Motor Car Differential Gear

The Principles of Back-Axle Transmission Demonstrated by a New Meccano Model

By Edgar Wright

In the February "M.M." our contributor explained the mechanical principles involved in steering a motor car, and described a Meccano model of Ackermann steering gear. Below he deals with rear axle transmission, and describes a Meccano "spur-gear" differential that may be used as an alternative to the differential gear at present fitted to the Meccano motor chassis (Model No. 701). The type of differential represented in the latter model is more common in actual practice, but a good deal of useful information will be obtained from the construction of the gear shown in the accompanying article, and many readers may prefer to use this new form in their Meccano motor cars.

IN the article entitled "Steering a Motor Car," which appeared in the February issue of the "*M.M.*" it was explained that when a car travels in a curved or circular path, the two front road wheels must each describe an arc struck from the centre of the circle or portion of a circle in which the car moves, and the outer wheel must naturally follow an arc of greater radius than the wheel that is nearer to the centre. This will be clear on reference to Fig. 3, which is reproduced from the February issue for the benefit of those readers who are unable to refer back to that number.

The drawing is intended to represent a car turning a corner and in doing so the wheels must describe an arc or portion of a circle whose centre point is shown at A. It is obvious that the radius AC of the outer wheel (that is its distance from the centre A) is greater than the radius AB of the inner wheel. Since this is the case, it will be clear that the outer or farthermost road wheel must traverse a greater distance or revolve a greater number of times than the inner wheel.

The difference in speed thus set up between the two wheels is not important in the case of the front wheels, for they are both free to turn on their individual axles; but it is obvious that since the rear or driving wheels are similarly placed in regard to the central point A, the same rule must apply to them. To state this more plainly, the rear wheels should rotate at different speeds when the car moves in a curve, otherwise slip will take place between the tyres and the road surface, which would result, at least in the heavier types of cars, in damage to the tyres and in more or less serious inconvenience to the steering. But both these wheels must be driven constantly from the engine, and each must receive an equal amount of driving power. Therefore it is necessary to incorporate in the back axle, or in a supplementary shaft connected at each end to one of the rear wheels by means of chain or belt drive, some device that will transmit the power evenly to the wheels and at the same time allow for the difference in speed that arises immediately the car deviates to any extent from the straight.

Principle of Differential Gear

The mechanism that fulfils these functions is known as a "differential" or balance gear. Its operation may be followed from studying Fig. 1, which is intended to illustrate the principle of the apparatus only.

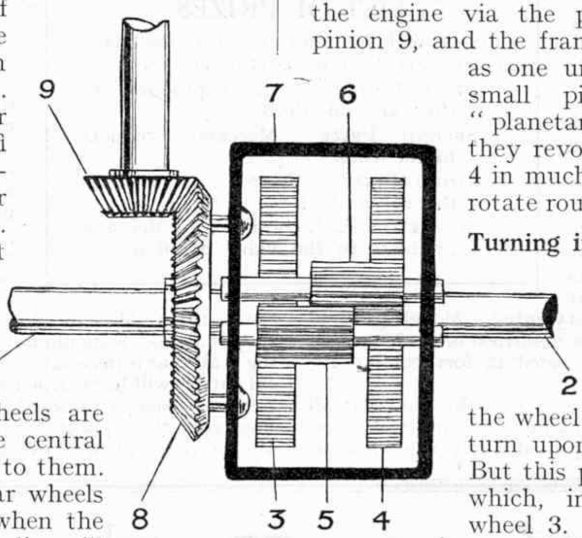


Fig. 1

The back axle of the car is composed of two separate sections 1 and 2, each of which carries at its outer end one of the road wheels. The shaft 1 is rigid with the gear wheel 3 and shaft 2 is secured in a similar wheel 4. The small pinions 5 and 6 are mounted so as to be in constant engagement with each other. Pinion 5 also engages with the gear wheel 3 and pinion 6 with the wheel 4. The spindles on which the pinions are mounted are journalled in a frame or cage 7 rigidly fastened to a large crown bevel 8, which is free on the shaft 1. The crown wheel 8 receives the driving power imparted by the engine via the propeller shaft and small bevel pinion 9, and the frame 7 and pinions 5 and 6 rotate as one unit with the crown wheel. The small pinions are sometimes termed "planetary" wheels, for the reason that they revolve round the gear wheels 3 and 4 in much the same manner as the planets rotate round the sun.

Turning in a Small Circle

Now suppose that for some reason the road wheel on shaft 2 is immovable and that the frame 7 and the bevel 8 are rotated by the engine. Since the wheel 4 is stationary the pinion 6 must turn upon its spindle as it rolls round 4. But this pinion 6 is in engagement with 5, which, in turn, meshes with the gear wheel 3. Therefore the wheel 3 must be rotated from the action of the pinion 6 as it rolls round 4, thereby driving the other road wheel on shaft 1. The whole power of the engine is now absorbed in the rotation of this road wheel, which, if resting upon the ground, will cause the car to turn in a small circle.

It must be understood that rotation of the pinions about their own spindles can only take place when the resistance on the wheels 3 and 4 differs, for when the pinions rotate one of the gear wheels must turn faster than the other. If the shafts 1 and 2 are equally difficult to turn there is no inducement for the pinions to commence to rotate, so the road wheels are driven at equal speeds and the car travels in a straight line.

When the car turns a corner the speed of the inner road wheel tends to fall off, the resistance increases on the gear wheel connected to it, and the pinions commence to rotate, thereby driving the outer wheel at a greater speed. The difference in the speed of the two wheels varies of course, with the degree of the curve described by the car.

The New Meccano Differential Gear

The type of differential shown in Fig. 1 makes use of

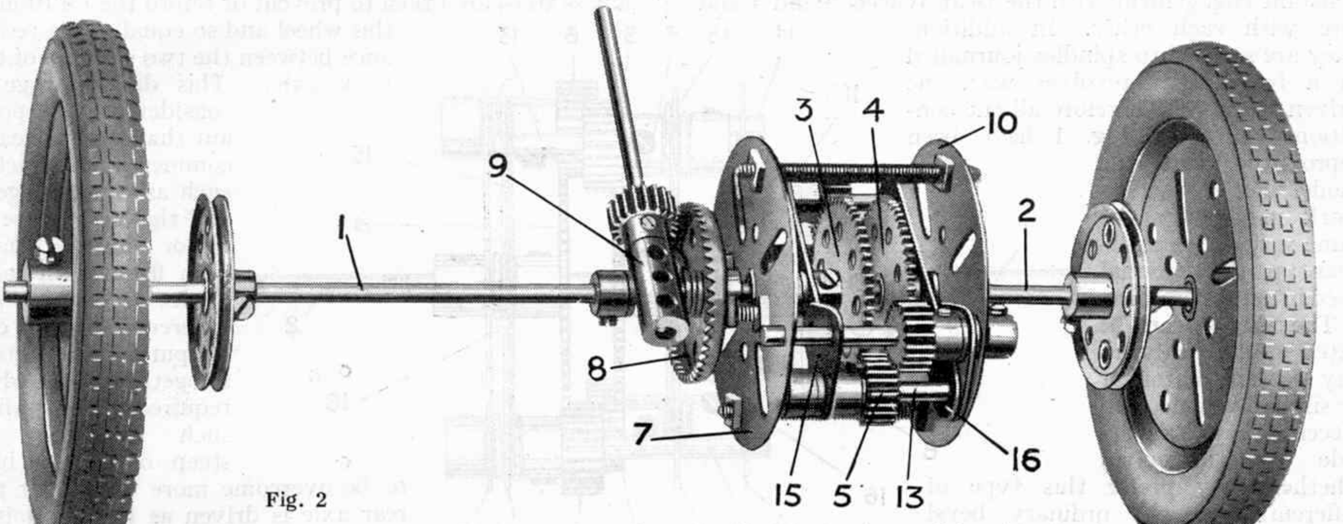


Fig. 2

The Meccano Spur-gear Differential incorporated in the back axle of a model motor chassis

ordinary spur gearing, but in actual practice bevel gearing is more often employed, the gear wheels 3 and 4 being replaced by two large bevels and the pair of pinions 5 and 6 by a small bevel pinion which meshes with the two larger bevels. In both types the planetary pinions are reproduced several times to obtain added strength and smoothness of operation. Two, three or even four pairs of spur pinions are used in the one case and two, three, or four bevel pinions in the other. The bevel type of differential is well represented in Meccano by the gear used in the back axle of the existing model motor chassis (see Standard Mechanism No. 251). The model differential about to be described is based on the straight-toothed or spur gear type, which has not hitherto been reproduced in Meccano.

