Mr. Lewis Olrick said the question of liquid fuels was one with which he had had some experience, and he thought it might be interesting to direct attention to diagrams taken from the working drawings of a boiler executed by order of the Government, and fitted with liquid fuel. Figs. 1, 2, and 3, Plate 4, represented a small "Field" boiler made to replace another tubular boiler taken out of an official launch, No. 16, belonging to the Chief Constructor at Woolwich, so that it was necessary to make it of the same external dimensions. It was necessary to fit two pairs of engines, one on each side of the boiler, exactly to the foundation in the ship; the peculiar construction, therefore, was no fault of his. The Author had stated that the boiler was too short, but that was a simple matter of necessity. Fig. 1 was a cross section of the boiler. Fig. 2 was a longitudinal section showing the injector, the superheater, the first bridge, the deflector, the second bridge, and the means of inlet to the chimney; this arrangement was to give the gases the longest course, so that they might part with more heat than would be possible if there was a straight passage to the chimney. Fig. 3 was an end view showing the oil tank and the piping carrying steam from the boiler, and oil from the tank to the injector; also by dotted lines an end view of the superheater. Fig. 4 was a section of the injector. The injector had one entrance for the steam, and one for the oil; but the entrances could be varied if necessary, the central cone carrying the steam and the annular space the oil, or *vice versâ*. This arrangement of injector had been adopted in a number of instances, and had worked satisfactorily. The superheater served to heat the steam considerably above the ordinary temperature corresponding to the pressure of the steam, and in many instances better results were obtained when the steam was superheated. The reason, he believed, was that some of the hydrogen was utilised that could not otherwise be burned. As soon as the injector was started, by putting on a handful of shavings so as always to have a flame to begin with, the flame ascended over the first bridge, or amongst the tubes; the deflector then compelled it to go down again, next it rose over the second bridge, and finally reached the entrance at the bottom of the chimney, or through the small annular space at the top. The boiler was tested to 250 lbs., and worked at a pressure of 180 lbs. It drove two pairs of engines, with $4\frac{1}{2}$-inch cylinders, at one hundred and sixty revolutions per minute, under a pressure of 90 lbs. The heating surface in the fire-box was 45 square feet, and in the "Field" tubes 82 feet, making a total of 127 square feet. With coal the mean evaporation, in a trial of seven hours, was 7·1 lbs. of water per lb. of fuel, the engines making one hundred and fifty revolutions per minute under 90 lbs. pressure of steam. With oil the evaporation rose during the same number of hours to 10·2 lbs. per lb. of fuel, making the same number of revolutions under the same pressure, showing an increased efficiency of 44 per cent.

Figs. 5, 6, 7, and 8, Plate 4, represented a double-flued Cornish boiler fitted with Mr. Aydon's apparatus for burning liquid fuel. The boiler was 30 feet long and 7 feet in diameter, and had two flues each of 7 feet 6 inches in diameter. It belonged to Mr. Duncan, and was used at a sugar refinery at Lavenham. Fig. 5 was a cross section showing the superheater. Fig. 6 was a sectional plan showing the superheater and external arrangement of the injector and piping. Fig. 7 was an end view showing the arrangement by which the steam could either be taken direct from the boiler, or be allowed to pass through the superheater before reaching the injector. Fig. 8 was a longitudinal section showing the position of the injector, and a section of the superheater. The mode of fitting it was of the simplest description, and heated the steam to a temperature of 600°, the ordinary temperature of the steam being 307°. The steam-pipe took the steam first direct from the boiler into the injector without passing the superheater. The main oil-pipe led from the tank to the boiler. When the steam was afterwards made to pass through the superheater, better results were obtained than with the steam taken direct from the boiler. The plan of leaving the fire-bars in the usual way was very convenient, because it was necessary to get up steam with coals, and then the liquid fluid apparatus could be used. All the ashes were left on the fire-bars, and if there was flame enough, oil was simply turned on by a jet of steam; if there was not enough, it was necessary to produce it before the apparatus could be started. On one occasion the apparatus was reported to be very dangerous; but the fact was the rule laid down had not been followed, viz., that when the apparatus was to be started, it was necessary that a flame should be kindled by lighting one or two handfuls of shavings and then putting oil on them. It appeared that after the dinner hour the apparatus was started by merely squirting the oil on the ashes that were nearly extinct, the consequence was that gas formed, and, suddenly igniting, an explosion took place.

