going round and advising one to reduce the fire grate surface. I think if we take the author's idea of the thing, without taking some other method of increasing the heating surface of the boiler, as engineers we are likely to get into trouble for burning more coal. I can vouch for certain ships that have been crossing the Irish Channel for the last twenty years. Some years ago an experiment was made as regards reducing the coal consumption on those ships, and it was found that they could be run at a speed of 22 knots across the Channel with only half fire grate surface; that was by using the clinkers and banking them up and causing a general heat to be generated at the back of the furnace. There were also experiments with spiral retarders. They used to take from 60 to 70 tons every time they crossed the Channel; they cut it down to 35 tons, and those ships have been going across the Channel on that consumption for the last fourteen years to my knowledge.

Mr. J. Thom: We must thank Mr. Wells very much for his excellent theoretical and practical paper. Probably the theoretical side may be a little more than the average engineer has to contend with in everyday work, but as brought forward by Mr. Wells there are a good many points on which he is not satisfied that the marine engineers are doing the best they can with the fuel in their boilers. Probably all the points he brings up, or many of them, are not quite applicable to the marine boiler, but possibly quite applicable in cases such as the locomotive boiler. We all know a locomotive boiler is a different boiler from any other, and that the surfaces he has been speaking of with regard to efficiency are entirely changed when the boiler is in motion on a railway than when standing still. There is no question it is the most efficient boiler in the world when at its work for its size and surfaces. But the reason of this is not quite because of extra draught or other details like that, but simply because of the agitation and the knocking effect given to the boiler, which assist in getting the globules of steam to leave the heating surfaces more freely than they would do if the boiler was at rest. When this action is going on ebulition is much more free. As far as I can follow at present the marine boiler is very different in many ways from the comparisons given in some of these tables. You reduce the consumption per square foot of grate, but leave the other surfaces the same. While using a good grade of coal you could reduce the fire grate, but when using inferior coal you require the fire grate at its utmost size. The marine engineer very seldom gets boilers on board where it is necessary to reduce the utmost steaming capacity. Usually they are worked pretty well at full power all the time. Generally you cannot make too fast a voyage—that is the way to put it; you can go too fast for the quantity of coal you have on board, but never get too quickly to the next port. Of course, one sometimes has to run to booked times, like a train, but as a rule this is not necessary with the average vessel at sea.

Mr. Wells gave us a blackboard sketch illustrating the flow of gases by comparing them with liquids. Well, now, I don't quite agree with him there. The laws appertaining to the flow of liquids are quite different from gases, although there might be some resemblance. I think you must also take the density of the liquid into consideration, and the pressure.

With regard to the size of the safety valve, the rule has been, as far as I remember, that safety valves may not be made less than 2 ins. diameter; after that they go up in proportion to the heating surface. The various principles in stoking during the last twenty years have changed very much. Forced draught has come along, and the rate of burning fuel per foot of grate has increased radically. Also, the marine boiler has to be made suitable to burn inferior coal in any country or in any climate, which complicates the difficulties. If you are in a country with a mean temperature of 60° to 70° F. it is easy to make arrangements for burning inferior coal, but if you are in a tropical country where you have 120° half the day and not less than 90° at night, it is a very different matter, and all the rules which hold good in one place will not do so in the other. The marine boiler has to be fairly efficient under all these conditions.

We must thank Mr. Wells very much for bringing such an excellent paper before us, and for making us think seriously in figures. Mostly the marine engineer does not like to do so, but he is forced occasionally, and I think it is good that he has to do so.

Mr. FIELDEN: With regard to what Mr. Wells said about Mr. Isherwood's figures, I disagree that half the heating surface was cut out. If half the tubes are closed up, it does not follow that half the heating surface is cut out. I think the whole thing hinges on what is effective heating surface in any one boiler and what is not.

Heating surface is estimated in marine work to be the heating surface up to the front tube plate, but there is a degree of efficiency of heating surface, and the rule for safety valves might have been based on the heating surface of combustion chambers and furnaces only, but the rule for size of safety valves has to be elastic to suit all designers of boilers, and, therefore, all heating surfaces were included.

I think it would do good if records were kept of marine boilers. Tubes are swept or scraped internally, retarders are used to obtain a scouring action; but what goes on outside the tube? Furnaces and combustion chambers are scaled and kept clean, but the tubes gather scale until it is often $\frac{1}{4}$ in. thick, because it is very difficult, and often an impossibility to clean them properly.

We ought to get some information as to the true value of the heating surface of tubes in marine boilers, and our sea-going members might help us in this matter.

