charcoal of our ancestors have been displaced by the combination resulting from the treatment of cotton with nitric acid. The difference in the energy of the ordinary slow-burning powder and of the smokeless powder now used can be seen by consulting any table where the two are compared. One which I recently examined showed that guns, otherwise practically identical, required with the same weight of projectile three times the weight of ordinary powder to get the same velocity as with smokeless powder.

We must not forget, while discussing ordnance, the remarkable development of what are known as "quick-firing guns." This, as you know, is really the adaptation to large guns of the kind of ammunition and breech mechanism used on the modern small arms, and it has been carried so far that modern quick-firing guns are now made of as large caliber as eight inches, giving a muzzle energy of over 10,000 foot-tons, while the number of times the gun can be discharged in a given interval is about double that of the ordinary breech-loader. In the smaller sizes of these quick-firing guns the rapidity of fire is almost incredible, and I remember being particularly struck by the results of repeated trials showing that it was possible from a six-pounder to have five projectiles in the air at once.

More than a quarter of a century ago what are now known as machine guns were introduced; that is, weapons of small caliber approximating to that of ordinary small arms and slightly larger were so arranged that the ammunition could be fed almost continuously and the rapidity of fire be so great that a single weapon would be equal to a company of soldiers. As you are doubtless aware, the Gatling gun was the earliest of these. These, too, have been developed during the intervening years, until it would seem that finality has almost been reached in the Maxim gun, where when once started it continues to discharge itself by the effect of its own recoil, until the old metaphor "iron rain and leaden hail" becomes a simple matter of fact. The Maxim gun will fire 600 shots per minute from a caliber of 0.45 inch or less.

We come now to the machinery of the modern vessel, and I trust that you will pardon me if I go into greater detail here, because this is my own special field and one where it has been my lot to have been intimately associated with the construction of our new fleet. Here, more than almost anywhere else in the war vessel, the constant demand has been for greater power on less weight, and at the same time the demand has also been for thoroughly reliable machinery that would also be economical.

Progress has been so rapid that it sometimes seems that we hardly have time to get out a design as nearly perfect as possible and see it thoroughly tested in service before improvements have been suggested that render what appeared so perfect relatively obsolete.

Shortly before I became Engineer-in-Chief of the Navy, forced draught had been reintroduced, after many years of disuse, which at once gave an enormous increase of boiler power with a very slight increase of weight, due to the burning of a much larger amount of coal on a given grate surface. The shell boiler was developed until its design seemed nearly perfect, but we were confronted with the problem of getting plates sufficiently thick to withstand the increasing steam pressures in the large boilers and still be able to properly work the plates in our shops. The weight of these boilers was always very great for the power developed, and in the large sizes which they had reached the utmost skill was necessary for their proper care and maintenance. Shortly before the time had come when further progress with the shell boiler seemed impossible, the water-tube boiler was developed to such a point that it gave us the necessary solution of the problem, and it now seems quite certain that, for some time to come at least, the boiler problem has resolved itself into a determination of the best form of water-tube boiler, inasmuch as we are now sure that we can construct boilers which will withstand any pressures that are likely to be used and which are satisfactory in every other respect. These boilers offer almost absolute safety against disastrous explosion, afford a great reduction in weight, and are built to withstand comparatively rough treatment as far as heat is concerned, thus giving freedom from such troubles as leaky tubes and leaky seams, to which large shell boilers were very liable.

The demand for reduction of weights in the engines has been met by the use of stronger materials, and also their disposition in shapes where a given weight of material offers the greatest resistance.

We thus have steel castings to replace cast iron; hollow forgings of oil-tempered steel, and the uses of bronzes of double the strength of the older compositions. Besides the greater strength of the materials, just as important an item is their much greater reliability. Our manufacturers to-day can furnish us with forgings where we know that the results obtained on test pieces will be absolutely true of every part of the whole mass.