Fig. 2 is a general view of the Meccano "spur" differential, and the diagrams in Figs. 4 and 5 (see next page) show respectively the side and end elevations of the mechanism. The following details should help to make the construction of the model quite clear:—

The Axle Rods 1 and 2 (Fig. 2) form the shafts carrying the road wheels of the vehicle and are separate one from the other, as in Fig. 1. The Rod 1 is secured in the boss of a 57-teeth Gear Wheel 3 and a similar wheel 4 is fixed to the Rod 2. The extreme end of the latter Rod is inserted in the centre of the Gear Wheel 3, which thus serves as an additional support, but it should be noted that the Rod is free to turn independently of this wheel.

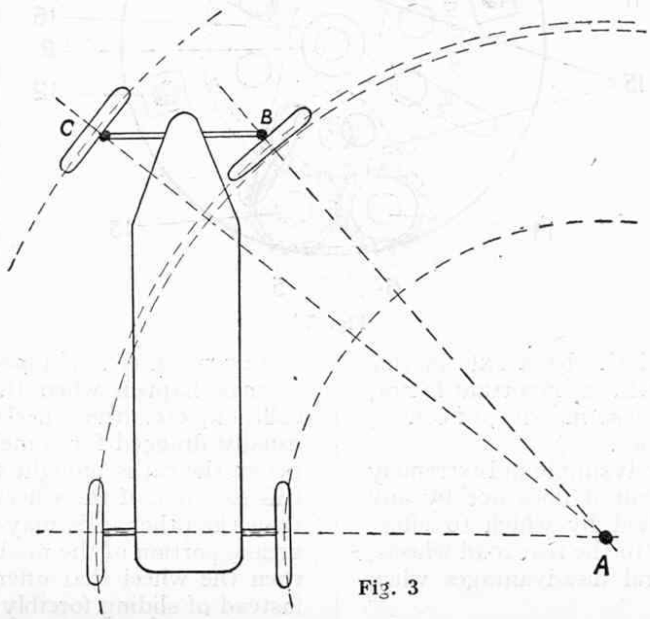


Fig. 3

The rear end of the propeller shaft is journalled in the Coupling 9, which is free on the Rod 1, and a 19-teeth Pinion on the propeller shaft drives the $1\frac{1}{2}''$ Contrate Wheel 8. The latter is secured by two $\frac{1}{2}''$ Bolts to a Face Plate 7 which, together with another Face Plate 10, forms a revolving frame corresponding to 7 in Fig 1. The Face Plates are bolted together by two 2″ Screwed Rods, the positions of which are indicated at 11 and 12 in Fig. 5. A portion of one of these Rods is also shown at 11 in Fig. 4, the remainder of the rod having been omitted for the sake of clearness. The Face Plates are free to turn about the axles 1 and 2.

The Planetary Pinions

The revolving frame carries two pairs of planetary wheels, each pair consisting of $\frac{1}{2}''$ Pinions 5 and 6 secured respectively to a $1\frac{1}{2}''$ Rod 13 and a 2″ Rod 14 (see Fig. 4). The Rods 14 are journalled in opposite holes in the Face Plates and each Rod carries two 1″ Triangular Plates 15, a Washer being placed on each side of the Plate 15 that adjoins the Pinion 6. The Rods 13 also pass through holes in these Triangular Plates and in addition each Rod 13 passes through the end holes in two $2\frac{1}{2}''$ Strips 16, the centre holes of which engage the axles 1 and 2. Each Strip 16 is spaced away from its adjoining Face Plate by means of two Washers.

The Rods 13 do not engage in any way with the Face Plates, but the arrangement of the $2\frac{1}{2}''$ Strips and Triangular Plates provides ample bearings in which they may turn; the Triangular Plates ensure proper alignment between the Rods 13 and 14, while the $2\frac{1}{2}''$ Strips maintain the Rods 13 at the correct distance from the axles 1 and 2. The arrangement of the Rods 13 and 14 and their bearings will be followed more easily perhaps on reference to Fig. 5, which is an end elevation of the Face Plate 10 and adjacent parts.

It may be noted that the differential movement may be obtained with only one pair of Pinions 5 and 6, but the second pair has been added with the object of increasing the strength and reliability of the device as well as to balance the stresses set up by the various elements revolving about the back axle.

Now it will be seen that the Pinions 5 and 6 are in constant engagement with the Gear Wheels 3 and 4 and also with each other. In addition, they are secured to spindles journalled in a frame that revolves with the driven wheel 8. Therefore all the conditions shown in Fig. 1 have been reproduced and the model will be found to work in exactly the same way as the spur-gear type of differential used in actual practice.

The model can be fitted quite easily to any Meccano motor car or similar vehicle, and Meccano boys can decide for themselves whether they prefer this type of differential or the ordinary bevel type with which they are already familiar.

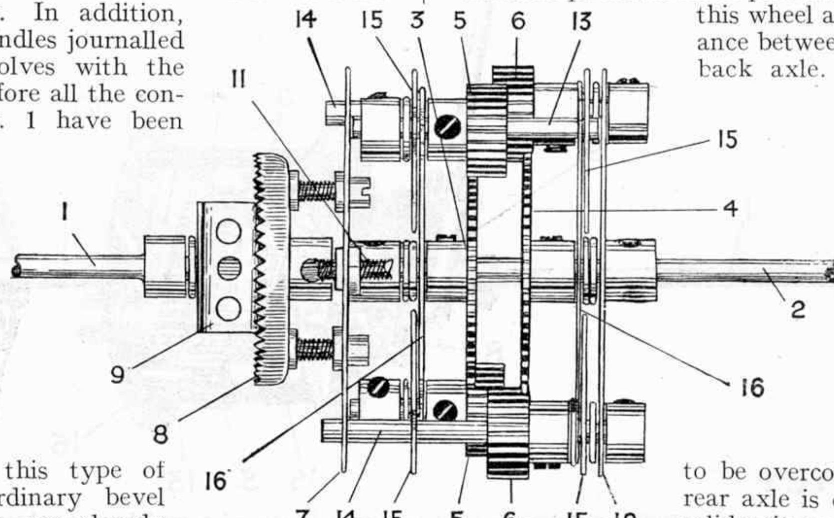


Fig. 4

Disadvantages of the Differential

It has already been indicated that the differential is not always embodied in the back axle. In the heavier types of motor lorry, for example, it is carried usually in the chassis frame, in which case each of the driving shafts is fitted at its outer end with a small sprocket by means of which the drive is led to the rear wheels through chain gearing. In a layout of this kind the rear axle is described as " dead," because the road wheels run freely on its ends without the axle itself rotating; the axle serves merely as a distance piece and to support the weight of the vehicle. A " live " axle is one that embodies the differential and actually transmits the drive to the wheels.

