13th September, 1917.

SOME SUGGESTIONS FOR IMPROVING THE EFFICIENCY OF FUEL ECONOMIZERS.

By H. SHAW.

At the present time, any suggestion to aid economy should make an instant appeal. It is notorious that in those countries producing coal cheaply economy in the use of it receives too little consideration. It must be remembered, however, that whereas ten years ago we might still have claimed that coal was a cheap commodity in Australia, its cost has practically doubled during that time. The improvements in the thermal efficiency of prime movers have been remarkable during the last fifteen years, but the economy of the boiler has remained practically stationary, and as the fuel bill is the largest part of the operating expense of any power plant, it is essential to obtain from it the greatest possible number of B.T.Us. It is not the intention to enter closely into the general question of the advantage of fuel economisers, but rather to express in these notes a few suggestions for making them justify their name more fully than they do now.

The use of economisers in any plant may depend ultimately on whether it will show a good return on the money invested, and he had no doubt that in the majority of boiler installations the judicious use of this form of heating surface could be justified. They all knew how little value relatively the after part of the heating surface of boilers was, especially if any attempt was made to reduce the temperature of the reject gases below 600 deg. F., and it was the value of the economiser in relation to the heating surface of the boiler which, in his opinion, did not always receive proper appreciation. He could very easily quote

instances to show how, in many cases, it would be cheaper in first cost, more economical in fuel, and cheaper to operate, if less boiler surface and more economiser surface was installed. There was also the question that a reduction in the number of hands required was, in itself, an important factor apart from actual saving of money.

Economisers, like many other things, have often been condemned because they have failed to come up to excessive claims, but properly controlled there is no doubt that they almost invariably result in a very profitable saving. The average of some eighty tests from all sources, as published by Bryan Donkin twenty years ago, showed that the average thermal efficiency of or percentage of total fuel saved by the economisers was 9.6, the heating surface of boilers and economisers being practically equal. Compared with the above, 87 economisers of typical industrial plants, tested scientifically in Great Britain recently, showed that for a similar ratio of boiler to economiser surface, the average thermal efficiency was 10.2 per cent.

The experience of the C.S.R. Co., which had nearly 100,000 sq. ft. of economiser heating surface installed in 17 factories, containing over a quarter of a million square feet of boiler surface, and covering an area of eight acres, and the results from each one of which were recorded weekly throughout its work, showed that a thermal efficiency of 10½ per cent. was obtained from a rather smaller proportion of economiser heating surface to that of the boilers. It may be as well to explain that this efficiency figure is the saving expressed as a percentage of the total heat supplied to the boilers, the economiser efficiency taken as a heat-saving appliance, and expressed as a percentage of heat supplied to itself, may be taken as usually from 40 to 50 per cent. That there was room for saving in many of the boiler plants operating to-day goes without saying, and the use of economisers was increasing, especially in

plants where the boilers had to be forced, for it seemed to be more generally recognised that for plants in which forcing takes place, economiser heating surface was most valuable. At the same time, he thought it may be taken that, if economisers show more than ten to twelve per cent. thermal efficiency, that either the rest of the boiler plant is not doing quite satisfactory work, or the proportion of boiler to economiser heating surface is not the best. On the other hand, if no greater saving than five to six per cent. in thermal efficiency can be shown, then they are not justified. A common rule for the proportion of economisers is one square foot of economiser surface for every six pounds of water evaporated per hour by the boiler plant. Sometimes this figure varies between limits 5 to 7. However, no rule of thumb should be followed. The most desirable amount of heating surface depends not only upon the fuel saving, but on the cost of coal, the cost of maintenance, and of labour for operating. As the standard British economiser tube has ten square feet of heating surface, and holds approximately six gallons of water, and as 6lbs. of water per square foot of H.S. is a rate of evaporation obtained in many boilers, it means that an economiser in the proportion given above would hold approximately one hour's feed water supply. Although, no doubt, it is possible to deduce a formula to indicate the relation which must exist between the several factors involved, there are so many variables, it is questionable whether a useful formula would be the result.

A number of instances of actual work being performed were here described by the author, and from these a fairly close idea could be obtained as to the approximate results that might be expected with the proportions given.