Weights have also been greatly reduced by using engines which run at much greater speeds than formerly obtained. This seems a sufficiently simple matter, and yet it was not possible until the improvement came in materials, combined with an accurate scientific knowledge of some of the questions confronting the marine engineer, which had formerly been solved almost by rule of thumb. This is notably the case with propeller design, for it was the mistaken notions on this point that really held down the engine speeds. Inasmuch as the whole office of the motive machinery is to turn the propellers, it might seem that it would be necessary to design the propeller first and make everything else to suit it, but, fortunately, now that we have accurate scientific knowledge of the conditions governing propeller design, we know that the propeller can be arranged to suit almost any speeds found desirable for the engines, and this enables us to choose engine speeds which will give us both lighter and more economical ones than were possible in olden days.

A problem in the design of engines for war vessels which is of considerable difficulty, and the solution of which is not yet thoroughly satisfactory, is that of securing economical results at ordinary cruising speeds, with the capacity for the power necessary at maximum speeds. As you are doubtless aware, the power necessary to drive a vessel varies approximately as the cube of the speed, so that if, as is ordinarily the case, the

cruising speed is about half the maximum, the power to be developed is one-eighth or less of the maximum. As was very cleverly expressed by one of my former assistants (Prof. Hollis) some years ago, the problem is like that of having a beast of burden whose maximum power will be that of an elephant, but whose appetite is so adjustable that he could be economically used for work which could be performed by a donkey. You well know that an elephant would eat about the same whatever work he was doing, and while this is not exactly true of a steam engine, it nevertheless is true that its economy when worked at powers which are such a small percentage of the maximum is very much reduced. In some of our ships we have tried to solve this by arranging two sets of engines on each shaft, so that at the moderate powers the forward set can be uncoupled. The ill-fated "Maine" had an arrangement whereby the large cylinders of her triple expansion engines could be disconnected, leaving the engines to run as smaller compounds at cruising speeds. A somewhat similar arrangement is in use on the "Nashville," where the large cylinder of a quadruple expansion engine can be thrown out, leaving a triple expansion for lower powers. The objection to all of these is that if it becomes necessary in an emergency to get full power, it is often impossible to stop to couple up. This was exemplified in a marked way in the case of the "Brooklyn" during the fight at Santiago. She was cruising with her after engines only when Cervera's fleet came out, and it was felt that there was not time to stop to couple up, which would have necessitated from twenty minutes to half an hour. The distribution of the power among more than two shafts offers another solution, which was used on the "Columbia" and "Minneapolis." Personally I believe that this system, if properly carried out, would be entirely satisfactory, but it would involve the use of the center screw only for ordinary cruising, and a ship, as you doubtless know, is not so handy with one screw as with two. Our latest design to meet the desire to use two screws and still get relatively small engines for cruising speeds is to use three screws but make the engine driving the center one-half the total power, leaving each of the wing screws to develop only a quarter of the full power. We have not as yet built any vessels on this plan, so that while theoretically we have every reason to anticipate entire success, it has not as yet been tried in practice.

A very interesting illustration of the application of ingenuity and scientific knowledge is the method adopted for balancing the engines so as to avoid vibration of the hull. As engine speeds and hull dimensions increased, there came a combination of circumstances, causing excessive vibration of the hull, due to unbalanced inertia stresses of the reciprocating parts of the engines. The solution is a very simple adaptation of a type of engine desirable for other reasons with a special arrangement of crank angles and weights of reciprocating parts. The adoption of the steam turbine has also been suggested to accomplish this same object, and turbines have been employed on some torpedo boats. With certain very promising features, there are, however, some great disadvantages, and before the steam turbine becomes a formidable rival of the ordinary type of engine an enormous amount of skill and ingenuity must be exercised, and the lines along which they can act are not yet apparent.

