HOW TO CONSTRUCT AN EXPERIMENTAL POLYPHASE MOTOR.

BY A. W. FORSTALL, S. J.

The polyphase current motor, though in more ways than one the motor of the future, remains comparatively little known. Nor are reasons for this rather negative state of mind far to seek. There is, first of all, the widely prevailing idea that the production of polyphase currents presupposes what is technically known as a polyphase generator, a costly machine, which but few are able to provide themselves with. But entirely apart from all such material considerations, the ordinary experimenter is simply overawed by the formidable problem of that intangible difference of phase, which as a matter of fact must be exactly one-fourth or one-third of a cycle. In other words, if 60 cycles are passed through in one second, the operator must secure a lag of one current behind another, corresponding to an interval of time not exceeding 1/180 of a second.

The difficulty here calling for solution is kin to the mechanical difficulty which presented itself in the early days of the steam engine. Though sufficient steam was turned on, the engine would frequently refuse to start; it had stopped on a dead center. What was done to prevent this embarrassment? The trucks were fitted out with two cranks at right angles to each other, so that the impulse of one would be given a quarter of a period later than that of the other. Similarly, the armature of a diphase motor will not rotate, if it receives the oscillatory impulse of only a single alternating current; and even when two impulses are given it from two alternating currents that are moving perfectly in step, one with the other, increasing or decreasing their values at exactly the same time, no torque will be produced, and consequently the armature will not turn. But if the impulse of one current is made to be at or move toward its maximum, while the impulse of the other is passing through its minimum value, then the armature, even under a proportionate load, must immediately begin to turn. This coincidence of different values of the impulses of two alternating currents is precisely what is meant by the difference of phase between two currents, or the lag of one behind the other. Hence, to make two currents diphase, the mechanical disposition referred to as applied to the steam engine must in some way be realized electrically.

In the commercial "diphaser" (a generator so constructed that it delivers two alternating currents differing by just one-fourth of a cycle) the characteristic feature is, that it is fitted with two similar armatures mounted on the same shaft, one of them, however, being shifted angularly in respect to the other, so as to generate two currents with the proper relation of phase. But there is a way of generating diphase and triphase currents, without the use of such diphase and triphase generators. If the reader is interested in the theme of this article, he should read carefully the experiments of Mr. N. Tesla, which are described minutely in No. 944 of the Scientific American Supplement (February 3, 1894). Mr. N. Tesla clearly establishes the fact that a polyphase generator is not indispensable to operate a polyphase motor; he makes one alternating current from an ordinary uniphase generator serve the purpose of a polyphase generator, by dividing the current into two, and securing to the one the proper degree of lag relatively to the other. To explain how this simpler kind of polyphase arrangement can be constructed and adjusted, very much more easily and cheaply than one would on first thought imagine, is the adequate *raison d'être* of the present essay.

The small motor represented in the accompanying illustrations was actually constructed at a trifling cost, and without the use of any delicate measuring instruments. The finished machine (but without the electro-magnet and a few accessory parts) is exhibited in Fig. 2. The general disposition of the diphasing apparatus will be readily understood from an inspection of Fig. 1. *A* is the knob at which the uniphase alternating current (104-volt, 60-cycle) has been tapped. At *O* this current is divided, one portion being conducted through wire *J*, electro-magnet *M M'*, field coil *C*; the other portion through wire *I*, resistance coil *R*, field coil *C'*. At *O'* the two are again united in one wire with exit at knob *B*. Now, if one of these currents between *O* and *O'*, say the lower *O I R C' H O'*, is made to lag behind the upper *O J M M' C L O'* exactly one-fourth of a cycle, then the space at *a*, where the axes of the two coils meet, will be the seat of a diphase rotating field, and in consequence, any suitable armature supported there so as to be free to rotate must, owing to the torque to which it is subjected, spontaneously begin to revolve. In our case the difference of phase is a function of two properly varied factors: the self-induction of the upper circuit and the resistance of the lower one. The self-induction of the first circuit is constituted partly by the electro-magnet, *M M'*, and partly by the field coil *C*. The resistance of the second is *R*.