The chief advantage of the " dead " axle method lies in the fact that it reduces the unsprung weight (i.e. that of the back axle) to a minimum, but the objections to its application to ordinary touring cars are, principally, the noise created by the chain drive and the excessive wear and tear to which the chains are subjected. Moreover, the weight of the back axle in this class of car does not constitute such an important factor, since its construction is not nearly so massive, of course, as in the big commercial vehicles.

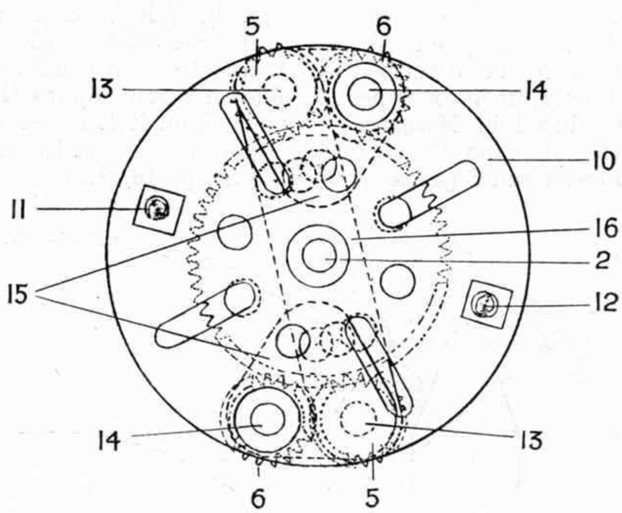


Fig. 5

The differential is a comparatively simple and extremely ingenious piece of mechanism, but it does not by any means represent the ideal method by which to effect smooth transmission of the drive to the rear road wheels, for it is found to possess several disadvantages when put into practice.

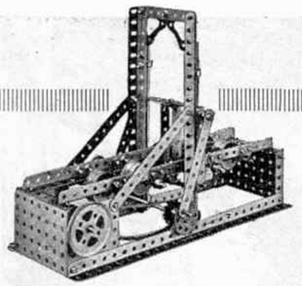
For example, it makes no provision for the application of increased power to the particular driving wheel that requires it most. Suppose one rear wheel of a motor car becomes firmly stuck in mud while the other rests on a smooth or greasy surface over which the tyre slips easily. The power of the engine is wasted in turning the free wheel at great speed, and the car will remain fast unless steps are taken to prevent or retard the rotation of this wheel and so equalise the resistance between the two sections of the back axle. This disadvantage is considered so important that certain heavy commercial vehicles, such as steam wagons and the larger type of motor lorries, have been fitted with some device with which the differential gear can be put out of action altogether as and when required. This enables such difficulties as steep or greasy hills to be overcome more easily, for the rear axle is driven as though it is a solid unit, and it is then impossible for one wheel to slip round without the other.

Again, if the brake on one of the rear wheels is more efficient or acts slightly in advance of that on the other wheel, the entire power of the engine is directed momentarily on that wheel which receives the least braking effect.

A Remarkable Spectacle

A very curious result for which the differential is responsible may often be seen in any busy street. This is the spectacle presented by a car that, having been braked suddenly, skids along for a few feet with one rear wheel revolving very rapidly *backward,* or in the opposite direction to that in which the car is moving. This strange effect is produced in cars that are equipped with a brake on the propeller shaft behind the gear box, and is caused by violent application of this brake, as will be understood from the following :—

The sudden stoppage of the propeller shaft and its pinion (corresponding to 9 in Fig. 1) arrests the rotation of the crown bevel 8 and its subsidiary frame 7 carrying the planetary wheels. If a motor car is braked very suddenly, as may happen when the driver attempts to avoid a collision, etc., the wheels, though securely locked, are usually dragged for some little distance along the road before the car is brought finally to rest. But suppose in this case one of the wheels grips the road more securely than the other (this may easily happen on account of a greasy portion of the road surface or a badly worn tyre); then the wheel that offers most resistance will revolve instead of sliding forcibly over the (*Continued on page* 357)



Suggestions Section

Edited by "Spanner"

(79)—Radius Indicator for Meccano Cranes

(G. S. Marsh, Thornton-le-Fylde, Blackpool)

MOST Meccano boys probably know that the load capacity of a crane varies according to the particular angle of the jib, for the nearer the latter approaches the horizontal position the greater will be the strains upon it in proportion to the load.

This statement may be verified quite easily by applying the principle of the triangle of forces which, it will be remembered, is summarised on page 202 of the complete Manual of Instructions as follows: "If three forces meet at a point and are in equilibrium, and we know one of the forces, we may determine the other two by drawing a triangle, making each side parallel to the direction of one of the forces, and comparing the dimensions of the three sides." It will be found that these dimensions are in the same proportion as the three forces. For example, supposing the side corresponding to the known force is four units in length and the others are eight and ten units, and supposing the known force is four tons, then we know that the other two forces must equal eight and ten tons respectively.

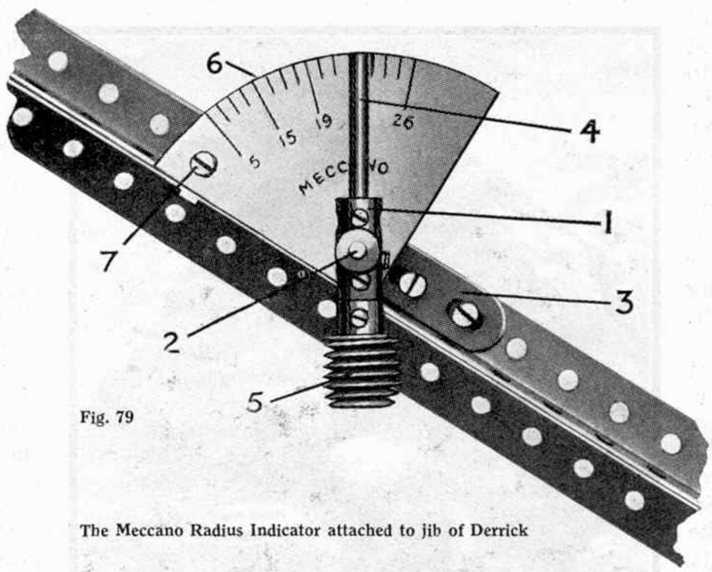


Fig. 79

The Meccano Radius Indicator attached to jib of Derrick

Determining the Strength of a Crane

In the case of a crane the three forces are (a) the load suspended from the head of the jib, (b) the tension member, or tie, which supports the jib (in luffing cranes the operating cable or chains, etc., with which the jib is raised or lowered correspond to the tie members), and (c) the jib, which acts as a strut to withstand the compressive force exerted by the combination of (a) and (b). All three forces meet in the head of the jib and counterbalance each other; that is to say, they are in equilibrium.

By drawing one or two triangles and showing the side that is parallel to the jib in a different position in each triangle, it will be found that the strains that the crane structure must withstand increase as the jib approaches more nearly the horizontal position, as stated in our opening paragraph. It should be noted that the disposition and proportion of the strains or forces vary according to the particular type of crane.

These facts render it impossible for an engineer to build a luffing crane that will lift a specified load with equal facility at any position of the jib. He therefore designs his crane to lift a certain load at a certain radius, the radius being measured from the point about which the crane pivots to a point immediately beneath the load hook. Thus a swivelling and luffing crane that is described in the specification as capable of raising with safety a load of 20 tons at a radius of 20 feet may be able to lift only 10 tons or thereabouts at a radius of 35 feet.