With regard to the question of economy, when liquid fuel was about ½*d.* per gallon, the efficiency was from three to five times that of coal. That was the original price of the heavy oil, the refuse from tar distillery; but when Government began to use it, the price was increased to such an extent that what was gained in efficiency was lost in price. The weight of the oil was about 65 lbs. per cubic foot. There could be no doubt, however, that, both in the Royal Navy and in the mercantile marine, even if the price of the oil were the same as that of coal, the advantage of using it would be very great. A much larger supply of fuel could be kept on board, in hot climates the stokers would not suffer as they did at present, and the same-sized boiler could be made to give double or treble the amount of steam.

Admiral SELWYN said he had often drawn attention to this subject, which appeared to him to be one of the utmost importance, involving not only an economy of fuel for steam purposes, but a condensation of fuel. In steamers, particularly in the Royal Navy, the question of the quantity of fuel that could be carried was of the greatest importance, as efficient sails had been entirely given up. No steamer in the British Navy could carry more coal than was required for three days' full steam. No doubt a steamer could go at a slow speed for a greater number of days by using an expansion arrangement; but three days was the limit of consumption at full power. If the enemy was going at 15 knots an hour, it would not do for her pursuer to go more slowly. The system described in the Paper would, according to all trials that he had made and seen, at least give nine days' consumption instead of three. The system was also of importance, as teaching for the first time that fuel could be burnt so as to produce the full calorific value assigned to it by chemists. He desired to refer shortly to a Paper he had written on the subject for another Institution. In the trials at Woolwich Dockyard, made under his superintendence, it was first ascertained from the chemists that, according to the chemical composition, the fuel was capable of evaporating 17½ lbs. of water by each lb. of oil; and the amount actually evaporated was 16·1 lbs. There was a loss of 2·7 units of heat up the chimney; so that apparently 18·8 units of heat were produced, instead of 17·5. How was the excess obtained? Unmistakably, because the hydrogen of the steam was burned; and it was to that point that he desired to draw attention. Bunsen and Fyfe stated[1]: "Red-hot coal and aqueous vapour mutually decomposed each other into hydrogen and carbonic-oxide gases, with some carbonic acid, both of which, if sufficient oxygen be present,

[1] *Vide* Transactions of the Institution of Naval Architects, 1870, p. 161.

burn with the production of a white heat to form water and carbonic acid; numerous observations showed further that the additional heat evolved more than compensated for the fuel used in producing the vapour." His own experiments corroborated that fact. The instant the temperature of the steam was raised by superheating before uniting it with the oil, it was found that the hydrogen of the steam was more perfectly burnt; and the higher the pressure of the steam the better it combined with the oil, and the better the hydrogen of the steam burnt; so that if a proper heat could be got in the furnace by the use of fire-brick chambers, it might be hoped to burn the whole of the steam used for blowing in the oil. "If the hydrogen had been perfectly burnt in my experiments, and the quantity of hydrogen present in the steam had been only that due to the 1 lb. of water (equal to 1 lb. of steam) which was used per lb. of fuel to blow in the hydrocarbon oil, we should, on this account, have to add to the calorific effect obtainable from the fuel, as above, viz., 17·5 lbs., a further quantity of 7·062 lbs. obtainable from the perfect combustion of the hydrogen in the steam; and if in the boiler used there was no loss of heat up the chimney, and the theoretical result had been realised, a total evaporation of 24·562 lbs. of water per lb. of fuel and steam would have been obtained. Again, if a higher class of hydrocarbon had been used, such as is common enough, with a calorific value of 22 instead of 17·5, our total evaporative effect would have been 29, or four times as much as we get with badly burnt coal."[1] In many of the experiments in England, America, and elsewhere, the extraordinary results obtained were due to the fact that the heat of the combustion chamber was very great. "The highest calorific value obtainable from liquid hydrocarbons appears to be that derived from the 'sextane' of Hofmann, the composition of which is C. 72 per cent., H. 28 per cent., but this is not to be had in commercial quantities. Its calorific value is 28·72."[1] "The heat of burning hydrogen is 5,775° Fahr. No such heat was ever obtained during the Woolwich experiments, but it was obtained at Messrs. Griffiths' factory, Victoria Park, and there, in a proper fire-brick combustion-chamber, built inside the boiler, 160 gallons of oil per day did the work of 3 tons of coal, or an evaporative effect of 46 lbs. of water was obtained by the use of 1 lb. of fuel plus 1 lb. of steam."[1] At the trial he was at a loss to account for the result. He tried the chemical composition of the oil, and found that the

[1] *Vide* Journal of the Royal United Service Institution, vol. xxi. p. 119.

