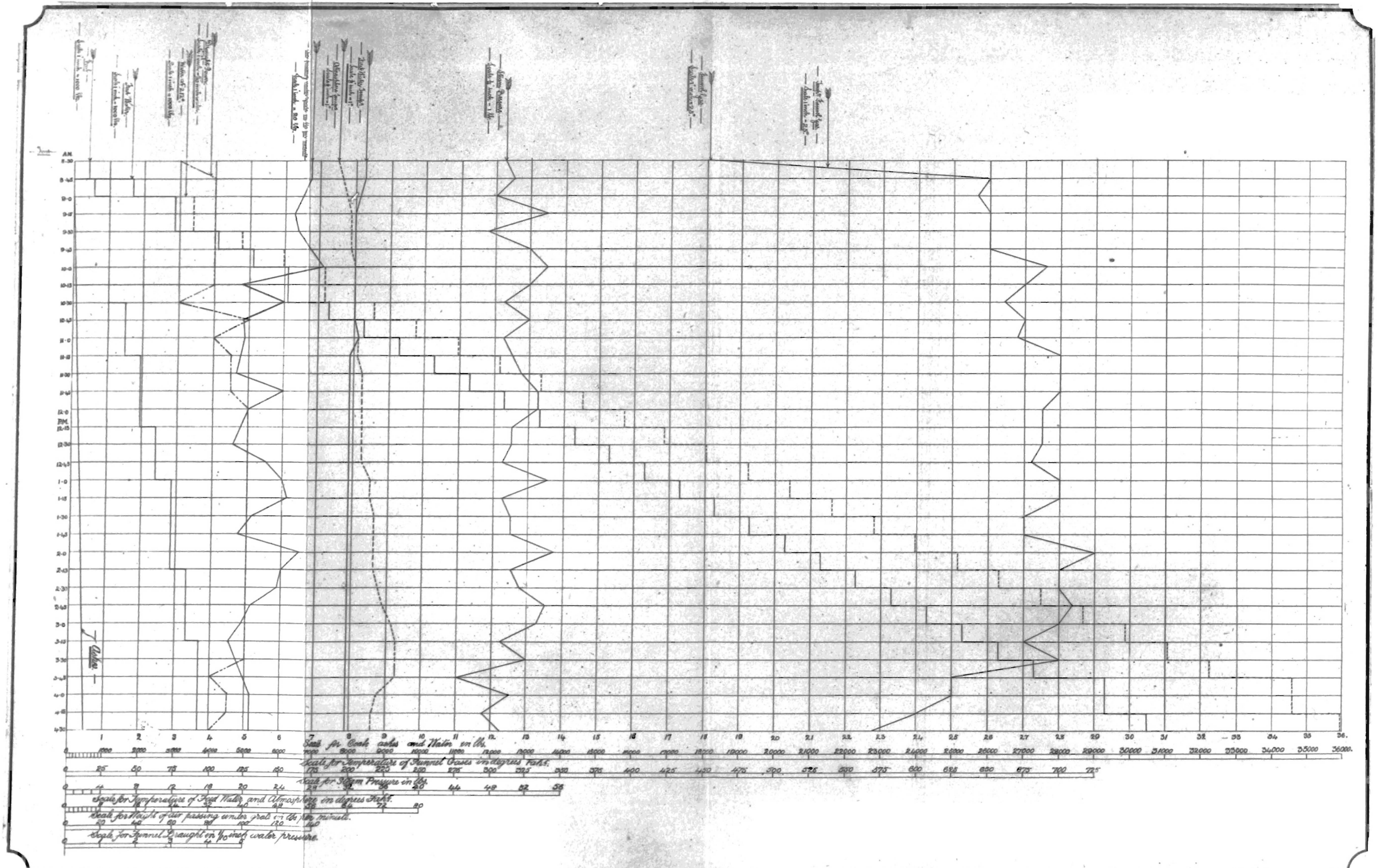
and as it was the custom to test boilers to twice the working pressure, we had only 20 per cent. of a margin left. Of course, if the test pressure were reduced, this margin would be increased, but keeping in view the amount of deterioration that took place in boiler shells, and also the racking strains they were subject to, he thought a factor of safety of 5 might very well be left standing.