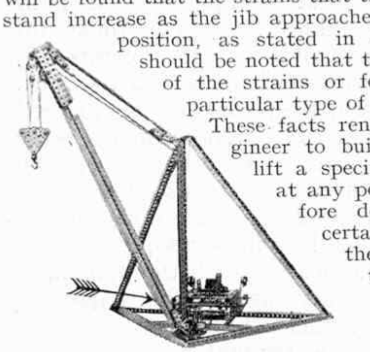


Fig. 79a. Showing position of indicator in the Stiff Leg Derrick

Therefore, when lifting a heavy load with a crane of this type, care must be taken to see that the jib is at the proper angle to cope with that load. A margin of safety is allowed, of course, for each of the various positions of the jib, but if this margin is overstepped, excessive strains may be set up in the structure and machinery. It is to minimise the possibility of such a mistake being made that a radius indicator is fitted to the majority of luffing cranes. A glance at this indicator tells the operator the position of the jib and the maximum load that he can handle safely without increasing the angle of the jib. Hence the device not only saves time but also obviates a considerable risk of accidents.

A radius indicator may easily be constructed in Meccano and fitted to any model crane that is equipped with luffing mechanism, and a device of this kind will increase the realism and interest of a model to a remarkable extent. The indicator illustrated on this page was designed by George S. Marsh, of Thornton-le-Fylde, Blackpool.

Construction of the Meccano Indicator

Fig. 79 shows the indicator attached to the side of the jib in the Meccano Stiff Leg Derrick (Model No. 709) and the actual position of the device in relation to the remainder of the model is indicated more clearly by the arrow in Fig. 79a.

The Coupling 1 is free to turn about the 1½" Axle Rod 2, which is gripped in the boss of a Crank 3 bolted to the upturned flanges of the jib girders. It carries in its upper end a further 1½" Rod 4 and in its lower end a 1" Rod on which is secured the Worm 5. The weight of the latter serves to keep the Rod 4 always vertical, no matter in what position the jib is placed. A dial 6, shaped from a piece of stout cardboard, is bolted at 7 to an Angle Bracket attached to the jib. The Rod 2 passes through a hole in the dial and carries two or three Washers to space the Coupling 1 away from the card so that the Worm 4 will clear the edges of the girders forming the jib.

The dial moves with the crane, and the Rod 4, remaining vertical, acts as a pointer and registers the variations in the angle of the jib. It is a simple matter to set the jib in different positions, and to mark on the card the radius of the area covered by the load hook for each position of the pointer.

Our contributor points out that an indicator of this type proves very useful when loading, say, a stationary lorry or railway wagon, for the jib-angle required to bring the load directly over the vehicle having once been noted, each succeeding load can be swung round and luffed immediately to the correct position. In addition, interesting experiments may be made by means of the indicator and the load capacity and efficiency of various types of Meccano cranes tested.

(80)—A Meccano Vernier Condenser

Fig. 80 shows an efficient vernier condenser that may be constructed very easily from Meccano parts. This simple model provides extremely fine tuning facilities and those of our readers who are radio enthusiasts should find it extremely useful.

Referring to the illustration, it will be seen that the condenser plates 1 and 2 are formed from two Face Plates. Plate 1 is immovable and is secured by its set-screw to a 1″ Axle Rod held in the Collar 3. The set-screw of the latter has been removed and replaced by a 2″ Threaded Rod, which is fixed in a vertical position in the boss of a Threaded Crank 4.

This Crank 4 is secured by means of two Meccano 6 B.A. Bolts to the $5\frac{1}{2}'' \times 2\frac{1}{2}''$ Flanged Plate forming the base, and is insulated therefrom by Insulating Bushes and Washers placed upon the bolts above and below the Crank. Another Insulating Bush is placed on each bolt below the base plate before the nuts are finally tightened into position. It will be noticed that the terminal 5 is attached to a $1\frac{1}{2}''$ Strip forming an extension of the Crank 4; the object of this extension is to prevent the connecting wires from touching the base plate.

The movable condenser plate 2 is secured to a 2″ Threaded Rod, which engages the longitudinal bore of the Threaded Boss 6. The Boss is supported on another vertical Rod secured in a second Threaded Crank bolted to and insulated from the base plate in the same manner as the Crank 4. The set-screw 7 inserted in the Threaded Boss 6 may be used to reduce play in the horizontal Threaded Rod. The handle of the condenser is formed by a Threaded Pin secured to the face of a Bush Wheel, and another terminal 8 is provided for connecting purposes.

The Meccano Threaded Rods are cut with thirty-two threads to the inch; hence one complete revolution of the hand-wheel effects an alteration equal to 1/32″ in the distance between the Condenser plates.

In operation it will be found that an insulated handle must be used in place of the Threaded Pin unless the terminal 8 of the movable plate 2 can be connected to earth or to the positive terminal of the H.T. battery. If a circuit of this description is used the insulation of the plate and its support becomes unnecessary and the fibre washers may be removed without any disadvantage.

Alternative Designs

Other types of Meccano condensers will probably suggest themselves to the reader. A popular type is that which employs a movable plate arranged between two fixed plates in such a way that its whole area may be gradually inserted between the fixed plates or withdrawn as desired. The fixed plates are connected together electrically, but the bearings of the movable plate must be insulated, of course. The latter plate should be connected to the earth or to the positive side of the H.T. battery.

It should be noted that where electrical contact is required between Meccano parts, the enamelled pieces should not be used.

The following readers have submitted interesting suggestions concerning the construction of Meccano condensers or vernier coil-holders on similar principles to those described above, and each will receive a special Certificate of Merit: J. E. Harris, Clacton-on-Sea; L. S. Owen, London, N.20; W. Halliwell, Marsden, near Huddersfield; L. Stevenson, Karachi, India; and C. A. Croughton, London, S.E.23.

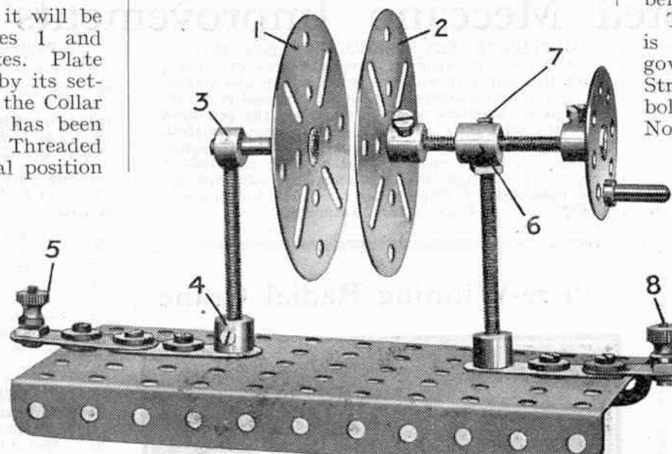


Fig. 80

(81)—Non-Slip Belt Pulley

P. Short (Wallington) points out that an efficient non-slipping continuous cord drive may be obtained in any Meccano model by substituting for each driving pulley two Bevel Wheels placed face to face, so that the sloping edges of their teeth form a V-groove to receive the cord. An alternative and more economical method is to use a Bush Wheel in place of one of the Bevel Wheels.

(82)—Self-Acting Drilling Machine

(G. K. Hooper, Liscard, Wallasey)

Fig. 82 shows an interesting Meccano model of a type of drilling machine that automatically adjusts the pressure of the drill and removes the tool from the work when the speed of the machine drops below a certain limit.