quantity of water theoretically to be vaporised was 21 or 22 lbs.; taking the hydrogen in the steam, he obtained about 7 lbs. more. How was the difference to be accounted for? "Recent chemical experiments have shown that decomposition of water takes place whenever steam is passed over heated coke or carbon. Hydrogen, carbonic oxide, and carbonic acid are produced. The analysis of the gas obtained by passing steam over red-hot charcoal for some hours gave as a mean—carbonic acid, 20 per cent.; carbonic oxide, 20 per cent.; hydrogen, 60 per cent. If metal, such as iron, be present, it adds to the quantity of hydrogen according to another action, in which there is a combination with the iron, and this mixture of gases is inflammable, and burns with a non-luminous but hot flame, the heat of which would be increased if the carbonic acid were previously removed." Thus it appeared that, so far as the chemical question was concerned, it was perfectly possible to produce and burn with good effect the combustible gases contained in water-vapour under certain conditions, not in themselves difficult of fulfilment; the first thing was a sufficiently hot chamber, the second the presence of carbon in any of its forms, and the third the presence of iron or some such metal. Now, for the effect to be expected which was to induce a trial of the experiment. If 60 per cent. of every lb. of steam blown in with, and used to blow in, the hydrocarbon were hydrogen with 20 per cent. carbonic oxide and 20 per cent. carbonic acid, a proportion of 80 per cent. was rendered combustible; even without the presence of iron this should give more than 48 units of heat, 38 being due to the hydrogen alone, and 10½ to the carbonic oxide. Those observations showed how imperfectly fuel was now burned. The experiments had not been continued, partly on account of the cupidity of those who had run up the price of the dead oil used. There was, however, an unlimited supply of it. It could be obtained from the blue shale at Poole, in Dorsetshire, at the rate of 40 gallons per ton, and there was no doubt that when its full value was understood, both for metallurgical purposes and for the use of shipping, the subject would again receive attention. He did not think that any better plans of burning would be found than those already adopted. He congratulated the Author on the result of his working. He had been of late years connected with mines, and one of the chief difficulties experienced in the reduction of metals had been the introduction with the fuel of a great many things that were not desired. In smelting ores engineers would be glad to resort to something like oil, which was a perfectly pure fuel. The metallurgical question had come, to a certain extent, under his notice in the Woolwich experiments. The ordinary bolts of iron in the pieces of wood used to light the fire with came out with all the qualities of the best Swedish iron; they were diminished considerably in size, but they came out perfectly fit for making harpoon iron. Some metallurgists were now using the system for all their crucibles, and they were able to deal with platinum by the heat obtainable from liquid fuel as they formerly dealt with lead. For that and for many other purposes he believed liquid fuel would be employed, and he hoped the experiments of the Author and of others would be carried on until the importance of the subject was universally recognised.

Dr. Paul said the attention he had been able to give to the subject had led him to an opinion entirely unfavourable to the use of liquid fuel as a substitute for the ordinary materials. With regard to petroleum, which was found in America, in the east of Europe, round the Caspian, and elsewhere to a considerable extent, the principal objection to its use was the extreme volatility of a very large portion of it. From 30 to 40 per cent. of the American petroleum was capable of assuming a gaseous form at the ordinary temperature of the atmosphere, and that vaporised portion, when mixed with air, formed a gas as explosive as ordinary coal-gas under similar circumstances. The use of such a material would be extremely undesirable under conditions such as obtained in the stoke-hole of a vessel. The next objection to it was the cost. At present it was exceedingly cheap, about 6*d*. per gallon, representing 8½ or 9 lbs., or from £5 to £6 per ton. The calorific power of average petroleum was about one-third more than that of steam coal. Another objection to the use of natural oils was the small quantity available for the purpose. The quantity raised in America did not exceed 600,000 tons a year, which was altogether insignificant for the supply of either the mercantile or naval marine. With reference to the artificial oil obtainable by distilling coal or shale, he believed there were few shales that would yield as much as 40 gallons per ton, but even at that rate it would be very costly. To obtain 3 cwt. of the oil a ton of the raw material would be required, and how would that have to be dealt with? It would have to be put into retorts, and fuel would have to be consumed to distil the oil out of it, and that would go far to neutralise any advantage which the oil might possess as fuel when compared, for instance, with Aberdare coal. With regard to the volatility and the obtainable quantity, the objections were not so strong as they were against petroleum; but the oil contained a large proportion of easily volatilisable material which would form an explosive mixture with air. The dead oil or creosote certainly presented great recommendations for use as fuel. It was exceedingly dense, weighing from 11½ to 12 lbs. per gallon. In case of accident this oil would sink instead of floating and taking fire as petroleum or shale oil would do. It burned readily, and was cheap, but the quantity to be obtained was small. There were circumstances under which the use of the material was advantageous, but they differed from the circumstances under which the fuel was used in the Navy. To a tar distiller the oil was a nuisance, and of course it would be a great advantage to him to use it as fuel, but that afforded no argument for introducing it into steam vessels. No doubt it was very cheap, about ½*d.* per gallon, but as soon as there came to be a demand for it the price would of course be increased. There was one use of liquid fuel in the heating furnaces for bending boiler plates which seemed to promise considerable success. The advantage there was that a highly carburetted atmosphere was obtained in the furnace, and none of the cutting or oxidation of the surface was brought about that was often so prejudicial in the working of iron plates. He believed that at Woolwich Arsenal and elsewhere that mode of bending boiler plates and armour plates had been found advantageous. He was glad to find that the statements made with regard to the use of liquid fuel were of a much less immoderate character than they were twelve or fourteen years ago, when it was said that 1 ton of liquid fuel was equal to 5 or 6 tons of coal. With reference to the advantages to be gained by the burning of steam, he was surprised that Admiral Selwyn had not yet divested his mind of that phantasm. If he was still following out that idea, why did he not go further, and, instead of expending heat in producing steam, use a jet of water and burn it at once? It had always appeared to him that the use of liquid fuel had all the defects of a half-measure, missing many of the advantages of solid fuel, and falling short of the signal benefits realised by the use of fuel in a gaseous form. That appeared to be the most natural and scientific mode of applying fuel, because, however coal or wood, or peat, or even liquid fuel was burned in a furnace, the first effect was the conversion of a considerable portion of the material into gas. Some of the greatest advances made in the use of fuel had been secured by the ingenious applications of Dr. Siemens for applying fuel in the gaseous form to the various purposes required.

