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Lecture on An Improved Apparatus for Warping, Winding, Hoisting, etc., on Board Ship.

By MR. JAS. A. LIDDLE.

READ

Monday, March 21, 1910.

Chairman: Mr. JOHN McLAREN (Member of Council).

The utilization of electrical machinery on board ship differs entirely from that of electrical machinery on land. A considerable amount of electrical machinery for marine use must be capable of developing its full power even whilst turning a half somersault. Deck or exposed electrical machinery must be capable of doing all sorts of diving performances without being any the worse. Also it must be able to withstand long periods of dampness and probably of disuse under the most unfavourable conditions, and yet be capable of starting up at any instant. The starting and controlling apparatus must be of the simplest character possible, so simple, in fact, that the ordinary deck hand could control the deck electrical machinery, even though he had never seen the machine before. Any one designing electrical machinery for marine work must take into consideration many points never required in the design of electrical machinery for use on land.

If we except the steam turbine we may consider present day marine machinery as slow moving. During the past few years the average speed of nearly all types of land machinery has increased by leaps and bounds. The reason for this is obvious. By doubling the speed of a machine we may expect double the power from the machine, whilst the weight, price and size remain unchanged. Lately I had the opportunity of seeing three prime movers of nearly the same power but of vastly different dates. To make the three more interesting I might say they were situated within two miles of the place where James Watt made his first steam engine. The first was an old atmospheric condensing steam engine making thirty to forty strokes per minute, weighing several tons, and with its guide ropes, levers, etc., occupying about 15 ft. by 15 ft. by 20 ft. This engine has no doubt some advantages, for instance, a man might wrap a cloth round his hand, lift off the safety valve, and have a peep into the boiler without stopping the engine. The second prime mover of interest was a De Laval steam turbine running at something like 20,000 revs. per minute, and weighing a few cwts., and occupying a few cubic feet. The third was an electric motor running at 1,500 revs. per minute, weighing a few cwts., and occupying a few cubic feet.

No shipbuilder of the present day would dream of building a ship and fitting it with atmospheric condensing engines because the ship would not be capable of carrying sufficient engine power to drive her at a reasonable speed, far less able to carry a cargo in addition. As we step up the ladder of improvement we fit ships with high speed, light machinery giving them greater carrying and greater earning capacity. This is pretty much the case so far as the engine room is concerned, but during the past twenty years there has been very little improvement in auxiliary machinery. Looking at the deck of a large cargo steamer, one is very much surprised that owners are content to send their ships out with such cargoes of deck machinery. Strength, efficiency, and reliability do not lie in weight and build, but in design.

In regard to ship auxiliary machinery there are at least four different efficiencies to be considered. There is the mechanical efficiency of the machine in question. This is the first important point for land work, but in marine work the mechanical efficiency is of no importance if the machine does not possess other high efficiencies such as, weight divided by power and volume divided by power; reliability, first cost together with annual expenditure, interest, sinking fund, upkeep, and insurance. All these and possibly several other efficiencies or properties have to be linked together. Even if a piece of auxiliary machinery having to the highest degree all the before enumerated properties was procurable, superintendent engineers and shipowners have great difficulties to overcome before introducing these on board ship because the majority of sea-going engineers have only a knowledge oi the steam engine and its characteristic properties. If given an internal combustion engine or an electrical motor they would subject it to the same working treatment as they would a steam engine. I hold that the designer of internal combustion engines and electrical machinery must meet superintendent engineers and shipowners half way. As probably most of the members have read Mr. McLaren's paper on "The Extended Uses of Electricity on board Ship," I will not touch on the high transmission efficiency to be effected by making use of electrical power instead of steam power for driving auxiliaries on board ship. However, matters must be considered from all points of view. For instance, a De Laval steam turbine *of itself* has a very high efficiency, but if coupled direct to a ship's propeller the combined efficiency will be very, very low, therefore, notwithstanding its high efficiency, the De Laval steam turbine must be passed over. Similarly with electric motors; a well designed electric motor should give an efficiency somewhere between 85 per cent. and 90 per cent., but unless it can be coupled to a machine in such a manner that it gives a good combined efficiency from every point requiring consideration for marine work, it must be discarded as useless. From a theoretical point of view, the power which an electrical motor will develop depends entirely upon its speed and temperature rise. In the design of electrical motors for marine work, these are two very important quantities to be fixed, because if there is no limit to speed and no limit to temperature rise we may design marine motors as small and as light as we please. Taking temperature rise first ; the size and weight must be controlled by the class of insulating material at our disposal, but for present day practice no part of a motor should be allowed to heat above 90 degrees Centigrade. Now what determines the motor speed ? The rotating agents present in an electric motor are lines of magnetic force acting at right angles to electric current. As neither of these has any wearing-out effect upon the materials through which they pass we lose nothing and gain everything by increasing the speed of the motor. However, as no person has yet been able to invent a means whereby two elements may rotate relative to each other without bearing or friction, our motor speed becomes limited from bearing friction. Then in continuous current motors we have the brushes and commutator. Experiment has determined that to give good commutation the commutator speed must lie between 2,000 ft. per minute and 3,000, and nearer 3,000 than 2,000. Thus, if we want high spindle speed the diameter of the commutator must be small, and above certain speeds it becomes impossible to construct the commutator to give satisfaction. With speeds up to about 2,000 revs. per minute in sizes up to say 30 h.p. there is nothing in commutator or bearing design to prevent good results. In alternating and continuous current motors we have to reckon with centrifugal force, but the main factor in determining the speed is the transmitting agent which connects and links up our speed spindle to the machine to be driven. It is here we are brought face to face with the problem which, if solved, will save 75 per cent. to 100 per cent. compared to the present methods of working auxiliary machinery. There is a general impression abroad among builders of winches, capstans, hoists, etc., that slow speed motors are essential. Certainly, if resistances or controllers are used to regulate or adjust the speed, slow speed is essential, because a continuous current motor which has its speed varied must have a variable commutator speed, and no design can allow of a great variation of commutator speed without injurious sparking at the brushes. Therefore, motors used in conjunction with controllers must be of slow speed, and even then the commutation and sparking cannot be entirely avoided. Further, the use of resistances or controllers for regulating the speed entails a waste of energy, and every motor fitted with a controller must be considerably larger and heavier than one without.