The CHAIRMAN: I am sure we are all very much indebted to Mr. Wells for this most instructive paper. Some criticisms have been made with regard to deductions made from experiments of locomotive boilers. I think marine engineers are in a great measure to blame for this. The data presented to us here has never been attempted to be taken from marine boilers. The experiments and deductions that Mr. Wells has shown us are most valuable to marine engineers. The principles of combustion and evaporation are impressed throughout his paper, which is so exhaustive that I could not attempt for one moment to criticise it. I think it would only be justice for all the members who are present to send in written criticisms, and Mr. Wells would reply to these later. In these times it is so difficult to get people together for an adjourned discussion; at the same time, if you wish that an adjourned discussion should take place, perhaps it might be beneficial. Mr. Wells, I think, refers in his paper to the impossibility of having complete combustion in the combustion chambers. That is one of the most important problems in any boiler. Too often combustion is incomplete, probably through defective fire grate, defective air openings and defective capacity in the combustion chambers. My experience so far is that the best combustion, at least in marine boilers, is obtained where you have the large furnace and the large combustion chamber. The question of heating surface has been criticised. Heating surface is, I agree with Mr. Fielden, some guide as to the capacity of the boiler, and I think the committee which has just been sitting on framing a rule for the size of the safety valve have been wisely guided in the decision they have come to. I have no doubt Mr. Wells is absolutely correct, if a fire grate could not be altered, but we marine engineers know that we are altering the fire grate continually, according to the quality of coal and other conditions. You may have a fire grate which is quite ample, say, for the best Welsh coal, but you get into a foreign port and get some muck and dirt that cannot be burned at all without increasing the fire grate. The grate surface is continually varying in marine boilers, but the heating surface never varies, and it is some guide. I agree with Mr. Fielden also that to get the best results on a trial trip, heating surface is often crowded in the boiler in order to make a show on the trial trip. Mr. Wells' illustration in connection with retarding the gases through the tubes is most interesting, and it shows the importance of bringing the heated gases into contact with the heating surfaces. I agree with the speakers who have expressed the opinion that the ordinary spiral retarder has been the most beneficial, at least in the marine boiler. All sorts of methods have been devised: driving ferrules into the tubes, for instance, but they never last any time; they burn out, and often lead to tube troubles in the back end. Mr. Fielden is quite correct when he says these spiral retarders should not be more than two-thirds of the length of the tube. As I said at the beginning of my remarks, I will not attempt to criticise the paper, but if it is agreed that we should read it carefully and digest it, and write something down which will be of value to the discussion, I, for one, will be pleased to do my part of it. I would like the expression of the meeting as to whether we should adjourn the discussion after Mr. Wells has replied.

AUTHOR'S REPLY.

The object of the paper was to raise a discussion upon the value of "Heating Surface," and to make this possible it was necessary to cite actual results in order to make an appeal equally to the so-called practical engineer, and the so-called scientific engineer. The type of boiler best known to the members of this Institute is naturally the "Scotch," but so far as the Author is aware there are very few tests of this type upon record, and none in which the ratio of heating surface to grate area was varied, consequently experiments upon Marine Boilers could not be quoted other than those of "Isherwood." In making experiments upon boilers there are many points that must be watched, and variations in the quality of the fuel, the efficiency of the combustion, quantity of ash, etc., are just as important to record as the weight of fuel consumed, and quantity of water evaporated. Bearing these points in mind, the best series of experiments available appeared to be those examined with great minuteness by Mr. Fry, and surely these results cannot be brushed aside because the boilers tested were of the locomotive type. They appeared to the Author to be very apt, seeing that in that type, the heating surface could be very readily varied without involving expensive structural alterations, and therefore, possibly influence in some way (more or less obscure and difficult to allow for) the results obtained. Besides these reasons, locomotive boilers are not altogether unknown at sea. Further, the question involved was the "value of heating surface," and the Scotch boiler, very closely resembles the Loco. type in the matter of the ratio of tube surface to grate area.

It was difficult to understand why each speaker lamented that reliance had been placed upon locomotive boiler experiments, when those of Isherwood were made upon marine boilers of the multi-tubular type, and interesting to note that each speaker in his way conceded the point that the heating surface provided by the tubes is usually excessive. Upon this point Mr. Fielden states: "I disagree that half the heating surface was cut out. If half the tubes are closed up, it does not follow that half the heating surface is cut out. I think the whole thing hinges on what is effective heating surface in any one boiler and what is not." It would have been very useful if Mr. Fielden had gone on to say how his Committee (which he was defending) had instructed boiler makers and users how to measure the "total heating surface of boilers in square feet," if the *tube surface* was to be *discounted* or *ignored*. Mr. Shanks expressed agreement that heating surface was often unduly augmented by crowding tubes into a boiler. On the whole the Author is satisfied that the members present agreed with him that "tube surface" in boilers is frequently excessive in amount.

The Author does not follow Mr. Owen's remarks. His opening statement reads: "as regards increasing the fire-grate in order to enlarge the efficiency of the boiler." Surely this is a slip of speech, for the Author cannot find in his paper any such statement, but on the contrary many of the experiments referred to cutting down the area of grate provided by the boiler maker, with a resulting increase of efficiency. The Author noted that Mr. Owen's experience confirmed the results given in the paper, as he gives a coal reduction of no less than 50 per cent.!