One of the variables above referred to is the infiltration of air into the boiler setting, flues and economisers, and this is a factor in boiler station design which often does

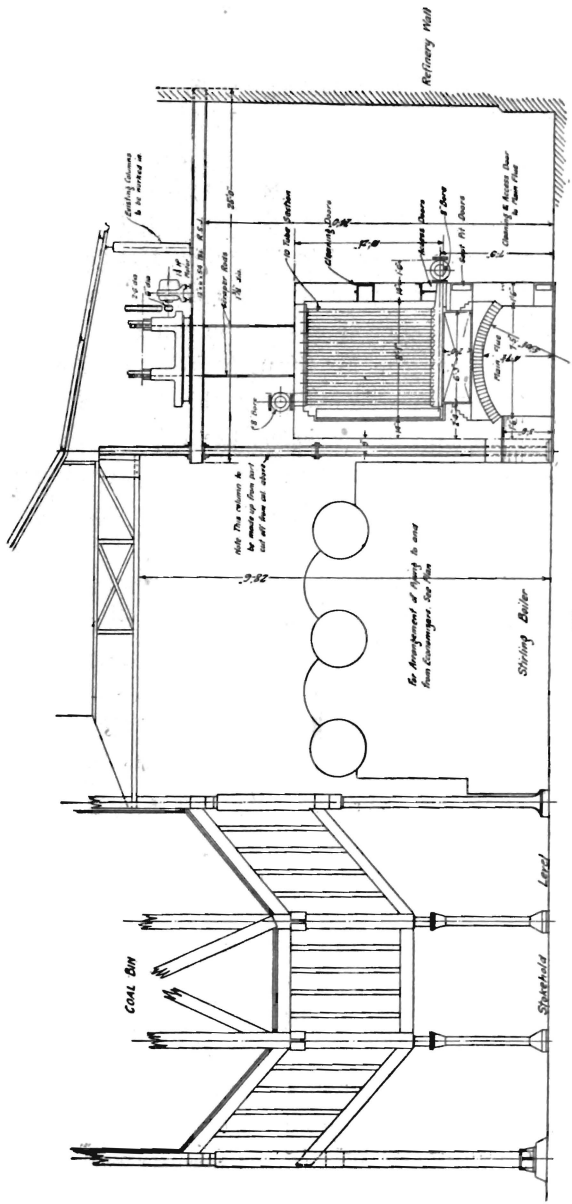
Refinery Wall
Existing Columns to be retained as
Stirling Boiler
COAL BIN
Stokehold Level

Fig. 1.

not receive proper consideration. Most of them had had some experience of cracked brick settings, but it is now more generally known that it pays handsomely to point up cracks immediately they appear, and to enable these to be seen, whitewashing on the outside is almost a regular practice.

Perhaps the most important source of air leakage into economisers is through the scraper chain holes, and when it is realised that no less than 24 cubic feet of air per minute will flow through a hole one square inch in area under a pressure of $\frac{3}{4}$in. of water, one can readily imagine how the constant flow of air through these chain holes can become quite serious. To overcome this leakage in economiser plants already under cover, the C.S.R. Co. adopted the practice of raising the scraper-driving gear up to such a height as to allow of the scrapers being operated by rods in place of chains, as shown on Fig. 1.

This is an inexpensive alteration, and he believed well worth while. In other new installations erected outside boiler houses, and for which a roof would, in any case, have been necessary, the practice has been adopted of designing the roof over the economisers in such a way as to make the space between the tops of economisers and the roof approximately air-tight. Fig. 2 gives some details of the housings in use, and as a clear indication of the effectiveness of this design in preventing air leakage, it is very noticeable the difficulty in opening and closing the door leading to the space; in fact, if one is not prepared for it, the door is likely to be pulled out of one's hand. The extra cost of making these housings air-tight is very little, and we are sure is quite justified. In America, where economisers are more rapidly coming into use, the practice is being adopted of plating the sides of the economisers in a similar way to the method adopted in many water tube boilers. Not only does this reduce the possibility of air leakage through