For many reasons I would not use any means of controlling the motor speed. What I would propose for continuous current, is a compound wound motor fitted with commutating poles. The motor would of course be designed for constant speed. Such a motor can be made to run absolutely without sparking on any load and under any variation of load, no matter how sudden. I have had a motor as described running at 1,700 revs. per minute, doing regular work for seven months without having the commutator or brushes looked to. The motor in question works on variable load and is very often severely over-loaded. With high speed continuous current motors, properly designed commutator and brushes have no particular drawback.

Squirrel cage, three phase, alternating current, high speed motors meet my ideal design for use with capstans, winches, etc., on board ship. These motors need only be 100 volts or thereabout. With the system I propose the three-phase, squirrel cage motor would require absolutely no attention from the ship's engineers. The only examination it would require would be at the time of the ship's annual overhaul. Whether the system adopted be continuous or alternating current I would not make use of any electrical speed control on the motors, because, when an electrical speed control is brought to act upon a motor, the size and weight of the motor must be considerably increased, and again high speed motors do not lend themselves to speed control. My design so far has been to get rid of superfluous weight and volume, and if I bring in electrical speed control I immediately lose what I have tried to gain. Considering the present electrical qualification of sea-going men, supplying an electrical motor with a variable speed control means that the motor will in all probability be standing at the moment when it is most required. All electrical contact systems, hot wires, etc., have a certain amount of unreliability about them, especially if used in various climates. I find even with men on shore who have far more opportunities of learning how to detect electrical faults than men at sea can have, they will blame the motor for being burnt out or the like, when the fault may only mean a broken wire in the controller which could be repaired in an instant if the man had the ability or experience to find it. Thus there are six distinct gains to be effected by the use of high speed motors without electrical speed control.

1st, the weight divided by the power gives high efficiency; 2nd, the volume divided by the power gives high efficiency; 3rd, the power turned out divided by the power put in gives high efficiency; 4th, reliability; 5th, small cost of up-keep; 6th, low first cost.

With continuous current motors of all sizes above say a quarter-horse power and alternating current squirrel cage motors above say five-horse power, some form of starter must be used to check the current until the rotating part of the motor gets up sufficient speed to protect itself. Wire starters have some of the drawbacks shown in wire controllers, and we are again faced with the difficulty of unskilled operators, therefore I propose dispensing with the ordinary motor starter which is generally constructed of wires and sliding copper contacts. In ship work the resistance wires when heated quickly oxidise and crumble away, and are a source of constant trouble. The sliding copper contacts when used with insufficient care become burred and burnt at the corners, and thus tend to stick. When left idle for some time they become encrusted with verdigris which prevents good contact. I dispense with sliding contacts altogether, in fact I do away with every movable electrical part in the starter, so that the electrical conditions remain always unaltered and require absolutely no attention. I make the resistance of the simplest possible construction, so simple in fact that it can be renewed at any part of the world if need be, without costing one farthing. The resistance I use is fresh water with soda or oxide of sodium. If fresh water and soda cannot be obtained for this purpose, sea water without the added soda may be used.

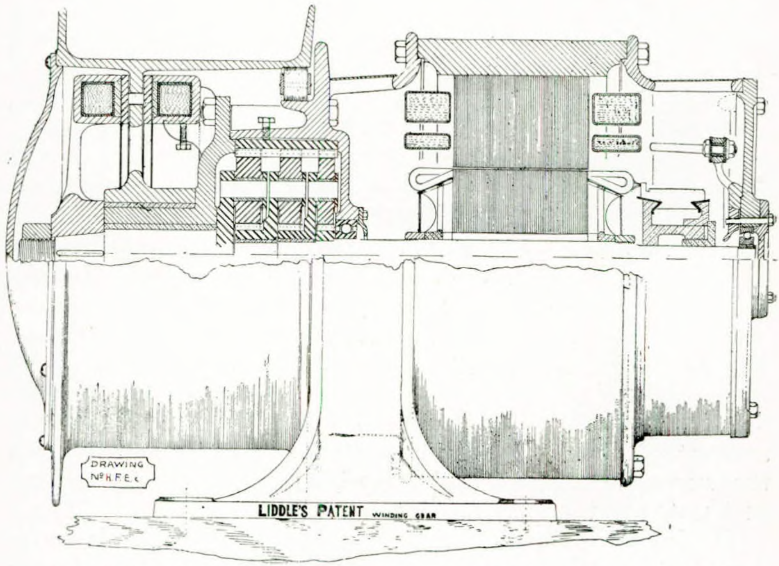
The only electrical point requiring consideration is the switch for starting or stopping the motors. The mechanical action of this switch should be such that its blades have no intermediate position between full on and full off, or full off and full on, or in other words it must be impossible for the operator to hold the switch in any mid-position. This switch can be arranged to work mechanically by means of lever, pedal, wheel, key or any other desired method. So far as the electric motor is concerned, everything is automatic and is quite independent of the person acting as operator.

Before leaving the high speed electrical motor there is a point worth drawing attention to, viz., vertical spindle motors. With these, even though the ship has a considerable list the working conditions remain unchanged, and all out of balance forces such as gravity effects are eliminated. Within the past few years several prominent motor builders made use of ball bearings on motors. On horizontal motors these proved failures and the motor builders were obliged to go back to the old type of bearing. With vertical spindle motors ball bearings have proved a perfect success, and can be run for twelve months on one lubrication. In ship work there are numerous advantages to be gained by the use of vertical spindle motors. Time is too limited to allow of my going into this subject here, but from practical experience I could produce many points in favour of the vertical spindle motor which would recommend it to the attention of marine engineers.

I must now come to the question of gearing or linking up of the high and constant speed motor to capstans, winches, and other ship auxiliaries. Belting is suitable for fairly high speeds, but is quite out of the question in ship work. I might consider worm or skew gearing. These gears have practically reached their zenith of perfection, but the improvements which have been made in worm gears have been reached more through practical experience and tests than through theoretical calculations. In fact, from theoretical calculation it is impossible to design a worm and worm wheel with a bearing surface contact greater than the theoretical plane, and that only for one tooth. To me the worm and worm wheel have a resemblance to Cook and Peary. There is a certain amount of doubt as to the pole which was reached. With the worm and worm wheel there is always a certain amount of doubt as to the tooth surface in bearing contact.