Out of stiff thin pasteboard make two tubes, each 3.5 inches long and about 0.75 inch in diameter. Around each of these tubes wrap about 33 feet of No. 22 copper magnet wire (B. & S.), allowing the ends to project 4 inches. Next provide these coils with laminated iron cores, constructed as follows: Take a ribbon of Russian sheet iron (such as is used for stove and furnace trimmings) 18 feet long and a trifle less than 0.5 inch wide. Cut it into 50 (25 for each core) rectangular pieces, each 4.25 inches long. Prepare also 48 (24 for each core) pieces of paper, slightly longer and wider than the iron rectangles. Of these pieces of iron and of paper make two equal piles, placing iron and paper alternately. After filing these cores true and wrapping each tight with tape, insert one into each of the tubes, and you have your field coils finished. As for the resistance *R*, one of the flat coils used by tailors for heating their irons by electricity will answer the purpose very well. They are generally 3 x 3.5 inches, and are on the market for 50 cents and upward. The electro-magnet on the upper circuit is made up of 25 pounds of No. 12 copper magnet wire (B. & S.) corresponding to a resistance of 2 ohms. This was found to be more than enough to prevent heating. It may be well to note that the self-induction of the field coil alone without that of this electro-

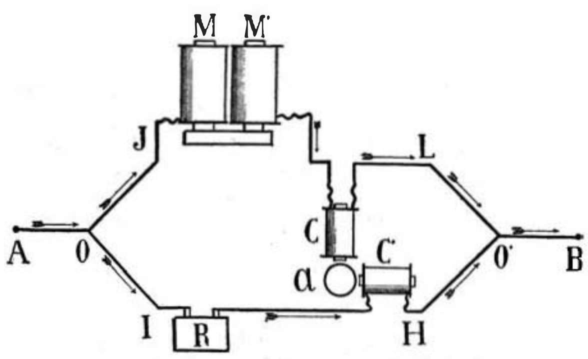


Fig. 1.—DIAGRAM OF CONNECTIONS FOR POLYPHASE MOTOR.

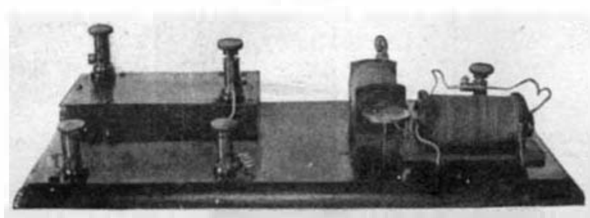


Fig. 2.—AN EXPERIMENTAL POLYPHASE MOTOR.

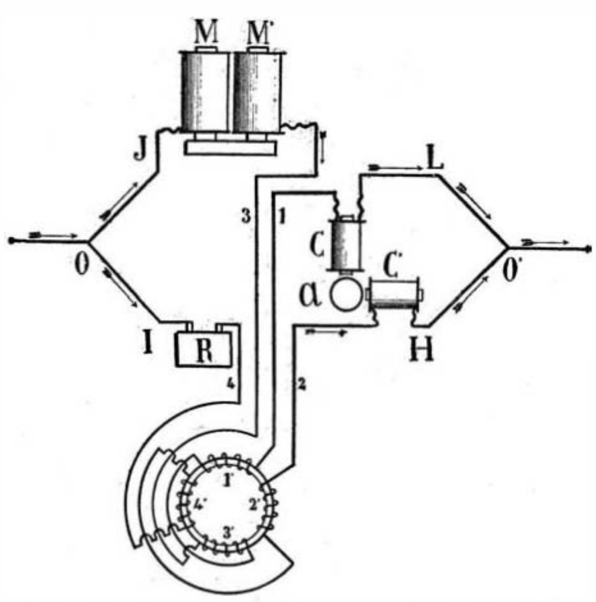


Fig. 3.—DIAGRAM OF CONNECTIONS FOR FOUR-COIL CIRCULAR FIELD.

magnet would suffice. In fact, if no electro-magnet is at hand, a second heating coil similar to the first may take the place of the electro-magnet.

Now connect everything as in Fig. 1. To test these circuits, turn on the current for only a few seconds. Should undue heat manifest itself in any part of the circuits, a few yards of German silver wire inserted into that circuit will bring the local heat under control. When the heat is not too intense after the current is on for three or four minutes, you may proceed to the final adjustment, namely, the securing of the required difference of phase between the two circuits.