The vertical drill shaft 4 (an 8″ Axle Rod) is fitted at the top with a centrifugal governor, consisting of two pairs of $2\frac{1}{2}''$ Strips 1 pivotally attached by means of bolts and nuts (see Standard Mechanism No. 263) to Angle Brackets bolted to two Bush Wheels 2 and 3.

The upper Bush Wheel 2 is secured to the vertical Rod, but the wheel 3 is without a set-screw. The latter wheel is secured by means of two $\frac{3}{4}''$ Bolts to another Bush Wheel 5, which also is free on the Rod 4. These Bush Wheels 3 and 5 are prevented from moving vertically by means of two $\frac{3}{4}''$ Bolts inserted in place of the set-screws in two Collars 6, which are held fast on 1″ Axle Rods inserted in opposite ends of a Coupling that is secured by its centre transverse hole to a third 1″ Rod 7 gripped in the boss of a $1\frac{1}{2}''$ Pulley Wheel 8. The Pulley 8 is bolted rigidly to a $2\frac{1}{2}'' \times \frac{1}{2}''$ Double Angle Strip at the top of the framework.

The two pairs of $2\frac{1}{2}''$ Strips 1 are pivotally attached to one another by means of the bolts 9. These bolts also serve to secure a Spring 10 that tends to draw inward the weights 11, each of which consists of 1″ fixed and 1″ loose Pulley Wheels secured together by means of a $\frac{3}{4}''$ Bolt.

Centrifugal Force

The vertical Rod 4 carries two $\frac{1}{2}''$ Pinions 12 butted together in the manner shown. These pinions are in constant engagement with the $1\frac{1}{2}''$ Contrate Wheel 13 secured to the shaft of the operating handle. The Coupling 14 serves as a chuck to receive the drill 15, which, of course, is not a Meccano part.

As the speed of the shaft 4 increases the weights 11 tend to fly outward, owing to the centrifugal force set up by their rapid rotation, and since the wheels 3 and 5 are unable to rise, the Bush Wheel 2 commences to descend, thereby pushing the Rod 4 downward and applying the drill to the work. In doing this, however, it must extend the tension spring 10; hence, immediately the speed of the shaft 4 drops, the spring reasserts itself and raises the Bush Wheel 2 to its former position.

The Collar 16 serves to prevent the Rod 4 descending too far. Care should be taken to see that the teeth of the Pinions 12 coincide exactly, for they must remain in engagement with the Contrate Wheel 13 throughout the vertical movement of the drill-shaft.

Parts Required:

2 of No. 1B	1 of No. 13A	3 of No. 24
4 " " 2	1 " " 15A	2 " " 26
2 " " 4	3 " " 18B	1 " " 28
5 " " 5	1 " " 19B	62 " " 37
2 " " 8	1 " " 21	1 " " 43
2 " " 10	2 " " 22	1 " " 45
6 " " 12	2 " " 22A	6 " " 48A
		2 " " 48B
		1 " " 52
		2 " " 53
		4 " " 59
		2 " " 63
		6 " " 111
		1 " " 115
		2 " " 126A

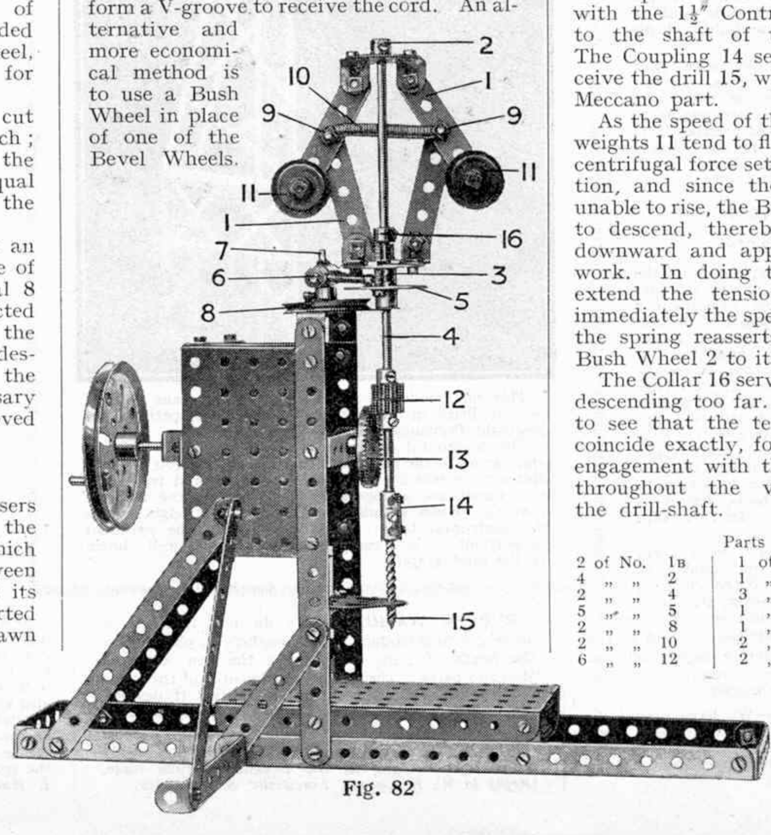


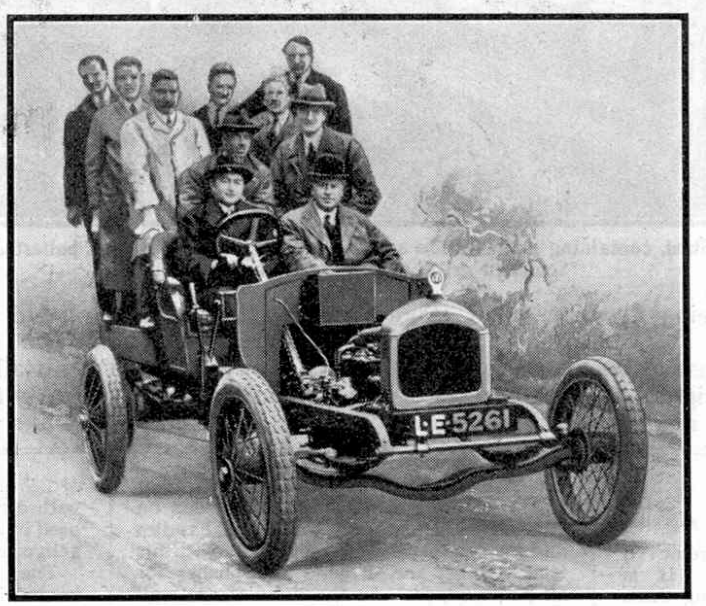
Fig. 82

Motor Cars Without Gears

Success of the Constantinesco Torque Converter

SOME of our readers may remember that three years ago we dealt with a remarkable invention, the Constantinesco Torque Converter. This invention, which we described as being "an invention of promise," was then more or less in an experimental state. Now it has been applied in a practical manner to motor-cars, six of which, fitted with the device, were last year exhibited at the Paris Motor Show, three in the Grand Pallais and three outside giving demonstrations to the public. During the time of the Motor Show at Olympia, these cars were exhibited at Devonshire House, and are now shown at the Constantinesco Laboratory, 130, Wilton Street, S.W.1, near Victoria Station.

The Torque Converter is the invention of Mr. Constantinesco, a Roumanian engineer who did a great deal of useful work in this country during the war. Many inventions stand to his credit and perhaps the best-known of all is the high-speed timing apparatus for machine guns, by means of which 2,000 rounds per minute may be fired through aeroplane propellers revolving 1,500 to the minute. This invention, which at once made the Allies' aeroplanes immensely superior to the Germans, was fitted to over 40,000 British and to many thousands of American aeroplanes.