The loss of energy due to friction between two solids varies directly as the pressure between the solids and is practically independent of the area in contact, but it must be remembered that if we exceed a certain pressure there is no such thing as a solid. After we pass the critical pressure the law of friction becomes of the fluid order. The loss of energy due to friction varies as the velocity squared. At slow speeds fluid friction is very small.

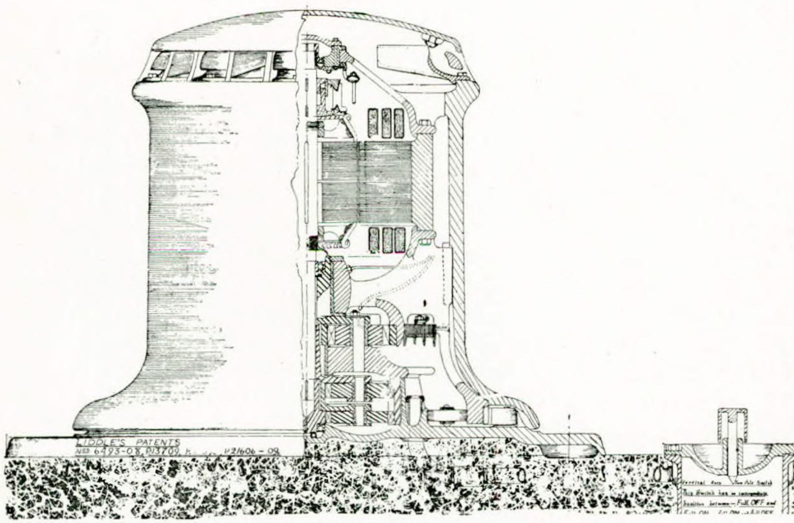
The laws of Nature cannot be altered to suit our convenience. If we aim at success we must design to take the greatest advantage possible of these laws. Before we decide whether a worm and worm wheel are to be of use in connecting high speed motors to capstans, winches, etc., the critical pressure per square inch which the worm and worm wheel material will withstand must be found, and the greatest rubbing velocity permissible must be discovered. The rubbing velocity between the worm helix and the worm wheel is to a certain extent dependent upon the lubricant, but after a certain pressure has been reached no lubricant is of any use. Again, we know that if a worm and worm wheel cannot be driven backwards, the mechanical efficiency is less than 50 per cent. Further, if they can be driven backwards, the speed reducing factor is small. From the aforegoing it will be seen that the useful



SELF-CONTAINED HOIST, WITH ANY REDUCTION. CAN BE MADE PORTABLE.

purpose of a worm gear is generally with very light loads if the speed is fairly high. If the load is to be heavy, the speed must be very very slow, and if the efficiency is to be above 50 per cent., the reducing factor must be small. From this it will be seen that I must either discard my high speed motors or the worm gear.

Considering ordinary gears we have several different styles and types to select from, viz. rawhide, fibre, paper, bronze, cast iron, cast steel, forged steel, etc. Then there are the types of teeth, such as plain, helical, double helical, of involute, cycloidal, or other form. I do not think there is any place in which we could gain more information regarding wheel teeth than at a motor garage where old motor cars of every description are repaired. Within the past dozen years a new class of engineering has sprung up. It has doubtless many lessons to learn from the older system but the older system has doubtless some lesson to learn from the new. I must say that I was completely beaten regarding successful gearing of the high speed motor until I considered all types

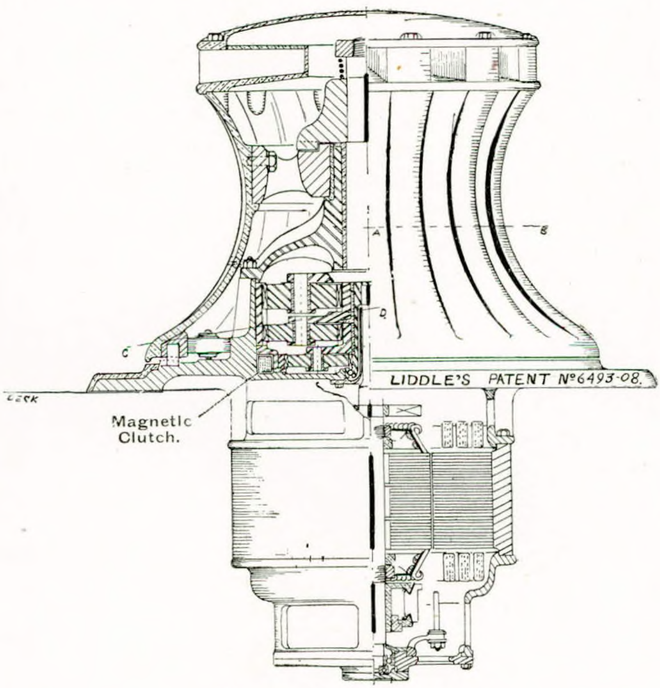


SELF-CONTAINED ELECTRIC CAPSTAN.

of motor car gears. Having now selected a forged steel, machine cut, case hardened, short-toothed gear, I can settle the maximum speed of my electric motor. With ordinary teeth these gears may have a velocity of 6,000 feet per minute. From this it will be seen that the continuous current motor speed is settled by the commutator, and the alternating current motor speed cannot be much in excess of that of the continuous. Therefore I select speeds of 1,700 to 2,000 up to 5 h.p., 1,000 to 1,500 from 5 to 20 h.p. etc. A 2,000 rev. per minute motor could be fitted with a pinion one foot in diameter without exceeding the speed limit. On a motor of 2,000 revs. per minute, however, I do not require a pinion of more than 3 or 4 inches in diameter, thus the tooth velocity is only one third or one quarter the permissible velocity. Further these gears are at least twelve times stronger than similar gears in cast iron. In other words a forged steel pinion having machine cut, case hardened teeth 1 inch wide. will do work which would break a cast-iron pinion 12 inches in width.