I have already referred to the three vital elements in warship design as offense, defense and mobility, and the best combinations of these features to secure maximum results tax the judgment and experience of the designer, as well as his skill and ingenuity. If time permitted, it would be of the greatest interest to show how the necessity of maximum results in particular items has given us special classes of vessels. Thus in the battleship, which must give and take heavy blows, mobility or speed has been sacrificed, while in the armored cruiser both guns and armor have been reduced to secure high speed. In the torpedo boat, speed is absolutely vital and everything else is sacrificed to it. The tendency just now seems to be along the line of having only one class of armored vessels, which will be very powerful armored cruisers with good armor protection and high speed. This means a vessel of about 12,000 to 14,000 tons displacement, with 8 to 10 inches of Krupp armor, a battery of 10-inch rapid-fire guns, and a speed of about 20 to 21 knots.

We have now given a hasty glance at the principal elements of the modern war vessel, although I regret that the limited time at my command has forbidden the consideration of many features which could not have failed to be of interest to you, such as the workshops on board where the necessary routine repairs are made to keep the great machine in working order; the electric installation for lighting the various portions of the ship and providing the searchlights; the elaborate drainage system with the necessary pumps; and the torpedoes, with their wonderfully intricate and delicate machinery, which is so arranged as to work automatically after being discharged from the ship, in a way that would seem to indicate human control at every moment. I trust, however, that you will have heard enough to satisfy you that the theme of my remarks is fully borne out by the facts which have been adduced.

The truth is, that in every department of life there has been a tremendous advance, due to the exercise of skill, ingenuity, and scientific knowledge, with which the modern war vessel has thoroughly kept pace. A moment's reflection would, of course, make it very clear to us that it would be impossible to build war vessels such as we now possess unless there had been a corresponding development in every other manufacturing industry. Governor Roosevelt, when Assistant Secretary of the Navy, touched upon a very important matter connected with this subject in discussing what was known as the "Personnel Bill." In comparing the development of naval science to the point where it became necessary for every officer in the navy to be an engineer, so that it is necessary for the modern admiral to know many things of which our great Farragut, for example, was ignorant, he said that it would, of course, require vastly greater skill to handle the complicated mechanism which the modern war vessel is than one of the old ones, but that, just as we had always been able to produce competent men to handle the less complicated vessels of former times, so without doubt we would get competent men to handle

those of to-day. He had learned the fact that the modern warship is a vast engine, and to be properly controlled must be handled by engineers. Congress has in the Personnel Bill provided and directed that, as soon as we can make the necessary arrangements, every officer in the navy charged with the handling of a vessel shall be a trained engineer, and, therefore, we may be sure that however complicated and delicate the organisms of the machine become, we shall have officers who, by education and experience, are fitted to properly care for the valuable and delicate machines intrusted to them.

I have had a part in two wars, in both of which the navy played an important part and became dear to the people, and I have also passed through the intervening interval, during much of which the navy seemed to be entirely forgotten. I sincerely trust that as the late war showed we not only know how to build good ships but to make them go and to fight them, our fellow citizens in civil life will see to it that the navy is maintained in a state of the highest efficiency, both as to personnel and material, ever ready for efficient use when needed. In this work, which on both sides is a matter for engineers, this institute has a vital interest, and I trust that, just as your influence has for seventy-five years been on the side of the general advancement of engineering in the mechanic arts, so it will be on the side of their advancement in the navy.

THE CHARGING AND CARE OF AUTOMOBILE BATTERIES.

By THEODORE D. BUNCE.

It is certainly not necessary that the owner of an electric automobile should be thoroughly acquainted with every detail of the construction of his vehicle, both mechanical and electrical, any more than we would expect every driver of a horse to be a veterinarian. But if every owner were as conversant with the general makeup and needs of his machine as the experienced driver is in the care and handling of his horse this article would be uncalled for. It is probable that the majority of automobile owners will not care to study the scientific construction of the batteries that furnish the power for their machines, but they will wish to have a practical knowledge of their working.