Several of the speakers referred to the fire-grate as liable to alterations after the boilers are put into commission, a fact that was well known to the Author, also that the fuel was not of constant quality, the latter of course being naturally the cause of the variation of the fire-grate area. Perhaps the Author may be allowed to quote from the *second* paragraph upon this point. "A knowledge of its ability and capacity to burn coal is a much better index of the power of the boiler to meet the demand for steam." This still remains the opinion of the author after considering the views expressed in the discussion. He agrees that the amount of steam produced depends upon the weight of fuel (coal, oil, coke, wood, etc., as the case may be) that can be consumed per hour by the furnace, whatever the grate arrangements at the moment may be, and further this maximum rate of heat production, is (if not should be) well known to the engineers responsible for the construction of the boilers, also those in whose care they are to be placed when in use.

Mr. Thom comments upon the results of the loco. experiments and the Lancashire type, and assumes that the loco. boiler was in motion; but this boiler was tested in a yard quite independently of the locomotive, so that as regards vibration it was upon the same terms as the Lancashire boiler with which it is immediately compared. The Author is afraid that Mr. Thom misunderstood him when speaking of fluid motion, for the beautiful experiment illustrating turbulent motion in the flow of water, was only cited to make quite clear, what was to be understood by the turbulent motion of gases. The boiler user should aim at obtaining turbulent flow in his smoke tubes, and to obtain this condition a high velocity is necessary which connotes a smaller area of tube opening than usually obtains in boiler design. It is this higher velocity of flow that is assured by plugging up the tubes, which leads to the increased rate of evaporation, and not as was suggested less excess air, because the draught conditions, and furnace arrangements were not varied, only the flue area through the tubes reduced. The weight of fuel consumed remaining the same meant that the weight of flue gases passing would remain unaltered.

The Author thanks Mr. McLaren for his experience in the matter of furnace volumes which supports the view expressed in the paper.

The Author appreciated very highly the many kind things said, particularly the form of expressions used, and trust that this considered reply to the chief points raised, will be the best acknowledgment possible of the kind things said.

Contributions to the discussion are invited.

Notes.

DEMOBILISATION.—Attention is directed to the Regulations with the object of obtaining Permits for Engineer Apprentices and Students to return to their work as soon as possible. Application should be made to the Ministry of Labour for Forms R.C.T.V. by employers or principals of the Technical Colleges. These require to be filled in and a copy sent to the Ministry of Labour and a copy to the apprentice or student, who also requires to confirm the application on Form Z.15. The two Forms, R.C.T.V. and Z.15, are compared on being received by the Minister of Labour, who then issues a recommendation to the War Office in accordance with the circumstances of each application. As there is at present no general order for Demobilisation it is important that the applications should be dealt with at once. The importance of this announcement is emphasised in view of the re-institution of the Lloyd's Register Scholarship in connection with the Institute and the examination of candidates in the course of the summer, to give time for preparation and arrangements for entry into the College chosen by the successful candidates.

THE MANUFACTURE OF STEEL.—The following paragraph is from *The Engineer and Iron Trades Advertiser*:—

> Molybdenum is a substance which is playing a part in the present war. Used in hardening the steel which is used in the rifling of the big guns, it is reported to have increased the life of the guns twenty times, and many projectiles are also hardened with molybdenum, as well as a great deal of armour plate which was formerly hardened with tungsten or vanadium. It is estimated, too, that the amount of molybdenum required to harden steel is only about one-half to one-third the amount of tunsten which is necessary to give the same result. The output from the province of Quebec at the present time is perhaps the largest in the world. In 1916 Quebec produced 129,275 lbs., valued at £25,853.

REPATRIATED PRISONERS OF WAR.

Several of our Members who were imprisoned during the war or reported as missing, we are still without definite information regarding them, and we would be glad to hear from their friends on the subject. The following is a list of those who have suffered. We have been in communication with some, but not with all.

* W. J. A. Chisholm,	Member	Jas. Strain	Member
* T. M. McLean	,,	† W. Walton	,,
Alexr. Rolland	,,	* G. M. Wilson	,,
† Geo. Simpson	,,	* F. D. Anderson,	Associate
Arthur Steers	,,		

MR. W. J. A. CHISHOLM.

Among those who have returned home from captivity is Mr. W. J. A. Chisholm, who was second Engineer of the *Saxon Prince* when captured by the *Moewe*, in February, 1916, so that he has had some $2\frac{3}{4}$ years experience of a prisoner's life to relate. Mr. Chisholm was born in 1884, at Cullercoats, Northumberland, where he received his early education, and afterwards extended it at the Sunderland Technical College. He obtained his engineering training at the works of Messrs. Armstrong, Mitchell and Co., and the Sunderland Forge Co. in electrical machinery for four years, and in marine engineering for

* These have returned home. † Missing.

three years with the North Eastern Marine Engineering Co. He joined the Prince Line as a junior engineer, in 1905, and in 1908 passed for his chief's certificate, and was afterwards appointed second engineer of the *Saxon Prince*. He was elected a member of the Institute of Marine Engineers in 1911. He was first taken to Humeln prison camp, thence he was shifted to Ruhleben, then to Brandenberg, to Stroken, to Bad Colberg, and finally to Holland in May, 1918, whence he was liberated by exchange in October.