The next point is the arrangement of these gears in such a manner to gain the greatest advantages. I again consulted motor car gear and gear box design, but failed to find exactly what I wanted. I found numerous examples, however, the worm parts of which showed me what to refrain from doing. In avoiding these defects of design I was led into a form of gear which has given very surprising results, results of which I had not the slightest thought when I designed the gear. Some of these are of vast importance in conjunction with any geared electric motor. Every electric motor when overloaded, or in other words when working under crane rated conditions, loses in efficiency on increase of load. If the motor is geared to the capstan, winch, etc., by means of gear which also falls in efficiency when the load is increased the combined efficiency must necessarily be poor, and as the load increases the current consumption will increase out of all proportion with the increase of load, and as a rule the safety fuse will blow. In marine work for the fuse to blow might mean disaster. In the bulk of electrical machinery for deck use, the safety fuses must only be safeguards against electrical breakdown.

With high speeds, balance of motion is very important, otherwise serious vibrations would be set up. By balance of motion I mean all turning effort forces, mass, reaction, etc. If these forces are balanced, so that all forces in common balance act at 90° to the common axis of motion, and all act in a common plane with their common point of action lying in the common axis of motion, then every force is neutralizing every other force, and all the energy imparted by the motor spindle to the gear is imparted by the first set of gears to the second set, and thus on until it is used in doing external work such as warping, hoisting, etc. If these theoretical conditions existed, the gear efficiency would be 100 per cent., but such conditions are impossible. It is possible to very nearly balance all forces, but it is impossible to avoid a certain amount of friction. The friction with which I have to deal always falls under the law of friction between two solids, therefore the loss of energy due to friction is directly proportionate to the pressure between moving parts. As all forces are balanced, the only pressure between moving parts takes place at the



MARINE ELECTRIC CAPSTAN.

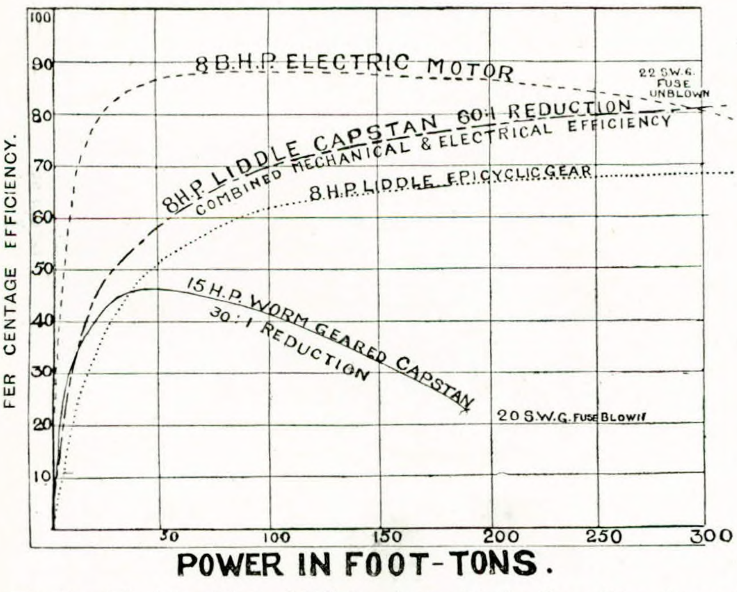
planet studs, and the faces of wheel teeth. At these points the relative movement is very small, the contact surface is large in proportion to the pressure acting on it, therefore the loss of energy is small, and as the wear of parts is always proportionate to the frictional energy wasted, it follows that the wear of parts is small. From tests made on this gear it was found that the gear efficiency increased as the load was increased, thus the gear assists the motor on heavy loads, and the current consumption of a motor thus geared may be looked upon as directly proportionate to the load. One of the great advantages of this gear from a constructional point of view is that every part is acted upon by known forces, the majority of them being simple shearing forces, therefore it is an easy matter for the designer to calculate every tooth and pin, allowing an equal factor of safety throughout without any fear of unknown influences disturbing or affecting the structure.

In arranging any warping, hauling, or hoisting mechanism comprising a motor, gear, and winding apparatus, I always design it so that of itself it is a complete structure having the main casting in one piece, and such that it is always subjected to the lateral stress of the rope, thus the driving motor and the gear are only subjected to balanced turning effort. Then regarding the space occupied by this gear. A 50 to 1 reduction was fitted to a 5 h.p. motor. The overall dimensions of the gear case were $10\frac{1}{2}$ inches in diameter, by $3\frac{1}{2}$ wide. Pinions meshing into each other did not differ in diameters more than $2\frac{1}{2}$ to 1. To give a reduction of 350 to 1 at 5 h.p., the gear added to the motor would only require to be 5 inches instead of $3\frac{1}{2}$ as in the former case. Such gears when fitted to the vertical spindle motor and lubricated with thick black cylinder oil, and after being a short time in use, run perfectly silently and without the slightest vibration. These gears fitted to horizontal spindle motors run fairly silently, but not to equal the vertical spindle type. An electrical capstan, winch, or hoist as before described has weight and volume cut down to a minimum whilst the electrical-mechanical efficiency is the highest ever obtained. The current consumption for work done is the lowest possible. The life of such a capstan is difficult to determine, but from examination for wear on those working, I should certainly say it will exceed the life of the present day steamship.

Were it not for the low efficiency, steam is an ideal prime mover for warping and hoisting machinery. Its compressive or cushioning properties are exactly what is wanted. For instance, a steam capstan when warping on ship board automatically slows down as the tension on the warp increases. When the tension exceeds a certain limit the capstan will stand with the steam pressure on. To be a success an electrical capstan must do likewise. If it cannot do so it is a failure.

This is where electricity fails because an electric motor keeps up a constant speed quite independent of the pull on the warp. The current increases as the pull, but the speed remains constant. To get over this difficulty an electrical control is used. I have, however, already decided against any electrical control on the motor. I have before given certain reasons for doing so, but here I will give yet another. Electricity has practically the same velocity as light. There is a certain time element in its heating action to cause fusing, etc. I hold that the most alert men we have are not sufficiently alert to

ELECTRIC CAPSTAN TESTS



The Royal Society of Arts of Edinburgh appointed a Committee of experts to enquire into the claims of this gear, and the above curves show the results of their examination when they tested an 8 H.P. Liddle Capstan to 22 H.P. These figures are duly authenticated, and the Society have awarded Mr. Liddle their medal and Keith prize for this gear.

deal by hand with electrical energy supplied to an electrical capstan. One slip in the operator's acticns blows the safety fuses, and the ship is left to the wind. I propose to make the warping action of the capstan almost entirely automatic. I propose attaching to the circumference of the internal toothed wheel a magnetic disc, or oil clutch which can be timed to slip at a warping pressure below that necessary to blow the safety fuses. When such a capstan is warping it will warp at full speed until the warp is under full tension. Then it will automatically stop, and when the tension is slightly slackened it will recommence warping. It will continue in this way until the ship is warped to its destination. The fuses will not blow unless an electrical breakdown occurs.