Mr. E. F. BAMBER remarked that the greatest portion of the loss in a steam engine did not take place in the furnace. In the best regulated furnaces with draught only about one-fifth was lost. According to a statement in the Paper, that would be reduced to one-tenth; but when that one-tenth was multiplied by the ratio of the difference between the temperature of condensation and the temperature to which the steam was raised in the boiler, to this latter temperature on the absolute scale, it came out eventually that there was only about one-fortieth in favour of liquid fuel. With regard to the cost, he was surprised at the statements that had been made. At 1½*d.* per gallon, liquid fuel would be about the price of coal; but at 6*d.* a gallon it would, of course, be much more expensive. For smelting and metallurgical purposes, the use of liquid fuel was important. It had been stated that 1 ton of iron was heated with 35 cwt. of coal in an ordinary furnace, and by about one-fourth of that amount when liquid fuel was used, which was, of course, an enormous advantage. But in economical furnaces, such as the Regenerative Gas furnace, 1 ton of metal would be re-heated with 17 cwt. of coal; and when the price of coal was taken into consideration, the advantage was greatly on its side. Reference had been made to the production of heat from substances which had already entered into combustion. It was surely a well known fact that in steam the hydrogen was already burned, and if it were reproduced, as much heat must be used as it gave up. The economical application of steam was in decomposing it by heat which would otherwise be lost in radiation, as in the Regenerative Gas furnace, underneath the hearth of the producer of which a slight amount of water was put, and the heat which otherwise would be wasted decomposed the water into its constituents hydrogen and oxygen, thereby enriching the produced gas. But the idea of turning water into fuel with advantage, except with waste energy, was one which he could not accept.

Admiral SELWYN said that the words he had quoted on that subject were not his own, but those of Professor Bunsen and Mr. Fyfe.

Mr. CRAMPTON thought it desirable to keep as nearly as possible to actual practice. No one could expect to get more out of a thing than there was in it. There was unquestionably great value in liquid fuel. Liquid fuels would not evaporate, theoretically, more than 17 or 18 lbs. of water. Coal theoretically evaporated 13 or 14 lbs.; the difference, therefore, was as 13 to 18, and no more; and if the price of liquid fuel was proportionately higher, it was clear that in that respect there was no advantage attending it. As to burning water, no one could believe that more could be got out of water after it was vaporised or decomposed than there was in the heat used to vaporise or decompose it. If anything could be done with water, why should it not be used direct, so as to save fuel altogether? In examining questions of that kind, it was desirable to keep as far as possible to the evaporation of water, which was a matter that could be dealt with; but when it was put into reverberatory furnaces, the results were very fallacious. With regard to coal, he thought nothing of heating 1 ton of scrap iron with 3½ cwt. of coal in a powdered state; but in a comparison mentioned in the Paper, 30 cwt. of coal had been employed to do the same work. Such comparisons were, of course, useless. He had paid some attention to the subject of liquid fuel years ago; he found such fuel dangerous to deal with, and he should be sorry to have anything to do with it. In a factory where there was a waste product to be had at a low cost he might be disposed to use it, especially the dead oils, the burning of which was attended with no great danger; but if such products were used to any extent the price would soon go up. He had made a calculation with Mr. E. J. Reed, C.B., M. Inst. C.E., the late Constructor of the Navy, that one large steamboat company would consume all that could be obtained. It would be found that to make the oils from shale would cost more than 18*s.* a ton.