This apparently over-delicate task is accomplished quite easily by tests with any small magnetic compass. (Should you have none at hand, make one. Magnetize by friction a piece of watch-spring one inch long and weighing one gramme or so; to make it balance, and to enable it to swing horizontally on a vertical axis, make a small indentation at its center.) Set the compass on a plane with the cores of the field coils, and at the point where the axes of the cores meet. Turn on the current; with the point of a pencil spin the compass rapidly on its support. The needle may possibly rotate so regularly that it overcomes all dead points, and so briskly that it is invisible. In this case, you need no further test; you have struck the proper relation of phase that must exist between the two currents. It is more likely, however, that the needle will move only slowly and irregularly or only quiver. Should it manifest a decided tendency to move in one direction, try to help it on by removing from or adding to the coils of the upper circuit a moderate length of wire. Once you notice that the tendency to turn in either direction is given or increased by adding to or subtracting from the coils in one circuit, or by increasing or diminishing the resistance *R* in the other, continue this process of adding or subtracting, until the needle rotates as above described. The principle constantly applied in this last adjustment is this: an increase of self-induction in the upper circuit increases the difference of phase between its current and that of the line; while an additional resistance introduced into the lower circuit diminishes the difference of phase between this current and that of the line. Thus the increase of either factor produces a greater difference of phase between the two circuits of the field coils.

The motor is now adjusted. Remove the compass and put in its stead the armature, a circular piece of soft iron 1.25 inches in diameter and a little less than ⅛ inch in thickness. You may vary your experiments by using armatures or rotors of different types and materials. When needed, a short piece of glass tubing sealed at one end may be inserted through a hole in the center of the disk, to serve as a bearing. Always set up the armatures as was directed for the compass.

A very interesting and highly instructive addition to the motor just described will be a four-coil circular field, as shown in Fig. 3. The core of this is constructed in a way similar to that in which the field coils of Fig. 1 were constructed. Take a continuous ribbon of sheet iron about 0.5 inch wide and 18 feet long, and also a ribbon of paper slightly wider. Make the first turn of iron so that the diameter of the inner circular field will be 2 inches. Roll up the iron ribbon so that each turn of iron will be separated from the next by paper, until you have a ring of square section. Wrap this ring core with tape. To provide the proper coils, divide the core into four equal sections marked in order 1', 2', 3', 4'; only the two middle quarters of each section are to be covered by the coils, 16.5 feet of No. 25 copper magnet wire being wrapped around that portion of each section. Coils on sections 1' and 3' must be wound in exactly the same way; those on sections 2' and 4' must also correspond to each other. If you begin wrapping section 1' say from the side toward section 2' and make turns of wire clockwise, then section 3' must also be begun from the side toward section 2', and the convolutions of its wire must also be clockwise, so as to develop two poles of the same name on the same side of the armature. If you begin section 2' say from the side toward section 3' and make the convolutions the reverse of clockwise, then section 4' must also be wrapped beginning from the side toward section 3', and the convolutions must be made as in winding section 2', so that this set may also develop two poles of the same name on the same side of the armature. At the beginning and at the end of each coil allow the wire to project about 4 inches. Then connect the wire projecting at the end of coil on section 1' with that projecting at the beginning of coil 3', bringing the wires around the outer rim of the core. Insert these two coils thus compounded into the circuit of say field coil *C*, between *C* and *M'*. Connect coils 2' and 4' into a compound coil, and insert it into the circuit of field coil *C'* between *H* and *R* of Fig. 1, exactly adapting the directions given for connection and insertion of coils 1' and 3'.

You have now a four-coil armature; each single coil develops two poles, hence there are in all eight poles. But, owing to the special winding, the four poles of coils 1' and 3' are gathered into two, one located at the middle of section 2', the other at the middle of section 4'; and in the same way, the four poles of coils 2' and 4' are gathered into two, one located at the middle of section 1', the other at the middle of section 3'. Moreover, even these two sets of compound poles finally merge into two, one north and the other south. So this four-coil armature produces an eight-pole field, if you simply count the magnetic poles generated; but these reduce themselves to a two-pole rotating field.

On a vertical pivot at the center of the four-coil field set up different kinds of armatures, and they will rotate under the influence of the two-pole diphase field. Thus, try an armature in the shape of a hollow cylinder of brass or copper one inch long and one inch and a quarter in diameter (Arago's rotations). Put a cork into the cylinder and a glass bearing in the cork. (Less than 10 grammes in all.) Another armature might be a small rectangular plate of soft iron 1.5 inches long wrapped at each extremity with 6 feet of No. 25 copper magnet wire, so as to develop two consequent poles. The piece of iron may be 0.25 inch wide and ⅛ inch thick. It will also need a glass bearing. The brass and even the copper armature will not revolve very fast in the circular field; they will not revolve at all in the field of Fig. 2. It is this very experiment which for a long time puzzled Mr. W. de Fonvielle while he was conducting his known researches of 1880.* All the other armatures to be used here must be more carefully balanced than those used in the two-coil field of Fig. 2, since the effects produced in the circular field are notably more energetic.