The first car to be fitted with the Torque Converter. Driven by a 10 h.p. engine it was tested successfully in May 1923

The practical application of the Torque Converter to motor-cars is of such interest, and the invention itself of such far-reaching importance, that we think our readers will be glad to have full details of it. More especially so as the Converter has now been included in our "Standard Mechanisms" Manual, because we believe that there are numerous applications of the principle to Meccano models.

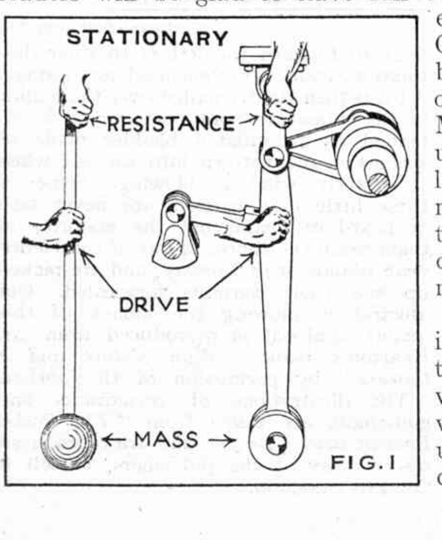


FIG. 1

Before describing its application to motor-cars, which application will eliminate the use of the ordinary clutch and gear-box, it is desirable to explain the principle on which the Converter depends. In this connection it may be mentioned that Mr. Constantinesco told the writer that without falling back on advanced mathematics and highly technical engineering knowledge, it is impossible for him to explain how the results are obtained so that the non-technical reader could understand. If the inventor himself finds it impossible to give this information, our readers will readily realise that the writer is confronted by a task of some difficulty! However, a Meccano model of the Converter was built some little time ago and it remains to-day the only practical means by which the non-technical reader can understand how the Torque Converter functions.

Before we go on to describe the construction and working of this model and later see how the Converter is applied in actual practice, we will endeavour to convey some idea of the working principle underlying the device.

The majority of mechanisms used for the purpose of power transmission are direct or indirect applications of the principles of the lever, as demonstrated by Archimedes. The principle of the Torque Converter throws a new light on the classical boast of the famous Greek mathematician—that he "could lift the world if he were given a fixed point." If this is taken to mean that given a suitable lever and a fixed point, a small force can produce as big a force as required, then the Torque Converter fulfils this interpretation. It has this essential difference from the ordinary lever, however, that a fixed point is no longer necessary for its applications—although this does not enable it to be applied to lifting the Earth!

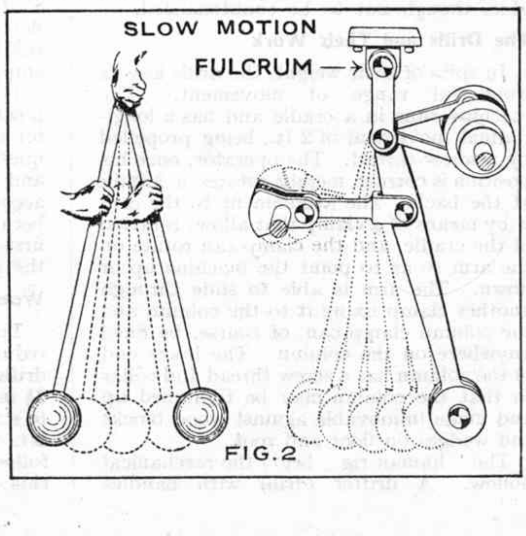
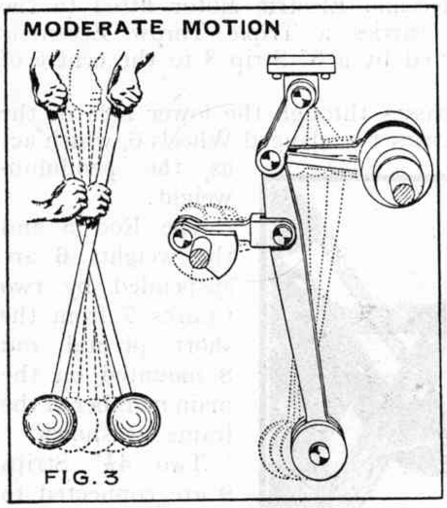


FIG. 2



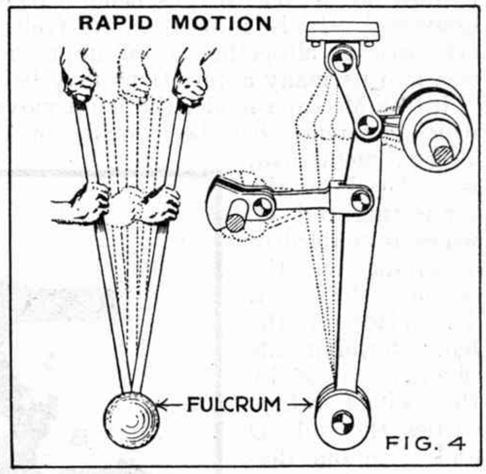
The ordinary rules of static mechanics do not apply to the Torque Converter, and it is only by the consideration of the elements "Time" and "Mass" that the behaviour of the Converter can be explained. As has already been mentioned, for a complete understanding of its working mathematics of a high order are required.

The invention may be described as a practical illustration of the principle of Relativity applied to the all-important problem of automatic transmission. We are here sailing in rather deep waters, however, but we will endeavour to obtain a rough idea of what it is all about from a simple analogy by means of a walking stick with a heavy knob. This stick is held by the right hand suspended with the knob downwards and held by the left hand a few inches below the tip. On swinging the stick gently to-and-fro it is noticeable that the stick swings easily, pivoting in the thumb and finger of the right hand. This easy and pendulum-like swinging of the stick continues as long as the impulses given to it by the left hand are not excessive. If the frequency of the impulses be increased, however, a different state is set up. This is evidenced by an increase in pressure conveyed to the right hand that is acting as a pivot for the stick.

As the impulses increase in frequency a change in equilibrium takes place, so that instead of the stick tending to pivot between finger and thumb of the right hand, the pivot shifts down the stick At length, given a sufficiently high-frequency, the pivot moves to the opposite end of the stick and the knob becomes the pivotal point, whilst the pendulum-like movements are carried out by the hand in which the stick originally pivoted.

The original conditions have thus become entirely reversed. Instead of the knob oscillating to-and-fro and the right hand remaining at rest, with the tip of the stick pivoting in the finger and thumb, the knob ceases to oscillate and becomes the point upon which both stick and supporting hand now pivot. The oscillations originally performed by the knob are transferred to the other end of the stick and are now performed by the right hand. Expressed in engineering language, the technical term would be that the fulcrum has receded.

To the person holding the stick this change is made manifest in a very remarkable manner. As the impulses increase in frequency, the hand holding the tip of the stick finds itself compelled to yield to an irresistible increasing pressure. It is moved backwards and forwards by a powerful superior force, oscillating this way and that, with a degree that depends entirely on the frequency and amplitude of the impulses received by the stick.



It is important to realise that the pivotal point does not change suddenly from the tip of the stick to the knob, but moves slowly from one to the other, according to the frequency of the impulses received by the stick. If these are not sufficient, the fulcrum need never reach the knob. If the frequency varies, the position of the fulcrum will vary also every instant, its location alternating momentarily between the tip and the knob. If the oscillations decrease in intensity beyond a certain point, the pivotal point returns to the tip and the original order of things is restored.