Mr. LONGRIDGE said the extract from Bunsen and Fyfe, read by Admiral Selwyn, referred entirely to the action of steam thrown upon incandescent carbon, or coke. It was well known that when steam was thrown upon coke at a very high temperature decomposition took place: a portion of the oxygen was taken up by the carbon and formed carbonic oxide, and set free a portion of the hydrogen. That was, however, different from mixing it with the oils; and that any such result as had been stated—46 lbs. of water evaporated by 1 lb. of fuel and 1 lb. of steam—was, he thought, beyond all experience. That there was decomposition when steam was thrown upon incandescent carbon at a high temperature, there could be no doubt, and under some circumstances it would go to increase the value of the fuel to a limited extent. The main question in the Paper would have been put in a clearer light if the Author had given in each case a description of the oil that was used, and its cost per cwt. In one place the theoretical value was stated at 17·4, but instances were quoted in the Paper where it amounted to 28; so that apparently the oil could not have been the same; but taking the latter figure as the utmost effect, it was compared with coal in the same boiler. The result stated by the Author was greatly in favour of the oil. But the coal was only evaporating 6 lbs. of water per lb. of coal—only half of what coal could be made to do in properly constructed boilers. The Welsh coal, or the north country Hartley coal, could easily evaporate 12 lbs. He had himself evaporated 12·91 lbs. without any special apparatus or any special care. The actual theoretical value was about 14·57 lbs. It was not fair to make a comparison between coal evaporating 6 lbs. in a badly constructed boiler and oil evaporating 28 lbs., which possessed nearly double the evaporative power of oil mentioned in another part of the Paper. If high-priced petroleum was used, the price was to be set against the price of coal, viz., £7 or £8 per ton against £1 5*s.* to £1 10*s.*

Mr. G. F. Deacon thought that further light ought to be thrown upon the question of the price of the oils to which reference had been made. The heavy oil from the distillation of coal tar, known in commerce as creosote oil, but being in fact a substance distinct from true creosote, had been spoken of as one of the most suitable liquid fuels produced in this country. Boiled with pitch, it was largely used in the north of England for filling the joints of pavements, and for making a bituminous concrete pavement. In Liverpool this bituminous concrete was also used for the foundations of stone pavements. For the last three or four years he had used 50,000 to 100,000 gallons a year, and had paid for it about 2½*d.* a gallon; so that the price was not a merely nominal one even at the present time.

Mr. John Phillips said, some years ago an experiment had been made at Messrs. Rennie's works to test the relative value of the dense oil and coal. The experiment lasted a month for each boiler under trial. The consumption of the oil was found to be so nearly like that of coal that no advantage was obtained by the use of it, and it was abandoned. The cost of the oil as supplied was ½*d.* per gallon. The fuel came in in lumps, and a great deal of trouble was experienced in getting it into a liquid form; besides which its smell was very offensive.

Mr. Aydon, in reply, said when he began his experiments the price of dead oil or creosote, delivered at the Victoria docks, where it was used for preserving timber, was ¼*d.* per gallon, but when the process of burning oil proved successful, one person bought up or contracted for, as a speculation, the stocks of many of the tar distillers, amounting to about 3,000,000 gallons. The market price of oil was thereupon raised first to ½*d.* per gallon, then to $\frac{3}{4}d.$, and finally to $1d.$ and $2\frac{1}{2}d.$ per gallon. When, however, the price of dead oil was from $1\frac{1}{2}d.$ to $2d.$ per gallon, it was as costly as coal fuel, so that in a country like England, where coal was cheap, it would not be worth the trouble of using it. For this reason, the Messrs. Field had discontinued its employment. But the chief value of mineral oil as a fuel was that it gave greater carrying power to ships, and enabled them to make longer voyages without the necessity of calling for fuel at any of the coaling stations. By its means he believed it would be possible to send a vessel like the "Great Eastern" (or even smaller steamers), with the present coal space or bunkers adapted to store liquid fuel, to Australia and back without opening their furnace doors (except for lighting the fires for the return voyage) or taking in fresh fuel. With regard to the quantity of mineral oil obtainable, it was found in almost every country, from Sweden to Australia and from America to Japan. It was abundant in Asia, especially in Burmah, and on the south-west coast of the Caspian Sea; also in Egypt and in Turkey, in Gallicia and in Italy. In America and Canada, new oil districts were continually being opened up; and from 1860 to 1864, about 201,000,000 gallons had been produced or pumped. In 1864 alone it was 87,000,000 gallons. In 1865 the American Inland Revenue Commission reported a daily production for four States of 12,000 barrels, of say 42 gallons each. This was equal to a daily supply of 504,000 gallons. This quantity was irrespective of the produce of the other American States and of Canada. The island of Trinidad must also be included. It was almost one entire mass of oxidised mineral oil, from which liquid fuel could be obtained in large quantities. Granting, however, as Dr. Paul had stated, that America at present only produced 600,000 tons, or 134,400,000 gallons of oil per annum, that was not the quantity which could be raised, it was the restricted production due to the influence of the American and Canadian oil ring, who allowed only a certain quantity to be placed in the market and so kept up prices. However, he had no fear but that, when the demand for liquid fuel should arise, the supply would be forthcoming, and that at a reasonable cost.