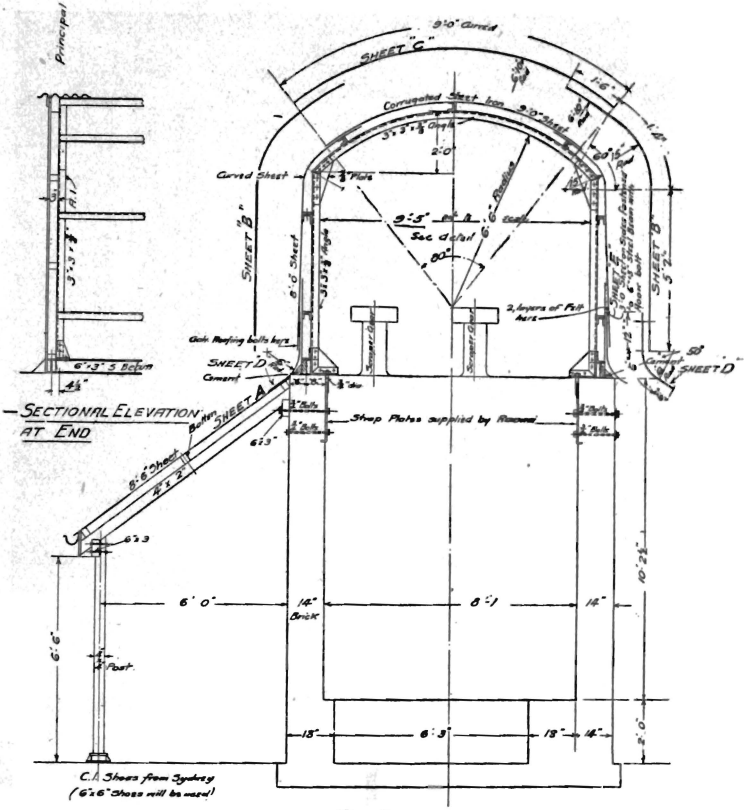

Fig. 2.

cracked brickwork sides, but it simplifies, by the easy removal of the plates, the examination of the tubes, and reduces the weight for elevated economisers. (See Fig. 3 for illustration.)

With increasing boiler pressures, the practice has, he understood, been adopted in some cases of using steel tubes in place of cast iron, but with ordinary pressures he was of the opinion that cast iron was quite satisfactory, should be just as cheap, and should withstand any corrosive action better, and it must be remembered that practically the only enemy of economiser installations is the corrosion of tubes inside and out.

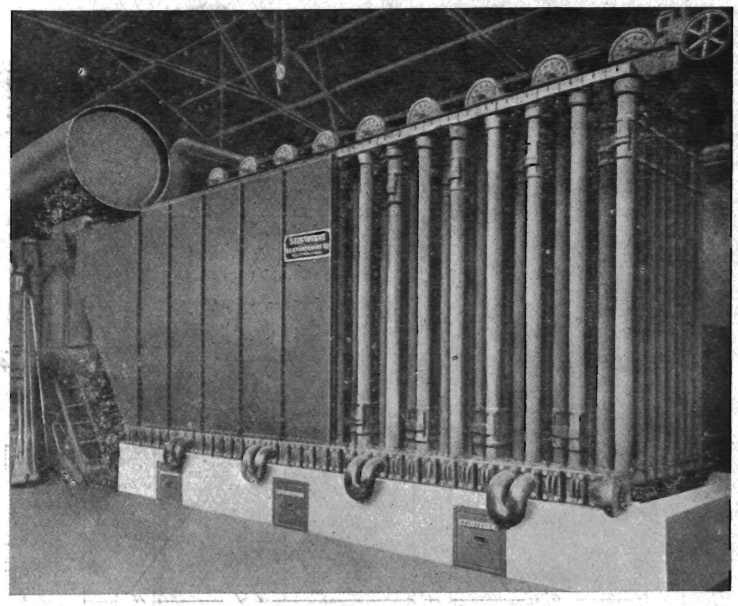

Fig. 3

With regard to the quality of the feed water, the same conditions practically apply to economisers as to boilers. You will know that, under no circumstances should an economiser be fed with water less than 90 deg. F. in temperature, but the practice has been adopted in the Company's economisers of setting aside two to three groups of tubes, i.e., eight or twelve sections each of either eight or ten tubes, and passing the whole of the feed water through these before it is delivered to the common main supplying the remainder of the economiser tubes.

In this way a "preheater" is practically obtained, and he found that perhaps 70 to 80 per cent. of the total mud deposited in the whole economiser is obtained from this section of the installation. This small portion only of the economiser requires frequent cleaning. He would here remark that the value of economisers as feed heaters is not

always recognised. By its slow heating, due to the low velocity of water through the tubes (less than one foot per minute through the preheater, and only 18 to 20 feet per hour through the remainder of the tubes, it lends itself admirably to the deposition of much of the mud in the water. Furthermore, the two or three groups forming this preheater are invariably arranged with space between each of them for a man to pass through, so that they may be regularly and easily examined in case of unusual corrosion or leakage taking place, although this is quite uncommon.