As regarded feed heating, it could hardly be said that this was the outcome of the last decade, as Weir had his patent feed heaters at work long before that time, and, he (the speaker) believed, could now hold their own against most of the new-comers. He did not think there could be much difference of opinion regarding the advantages to be obtained by heating the feed water before allowing it to mix with the water in the boiler; but great differences of opinion might arise as to how it should be done, and the economy to be obtained from any particular method. According to the figures given in the paper, Weir's system would give an economy of 3·6 per cent. when steam was taken from the intermediate receiver, and, if taken from the low-pressure receiver, would be about doubled, or say 7 per cent. These figures were, he considered, on the low side, for although 10 per cent. of the steam was taken from the receiver for heating purposes, and by so doing reduced the power in the low-pressure cylinder in proportion, yet we increased the power developed in the intermediate cylinder, so that in all probability the saving would come out about 8 per cent., a result which he very much doubted ever resulted in practice. Weir had also evaporators at work before the last decade, but, like the feed heaters, were not so extensively used then as now. With the high pressures now in use a fresh water make up was almost an absolute necessity. One of the latest systems of evaporators and feed heaters was Morrison's, of Hartlepool. It appeared to him to be a plain, sensible arrangement. The evaporator itself was of the usual type, but special attention had been paid to the means for cleaning; this was done by lifting the outer casing, and so exposing all the internal parts. But the feed heater was, he thought, at once the simplest and most rational apparatus for the purpose intended that had come under his notice, very much resembling an ordinary ejector. The steam generated in the evaporator passed into the heater, and was then mixed with the feed water on its way to the feed pump, thereby being condensed and heating the feed water at the same time. The usual method was to pass the steam into the condenser, and afterwards heat the feed water by steam in a special apparatus; but Morrison effected in one operation what had hitherto required two, and that without using any fresh steam, so that it must of necessity be more economical.

With regard to forced draught, it seemed to him to be a most remarkable statement that the vessels having forced draught had an economy of 15 per cent. over those working with natural draught. He was afraid if this matter was thoroughly investigated a large proportion of this would have to be credited to other causes. There was not the least doubt that with properly proportioned furnaces there would be a decided saving through more perfect combustion, but 15 per cent. was a very high figure; one of the best features in forced draught was the extra power which could be developed from a given boiler. He believed that 75 per cent. of the boiler power now usually put on board ships would be ample if fitted with forced draught. This would enable more deadweight cargo to be carried, in some vessels to a very considerable extent, or a higher rate of speed could be attained for the same coal consumption. As we got nearer perfection improvement was more and more difficult, but doubtless 1900 would see great improvements on what we were doing now. Perhaps the greatest of these would be a better method in the combustion of coal, and it was in this direction that he thought forced draught would play a leading part in the history of Marine Engineering.

DIAGRAM OF AN EVAPORATIVE TEST.

Carried out by Messrs. H. V. Ahrbecker and A. Christie at the works of Mort's Dock and Engineering Co., Balmain.



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In conclusion, he thought it would be of some interest to give the results of an evaporative test carried out recently by Mr. Ahrbecker and himself with one of the boilers at the works of Mort's Dock and Engineering Company, Limited, Balmain. The boiler was of the externally fired multitubular type of the following dimensions:—

Length	14 ft.
Diameter	6 ft.
Area of fire grate	22 sq. feet
Diameter of tubes	4 in.
Length of tubes	14 ft.
Number of tubes	60.
Tube surface	879 sq. feet.
Total heating surface	1,000 ,,
Ratio of tube surface to grate	39·9 to 1.
Ratio of total heating surface to grate ...	45 to 1.

The duration of the trial was eight hours; the observations were made every fifteen minutes; the average pressure of steam was 50·6 lbs. per square inch; and average temperature of the feed water was 63·6° Fah. The results obtained were as follows:—

Coal consumed	3,670 lbs.
Water evaporated	30,500 ,,
Coal consumed per square foot of fire grate area per hour	16·7 ,,
Water evaporated per lb. of coal...	8·31 ,,
Water evaporated from and at 212° Fah. per lb. of coal	9·81 ,,
Air passing into ash-pit per lb. of coal consumed ...	14·5 ,,
Average temperature of funnel gases	665° Fah.
Temperature of funnel gases at commencement of trial	450° ,,
Temperature of funnel gases at end of trial	590° ,,
Highest recorded temperature of funnel gases	725° ,,
Ash 12·8 per cent. of coal.	

The steam pressure was maintained constant throughout the trial.* So far there was but very little data in existence of the evaporative efficiency of Australian coals, and it was a matter for regret that such was the case.

Mr. H. V. Ahrbecker, in reply to a question, stated that the coal used was from the Mount Pleasant Colliery, and

* The results obtained are graphically shown in the diagram.

that he had made an analysis of it with the following result:—

Water	2·0
Volatile matter	17·7
Sulphur	·8
Carbon	68·5
Ash	11·0
	100·0
Specific gravity	1·322
Weight per cubic foot	82·52 lbs.