This inexpensive motor, working satisfactorily as it does, will illustrate many principles bearing on the theory of polyphase machinery, and in particular those involved in experiments such as the following: insufficiency of an oscillatory field to produce rotation; character of rotating fields; effects of self-induction and resistance on the difference of phase; bipolar diphase motor; four-coil diphase field; rotation of magnetized and non-magnetized armatures; Arago's rotations; reactions of Foucault's currents on the field; synchronism and asynchronism; three-wire diphase arrangement; reversal of rotation; self-starting, slip, etc.

Thus our experimental motor, though not recommended as having any commercial value, will yet be found very serviceable in the lecture room.

* Comptes-rendus de l'Academie des Sciences, 1er Semestre, 1880, p. 801.

THE SENSE OF SMELL IN SNAILS.

BY DR. ALFRED GRADENWITZ.

In the higher animals the various senses are localized in separate organs. This distribution, as we go down the scale of animal life, becomes less and less specialized, until in cellular forms it is hard if not impossible to distinguish any special sense organ. Mollusks may be said to occupy an intermediate position on this ladder of evolution. While they are in a measure possessed of true organs of sense, still these organs answer other purposes besides responding to sensations alone. An interesting instance of this behavior is afforded by *Helix pomatia*, the common snail, which has been recently made the subject of an extensive investigation by Prof. Emile Yung, of the University of Geneva, Switzerland. While previous naturalists had ascribed to the snail a strong sense of smell, it was not known where the sense organ was located. Prof. Yung shows that the sense is distributed over the entire body, in so far as it is not covered by the shell. Some parts, however, possess the sense of smell in a particularly high degree, viz., the two pairs of tentacles, the lips and the edges of the feet.

The following is one of the experiments made by Yung in carrying out his investigations. When a brush wetted with a drop of water was brought near a snail, immediate contact was necessary to produce a visible response, except in the case of the large tentacles which also contain an eye. Whenever the brush was brought within 1 millimeter of the eye, the tentacle was perceptibly deflected. Evidently this effect could be produced by the sense of sight, of heat, or of smell. Special experiments, however, proved the first two hypotheses to be inadmissible. Hence the sense of smell must be the cause of the snail's aversion.

In further investigating this sense Yung substituted camomile essence for the water. The odor was perceived at a distance of 4 millimeters. Whenever the brush was brought nearer to the animal (see Fig. 1), the tentacle would be deflected. Similarly the back would be depressed and the edge of the foot would be turned, when the camomile essence was brought near these parts of the body (see Fig. 2). Clearly the sense of smell is spread over a wide area. It may, however, be said that when repeating the same experiment, the response was found gradually to decrease in intensity, the snail becoming used to the stimulus. The sense of smell among lower animals plays an important part in the quest of food. Experiments made in this direction by Prof. Yung showed this rôle to be quite secondary in the case of snails, the food being perceived at maximum distances of only 15 to 20 centimeters, and 40 to 50 centimeters in some exceptional cases. The fact that snails are frequently found in kitchen gardens thus seems to be due not to their sense of smell, but to the moisture of the garden. The foregoing results are confirmed by histological investigations, the most sensitive parts of the body being found to possess especially large numbers of sensorial cells.

The subdivision and localization of the organs of the senses is thus seen to be rather elementary in the case of snails.

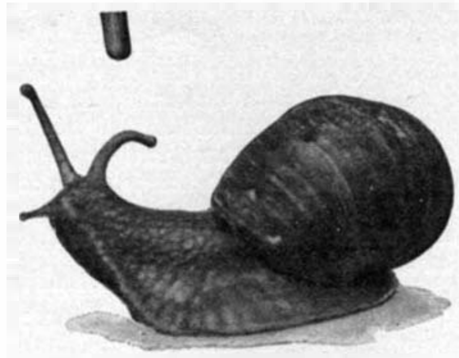


Fig. 1.—Snail Deflecting Left Tentacle at a Distance of 4 Millimeters from a Glass Rod Dipped in Camomile Essence.