An electrical apparatus has one very decided advantage over one driven by steam. Steam machinery can never exert more pull than there are lbs. pressure of steam on the pistons, whereas an electric motor can develop almost any power for a short interval. Owing to the possession of this property, an electrically driven windlass could entirely defeat a steam windlass if extracting a fouled anchor or at any similar process.

Mr. W. E. FARENDEN: Are these electrical capstans made to reverse?

Mr. LIDDLE: Yes, they can be worked either way, as the motor can easily be reversed. It is simply a matter of moving a switch so as to change the direction of the current through the armature or the field. Changing the direction of the current in the armature gives the best means of reversal because at the instant of reversal the poles should have maximum magnetization. In the case of an alternating squirrel cage motor it can also be reversed by moving a switch so as to change the connections of the different phases of the stator.

Mr. J. HOWIE: What would be the effect if the bearings were slack?

Mr. LIDDLE: I suppose Mr. Howie means the bearings of the planet pinions as no other bearings will ever get slack. There would be no bad effect as they would wear evenly. The pressure is equal on either side of the pinion pivots and it would not matter how slack these get; the slacker it gets the better it works. Owing to the perfect balance of all forces the planet pinions may be used until they simply become an externally toothed ring having a bearing hole several times the diameter of the bearing pins.

Mr. HOWIE: What are the wheels made of?

Mr. LIDDLE : Forged steel, with their teeth machine cut and carefully case-hardened.

CHAIRMAN : You have heard Mr. Liddle's paper and the descriptions he has given of this new application of electricity on board ship. It seems to be more a question of mechanical and electrical engineering. We have not much time left, and if any of the members would like to ask questions on any of the points that have been raised I am sure Mr. Liddle will be pleased to answer and explain things to your satisfaction.

Mr. W. P. DURTNALL : I have heard a good many papers on the subject of electro-mechanical power transmission, but I do not think I have heard one with greater pleasure and interest than the one we have heard to-night. Mr. Liddle has no doubt made a considerable study of the subject. As he states, and rightly so, if electrical engineers wish to be successful in the application of electricity for marine purposes, designers of such machinery and of internal combustion engines must study the demands of the marine engineer, as they are very different in many aspects from everyday land practice. He goes into the question in reference to the weight, and I could not help noticing that in some recent vessels of large power, motors with slow speeds in revolution have been adopted, and the totally enclosed type has also been adopted. By use of the epicyclic gear, as Mr. Liddle points out, great efficiency can be obtained, and it is surprising that greater use has not been made of it. Some time ago I had some correspondence with reference to a suitable gear in connexion with high-speed turbines and slow-speed propellers. I suggested having two series of epicyclic gear similar to that described this evening, three to one each, making a total of nine to one reduction. These gears go into large powers, and the difficulty in such a case is that one cannot get them under guarantees, but for gears up to about 100 H.P. it is a different matter altogether mechanically. The author states "a well-designed electric motor should give an efficiency somewhere between 85 per cent. and 90 per cent." ; of course that refers to a well-designed motor of, relatively speaking, small power, possibly motors of 50 or 100 H.P. ; you can easily get these efficiencies, if properly designed and constructed. But electrical motor designs can be made for very large powers. I showed a representation the other evening, at the Institution of Naval Architects, of a motor of 6,000 H.P., where the efficiency was

97 per cent., from tests in actual working at a steel works in the United States. In reference to the wearing effect on the materials, the type of gearing described by Mr. Liddle has some very interesting details on that point, because of the equal balancing that can be obtained between the pinion and these 2, 3 and 4 equalisers. The pressure is distributed on the teeth of the pinion, and there is, therefore, considerably less vibration and wear, which must, of course, all tend to increase the efficiency. Mr. Liddle does not strongly advocate the variation of speed for auxiliary driving, but, as he said, it is necessary sometimes for driving feed pumps and various other auxiliaries. I think some change of speed is necessary on motors, or it should be provided for at such times as when slowing-up the vessel, or loading, unloading, etc. The use of squirrel-cage alternating current motors Mr. Liddle says meets his ideal design. I think it would be difficult to design a motor better and more generally adapted to the conditions for auxiliary driving on board ship. If an equipment of this kind is fitted, I am sure praise will be given of the way in which it will work and the simplicity of design combined with great mechanical strength ; everything is in its favour from the mechanical engineering point of view. The liquid control Mr. Liddle showed is a very interesting thing. I have used similar contrivances with passenger lifts, hoists, etc., but he has simplified it very much by the water resistance. It is self-contained, and is, I think, a step in the right direction. It would, to a great extent, prevent sparking, but I think some attention in design would have to be given to it for it to be thoroughly reliable ; it would be well occasionally to look at it. He deals with the matter of vertical spindle motors. These are ideal in many respects. The wear and tear on ordinary bearings is caused principally by the unequal amount of wear on the different parts, and I think that point is deserving of great attention in connexion with the use of vertical spindle motors. I like his idea of the magnetic clutch for controlling. The magnetic clutch might be termed an electrical governor of torque. Break-downs have occurred in some of the naval vessels in warping the ship to the side when the tow comes on. The load tends to slow the armature, and out come the circuit breakers, with the result that electrical driving is pronounced a failure. If some simple and reliable methods of electrical clutches were tried the unnecessary difficulties recently made much of would be avoided. I would again thank Mr. Liddle

for the most interesting paper he has given and hope he will have great success with his system.