MR. W. J. A. CHISHOLM.

Mr. W. J. A. Chisholm has related his experience of prison life to *The Marine Engineer and Naval Architect*, and this is here reproduced with his protrait.

When the ss. *Saxon Prince* was sunk by the German raider, S.M.S. *Moewe*, 500 miles W.S.W. of the Fastnet, at 6.30 a.m. on February 25th, 1916, I was taken prisoner, with others, and on reaching the raider we were placed in the for'd 'tween deck with a guard over us. During the ten days' stay on the *Moewe* we were allowed, when circumstances permitted, to exercise each day for about ten to twenty minutes on the after deck.

The raider was a ship of apparently about eight thousand tons, with a very good speed, and was in course of construction when war broke out, being intended for the fruit trade, probably for carrying bananas, by the look of her internal fittings. The Germans were most particular that no one saw inside the engine room. I asked several times for permission, but was refused. The ship had apparently been of the flush deck type, but on being taken over by the German naval authorities some slight alterations were made to the deck structure, and a forecastle head and poop had been constructed. Under the forecastle head were concealed two six inch guns, one on the port and one on the starboard side, just abaft this on the fore deck were two more six inch guns, one on each side, also two eighteen inch torpedo tubes.

The torpedo tubes had apparently been fitted before the raider left port, then dismantled and again placed in position after the vessel had reached a suitable position at sea, for all the plates on the deck carrying the torpedo tubes were secured by bolts and nuts and not riveted, as the rest of the deck was. The compressers for the torpedo tubes were fitted in one of the deck houses, on the starboard side, abaft the engine room casing. On the poop a 4·7 gun was fitted, which was camouflaged to look like a hand steering gear, the gun being pointed forward, and a hand steering gear box placed over part of it with the barrel projecting through. A hand wheel, made in two parts, was fitted on the end of the barrel, and at a short distance the 4·7 would certainly be taken for hand steering gear.

On the after deck existed an arrangement, carried on the port and starboard side, for laying mines; this could be readily unshipped when not in use, and I think there must have been some similar arrangement fitted in the poop, as no one was allowed to go there. In the 'tween decks quite a large number of ring bolts were fitted, which had been used for securing mines and torpedo tubes, and the hoists used in normal times for discharging the fruit was fitted with electric motors and served as hoists for the mines, etc. The raider could be made to look like a well-deck ship in a very few minutes, by a series of thin plates, always kept handy, which were fitted with hook bolts and easily hung on the rails.

Graf. von Dohna, who commanded the *Moewe*, was a man of few words, and I understood the officers never had any idea what his next move would be, although they expected to be back in Germany early in March if all went well. The officers were mostly men who had been in the German mercantile marine when war broke out.

After sinking the ss. *Saxon Prince* the raider did not stop any more steamers, but proceeded to Germany, and after steaming a long way north they again painted ship and also painted the Swedish flag on the ship's side and flew that country's flag. The torpedo tubes and guns on the fore deck were covered with canvas. When the Faroe patrol was passed the crew seemed very confident that Germany would be reached safely, and after making the North Cape the vessel continued through territorial waters as far as possible, until, on the morning of March 4th, a dense fog came down. A submarine came out to convoy her through the German mine fields, and on passing up the Heligoland Bight the German High Sea Fleet welcomed the raider home. We reached Wilhelmshaven about 2 p.m. on March 4th.

The treatment on the raider was what might be expected under the peculiar circumstances. The prisoners were placed under guard in the 'tween decks and slept on the deck, with the exception of a few naval ratings who were taken off the *Appam*. These men were fortunate enough to have their hammocks with them, and were able to put them to good use. As the ship was nearing the end of her voyage, food became very scarce, and it was very difficult to exist on the ration supplied. Taking the treatment I have seen and received at the hands of the Germans, I think one is much better treated by the naval department than the military.

On arrival at Wilhelmshaven we were lined up on the quay, and though I had been in Germany several times before the war, I was soon to learn that the German at war was quite a different man than in times of peace, or perhaps I should say I was now to find out what the German really was. After lining up, we were handed over to a strong military escort, and marched round the town, apparently on exhibition to the public, who appeared to enjoy the sight very much. We reached the naval barracks about seven at night, and here we were placed in one room (100 men) at the very top of the barracks. This room was none too clean, and had been previously used for mobilisation purposes, sacks stuffed with straw were lying on the floor, one for each prisoner, and two thin blankets, about as thick as newspapers.

At 5 a.m. in the morning we were ordered to get up, roll up our straw sacks, and then allowed to have a wash without soap. After this, which took until about 7 a.m., as only two prisoners at a time were permitted to wash, we had served to us what was termed coffee and bread. The coffee had been brought along at

Tombstone erected by Prisoners of War to the Russian soldiers who died at Brandenburg.