In a general way the battery of the automobile may be compared with the horse. Both may be overworked with more or less disastrous results. The battery may, like its equine rival, be over as well as under fed, the latter condition in both being worse than the former. Both are the better off when not subjected to sudden starts, and both will last longer if not constantly pushed to their utmost capacity. Both renew their strength and usefulness after a reasonable rest, and last, but not least, both require when ill the care of an expert—the horse the veterinary surgeon and the battery the skilled electrician.

The motor, while forming an important part of the mechanism, is more a part of the vehicle proper than the battery, and receives attention with the general care of the machine. It is not intended in this article to discuss the construction or care of the motor, but to explain in a practical manner the battery, as it is the vital part of the mechanism. The general features of the battery should be understood by the owner or driver in order to obtain the best service and to economize the power.

The storage battery of an automobile usually consists of 40 to 44 cells, generally divided into four groups of 10 or 11 cells each. Each cell gives from $2\frac{1}{2}$ volts when fully charged to 1.75 volts each when it has arrived at the lowest potential it should be allowed to reach on discharge. This gives a maximum of from 100 to 110 volts and a minimum of from 70 to 77. As the majority of direct current circuits that would be used for charging are from 110 to 120 volts pressure, it is readily seen why 40 cells is the best number to use, as the 110-volt circuit will always give the necessary excess of pressure required to force the current through the cells, at the same time requiring the least amount of resistance for regulating.

In the majority of automobiles the change of speed is effected by grouping the cells in sets. It is for this reason that a multiple of four is used for the total number. Thus $44 \div 4 = 11$, or $40 \div 4 = 10$. The mechanism for operating takes care of this grouping. It will be found on removing the cells from the vehicle that each set of 10 or 11 cells are permanently connected in series—that is, the positive of one cell to the negative of the next, and so on. In the vehicle each set is connected either automatically or otherwise to the wires leading to the controller.

In charging, all the sets should be connected in series—that is, the four groups connected together, the positive of one group to the negative of the next. This is generally provided for by the manufacturer of the vehicle when the battery is to be charged in the vehicle. It is generally accomplished by disconnecting the motor wires and setting the controller at full speed. This is obvious, as all the cells are used in series when the full power is to be developed. It is important, however, to remember to disconnect the motor wires before turning the controller to full speed. If it is desired to charge the cells independently of the vehicle, or an individual test of the cells is to be made, they may be removed and connected in series, leaving a positive pole at one terminal and a negative at the other. The positive pole is generally indicated either by a + sign or by a red mark. The negative pole is sometimes indicated by a — sign, but it is more frequently unmarked.

Up to this point we are considering the cells in groups properly marked by the manufacturer, and the individual polarity of each cell may be disregarded until we have occasion to remove them from the group.

The electrolyte or fluid used in the cells is a mixture of sulphuric acid and water. The strength of this solution varies with the state of charge of the battery. When the cells are fully charged the solution is at its maximum strength, and becomes weaker in proportion to the amount of current taken out. The solution does not require replacing except when the cells are to be dismantled for cleaning or repairs. There should always be sufficient in the cells to cover the tops of the plates, as any portion left exposed is inactive and will deteriorate rapidly. There will always be a slight loss by evaporation or spilling, but this may be replaced by the addition of clean water. But should any con-

siderable amount be required, it is better to add acid, in order not to weaken the electrolytes. The plugs in the covers of the cells should be removed and the necessary water added to replace evaporation. A special rubber bulb with a small nozzle is made for this purpose.

The solution is a mixture of sulphuric acid and water of 22° by Baumé hydrometer, or a specific gravity of 1.180. Preparing with a hydrometer is better than mixing by measure or weight, as the density of the pure acid may vary. With the commercial acid the proportions by measure are 1 part sulphuric acid and 5 parts water. The solution should be made in a stone vessel or lead-lined tank. Put a sufficient quantity of water in the vessel and slowly pour in the acid, stirring it constantly with a glass rod or a piece of wood. The solution gets hot and becomes stronger as it cools. Test it with the hydrometer, and if it is of about 20° let it stand until cold, when either acid or water may be added to make it the exact strength required. Do not let the acid come in contact with any metal but lead. The pure acid is exceedingly corrosive, and the prepared solution will destroy clothing if not neutralized at once by ammonia or some other alkali.