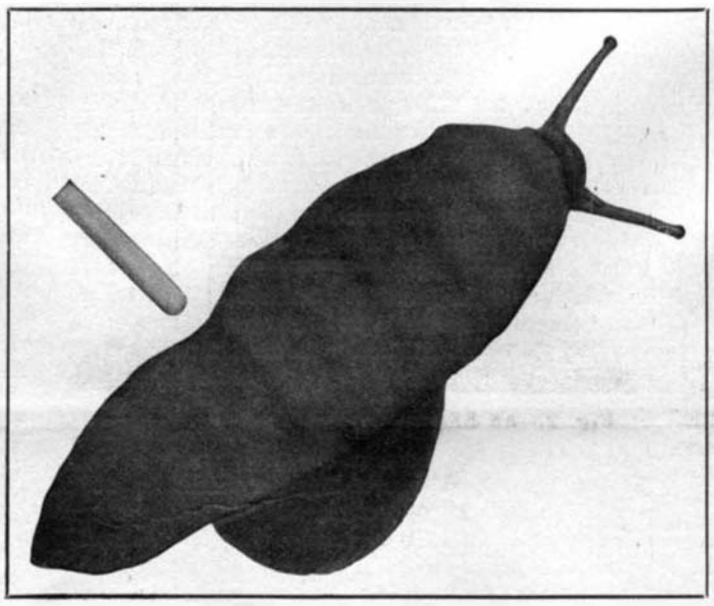


Fig. 2.—Snail Contracting the Edge of Its Foot at 2 Millimeters from a Glass Rod Dipped in Camomile Essence.

THE SENSE OF SMELL IN SNAILS.

A MACHINE FOR PICKING COTTON.

BY WILLIAM DALE.

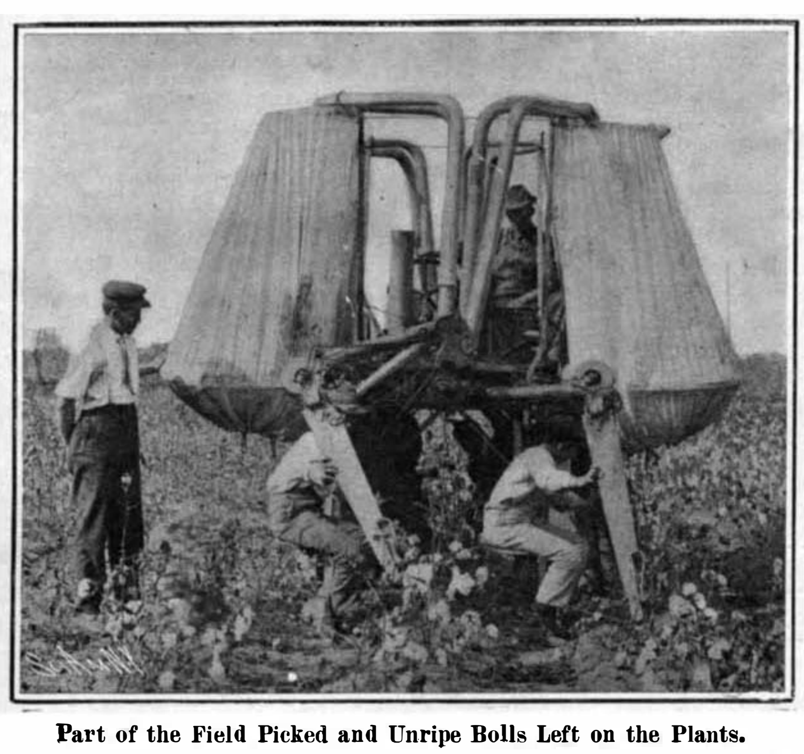
Since the invention of the mower, reaper, and binder operated by animal power and steam engines, the idea of utilizing mechanical means for harvesting the American cotton crop has been agitated. The revolution which was caused in agriculture by the modern methods of gathering the cereal crops indicated the saving in time and labor which could be effected in the southern cotton fields if a machine were perfected which would harvest the ripe cotton more expeditiously than the negro farm hand.

A number of devices has been invented to take the place of hand labor in gathering the cotton crop. With one exception, however, all of these have proved failures. The principal defect has been that the machines would harvest the immature as well as mature cotton. Those familiar with this branch of agriculture know that a field must be covered several times after the bolls begin to open, as, unlike grain, the cotton does not ripen with any uniformity. During the last harvesting season, however, a machine was employed in several of the Southern States, which proved to be not only a decided improvement over the ordinary hand method, but by its means only the ripe cotton was picked, the other plants being untouched.