Mr. Hector Kidd considered the results of the trial made by the last two speakers was very good. The average evaporative efficiency he had obtained from Southern coal ranged from 7½ lbs. to 8 lbs. of water per lb. of coal. Speaking of the "Acme" feed heater, he stated that at one of his company's mills they found no difficulty in running two engines when this feed heater was used, but without it it was necessary to use two boilers. With marine boilers the results obtained were equally satisfactory. In one case a steamer of theirs, having engines of 90 horse power, the engineer reported a saving of one ton of coals per week since the "Acme" heater had been fitted, the boiler steaming much more freely than before its introduction. His company were so satisfied with its working, that at the present time they were fitting eighteen of their boilers with them.

Mr. J. S. Fitzmaurice said that but for a definite statement made in Mr. Blechynden's very interesting paper relating to feed heating he would not have taken part in the discussion, as marine engineering was a subject on which he could not speak with any degree of authority. After referring to the advantages gained by heating the feed water by passing steam from the high or low pressure exhaust to hot well, Mr. Blechynden made the following statement: "Also others which heat the feed in a series of pipes within the boiler, so that it is introduced into the water in the boiler practically at boiling temperature. This is economical, however, only in the sense that wear and tear of the boiler is saved. In principle the plan does not involve the economy of fuel." In making such a statement Mr. Blechynden must have had some foundation for it, but from tests recently made with a feed heater of this type by him (the speaker), Mr. Blechynden was in error. In February last an "Acme" feed heater and purifier was fitted in the Parliament House electric light boiler (20 h.p. nominal, by Marshall and Son). This heater consisted of a U-shaped W. I. pipe fitted in steam space of boiler, one end of which was connected to feed pump, the other to blow-off pipe—at which end half-a-dozen small holes were drilled on the upper side of pipe out of which the water passed into the boiler practically at the same temperature as the steam surrounding it. At rough trials made in February a saving of about 16 per cent. of fuel resulted, but to be more precise he made four trials early this month, but, owing to the extensive alterations and additions about to be made in the Parliamentary buildings, necessitating the removal of about 200 of the present electric light fixtures, he was unable to extend the test beyond three hours each, members would therefore easily understand the difficulty of making very accurate observations, or obtaining satisfactory results on such a small load and in the time; however, they were accurate enough to prove that a very substantial saving was gained by this method of feed heating—

—	Without Feed Heater.		With Feed Heater.	
Tests	1	2	3	4
Duration of trial	3 hours	3 hours	3 hours	3 hours
Steam per square inch in lbs.	125	128	128	128
Revolutions per minute	116	118	118	118
Ampères	224	240	233	233
Volts	112	111	111	111
Electrical horse power	33·63	35·7	34·6	34·6
Total coal used in lbs.	440	436	374	343
Coal used per electrical h.p. per hour	**4·36**	**4·07**	**3·6**	**3·3** lbs.
Temperature of water in feed well	75°	125°	77°	128° F.
Furnace draught	$\frac{3}{16}$"	$\frac{3}{16}$"	$\frac{3}{16}$"	$\frac{3}{16}$"
Smoke stack draught	Min. $\frac{1}{2}$"	Max. $\frac{3}{4}$"	Mean $\frac{5}{8}$"	...
Total water consumed in lbs.	2,700	2,600	2,550	2,550
Water per electrical h.p. in lbs. per hour	26·7	24·27	24·5	24·5

By reference to Tests 1 and 2, it would be seen that the consumption of coal per electrical horse power was 4·36 lbs. and 4·07 lbs. per hour, and the temperature of feed water in tank 75° and 120° Fah. respectively, showing a saving of 6·4 by raising the temperature of feed water 50° Fah. In these tests the feed heater was disconnected. Now, turning to Tests 3 and 4, which were made with feed heater connected, a substantial decrease in the coal consumption was shown, being only 3·6 and 3·3 lbs. of coal per electrical horse power per hour, and the temperature of feed water in tank 77° and 128° Fah. respectively, thus effecting a comparative saving of 8·3 per cent. by feeding at the higher temperature. The relative saving in consumption of fuel per electrical horse power was as follows:—

	Test 3 *v.*	Test 1	=	17·4	per cent.
	„ 4 *v.*	„ 1	=	24·3	„
	„ 3 *v.*	„ 2	=	11·5	„
*	„ 4 *v.*	„ 2	=	18·9	„