5 a.m., when we were first awakened, and by 7 a.m. it was almost a block of ice. At mid-day we were marched to the cook house, where we received a bowl of potatoes and were allowed to take our dinner in a room adjoining. Directly this was over, we were marched back again to our room, and at six in the evening were served with another bowl of coffee. At the time I

thought this bill of fare was too bad for words, but after two years and three months in different camps in Germany I found that this was the best food I ever received from German hands.

Exercise was permitted for about twenty minutes each day here, and when we had orders to move to Hameln lager, on March 16th, I was very pleased. I left Wilhelmshaven on March 10th and arrived at Hameln, in the 10th Army Corps, the same evening. The attack on Verdun was in progress at this time, and the German people were in very good spirits, and appeared to be under the impression that Verdun would fall, two months later would see France out of the war, and England would then make peace with Germany.

On the camp authorities taking charge of us, they gave to each man a tin disc, about 1 inch in diameter, attached to a piece of string, with a number stamped thereon, and we were instructed to wear it round the neck as they were the prison numbers, and if not produced when called upon we should be strafed. Next we were put into a small compound, and told we were in quarantine for at least sixteen days, though the actual period was eighteen days, during which time communication with any of the other prisoners was not allowed. After quarantine had expired we were allowed to go round the camp at will. We paraded at seven in the morning, and those men required for work were picked out and the others allowed to go back to their huts.

In this camp the British prisoners confined were composed mostly of men of the old army, and although treatment at this time was bad, they assured me it was quite good compared with what they had gone through in the early days, for when they arrived in the camp there were no huts and no blankets to cover them. The Germans certainly treated these men worse than cattle. Men were continually being sent out to work and coming back again, having refused to perform the task allotted to them, as in many cases when they arrived at their destination it proved to be a munition factory. For refusing to work a common form of punishment was several days in a dark cell on bread and water, and I saw several of our soldiers brought in after completing this term of strafe, and their condition was too bad to describe. The thing that struck me most was the spirit of our Tommies, the way they refused to work on munitions and the manner in which they took their punishment; the Germans certainly did all in their power to break their hearts and spirit, but to no purpose.

During my stay in this camp the Germans took reprisals on the French prisoners, taking the bread out of their parcels, and sending all those who had been used to light work in civil life to the Russian Front to work behind the lines and make roads.

The Germans issued the *Continental Times*, a newspaper printed in English and specially got up for the prisoners, and the victories the Germans had gained, according to this paper, were something enormous. We were told that if we wanted the publication we would have to buy it, and as not one man in the camp would take a copy the Germans were very disgusted. The prisoners not working were allowed to exercise from 2.30 p.m. to 7 p.m., when they had to return to their huts; at 8 p.m. the doors were locked for the night and the guard placed inside the camp. The food supplied was very bad, in fact, too bad to describe, and had it not been for the parcels sent out from England most of the prisoners would have died.

Funeral of J. B. Genower, A.B., H.M.S. *Nestor*, burned to death at Brandenburg, 9th March, 1917.

On June 7th, 1916, I left Hameln camp for Ruhleben, arriving there the same day. On my way to Ruhleben I had to wait in Hanover station for about one hour, and while there several troop trains passed through on the way to the East and West Fronts. The troops seemed to be in very good spirits, and the carriages were decorated with flowers, etc. One large hospital train arrived, and the cases were moved to the different hospitals in Hanover; they appeared to be all bad cases, and everyone a stretcher case. On several of the stretchers the men's service boots were hanging, although the men seemed nearer dead than alive. With the exception that the people seemed very interested in the prisoners, and evidently thought we had been taken by their U boats, there was nothing much to comment on during the railway journey, but I may add that we travelled from four in the morning until six in the evening and had nothing to eat during that time.

On arrival at Ruhleben I was very much surprised to observe the great difference existing between a civilian camp and a working lager. In the early days of the war the civilians received very bad treatment, especially the officers and men of the ships at Hamburg when war commenced, and there is no doubt about it at all that they were in a starving condition when the first parcels of food arrived from England. When I arrived I found that the prisoners had practically their own civil administration in the camp under the German military, and the place was very well organised; the living accommodation was certainly very bad, and being very badly lighted it had a great effect on one's eyes.

Prisoners were housed in horse boxes and hay lofts of the Spandau racecourse. Four to six men were put into each box, and how many in each loft I could not really say, but they were certainly full. A few wooden huts were also erected to accommodate some of the prisoners, while those who had German sympathies were kept in the tea house, near the racecourse; the other prisoners seldom ever spoke to these men. Quite a number of the prisoners could not speak a word of English when they were interned. In the camp there was certainly plenty to occupy one's time, technical classes of all kinds, golf, football, cricket, boxing, tennis, a theatre, cinema, concerts, and a debating society, in fact, the place was run on the lines of a small town. The prisoners, however, had to depend on the food sent out from England.