A great deal had been said and written about the absurdity of the idea of extra heat being derived from the use of steam in combination with the hydrocarbons. Dr. Paul appeared surprised at Admiral Selwyn being of opinion that such was the case. He thought it was not the first so-called phantasm or chimerical idea that had been of use to chemical science. Dr. Paul also stated that by using liquid fuel many of the advantages of solid fuel, and the great benefits arising from gaseous fuel as in the Siemens furnace, were lost; but as all fuel must be converted into the gaseous form before it could be consumed, he did not see the drift of the argument. Chemists ignored the fact that they were not dealing with a solid body like coal, but would treat the liquid hydrocarbons as if they were solid carbon. To such view of the case he strongly objected, for here was a fuel naturally prepared the first stage towards gasification, as to effect the same object artificially six thousand or more heat units would have to be expended, which heat would become latent and so be lost as useful work. Now these six thousand heat units, added to the fifteen thousand heat units, derived from converting or burning carbon into $CO_2$, would give twenty-one thousand heat units, which the late Professor Rankine stated to be the amount due to gaseous carbon. American mineral oil had the following constituents: carbon, 86; hydrogen 14 = 100. Taking the above estimate for the calorific value of gaseous carbon, the result was 26,887 lbs. of water per lb. of fuel. This approximated to the calorific value calculated by Professor Hofmann. The analysis of the dead oil used in the experiments at Woolwich furnished, according to Professor Church, the following result: carbon, 86·48; hydrogen, 7·06; oxygen or refuse, 6·46 = 100. This gave, for the calorific value, 22·18 lbs. of water, after deducting the oxygen, as against 17·50 lbs. of water, taking the carbon as solid. In this view of the case there need not be much surprise at the results obtained by different experimenters with liquid fuel. Mr. Bamber had made a mistake in calculating the relative value of coal and oil fuel: for 1 ton of dead oil at ½*d.* per gallon of 10 lbs. would be 9*s.* 4*d.*, whereas the cost of 1 ton of Aberdare steam coal came to from 25*s.* to 30*s.*, or about three times as much; so that estimating the efficiency of oil at only twice that of coal, the relative cost would be as 1 to 6. He was aware that water, and therefore steam, was an oxide of hydrogen, the product of combustion, but he much doubted the assertion that it would take the same amount of heat for dissociation or decomposition into its constituent gases, if exhibited in the presence of gaseous carbon. As to using water alone as fuel, he had never heard the advocates of liquid fuel assert such a thing, although there could be no doubt but that it aided the combustion of liquid fuel when properly applied in the state of superheated steam.

Mr. Crampton's desire to keep as nearly as possible to actual practice had not been violated in the Paper, as the results stated therein were from experiments and practice on a large scale. The answer to the question, why not use water direct as a fuel? was that no product of thorough combustion could be employed by itself as fuel and burnt again, without decomposition and separation into its constituent gases. With regard to 3½ cwt. of coal heating 1 ton of scrap, he had no doubt of the fact; but it must be recollected that Mr. Crampton put fuel into the furnace in a very different state from that of the 30 cwt. mentioned in the Paper. In fact, Mr. Crampton assimilated it to liquid fuel. He had made experiments in Mr. Crampton's domain years ago, and could assure him that with highly superheated steam and finely pulverised coal he would obtain better results than with the air blast alone. If shale oil could be sold at 18*s.* or even £1 per ton, it would be cheaper and better than coal. To Mr. Longridge's remarks on the extract from Bunsen and Fyfe, quoted by Admiral Selwyn, he would answer that what took place between steam and incandescent coke took place in the fire brick combustion chamber of the oil furnace, between the superheated steam and the liquid hydrocarbons, with this difference, that in the latter case double decomposition ensued, also that the heat required to convert the coke into CO gas was saved to be utilised on other work. The theoretical value of the oil, 17·4 lbs., as used at Woolwich, was from an analysis made by Professor Church, and the estimate was made as if the carbon was solid. The general composition of creosote or the dead oils was as follows: carbon, 78; hydrogen, 6; oxygen, 16 = 100.