Mr. T. R. Stuart : Unlike Mr. Durtnall, I am certainly not in favour of the magnetic clutch. If we imagine a windlass to be of 50 H.P., with the motor running at full speed for an hour, there is sure to be some sparking in the clutch. Imagine all the 50 H.P. being wasted at the clutch ; I do not think it would be an advantage at all. I congratulate the author on appreciating the difference between marine and land practice ; that is a thing often lost sight of. I do not like his arrangement for the starting gear, however. If a winch is used on a voyage lasting about two months, although you might start with sea-water it would not be sea-water very long, as, of course, it would soon be boiling, and if you want to prevent oil mixing with the water, soda is one of the worst things you could put in it. In connexion with case-hardening, Mr. Liddle stated that all the strains were calculated, but in the event of the winch being brought up suddenly, the case-hardened teeth would be likely to break. Although they may be stronger while doing ordinary work, I do not think they would stand a sudden shock.

Mr. W. E. Farenden : The only point I would like to touch upon is with regard to the speed control. Motors are now being fitted extensively in our ships and speed regulation seems to be a most necessary thing. For the different speeds, pressure has to be put on the motor accordingly, and it seemed to me that Mr. Liddle went rather against the practice of having speed control, which appears to be a thing that cannot be dispensed with.

Mr. W. McLaren : I endorse the remarks that have been made as to the value of Mr. Liddle's paper, and think we are much indebted to him. He has come a long way to give us this demonstration and that is a point we ought to consider also. With regard to the weight and power question, I was surprised the other day at the Aeroplane Exhibition at the Olympia to find that we have come down to a horse-power weight of 3 lb., a drop of 6 lb. in twelve months. We have 50 H.P. motors weighing 106 lb., made by a Willesden firm. With regard to this De Laval steam turbine, Mr. Liddle does not give us any indication as to the power this turbine generated, and also the comparison with the motor. We would like to know the power, so that we may have an idea as to what may be reckoned upon for weight. A little further on he remarks upon the marine engineer not taking proper care of electrical machinery. He has had a few years to do so, and the number of electrical stations on shore that are in the charge of marine engineers goes to show that he is well qualified to look after this class of work. I do not think we can admit Mr. Liddle's suggestion on that point. He then comes to the question of the gear. This generally comes to a question of expense and as to which will compare most favourably, the slower speed motor, or the high-speed motor and light weight. Of course, we are entirely in the hands of the electrical engineer in this respect as to what he puts out for his standards. I was reminded of this the other day in reference to the American manufacture of motor-cars. They seem to stick to one design and can give you a duplicate at any time ; but while the English makers can give plenty of variety, it is hard to get a small piece replaced of the exact dimensions required. The author remarks upon effecting a saving of 75 to 100 per cent. if a proper transmitting agent is used. Of course, he particularly explained that this is not in reference to the earning capacity. I should like to ask him what kind of brushes he uses on the continuous current motor he speaks of which gives such favourable results. What kind of bearing does he use in the vertical spindle motor, and does this reference to twelve months' running on one lubrication mean that only a few drops of oil were used, or that it was running in oil ? Of course, with roller bearings for shaft running, a little is put on for the first lubrication and afterwards a good deal of lubrication is required. With regard to the worm gear, some time ago we had a visit to Silvertown, and they had powerful motors up to 150 or 200 H.P. working on worm gear and giving every satisfaction up to that time, although I could not say what it is doing now. Mr. Liddle seems to have reckoned up the steam winch for warping. There is no doubt in my mind that it is the most economical machine that one can warp a ship with. I do not say that it cannot be beaten, but with the uncertainty of load, sticking in the sand or mud, going through the canal, or under other difficulties, it has proved itself a very serviceable machine. In reference to the clutch, I should like more information as to its construction. Is it merely one plate on another, or a series of plates? In the last paragraph the author says "an electrical apparatus has one very decided advantage over one driven by steam," as the greater the pull, the greater the power developed, but that is only to a limited extent; you would require a factor of safety there.

Mr. J. Clark: It gives me pleasure to congratulate Mr. Liddle not only on his paper, but on his capstan and winch. I can quite understand Mr. Liddle's experience with the gear. It seems to me to be very much after the type of the "sun and planet" gear, and that gear has proved over and over again to be long lasting. Undoubtedly it is another case which proves that there are few problems in mechanical engineering which do not admit of a good deal being said on both sides of the question. There are one or two points in connexion with the paper upon which, I think, one can see the other side perhaps legitimately. Mr. Durtnall mentioned the efficiency of 97 per cent. in a large motor; so far as I know we have never equalled that in this country, but I think these high efficiencies are just about as elusive as a certain well-known gentleman in fiction. There is one point in Mr. Liddle's paper I am not very clear about; it is where he refers to induction motors of the squirrel-cage type. When reading the paper I was under the impression that his starting arrangements referred to these motors; I am not sure yet whether that is the case or not, but I do not see how it can refer to anything but a slip-ring motor. Then there was another point in connexion with liquid starters. In cold weather liquid starters give a great deal of trouble through freezing. With regard to ball bearings, undoubtedly ball bearings give excellent results. There are ball bearings in daily use running under a load of several tons, yet it seems to me they are somewhat unreliable; they may run for years, and they may give out in a day. One never knows when they may fail. I do not think there is anything better than the ordinary marine type of thrust bearing. Mr. Wm. McLaren spoke of the worm gear used in a factory we had pleasure of visiting some months ago. I remembered that at the time also. I do not quite agree with all that is said in connexion with this gear, such as for instance that the surface contact cannot be greater than the theoretical plane, and that for one tooth. There are worms where you can get far more than one tooth in gear if you wish. I think it would have added a great deal of interest if Mr. Liddle had quoted some results in his paper. I am a great believer in facts ; if facts are quoted in a paper one cannot get away from them. It has been a great pleasure to me to hear Mr. Liddle's paper.

Mr. LIDDLE : I will reply to the points in the order in which they were raised. The first I think was in reference to the magnetic clutch to be used on the marine type. I advocated a constant speed motor with a variable speed arrangement on the gear. We must arrive at something approaching the steam capstan before putting in the electrical one. If we cannot come up to it we must keep the electrical capstan ashore. A steam winch or steam capstan will stop until the strain goes off, but an electrical capstan won't stop, with the result that the fuses are blown, but I think the gentlemen who have spoken have a slight misunderstanding about the form of clutch I propose to adopt. This gear lends itself very well to such an arrangement, and I think the illustrations will help to explain the marine type.