A short while after Capt. Fryatt was taken out of this camp and shot, all the officers and men of the Mercantile Marine who had been captured on the high seas after war broke out were told that they had to leave the camp as they were going to be treated the same as military prisoners. On the morning of November 7th, 1916, we were all moved from Ruhleben to Brandenberg a/H, arriving there the same evening. The first impression one had of this place was a very bad one, and it did not improve on a

Overseas Officers at Bad. Colberg, April, 1918.   Canada, Australia, South Africa, Ceylon, etc.

longer acquaintance with it. It was here that in 1914, 880 Russian prisoners died from typhus in one month, and had it not been for a few Russian doctors, who volunteered to fight the disease, it is probable all the prisoners would have died.

The situation of the camp was about five kilometres from the town of Brandenberg, and it consisted of four or five very low brick buildings, and a number of wooden huts, with a large pond at one side, having a narrow outlet into the river Havel. There was very little rise and fall and this was impeded by an iron punt placed across the inlet which made the pond little better than one large cesspool. The sanitary arrangements up to October, 1917, were most deplorable, in fact, they were the worst I have experienced in the different camps I have been confined in. The accommodation was very bad and the food was just the general thing that is to be found in a prisoners-of-war camp in Germany. It is simply impossible for the prisoners to eat it until they are on the verge of starvation, and the amount supplied is not enough to exist on. It certainly is impossible to describe what the food really was, and I am of the firm opinion that no man in the British Empire would attempt to feed a pig with it. In this camp, as in others, the Germans were simply past masters in the art of strafing. Two ship's crews, taken prisoner by a submarine, were locked up in a small compound in the camp, and the only time that they saw or spoke to any of the other prisoners was on occasions when they went to the parcel office to draw their parcels. This went on for over twelve months, and eventually asking why they were treated in this manner, the only reply they could get was that the orders came from Berlin.

In the month of February, 1917, all the British prisoners in the camp were ordered to the camp bath for fumigation, and told to take food just enough to last them that night, as they would have to spend the night in a different tent. The prisoners reached the baths at 1 p.m., and after all the clothes had been put in the fumigator, the men were given a hot bath, and put into another room, and had to stand about until after 6 p.m., waiting for their clothes to be brought to them, and when the clothes arrived they were absolutely wet and one could wring the water out of them. This was during a time when a heavy frost was on, and about fourteen inches of ice on the pond in the camp. After getting our clothes on, we were marched back to another tent, all put in together, and instead of being one night, we were kept about sixteen days. It was certainly terrible in this place, as there were only straw mattresses for about 50 men, the others having to sleep on the bare boards. While in these quarters we were allowed coke enough to keep the fire going for two hours. Later the information was given that we were in quarantine, and precautionary measures were being taken, as typhus was suspected. The man suspected of having typhus was running about the camp next day, having had a slight attack of dysentery, due to having to eat camp food, as he had not received any parcels up to that date from England.

A thing that struck me most during this strafe, and I am sure it was nothing else, was that not one German doctor or any of the German officers ever came near us while thus isolated. If it had been done for health measures, why did they not improve the sanitary conditions of the camp, and why did they not isolate the whole camp, as all the Russian prisoners were allowed to go round the camp when they pleased. After being in this place for a fortnight, the Germans sent our parcels in, and as we had all been on the camp food for over a fortnight we were more than pleased to receive them.

The day after we were allowed out of quarantine a fire broke out in the strafe barracks, which resulted in four Russian prisoners, one French, and one British being burned to death without any chance whatever being given to them to get out of the burning building. The fire was probably due to defective heating arrangements, and when first noticed by the sentry he made no attempt to release the prisoners, although the keys hung on a board about six feet from where he stood. He evidently lost his head or acted under orders, I don't know which, for the house occupied by the commandant of the camp overlooked the strafe barracks and the servants in the house shouted to the sentry to release the prisoners. This he did not do, but continued to give the alarm. It was not long before the whole guard turned out, but some considerable time elapsed before the door of the strafe barrack was opened, and by that time it was impossible to get the doors of the cells open occupied by the men, and they were burned to death. After the fire hose had been laid some time no water was forthcoming, and on going down to the fire engine I found they could not get any water into the boiler. On examination I found the feed pipe leading from the tank to the boiler choked, and on disconnecting the pipe it proved to be frozen up. After thawing the pipe and replacing it, water was got into the boiler, but by the time water was ready the whole barrack was burnt to the ground. As the frosts were very heavy, the Germans had taken the precaution to drain the boiler, but evidently had overlooked the feed pipe. If the sentry had opened the doors when he first discovered the fire, all the prisoners could have been got out alive. With the disgraceful way the Germans handled the situation none of the other prisoners could do anything to attempt a rescue, as they were kept back from the fire by the German guard. After this the feeling among the prisoners in the camp became very bitter, and it would have taken very little to cause a riot.

Members' Addresses Wanted.