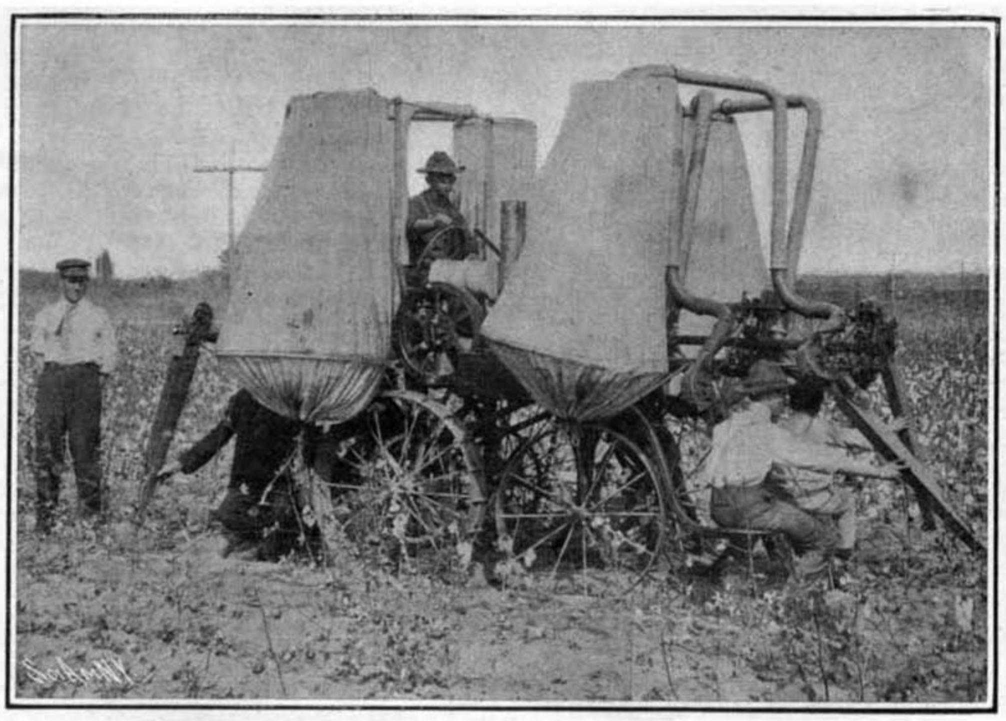
As the photographs show, this picker is notable for the simplicity of its construction. Power is obtained from an ordinary gasoline engine such as is utilized in automobiles of the smaller types. In fact, the engine installed in connection with the picker utilized in the field trials was taken from an Oldsmobile and developed but 8 horse-power. In moving the picker over the ground, gearing is employed as in traction engines. Sprocket chains pass around sprocket wheels on the rear axle, thence upward and around the driving shaft. The engine, which is mounted on the rear of the truck frame, as indicated in the photographs, is employed not only to move the picker over the field but to operate the mechanism by which the cotton is harvested and placed in the storage receptacles. There are four of the latter attached to the sides of the machine. They consist merely of cloth cylinders which are open at the top, the bottom ends being held together by strings so that when the cotton is to be removed it is only necessary to loosen the end by pulling the string, when the contents of the receptacle will fall out.

The lint is conveyed to the receptacles by tubes which are attached to the series of picking devices. The lower portions of these tubes, which are made of thin sheet iron, terminate in steel conduits of the same diameter inside. Each conduit or pipe contains a fan which serves two purposes. It "doffs" or cleans the cotton, blowing out any bits of leaves, casing, or other foreign matter which may have been caught up with the lint by the picker arm, and drives the lint through the tube into the receptacle with which it is connected, by air pressure.

The picker arms are dirigible in design and comprise eight in all, four attached to the forward section of the machine and four to the rear section, all of course being connected with the tubing leading to the cotton receivers and working in connection with fans. The picker arms are fastened to the conduits by means of hinged joints, and as the illustrations show, each consists of a case inclosing an endless belt which revolves upon pulleys placed at either end. This belt is provided with a series of curved teeth. At its outer end the upper part of the casing is cut away, so that the belt is exposed for several inches. When the cotton is to



Part of the Field Picked and Unripe Bolls Left on the Plants.



The Cotton-Picking Machine at Work.

A MACHINE FOR PICKING COTTON.