Again, in very long economisers, there is little doubt that, in some cases, the main supply pipe to the economiser is supplied too small in diameter. It should be made of such ample size that there is no inclination, on account of excessive friction, for the water to bye-pass through the nearest sections of the economiser, and thus not make each group do its full share of the work. The Company's practice is to make the supply main 9in. diameter for all sizes of economisers.

Although rather irrelevant, it might be of interest to mention that it has been frequently found advantageous in the construction of economisers and flues to use concrete instead of brickwork, as being cheaper, and less liable to cracking. This applies more particularly to Fiji, where bricks are not made locally, and the freight makes their cost of transportation very high. Of course, on one side of the economisers brick must be used, because of the necessity at some time (sooner or later) of removing the wall for examination or removal of the tubes. There are main boiler flues in use in Fiji constructed 8ft. in width, in which the roofs are either of reinforced slabs or reinforced arches, and it is known that the temperature in these at times has been over a thousand degrees F., and they have stood up to the work for a number of years. In practically all of the installations of the Company mechanical draft has been

adopted, and, except in the cities, where underfeed stokers are used for coal, induced draft fans are the standard practice, and anyone who has had experience of boiler stations in the Tropics, with the hot, still atmosphere at night time, will appreciate the necessity for having at his command a mechanical means of controlling the air supply to the boilers.

In conclusion, he would say that it has, of course, been impossible to treat exhaustively any of the facts submitted, but nevertheless he hoped that the notes would furnish a general indication of some of the lines upon which the efficiency of fuel economisers could be improved; and also he hoped they would help to impress the fact that rule of thumb calculations should not be used in fixing upon the relation between the heating surface of boilers and economisers.

Mr. Hector Kidd asked what the author considered the lowest temperature at which it was advisable to instal an economiser. Of course, if a boiler be pushed hard the waste gases would reach a temperature of 700 or 800 degrees, and an economiser would be necessary; but when the temperature leaving the boiler is reasonable, he questioned whether an economiser would be an economical advantage. If 490 degrees Fah. is the temperature in the main flue, and the feed water temperature is about 193 degrees, he thought it would be hardly worth while installing an economiser; possibly the cost of burning coal at 30/- to 35/- per ton would make it advisable.

In the case of raw sugar factories, where a large proportion of the fuel used is obtained from the crushed cane, assuming the coal value of the megass to be four times that of the coal consumed, or say 100 tons of coal per week and megass equal in evaporative value to 400 tons of coal is consumed per week, if an economiser plant be installed in such factory to produce an evaporative economy of, say,

7½ per cent. on the consumption of 100 plus 400 = 500 tons of coal per week, it would mean a saving of 7.5 × 500 ÷ 100 = 37½ per cent. of the value of the coal purchased.

The practice of passing the feed water through three groups of pipes to pre-heat it, and also of allowing some of the impurities to be deposited before entering the main body of the economiser pipes seems to me an important feature in the arrangement. The general practice in working economisers is to return some of the hot feed water to the suction of the feed pump, so that the water entering the economiser is about 90 degrees Fah.

To obtain satisfactory results with an economiser plant, it is important that the brickwork should be airtight. The plan of housing the top of the economiser, as explained by Mr. Shaw, would greatly minimise the air leaks through the scraper chain openings. This method might be further improved by housing in the driving gear with an airtight casing, and having the motor and worm wheels outside.

The American design of economiser referred to in the paper seems in some respects an improvement; it gives a better circulation of the gases owing to the staggered tubes, and as the sides are made of iron plates, they can be readily taken down to give access to the tubes.

Mr. Shaw's paper had been very interesting, and he was pleased to see that the figures quoted agreed with those of Mr. M. Longridge, who is a great authority on the economiser question. French authorities had also reached the same results that the rate of transmission is about 25 B.T.Us. per square feet of heating surface per 1 degree temperature difference.

Mr. Tournay-Hinde, referring to a diagram the author showed of the relationship between the temperature of the escaping gases, and the temperature of the feed water, called attention to stations No. 6 and 7, and asked why these two stations appeared to differ as much in their results as compared with the spots plotted for the remaining

15 stations. He asked if Mr. Shaw, in his reply, would explain why these two stations varied so much from the others.

The speaker then said he had much pleasure in proposing a joint vote of thanks to Messrs. Kidd and Shaw for their instructive papers.