The figures did not come out as he would have liked, but it was due to the short time at his disposal, but when Parliament re-assembled he would endeavour to make two lengthened tests to arrive at the exact saving. The figures quoted would at any rate be found near enough to refute Mr. Blechynden's statement. The tables referring to forced draught in Mr. Blechynden's paper showed very economical results in its adoption, but what he (the speaker) would like to know was the minimum amount of forced draught required to obtain the maximum economy. In the Marshall boiler referred to previously the furnace draught was $\frac{3}{16}$ in., and the smoke stack average draught $\frac{5}{8}$ in., this was caused by the exhaust steam from low-pressure cylinder exhausting up the stack. The pressure of draught over exhaust was $\frac{3}{4}$ in., and between exhaust and side of stack $\frac{1}{2}$ in. Would any economy of fuel be gained by increasing the draught? During the reading of the paper Mr. Cruickshank said he did not consider it right to connect

* This would be the actual saving if the figures are correct, as Test 2 is made under our ordinary running conditions.

the cylinders of compound engines together, as the difference in temperature between the high and the low was so great as to tend towards shearing the bolts off. How would this apply to engines where the cylinders formed one casting? There were many of this type in use. Would not the higher temperature be conducted towards the lower and thus raise the latter, and, in doing so, tend to maintain a more even pressure in the respective cylinders?

Mr. R. Pollock said that the tendency of the age was to increase the steam pressure in boilers, and if this continued would be necessary to adopt boilers of the water tube type, but, in doing so with surface condensing engines, a difficulty existed on account of the greasy nature of the feed water. This might be overcome by filtering the water after it left the hot well and prior to entering the feed pump. He was of the opinion that all feed water should be filtered, our attention had been so long concentrated on such impurities as lime and salt that we were apt to forget others that were as bad, and in some cases worse. Three of the largest steamers belonging to the Messageries Maritimes Company trading to this port were fitted with water-tube boilers, and he hoped that some member would obtain authoritative particulars of their working pressure, coal consumption, and other data in connection with them.

Mr. W. D. Cruickshank said he wished, before replying to the various remarks, to express on behalf of the Association his thanks to the author for the very able manner in which he had handled a deeply interesting subject. It was such practical papers that enabled us to keep in touch with modern practice, and it was highly desirable we should make the most of it, and he felt sure that Mr. Blechynden would be pleased to know that his paper was duly appreciated by Australian engineers.

As regarded forced draught, he considered it could only be viewed as a partial success—that is the practical results did not by any means come up to the theoretical expectations—for its maximum force appeared to be restricted to certainly not more than two inches of water, anything over that has, up to date, resulted in injuring the boilers; besides, it takes up a considerable amount of room, while the expense and hampering of the stoke-hold are also items for consideration. Then again the exceptional loss of pressure between the fan and the place of discharge is a serious difficulty, and it has been shown that in the marine trials of the "Fiona" the air pressure in trunk close to fan was ·86 in., at back of boiler (where it was discharged direct into combustion chamber) ·34 in., while under ash-pits it was only ·17 in. He quite agreed with the author that the whole of the 15 per cent. economy shown in Table 5 should not be credited to forced draught, and he believed that a minute examination would bring out that several other heat-saving appliances were factors helping to make up the total.

As regarded the trouble experienced with double-ended boilers in the Navy, he felt almost certain they were entirely due to defective design; because, in the first place, it was bad to have two furnaces common to one combustion chamber, and, secondly, because in ordinary practice all combustion chambers were made far too small, and he had no hesitation in affirming that if combustion chambers were self contained, and made about 50 per cent. larger, the efficiency of our boilers would be materially increased. This had been the speaker's own experience, and in designing boilers, and especially for high pressure, he never hesitated to increase their capacity and shorten the tubes in proportion. Referring to the efficiency of the different types of boilers, it was interesting to note that the ordinary return tubular marine boiler would compare favourably with any other.

The following figures taken from recent experiments were important:—

	Lbs. per sq. inch grate.	Lbs. water evaporated from 1 lb. coal.
Lancashire boiler, with Galloway tubes, Welsh coal	16	12
Cornish boiler, with Galloway tubes, good coal	19·5	11·56
Horizontal, internally fired boiler, through tubes, good coal	16·8	11·76
Horizontal, externally fired, Colonial type, good coal	16·4	11·3
Locomotive type boiler, stationary, good coal	20·0	11·5
Marine boiler, ordinary design, Welsh coal	19·0	12·23
Thorneycroft boiler, water tube, Welsh coal	...	13·4
Babcock and Wilcox boiler, Welsh coal	...	12·38
Belville boiler	...	11·71

These figures showed that the difference in the efficiency (for the number of pounds of water evaporated per pound of coal burnt) was not very great, hence the importance of having boilers that could always be cleaned, examined, and repaired in the shortest time and at the minimum expense.