In the accompanying illustrations (Figs. 1–4) are shown four phases of a simple experiment that may be performed by two persons standing at right angles to each other, and with the stick with a weighted end. Alongside these, on the right of each figure, are illustrations showing how the Converter itself would function in positions corresponding to those of the stick. In these latter illustrations the lower hand is replaced by a connecting rod moved by a crank, and the upper hand by two unidirectional devices, connected to the secondary shaft at the point where the resistance occurs.

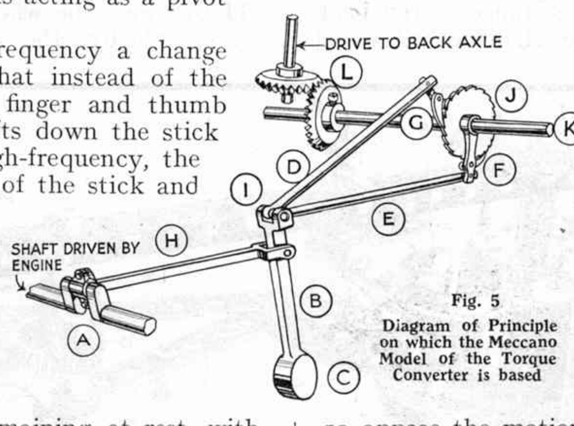


Fig. 5
Diagram of Principle on which the Meccano Model of the Torque Converter is based

It will be observed that a slow oscillatory motion (as in Fig. 2) merely serves to swing the pendulum to-and-fro, during which time the fulcrum of oscillation remains at the point of resistance. When the oscillatory motion at the drive is increased, however, it overcomes the resistance, and the fulcrum automatically comes down to some intermediary point, as shown in Fig. 3.

An even more rapid oscillatory motion, applied at the drive, causes the inertia of the knob to oppose the motion, and the resistance is completely overcome. The power hand has then no option but to move as if it were driven directly, the fulcrum being now at the bottom of the stick and in the pendulum knob (Fig. 4).

The Converter in Meccano

To pass on to the Meccano model, from a study of which a clearer idea of the Converter will be more easily obtained than by a perusal of any number of lengthy explanations in print.

The principle on which the Meccano model is based is demonstrated in Fig. 5, and it is desirable that this diagram should be closely studied, and its points of analogy with the real Converter thoroughly understood. It cannot be too strongly emphasised that the Meccano model is simply a demonstration of a principle, and it must not be regarded as being a model of the actual Converter. It is important to realise this, because otherwise an altogether wrong impression of the invention and its many applications may be obtained.

In the Meccano model the hand moving the stick, to which reference has been made in the experiments already mentioned, is replaced by the connecting rod H, which is coupled to a crank on the engine shaft A. The place of the hand forming the pivot is taken by the bolt I, which carries the rods D and E in our diagram. Impulses from the crank A are transferred by the pawls, F and G, to the toothed-wheel J, which in turn passes on the impulses—now converted into a turning movement—to the driving shaft K and so to the road wheels through the bevel gears L.

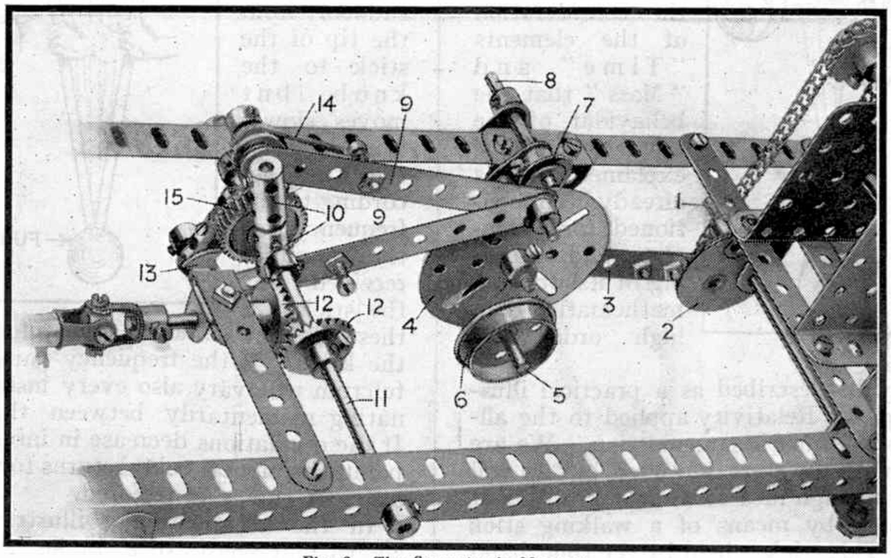


Fig. 6. The Converter in Meccano

When the engine is running slowly only a slight swinging movement is given to the lever carrying the weight, which movement is not sufficient to move the pawls on the toothed wheel J. As the speed of the engine increases, however, the weight is compelled to swing faster and faster, imposing an increasingly heavy force or load upon the pawls. At length this load becomes so great that the resistance of the back axle is overcome, the pawls move the toothed wheel and therefore vibrate the driving shaft, and the car moves forward.

The conditions of the analogy in Fig. 1 are simulated when the weight C in Fig. 5 swings without imparting any movement to the shaft through the pawls and toothed wheel. On the other hand, when the engine is running rapidly the fulcrum recedes and the weight C becomes the pivot, as it cannot respond to the rapidly-repeated impulses of the rod H with sufficient rapidity.

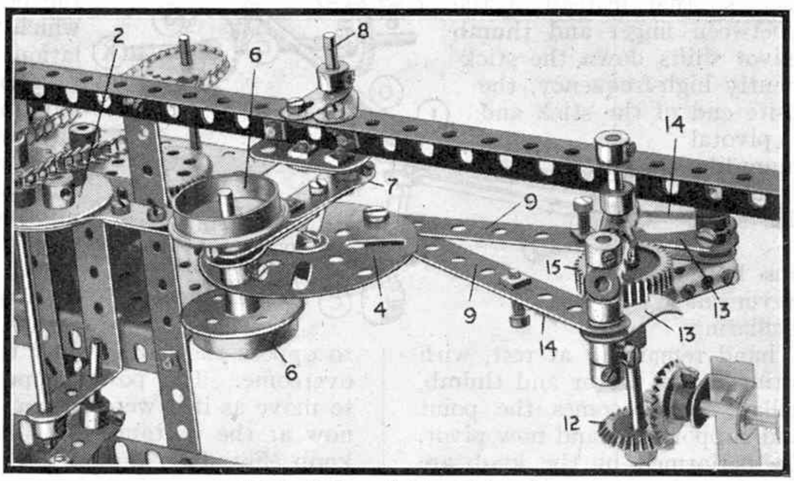


Fig. 7. Underneath View of Converter

The condition illustrated in Fig. 2 arises when the resistance caused by starting up the car is overcome, and when the lever pivots on the weight C. In these circumstances the drive from the engine is practically a direct drive to the back axle.

The Construction of the Meccano Model

Turning now to the actual construction of the Meccano model. The rod 1 (Fig. 6) is rotated by a sprocket chain from the Meccano Electric Motor fitted to the chassis. The rod carries a Triple Throw Eccentric 2, which is connected by a 3″ Strip 3 to the centre of a Face Plate 4.

A short rod 5 passes through the lower hole of the Face Plate and carries two flanged Wheels 6, which act as the pendulum weight.

The Rod 5 and the weights 6 are suspended by two Cranks 7 from the short pivotal rod 8 mounted on the main member of the frame as shown.