Mr. McEwin asked if the author could say what rate of improvement had been effected by the C.S.R. Co. in their several installations. Any work done which will economise in the use of coal is well worth considering. As for the cost of coal, he considered it is too cheap. The available supply of coal is small, and it is going to be much higher in price. If coal were more expensive now we would take more trouble to conserve it. Any work done towards using the waste heat that now passes through the flues from the boiler is of great value. Recent experiments that had been made in the burning of waste gases in the presence of an incandescent medium had been very successful. It was probable that the results obtained would have a far-reaching influence on economiser practice in the future. The incandescent media now available are calcined magnesia and carborundum.

He had been very much interested in Mr. Shaw's paper, and also in the paper read by Mr. Kidd, and had much pleasure in seconding the vote of thanks moved by Mr. Tournay-Hinde.

Mr. Holden said he would like to ask how often the soot was removed from the economiser soot chambers.

Mr. Shaw replied that this was done each week.

Mr. W. Sinclair said that he agreed that the plugging of leaks in brickwork was most important, and he cited a case where unusual leakage took place.

The President said that as reference had been made to the question of cleaning soot from the flues of economiser chambers, he would like to say that in Rowntree's chocolate factory in York, the cleaning of the flues by a vacuum cleaner was regularly carried out, and the C.S.R. Co. were making experiments in the same direction.

He had much pleasure in putting the vote of thanks to Messrs. Kidd and Shaw, for their interesting papers, to the meeting. At the same time, he would like to compliment the Association on the fact that it seemed to be successful in maintaining the interest of most of its past Presidents. Mr. Kidd had always shown this interest, and his paper that evening was another tangible evidence of the same spirit. He hoped later on, when matters had settled down in the city, to arrange for a visit of members of the Association to Messrs. Horderns' premises to view the pumps Mr. Kidd had described, and he thought they also had to thank Mr. S. Hordern for his invitation to members to inspect the plant, which undoubtedly appeared to be another remarkable testimony fo the ability of one of our most eminent past Presidents, Mr. Norman Selfe.

He then formally put the vote of thanks to the meeting, which was carried with acclamation.

Mr. H. KIDD, in reply, thanked the members for the hearty way in which they had received his short notes, and again emphasised the fact that the plant described could not be properly appreciated unless it was actually inspected, and he hoped that a visit would be arranged later, as the President had suggested.

Mr. H. SHAW, in reply, said with regard to the circulating back of a portion of the feed water in order to heat it, this device had been adopted, where necessary, in the Company's service, but, as a rule, the conditions were such that exhaust steam was available for the purpose. Mr. Kidd had asked the question as to what was considered the lowest temperature which would justify the installation of an economiser, but there were so many conditions surrounding the question that it was almost impossible to answer it without qualification. He would say, however, that he knew of several installations in which the gases entered the economisers at about 500 deg. F. Reference had been made to the question of the concrete flues, and he described how the covers of many of the big flues in the

C.S.R. Co.'s service were made of flat reinforced slabs, and jointed in such a way as to allow for expansion.

Mr. Tourney-Hinde had asked for an explanation of the reason why certain of the stations shown on the diagram the author presented, appeared to give much less efficient results than many of the others, but here again it would be impossible for the author to give reasons in detail; there were so many varying conditions surrounding the work, but he thought perhaps one of the reasons contributing to the inefficiency of one of the stations referred to was excess leakage of air. It would be noticed that on the diagram shown the proportion of economiser heating surface to boiler heating surface varied from .2 to .9. This was because of the above referred to varying conditions as to temperature of reject gases and temperature of feed water to the economiser, each case having to be separately considered before the proportion of economiser heating surface could be determined with some certainty of economical results. Broadly speaking, the diagram showed that for every $2\frac{1}{2}$ degrees drop in temperature of the flue gases the feed water was raised one degree.

Mr. Shaw expressed his appreciation of the generous manner in which the members had received his notes, but he felt sure that any suggestions for the improvement of boiler and economiser installations was a subject well worth consideration. He hoped he had been able to suggest some means of help to those engineers operating such plants.

Before declaring the business of the meeting closed, the President said it had occurred to him, on hearing Mr. Shaw's remarks about the concrete flues, to say that the question of expansion under heat was rather a complex one. He knew of actual flues in use built entirely of concrete, with reinforced arched tops, and of a continuous length of probably 100 feet, and which had carried reject gases of as high as 900 deg. F. for some years past, and they were still giving satisfactory results.