The addresses of the following are wanted owing to removals and communications being returned from the addresses given:—

Members.

Abraham, W. J., 26, St. Peter's Grove, Southsea.
Clark, C. W., 40, Shakespeare Road, Sydenham.
Craig, J. C., 33, Redcliffe Gardens, Ilford, E.
Coppinger, C. W., 143, Westcombe Hill, Blackheath, S.E.
Copeman, W. C. J., Wellsbank, Granville Road, Ilford, E.
Dadachanji, D. R., c/o Cowasji Dinshaw Bros., 25, Meadon Street, Bombay.
De Ritter, Sydney, 1, Agnes Street, Burdett Road, London, E.
Dowden, Percy P., Lincluden, Raynes Park, London.
Dawson, R. H., 58, Cavendish Drive, Leytonstone, N.E.
Elliott, John, 105, Osborne Road, Forest Gate, E.
Farmer, W. D., Glenellyn, Thornton, Fifeshire.
Fitch, E. L., 23, Muswell Road, Muswell Hill, N.
Forrester, W. G., 224, Burdett Road, Bow.
Ferguson, F. A., Springfield Park, Burnside, Rutherglen, Glasgow.
Grant, John, c/o I.M. Customs, 4, York Buildings, Hongkong.
Hawley, W. P., North Guards, Whitburn, Sunderland.
Hoxton, Robt., 4, Etta Street, Deptford, London, S.E.
Hesketh, J. E., 81, Borstall Avenue, Heath, Cardiff.
Howarth, C. A., 250, Kenmure Street, Pollokshields, Glasgow.
Jenkins, D., 26, Loudoun Square, Cardiff.
Jessel, Wm., 51, Francis Street, Leeds.
Johnson, E. J., c/o Manchester Aircraft Co., 29, Cowper Street, Manchester.
Kidby, E., 20, Richmond Gardens, Portswood, Southsea.
Kyle, A. R., Banksville, Welholme Road, Grimsby.

Leslie, W., 18, Queen's Road, Aberdeen.
Liddle, J. S., 28, Rutland Street, Edinburgh.
Lloyd, R. D., 127, Temple Road, Prenton, Birkenhead.
Lyddon, R. B., 67, Featherstone Road, King's Heather, Worcester.
Madden, G. A., 46, Springhill Gardens, Shawlands, Glasgow.
Morgan, Geo. U., c/o Yorks. Insurance Co., 83, Leopold Street, Leeds.
Nickson, E. N., 9, Cecil Road, Prenton, Cheshire.
O'Neil, R. S., 57, Gracechurch Street, E.C.
Outram, W. R., " Freshfield," Poplar Wall, Herne Hill, S.E.
Park, C. J., Prospect Villa, Wetherby, Yorks.
Pottie, David, 24, Bernard Street, Leith.
Rangdale, G. S., "Drayton," Bramber Road, North Finchley.
Rutter, J. E., c/o Ch. Transport Officer, Bombay.
Salisbury, Ben, 29, Maysoule Road, Battersea, S. W.
Sandy, Arthur, St. Lucia, St. Chad's Avenue, Portsmouth.
Seabrook, A. W., "Chyanporth," Lannoweth, Penzance.
Shand, G. A. A., c/o Sargeant & Co., Engineers, Brisbane, Queensland.
Shipton, H. J., 6, Mitchell Road, Central Park, East Ham.
Smith, F. A., Whetstone Croft, Wollands, Broughton-in-Furness.
Southron, G. C., H.M.S. *Agamemnon*, G.P.O., London.
Spencer, J. A., Thorburn House, Apollo Bunder, Bombay
Still, W., Brachendale, Fladgate Road, Leytonstone, N.E.
Taylor, Edw., 4, Ovington Terrace, Cardiff.
Taylor, F. W., 362, Green Lanes, Finsbury Park, N.
Trackrah, J., 8, Mentone Place, Little Woodhouse Street, Leeds.
Thomson, J. A., Auckland, New Zealand.
Tyson, David, 10, Brockenhurst Gardens, Mill Hill, N.W.
Watts, Frank, 146, Belgrave Road, Wanstead, E.
Williams, Chas., Bristol Waterworks, Blagdon, Bristol.

Associate-Members.

Donald, Ivan M. S., (Lieut., R.E.), 62, Nevern Square, Earl's Court, London.
Hollingsworth, C., 93, Grimsthorpe Road, Pitsmoon, Sheffield.
Macdonald, John, Dingley, Knockands, Morayshire.
Robertson, D. J., 7, Torus Road, Derby Lane, Stoneycroft, Liverpool.
Robson, J. B., 7A, Lownds Avenue, Bromley, Kent.

Spence, A. T., 45, Wellbrow Road, Walton, Liverpool.
Webb, Wm. F., c/o Boyd's Ice Factory, Bombay.

Associates.

Isaacs, A. W. R., 433, East India Dock Road, London, E. (Australia).
Jewitt, J. G., 143, Windermere, Durban, S. Africa.
Parsons, Robt., The Harbour, Tichborne Down, Alresford, Hants.