As it is impossible to use the hydrometer in the batteries made for automobile work, it will be necessary to withdraw some of the acid with a suction bulb or syringe, and a test made in a separate vessel. A convenient instrument is made for this purpose, called a hydrometer syringe. It is a combination of a suction bulb and a tube holding the hydrometer. As long as the cells are working uniformly it is not necessary to make any change in the acid, but should any cells be found of a low voltage, the acid will be correspondingly weak, and it may be difficult to make it recover its original strength by charging. If fresh solution is put in it should be diluted after the cell has been restored by charging, as the acid will then be found too strong. In no case ever pour the pure acid into the jar containing the plates.

The charging wires should be run to a convenient switchboard and should be connected to an ammeter, a rheostat, a main switch and the customary fuse block. The rheostat should be of large enough capacity to carry the maximum charging rate without overheating, and should have a sufficient number of steps for the regulation of the current. The polarity must be determined and the poles properly marked. If there is any possibility of the polarity being changed, a test with a polarity indicator should be made each time before turning on the current.

In most cases the cells will be charged in the wagon, and the directions given by the manufacturer should be followed. The charging plug furnished with the wagon should be attached to a cable of convenient length and the ends connected to the terminals on the switchboard. The polarity at the plug should then be tested and made to correspond with the marks on it. It is then inserted in the receptacle on the wagon. The rheostat is set with all the resistance in circuit and the current turned on. If plenty of time can be allowed in which to charge, the normal rate should be adhered to; but if it is necessary to hurry the charging, the maximum may be applied at first and then reduced as the cells begin to show signs of being charged.

As soon as the bubbles rise to the surface of the acid freely or the sound of bubbling can be plainly heard, the current should be reduced step by step as the bubbling continues, and if at the lowest point it still continues, it is evident the cells are nearly charged. It is advisable to continue charging at a low rate, as there may be some cells below the others, and they will have an opportunity to catch up, while an over-charge at a low rate will not injure the others.

If a battery has been over-discharged it will be necessary to continue the charge for a longer time, as even the bubbling will not be a sure indication of its being up to its full capacity. In the latter case the battery should be taken out of the vehicle and the plugs removed from the cells, so that each cell can be inspected. The gas that forms from the bubbling is explosive, so as much ventilation should be given as possible, and great care should be taken to have no fire allowed near. The cells should be examined by an incandescent lamp. They should all bubble uniformly on a low rate of charge.

After a heavy over-discharge even a prolonged charge will not always bring the cells back to their original condition, but if the following discharges are moderate the subsequent chargings will restore them. It is always advisable to charge the battery as soon as possible after it has been used, and if convenient give it a short charge shortly before taking out the vehicle.

When an automobile is used every day, two sets of batteries will be found of advantage, as there will be more opportunity to give them attention and a longer time to charge. In any case, frequent tests of the cells are recommended, as a fault once developed in a cell will become worse and lead to further trouble if not repaired at once.

We have endeavored to cover the principal points in the care of automobile batteries. Much more could be said of a technical nature. Other currents than the 110-volt circuit may be used for charging, but with the increase in the number of vehicles and charging facilities they will rarely be called upon.

A storage cell is made up of two groups of plates, called positive and negative. Each group has attached to it a connecting strip of lead. The plates alternate in the jar, so that one plate is of opposite sign to the next. They are kept from touching by various methods of insulation that allow of a free circulation of the solution. When the charging current passes in at one pole it reaches the next through the solution and effects a chemical change in the nature of the plates. When this chemical change is complete the cell is fully charged, and when the circuit is closed a reaction takes place and a chemical change of an opposite character occurs. This produces an electric current. No electricity is actually stored.—Horseless Age.

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