With my type of clutch fitted in conjunction with my gear on a 50 h.p. winch I fit a small resistance or regulator so that the gripping power of the clutch is always ready to be altered by the operator when desired. In the first place, my clutch acts as a safety overload escapement, always ensuring the motor or mechanism against serious jerks or overloads. These overloads sometimes come on very suddenly, in fact so suddenly that no operator is sufficiently alert to deal with them by means of a controlled speed motor. In the event of the overload continuing for some time, the operator would alter the regulator so as to weaken the clutch, the clutch could be freed altogether, then the motor would run light, there need not be 50 h.p. wasted at the clutch excepting for a few seconds or minutes as the case may be, until the operator grasps the situation. As the operator demagnetizes the clutch the motor's current consumption will fall, so that a considerable saving is effected. Of course, to vary the magnetization of my clutch an electrical control or regulator is necessary, but the current is usually between a quarter of an ampère and two ampères, therefore it is quite different from the control necessary on a 50 h.p. variable speed motor, where the current would often exceed 400 ampères. I might point out here that several of the Russian smaller naval vessels which have oil engines are fitted with magnetic clutches of 500 h.p. Of course no mechanical engineer would dream of running a clutch of any type under full load for hours at a time, and no electrical engineer would dream of holding a 50 h.p. motor with full load on and the current passing for hours through a controller. A great deal more heat would be generated and wasted with the controller system than would be wasted with my clutch system.

Regarding my oil-immersed patent liquid motor starter, which has no movable electrical current carrying parts. Mr. Stuart refers to the oil getting mixed with the water ; this is a very important point to raise, because at first I had that very same trouble to face. I tried several oils to find out the one most suitable. After some tests I selected an oil which appeared perfect for my purpose, but on ordering a quantity which I used in a large starter I was horrified to find that in less than a week the oil, water and soda had changed into a soap. I thought that my oil and water scheme was all up, but made up my mind to have one more trial. After having the oil analysed, I found that instead of being supplied with a pure mineral oil, as asked for, I had been supplied with a mixed (mineral and fish oil) hence the saponification. When I obtained pure mineral oil no mixing took place, and no renewal of oil, water or soda has as yet been required in any of my starters, which have been working for twelve months. If ever desired, these liquid starters may be used as speed controllers. They can be supplied for hand operation or made perfectly automatic as desired ; for capstan motor starting I make them all automatic.

Mr. Stuart also refers to case-hardened wheel teeth snapping across under sudden jerks. This is entirely a question of the class of steel used and knowledge of case-hardening. Certain grades of steel when case-hardened would become as brittle as ordinary cast-iron. The principal object of case-hardening is to prevent wear, but it should also strengthen the tooth. Case-hardened gears can only be relied upon if manufactured by experienced people who are constantly doing such work. For instance, gears that are to be run constantly day and night require slightly different treatment from gears that are only used on intermittent work. Mr. Farenden refers to the impossibility of dispensing with speed control on electric motors. I do not say that it can be dispensed with in every case, but there are a great many cases in which the clutch system will be found cheaper, more reliable, and far more flexible than a motor having its speed controlled by a resistance. Take, for instance, a winch working goods in a hatchway; the hook gets caught in the edge of the hatch; the controlled motor would at once blow its fuses or smash up something. Under exactly the same conditions my constant speed motor with clutch would simply run on, but winch barrel would stand with maximum stress on chain, the operator would reverse and all would be in working order, no time being wasted. A point I have scarcely touched upon is the controlling of the winch barrel winding speed by means of magnetic or disc clutch with constant speed motor. By regulating the current which excites the magnetic clutch the speed of the winding barrel can be instantly varied, the motor running all the time at full speed, but its current consumption varies directly as the speed of winding and load lifted. The heat generated at the clutch is less than half the amount of heat that would be generated in the control of a variable speed motor doing the same work, whilst the variable speed controlled motor has no safety device suitable for dealing with overload jerks, etc., such as load getting jammed or caught when hoisting at full speed. I can supply an alternating current magnet clutch, or rather clutch operated by alternating current, but in many cases a disc clutch would give almost the same result. Electric clutches have two outstanding advantages over any mechanical clutch. 1st. They can be operated from any distance away. 2nd. A much finer adjustment or variation can be given than with any mechanical clutch.

Mr. Clark: Can you operate it by alternating current?

Mr. Liddle: No, but it may be either in oil or a disc clutch may be used. This is a magnetic clutch in oil, but there is no reason why a disc clutch cannot be led in here. When an extra strong pull is desired it would then be necessary to put in stronger fuses and screw up the clutch. You could know what temperature to put your motor up to with safety. Then again, if great variation is wanted to warp up very quickly, this is the simplest gear to arrange that with. All that is required is to cut the internal toothed wheel in sections, and arrange that one section of the wheel locks with a set of planets and their carriers, then this rotates as a solid piece, giving no reduction in speed. It will give a speed of 50 ft. per minute, and thus cutting out a reduction of 4 to 1, the speed will be about 200 ft. per minute. Practically any speed can be given from zero upwards.

Mr. Durtnall: The torque will be constant at the lower speed.

Mr. Liddle: Yes, but you must have a design for the increased speed at reduced torque for quick warping; you have the extra gear.

Mr. Stuart: With these types of clutches you have overlooked the effect of the controller.

Mr. Liddle: But the speed is high and the power small.

Mr. Stuart: Would not the whole of the horse power be wasted at the clutch?

Mr. Liddle: No, there would be no waste, with five tons pull on the rope winding at 100 ft. per minute. You get the same effect in controllers, a more expensive matter, which is not required when you put on a gear. With regard to the liquid starter, several questions have been asked, one about putting the water in. The water should be put in when the machine is started, and it will easily run for two years with the same water. If you are going to use the starter for control, it would be necessary to have condensers on it. For a starter working on 18 h.p. motors the vessel containing the water is only 9 in. × 8 in., and there is no heating effect sufficient to vaporize or boil the liquid. The oil prevents any sparking tendency. I do not propose to use this on squirrel-cage motors; we must have slip ring motors for liquid starters. Squirrel-cage motors geared as I propose and fitted with clutch require no starter, simply a Star Delta switch. A starter as mine may be used in special cases when connected on the neutral point or star centre of stator windings. The question was also raised about the teeth breaking, and on this subject there is misunderstanding even among very good engineers. They even use cast steel blanks, machine-cut them, and then case-harden them. These are very little better than cast iron, and in some respects are quite as unreliable. If they are of forged steel you get them all alike. A good deal depends upon the case-hardening. I have never had an experience of a broken tooth in all the capstans I have put in.