Graduates.

Cordon, Cecil I., 6, Margaret Street, Greenock.
Heesem, J. M., 32, Mile End Road, London, E.
Robertson, A. E., 1,486, Fifth Avenue, Sunset, San Francisco.
Slack, H. J., 30, Claremont Road, Forest Gate, E.

Companions.

Garnham, F. M., 8, West Bank, Stamford Hill, N.
Menzies, J., Merton Abbey, S.W.
Moore, H. A. H., 78, Queen Victoria Street, S.W.
Skinner, W. R., 3, St. George's Square, Forest Gate, E.
Stephens, A., 9, Caversham Avenue, Palmer's Green, N.

Election of Members.

Members elected at a meeting of the Council held on December 17th, 1918:—

Members.

Alex. Cranston Butcher, Kilfargie, Western Australia.
Dugald Paul Cameron, 35, Whitehall Street, Glasgow
Francis A. Chater (Engr.-Comdr., R.N.), Piræus, Greece).
Chas. Herbert Foxwell (Engr.-Lieut. R.N.R.), 28, Wharfdale Gardens, Thornton Heath, S.W.
Francis Creighton Hully, 110, Felbrigge Road, Goodmayes, Essex.
Samuel Kirkham, "Kelvinside," Aintree, Liverpool.
John Brear Laycock, "Oakbank," Steeton, Yorks.
William Lewis, 5, Billiter Street, London.
Richard Lowe, Engineers' Association, Singapore.
Chas. Colville McMurchy (Engr.-Lieut., R.N.), "Benvue," Campbelltown.
Frank Roland Martin, 2, Albert Grove, Gt. Crosby.
John Charles Porter, 67, Mile End Avenue, Aberdeen.
John Renton, 26, Holly Avenue, Whitley Bay.
John Russell, 15, Crescent Road, Upton Manor.
Wm. Mountain Topham, 94, Montpelier Gardens, East Ham.
Stuart Taylor Williamson, c/o Molle & Co., Hong Kong.
James Wood, "The Rowans," Lusch, Aberdeenshire.

Associate-Member.

John Carmichael, Junr., 7, Monroe Road, Glasgow.

Graduate.

Douglas Lomas, Grove Street, Wilmslow, Manchester.

Transfer from Associate-Member to Member.

J. K. Thomas, 238, Albion Road, Stoke Newington.

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LLOYD'S REGISTER SCHOLARSHIPS AND ESSAY COMPETITIONS.

DEAR SIR,

As you may know of Junior Engineers or Apprentices whose qualifications should admit of them becoming candidates, your attention is directed to the following named awards in connection with the Institute, and the Regulations anent these :—

LLOYD'S REGISTER SCHOLARSHIPS.

SIR ARCHIBALD DENNY AWARD for Sea-going Members.

STEPHEN AWARDS for Associate Members' and Associates' Sections.

JOHN I. JACOB'S MEMORIAL AWARD for Graduate Section.

JOHN I. JACOB'S MEMORIAL OPEN COMPETITION AWARD for Apprentice Engineers.

Lloyd's Register Scholarships. These Scholarships, two in number, were founded in 1908 through the instrumentality of the late Mr. Jas. Dixon (Chairman, Lloyd's Registry of Shipping), Past President of the Institute. They are each tenable for two years at £50 per year.

Application should be made by intending candidates not later than May 1st, in order that arrangements may be made for the examination which will be held during July 24th and 25th. The examination will take place simultaneously in various centres selected to suit the convenience of candidates. The rules and regulations, with lists of subjects for examination, are as follows :—

I. The Scholarship is open for competition by examination to candidates who are British subjects*, and Graduates or Associates of the Institute of Marine Engineers, apprentices or junior engineers (not necessarily connected with the Institute), the age limit being not under 18 or over 24 years*. Preference will be given, in the event of equal marks, to the candidate who has been connected with the Institute for the longer period. The successful candidate, if not already associated, must join the Institute in the grade for which he is qualified.

II. The Scholarship is intended for such engineering students as could not otherwise pursue their studies at College day classes without its aid, and candidates are required to certify that they comply with this condition. An undertaking must be given by the successful candidate that he will continue his studies for the full period of the term, extending over two years.

III. The examination papers will be set from and based upon the following subjects :—

(*a*) Arithmetic, including the Metric System, and Algebra, to Quadratics.

(*b*) Elements of Statics, Dynamics, Thermodynamics, and Hydrostatics.

(*c*) Geometry, based upon Euclid, Books I., II., III., and IV.

(*d*) General Knowledge, English Composition.

(*e*) Mechanics, Principles and Problems.

(*f*) Language, Elementary French, German, Italian, Russian or Spanish, Construction and Translation.

(*g*) Plane Trigonometry, including Logarithms.

(*h*) Practical Engineering and Workshop Practice

* "British subjects" denotes all subjects who are of British parentage in its Imperial sense.