Two 4½″ Strips 9 are connected to the top hole of the Face Plate 4 and their other ends are connected to elements, each formed by two Couplings 10, secured on the short rods. The Couplings rock loosely on the driven rod 11, from which the drive to the differential is conveyed through the bevels 12.

The Pawls 13 are mounted on short rods secured in the outer holes of the Coupling (shown more clearly in Fig. 7), these Pawls being controlled by short tension springs 14 so that they are kept in contact with a 1″ Gear Wheel 15. When moving in one direction, they drive the Gear Wheel 15 and consequently the rod 11 to which the wheel is secured.

Technically, the theory of the mechanisms is as follows :—When the Electric Motor is running slowly, the pendulum tends to oscillate about the rod 8 and little, if any, movement is imparted to the Pawls—a state corresponding to a low power. Should the resistance to movement in the rear axle be great, however, the fulcrum recedes towards the weight 5. Owing to the inertia or reluctance to vibrate quickly the Face Plate then pivots about the weight and a greater force is exerted on the Strips 9 to drive the Shaft 10. In this way the gear accommodates itself automatically to the work to be done.

In operation the Rod 1 is rotated by the motor, the Eccentric 2 tends to drive the Strips 9 to-and-fro as the weight oscillates. This to-and-fro movement of the Strips 9 results in a corresponding movement of the Pawls. As the Pawls are mounted to lie in opposite directions around the Gear Wheel 15, the latter is driven in one constant direction in a series of pulsations.

(*To be continued next month*)

who was a very big man. The superintendent commented:

"The alleyways are very narrow, Chief."

I replied: "That's true, Captain; but we could not have put the number of passengers' rooms in if we had made them broader."

The manager, who was more accustomed to speaking French than English, said: "Just so, chief, you cannot cut five hams from one *porc*!"

So, when people tell me of something in another ship that we lack in the one I am in, if I know the other ship and her relative size, I also know that in many cases the other ship lacks something that we have, as "You cannot cut five hams from one *porc*!"

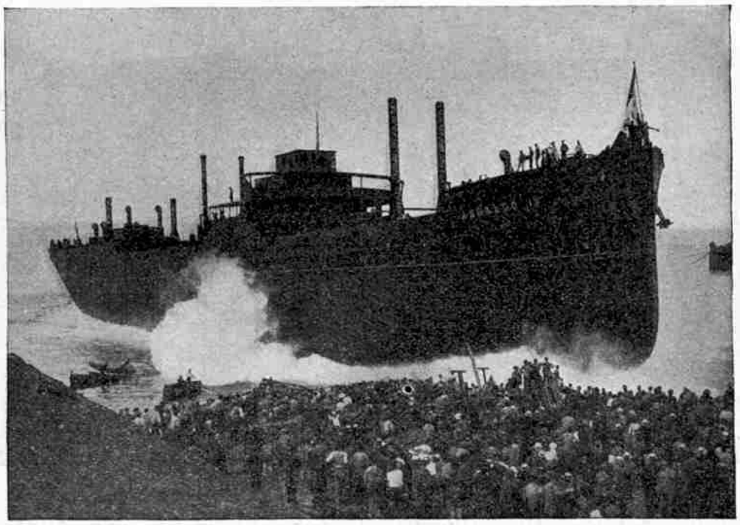
This consideration also applies to ornamental details. As in the case of any other business appliance, a ship is a commercial proposition, and only a certain amount of money can be laid out upon her. In the minds of our management, and in those of all shipowners of long experience, the most important factor in a ship's design is safety; the next is comfort; and then comes finish, elegance, or luxury.

Given the first factor, the second and third can be increased and improved as experience dictates and competition demands. The "*Belgenland*" was called the "Luxury Liner of 1923," but you may rest assured that the other factors were not sacrificed in earning that title.

After the plans have been passed and all details settled the construction of the hull and machinery is commenced. Shortly after this work has been put in hand, the Chief Engineer is sent to the shipyard as inspector for the owners, unless they have a permanent inspector at the shipyard. All tests of apparatus are carried out in his presence, and the workmanship must be to his satisfaction. It is his duty to notify the manager of the line, through his superintendent, of any cause for dissatisfaction, and to suggest any improvement on the original specification or designs that may occur to him. He makes a weekly report of progress to the manager.

As the work progresses other officials who will form part of the staff of the ship will come to the yard to assist in the work of inspection, and become conversant with the details of the hull and machinery equipment.

At certain stages of the work the manager of the line and his superintendents visit the ship, note progress, and suggest any alterations that they consider advisable. These visits become more frequent as time goes on, and there is greater scope for an increasing number of workmen on the job. When the "*Belgenland*" was nearing completion, for instance, there were night and day shifts of men, approximating 12,000 at work on, or for, this ship.



Our illustration, which shows a launch at an Italian shipyard, is from an interesting book "From Slip to Sea" by A. C. Hardy. This book will be reviewed in an early issue of the "M.M." but meantime those readers who wish to learn something more of the planning and building of a ship will do well to read the book mentioned

It takes from two to three years to build such a ship, but the time comes at last when the critical moment of launching the hull is over. It is then towed to a big crane where the engines, boilers, and heavy weights are placed on board. Stability tests are made, and a dock trial of the engines carried out. Then the ship is dry-docked and a final examination of the underwater hull, propellers, rudder, etc., carried out, while the finishing coats of paint are put on.

Then follows the official trial trip, on which tests are carried out for power, speed, and steering qualities. If these are successful, the vessel is handed over to the owners and their staff takes over the ship.

The last few months occupied in finishing the vessel are strenuous ones, for the shipyard heads, and for the owners' representatives at the yard. To any man with imagination it is rather a thrilling moment when the trial trip being over, the ship is stopped, and most of the shipyard men leave, to be replaced by the vessel's staff on the bridge and in the engine-room. In a few minutes the ship is again under way—this time as a new unit for the company's fleet.

This short account of the early days of a ship was broadcast by Captain Mackay on board the "Belgenland" when in the Bay of Bengal last year. It was subsequently printed in the "Ocean Ferry" and is reprinted here by special permission of the Editor of that Magazine.

A further article, in continuation of the broadcast talk, will be printed in an early issue of the "M.M."—EDITOR.

Motor Car Differential Gear—

(*Continued from page* 336)

road surface, for no braking effect has been applied to the rear axle itself.

The gear wheel secured to the shaft of this road wheel will turn in the direction in which the car is moving, and this sets in motion the pinions 5 and 6, because the latter must rotate about their own axles since they cannot revolve round the gear wheel (it will be remembered that the frame 7 is locked in position by the brake). The pinions, in turn, rotate the gear wheel secured to the shaft of the slipping road wheel, but it will be found by following the direction of rotation of the various wheels that this gear wheel revolves in the opposite direction to that in which the car moves.

It should be noted that if both the driving wheels grip the road equally, the resistance on the shafts 1 and 2 is also equal and there is no reason why the pinions should commence to turn. Both wheels will therefore remain immovable and the car will be brought quickly to a standstill.

Deleting the Differential

In view of these defects in the operation of the differential, the designers of certain light cars decided to leave it out altogether, and to fit a simple non-variable bevel drive between the propeller shaft and the back axle. When a car built in this way describes a curve or takes a corner one of the back tyres must slip on the road to allow for the differences in speed between the two wheels, and some surprise was caused in motoring circles when it was discovered that the cost of tyre renewals in such cars was not greater than in the more conventional differential-fitted vehicles.

Many patent devices have been produced within the last few years in connection with the differential, but none appear to show any really important improvement or advancement upon existing types. A fortune still awaits the man who invents a form of balance gear that will transmit the power of the engine to the driving wheels in an efficient manner, without the disadvantages mentioned above.