The oil in all the experiments was nearly the same in composition, but tried under different circumstances; hence the difference in the results. With reference to the comparison alluded to by Mr. Longridge, where an inferior fuel had been housed, it was the coal used upon the premises, and he could not compare it with any other coal. The boiler was not a badly constructed one, it had two flues, with Galloway tubes, and was quite equal to the average work of a coal-burning boiler. With Welsh coal he had no doubt far better results would have been obtained. Mr. Phillips, in his experiments, must have been served with an oil containing a large proportion of naphthaline and sulphur, in which case the mass would have to be heated, and as he was burning a sulphide of carbon, there could be no doubt that the smell would be very offensive.

In conclusion he ventured to say that, in a few years, when the value of liquid fuel came to be more known and appreciated, no solid fuel would be burnt in houses or large towns.

Mr. S. B. Boulton remarked, through the Secretary, that he had conducted experiments in burning liquid fuel on a large scale, at various intervals during the past few years. His experiments had been almost entirely made with creosote or heavy oil of tar, this being the cheapest of all kinds of oil available for fuel in England. As regarded the kind of apparatus to be used for liquid fuel, it was desirable that it should be of the simplest possible description, and so applied to the furnace as to enable the liquid fuel to be used alternately with coal, and without much trouble or expense in the transition. He strongly objected to any apparatus in which the oil was turned into vapour in a separate generator, as he considered such a system to be more costly to inaugurate and maintain, more dangerous in its application, and extremely likely to get out of order in practical working. The system which he preferred was that of dispersing the creosote, as it entered the furnace, by a jet of steam, and letting the spray thus formed play upon a small quantity of incandescent fuel. This system worked perfectly, and on that point he agreed with Mr. Aydon. The expense of the apparatus was trifling, consisting merely of a reservoir to contain the creosote, of a small pipe, leading from thence to the interior of the furnace, and of another pipe communicating with the steam boiler, the orifice of the second pipe being immediately below the orifice of the creosote pipe. By this means oil or coal could be burnt alternately, and the change from one kind of fuel to the other could be made at half an hour's notice as often as required.

The next question was one of cost. Creosote, although the cheapest kind of liquid fuel in this country, was not a refuse product. It might fairly be calculated that all the creosote manufactured in Europe from the distillation of coal tar was required for the preparation of timber. The price of creosote had varied during the last few years from 2*d.* to 3*d.* per gallon, sometimes reaching 3½*d.* Now he had found, upon an average of a great many trials of different boilers, that 1 ton of creosote would do the work of from 2 to 2½ tons of coal. Assuming, for the sake of calculation, that creosote was worth 2*d.* per gallon, taking 220 gallons to the ton, and supposing, moreover, that 1 ton of creosote performed twice the work of 1 ton of coal, it would be seen that the cost of the creosote burnt in place of 1 ton of coal would be 18*s.* 4*d.* This calculation, however, did not state the whole of the case. The production of creosote being limited, it would rise greatly in price if a large demand sprang up for it for consumption as fuel. It might be roughly stated that, for consumption in England, it would be a cheap fuel at 1*d.* per gallon; problematical as to economy at 2*d.*; and too expensive at 3*d.* The aspect of this question, however, changed if considered with respect to the consumption of liquid fuel by large steam vessels, and upon long sea voyages. The cost of fuel consumed on board of a steamer consisted not only of the price paid for it at the port of departure, but it was increased by the necessary sacrifice of tonnage-capacity in the vessel on board which it was consumed; and this last item of cost increased with the length of the voyage. If, therefore, creosote as a fuel would do the same duty as twice its weight of coal, it might, under certain circumstances, and upon long sea voyages, prove the more economical fuel. It might at times be of great importance that a vessel of war should be able to cruise for a long period before being obliged to put into port for a fresh supply of fuel. It would appear that, by burning liquid fuel, she could keep at sea for at least double the time that would be possible if she were burning coal. This led to the suggestion that it might perhaps be desirable for the British Admiralty to try further experiments on a large scale with some such simple form of apparatus as that which he had described, especially as creosote could be obtained in greater abundance in England than in any other country.