Mr. McLaren: That would depend on the class of steel you use.

Mr. Liddle: In fact, these gears are turned out of carbon steel bar, then machine-cut and case-hardened. Every one turned out is tested to nine or ten times its rated capacity, and as far as my knowledge goes there has never been a broken tooth.

Mr. McLaren: I wish the motor-car people did as much with their gears.

Mr. Liddle: It is the change of gear and the severe jerks which damage them so much. And on the other hand we get motor-car gears made sometimes from bad material and badly hardened. The question was raised as to the power of the turbine and motor. In one case there is in use a turbine of 15 h.p. working a centrifugal pump in a distillery, and a motor of 20 h.p. in a colliery also driving a pump. With regard to the upkeep, there used to be men standing by the three steam boilers looking after the coal constantly, whereas the motor can run all day without any one looking near it, and the consumption of electricity is very small. One gentleman spoke of my remarking upon marine engineers having no electrical knowledge. I did not refer to all engineers, as I am aware that in many stations the superintendent engineer has a first-class marine engineer's certificate, and that it is chiefly by going to sea that they have gained their experience. A great many marine engineers, however, may be able to attend an electric motor, but if a breakdown took place they would not know where to look for it. There are marine engineers and marine engineers. The type of brush used is the ordinary copper-plated carbon brush. It is very seldom that they go wrong. The capstan I referred to was sent to a gas works, where there was not a man in the place who knew anything about electricity, and they did not know the motor had brushes until I pointed it out. It had been in use seven months when I pointed this out; one of the brushes had shifted a little. The type of ball bearing used is Hoffmanns' Ball Bearing for side pressure, and also a thrust bearing to sustain the weight of the rotor. There is no trouble with the ball bearings on the capstans, and in every case after working for some time they have been found to be as rigid as when first put in. I have, however, avoided them in the horizontal type, as there might be more possibility of them going wrong in such a case. Something was said about the electrical capstan as compared with the steam capstan. In the steam capstan you have to accept the steam pressure of the boilers, you only get out of the capstan the speed of the piston, and the lbs. per square inch behind it. With the electrical motor, if the engineer had a correct knowledge of altering this clutch to fix it up and lock it, and put in suitable gauge of safety fuses, you could work your capstan up to a very much higher pull for short intervals and far in excess of the steam winch. Of course, with a marine winch it is a vertical barrel with a capstan head that I prefer, but I can supply horizontal type also. The question of the water freezing in the starter was touched upon, but the presence of the oil gets over that difficulty to a certain extent, and if 5 per cent. of glycerine is put in the water it will not freeze. With regard to the contact of the worm wheel, I merely mentioned that from a geometrical point of view only one tooth of the worm wheel and worm can possibly make contact. You can design a nut and screw to have a complete bearing surface, but as soon as you put the nut on a centre you get a radial motion of the nut helix. All the time you are driving, that helix is changing its place relative to the axis of the screw, but the helix of the screw is not changing its place relative to the screw axis. The better a worm is designed the more will be taken into account the velocity of the two surfaces, pressure per inch, etc. There are some worm gears very badly designed. I know of two such—one a capstan and the other for haulage; the capstan never did any work and was taken out again, the haulage is in an oil works, and there they had to keep a boy standing with a bucket of water ready, always throwing some on to the worm. At an oil works in Broxbourne, two years ago, ten worms were put in, and only two of these are now working. With regard to water getting into the ball bearings I have never come across such in any of my apparatus; in fact, no oil or water gets near the motor, everything is perfectly closed up. With regard to actual results, the following extracts are taken from letters received from users of these machines. The first is from a firm of pitwood importers and coal exporters of Glasgow, who say :—

In reply to your enquiry as to our opinion of your 18 h.p. electrical

Capstan fitted in our yard at Bo'ness, we have great pleasure in stating as follows :—

1. It has completely satisfied us in every respect.

2. There has been no perceptible wear on the gears or bearings after eighteen months' hard and continuous daily usage, although the first barrel head was worn away by the action of the ropes.

3. The gear box has run for seven months without being opened, and when opened at the end of that time no oil or grease was required.

4. The hum of the motor is the greatest noise proceeding from the capstan.

5. The capstan has proved absolutely reliable, and can far exceed its guaranteed pull. Its pulling powers seem to improve with age.

6. The current consumption is far below what we expected. The average consumption of electricity per day is one and five-eighths B.O.T. unit.

The capstan has shunted 100,000 tons of pitwood into and out of our yard over 240 yards of siding during the time it has been at work.

We have every confidence in recommending it to any one interested in capstan or haulage gear.

The owners of a colliery at Bo'ness also write as follows :—

Your Electric Capstan has now been in use at our colliery for over twelve months. We are pleased to say that the saving in haulage has far exceeded our expectations. To ensure the accuracy of our actual saving we put on a meter and have taken special readings of same, and we find that on the coal shipped the cost with your capstan is ·04 of one penny per ton, whereas with the horsework our actual cost over a number of years has been ·38 of one penny per ton.

Owing to the high speed of the motor, we were at first afraid that the tear and wear would be excessive, but we are glad to say that on a recent examination we found the gear to be in perfect order.

William C. Lynn,
General Manager.

The last which I will quote is from the Engineer and Manager of the Burgh of Hamilton Gas Works, who says :—

We have had your 18 h.p. electric Capstan working in connexion with our railway siding for the last six months, and during that time it has given us every satisfaction.

Owing to its compact form it occupies very little space, and is easily erected. The current required is very small, and the capstan is capable of doing a great deal more work than what you guarantee.

I am convinced, because of its lesser initial cost and low working expenses, and its great freedom from wear and tear, that, as it becomes better known to those requiring haulage of this kind, there will be a very large demand for it.

The meeting closed with a vote of thanks to Mr. Liddle, proposed by Mr. P. Smith, R.N.R., and seconded by Mr. W. E. Farenden.