The wonderful development in the manufacture of what (for want of a better name) was called mild steel was astonishing, and it was simply a revelation to know that the Steel Company of Scotland were now prepared to make plates 40 ft. long and 1½ in. thick, while the boiler shells of some of the new Atlantic liners were 1⅞ in. thick. As regarded machine caulking, it would be acknowledged that we were somewhat in advance, as Messrs. Hoskins, of Sydney, some three years ago designed and constructed a most original and practical tool, which had done really good work ever since. The experiments of Mr. John Scott, of Greenock, with a special boiler shell built 18 per cent. below Board of Trade rules were both important and interesting, and, taking into consideration the uniform quality and reliability of the steel, the Admiralty have for some years past reduced the shell scantlings by that amount, and many engineers were of opinion the Board of Trade and *Lloyd's* should do the same. With all due respect, he (the speaker) held that it would be a mistake to make this reduction, because, although for the very highest class of work the factor of safety was 5, still the limit of elasticity had to be, or at all events should be, considered; and, looking at it from that point of view, what had they got? Simply this, the ultimate strength of the steel was 28 tons, but its elastic limit was only 14 tons, so that they had only an actual margin of $2\frac{1}{2}$ instead of 5. and in his opinion that was too near the point where the material, although not actually broken, would be *permanently injured*, The statement that the rate of transmission of heat through a furnace plate was almost entirely dependent on the condition of its surface, and that the resistance due to the plates thickness was practically nothing, was a fact of which he was previously not aware, and had it been proposed to fit any boilers here with $\frac{3}{4}$ in. furnaces, and especially in those carrying 160 lbs., he did not think any engineer in Sydney would have cared to take the responsibility, but actual experience appeared to have demonstrated that the extra thickness was of no moment.

As to the advisability of bolting the cylinders rigidly together (in triples) he could not agree with the author, as the temperature differences would cause unequal expansion and throw an unknown shearing strain on the joint bolts.

Referring to the copper steam pipes, it had been demonstrated that their normal strength was reduced from 20 to 25 per cent. when they are raised to the temperature of steam at 160 to 200 lbs. per square inch, and this, of course, must be allowed for in determining their thickness, but there seemed to be an uncertainty about such pipes, and especially in the brazing which, when properly done, was as strong as the solid copper, but defects might exist in the brazing which could not be detected until an accident occurred. The securing of main steam pipes with iron or steel hoops was a proof of our helplessness, and was certainly not suggestive of confidence in our work. He could see no material difficulty in adopting iron or steel for steam pipes, as Mr. Taylor had done with such marked success, and the long practical test they had undergone appeared to amply justify their adoption. From results already obtained with steel tubes, manufactured by the Maunesmann process, it appeared likely that this difficult problem was in a fair way of being solved before long.

He was sorry he could not join issue with the author in his views regarding feed heating. He (the speaker) had found that there was a direct saving and economy in fuel if properly applied. Our standard method of feeding boilers he considered an abortion, and was not at all creditable to us as engineers, and he was quite prepared to justify this statement at any time.

Steel screw propellers had proved utter failures—worse than cast iron—principally because of the rapid corrosive action which often eat them through in a few months.

The tables accompanying the paper were well arranged and would be very useful for reference, in fact the author's whole effort was deserving of the best thanks of the engineering community.

He could not help expressing his regret that the author had not referred to the great development which had taken place in refrigerating machinery, as applied to steamships, because during the last decade this special branch of engineering has made greater strides than any other. The same may and, he thought, did apply to the electric lighting at sea. The successful development of refrigerating machinery was of very great importance to the Australian Colonies, because it had been the means of creating an industry in connection with which thousands of men were now employed, and all this was due, in a great measure, to the labours of the late T. S. Mort, who spent many thousands of pounds in trying to solve this difficult problem. As an instance of what could be done with this class of machinery he might mention that he visited a new steamer the other day, having two freezing plants, the forward one capable of freezing 170,000 and the after one 120,000 carcases, and that vessel could carry 6,000 tons of dead weight, exclusive of her bunkers, and steam 15 knots. In conclusion, he wished to thank them for the very keen interest they had shown in discussing the subject, and he expressed a hope that similar papers might be brought before the Institution with advantage.