Mr. O. C. D. Ross observed, through the Secretary, that the Paper dealt with the various modes hitherto adopted for burning liquid fuel, and with its application, first to boilers, secondly to metallurgical operations. It described plans by which oil was driven into a furnace as spray, together with steam, or compressed or heated air; but the excessive quantity of smoke and soot showed that it was being incompletely consumed, and these methods had been properly abandoned. Excepting for the purpose of heating, or converting the oil into vapour, air must always be the preferable medium for conveying it into a furnace, because it supplied the oxygen required for its combustion. It should be borne in mind that 1 lb. of carbon required for its combustion $2\frac{2}{3}$ lbs. of oxygen, or 11·61 lbs. (about 150 cubic feet) of air, and that consequently, whatever process of combustion might be adopted, this minimum quantity of air must be mixed with the oil vapour when driving it into a furnace. Even coal gas was not completely consumed unless mixed with sufficient air, as in a Bunsen burner. If steam was added, the volume of the products of combustion would be increased, over which the heat would be distributed, and the thermal effect of the fuel would be diminished; but as all heavy oils must be heated in order to be converted into vapour, which was an indispensable condition for ensuring their complete combustion, it was possible that local conditions might sometimes counteract the disadvantage of using steam. It appeared to him that a consideration of the cost of liquid fuel, as compared with coal, made it impossible to contemplate its application to all purposes for which coal was used. The experiments with creosote at Woolwich, in 1866-67, caused the price to be raised from $\frac{3}{4}$*d.* per gallon (or say 15*s.* per ton) to 4*d.* and even 6*d.* per gallon, and it was at that time asserted that the total annual production of creosote in England amounted to about 100,000 tons. So also the total quantity of petroleum now raised in America per year was under 1,000,000 tons, whereas the annual consumption of coal in Great Britain alone was now about 140,000,000 tons. At 8*d.* per gallon, the present cost of petroleum (or coal oil) was about £9 per ton. He could not, therefore, agree that oil was the "coming fuel"; the advocates of its application for all purposes would defeat their own object if they succeeded. There could, however, be no doubt that for certain special purposes, and in certain localities, liquid fuel would be both more economical and in other ways more advantageous than coal. For example, it would be far too costly for use, under ordinary conditions, in stationary boilers in England, because it would then have to compete with coal on a simple comparison of the calorific effects and relative cost, the first of which might be as 1 to $2\frac{1}{2}$ or 1 to 3, the second as 1 to 9. But on the other hand, it might be advantageously applied to the marine boilers of large ocean steamers, of pleasure yachts, and of men-of-war, because of the great saving which would be effected in the bulk of the fuel, besides its superior cleanliness, reduction in the number of stokers, absence of smoke, &c. Again, when high temperatures were required in a confined space, as in some metallurgical operations, vaporised oil had the advantage that it would burn with a much greater thermal heat, because it did not require the excessive quantity of air which was necessary for the disintegration of coal, and the waste of heat through the chimney of an ordinary reverberatory furnace would be enormously decreased when using oil vapour driven into the furnace in combination with air. Where coal was expensive and oil was cheap, as in the Caspian Sea and on the coast of South America, liquid fuel would be the cheaper of the two. Professor Macquorn Rankine had pointed out that whereas the evaporative power of solid carbon was 15, that of gaseous carbon (such as was obtained with oil vapour) was 21, whilst its useful thermal effect in metallurgical operations was many times greater than that of coal. Different qualities of oil required different temperatures to convert them into vapour; one oil might require to be heated to 400°, another would vaporise at ordinary temperatures. The latter would be gradually reduced in temperature by the vaporisation, and, unless that loss of heat was compensated, would give off a gradually diminishing quantity of vapour. These circumstances must be attended to when employing liquid fuel, and made it necessary that it should be used with care and under intelligent direction.

Mr. Aydon desired to reply, through the Secretary, to some of the remarks made by Mr. Ross, who assumed that the price of dead oil or liquid fuel was from 6*d.* to 8*d.* per gallon. This was out of the question, although no doubt the Government were charged that price. Whatever might be said, he should retain the opinion that within a comparatively short time no solid fuel would be burnt. Something like a corroboration of the theory held by Admiral Selwyn and himself, in contradistinction to chemists generally, was the dissociation of steam into its constituents more readily and at a lower temperature than was commonly supposed. From a brief account of experiments made before the American Scientific Society on this subject, he gathered that, when steam was passed through a platinum tube or coil at a temperature equal to a dull low red heat of wrought-iron plate, the resultant gases of decomposition were collected in a receiver over mercury. After sufficient had been collected, a lighted taper was inserted, when an explosion took place, thus showing that the gases were in the same proportion as before dissociation, and proving that the dissociation was not owing to the loss of oxygen to the metal of the platinum pipe.